The Ottawa Field-Naturalists’ Club

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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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COVER: Three species of shorebirds in the St. Lawrence River estuary at Kamouraska, Quebec, Canada: 13 Black-bellied Plovers (Pluvialis squatarola); two Red Knots (Calidris canutus; middle and bottom, walking to the right and behind vegetation); and a Short-billed Dowitcher (Limnodromus griseus; with beak under wing). See the article in this issue by Yves Turcotte, Jean-François Lamarre, and Joël Béty, pages 203–214. Photo: Jonathan Frenette, August 2009.
Annual and Seasonal Variation in Shorebird Abundance in the St. Lawrence River Estuary during Fall Migration

YVES TURCOTTE1, 4, JEAN-FRANÇOIS LAMARRE2, 3, and JOEL BÉTY2

1Département des sciences et techniques biologiques, Collège de La Pocatière, 140 4e Avenue, La Pocatière, Quebec G0R 1Z0 Canada
2Département de biologie et Centre d’études nordiques, Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, Quebec G5L 3A1 Canada
3Savoir Polaire Canada / Polar Knowledge Canada, Station de recherche du Canada dans l’extrême arctique / Canadian High Arctic Research Station, Cambridge Bay, Nunavut X0B 0C0 Canada
4Corresponding author: yturcotte@cegeplapocatiere.qc.ca


Many North American shorebird populations are declining. It is therefore urgent to identify major sites used during their annual cycle to achieve effective conservation measures. Our objective was to expand some aspects of the knowledge base needed to assess the ecological value of the St. Lawrence River Estuary for shorebird conservation. Here, we present the results of the most intensive shorebird survey ever conducted in the St. Lawrence River Estuary during fall migration. Surveys were conducted between St-Jean-Port-Joli and St-Simon-sur-Mer, Quebec, Canada, in 2011 and 2012, from late June/early July through late November, corresponding to the migration period of all species potentially present in the study area. The Semipalmated Sandpiper (Calidris pusilla) was one of the two most abundant species during both years of our study (most abundant species, followed by Dunlin [Calidris alpina] and Black-bellied Plover [Pluvialis squatarola] in 2011; second to Black-bellied Plover in 2012). Considering the entire shorebird community, abundance of individuals peaked in early September. Peak abundance occurred earlier for adults than for juveniles. For most species, juveniles largely outnumbered adults. Juveniles were relatively less abundant in 2012 than in 2011. This reflected a general trend observed in northeastern North America between those years, suggesting a lower breeding success in 2012. Given its importance as a staging site for juvenile birds (study area used annually by up to a few hundred thousand shorebirds) and therein, its conservation value, we recommend that the St. Lawrence River Estuary should be included within the Western Hemisphere Shorebird Reserve Network.

Key Words: Calidris pusilla; conservation; ecology; fall migration; migration timing; Semipalmated Sandpiper; shorebirds; St. Lawrence River Estuary; staging site; survey

Introduction

The ecological value of the St. Lawrence River Estuary for aquatic birds has long been recognized. Several thousand breeding colonial waterbirds belonging to 12 species (e.g., Double-crested Cormorant [Phalacrocorax auritus], Razorbill [Alca torda], and Black-legged Kittiwake [Rissa tridactyla]) are found on its numerous islands (Environment Canada 2016). Migrating (e.g., Snow Goose [Anser caerulescens]), breeding (e.g., American Black Duck [Anas rubripes]), and wintering...
(e.g., goldeneyes [Bucephala spp.]) waterfowl are also abundant (Belanger et al. 1998; Gauthier et al. 2005; Ouellet et al. 2010). However, shorebird use of the St. Lawrence River Estuary has not received much attention so far and, as a result, there are few published studies documenting the biology of this taxonomic group in this ecosystem.

Indeed, we are aware of only four peer-reviewed publications dealing with shorebird use of the St. Lawrence River Estuary. Michaud and Ferron (1986, 1990) documented foraging techniques and food selection in four species of shorebirds during fall migration. Maisonneuve et al. (1990) conducted extensive ground surveys along the St. Lawrence system (river, estuary, and gulf) during the early part of the fall migration (late July to late August). They reported the presence of about 110,000 shorebirds belonging to 22 species in the estuarine section of their study area. As this number was the result of single counts conducted only in selected locations and moreover, before the juvenile peak of abundance for most species, it is very likely that the total number of shorebirds using the St. Lawrence River Estuary during fall migration was underestimated.

More recently, Turcotte et al. (2013) studied seasonal change in body mass of Semipalmated Plover (Charadrius semipalmatus) and Semipalmated Sandpiper (Calidris pusilla) juveniles during fall migration. They found that mean body mass of birds captured on the southeast shore of the St. Lawrence River Estuary were similar to or higher than those of juveniles of both species captured along the North Atlantic coast.

It follows that the ecological value of the St. Lawrence River Estuary for this group has not yet been sufficiently assessed. As many North American shorebird populations are declining (Morrison et al. 2001; Bart et al. 2007; Jehl 2007; Hicklin and Chardine 2012; North American Bird Conservation Initiative Canada 2012), it is important to readily identify critical habitats and sites used during their annual cycle to achieve effective conservation objectives (Donaldson et al. 2000; Warnock 2010). Including the St. Lawrence River Estuary within the Western Hemisphere Shorebird Reserve Network (Western Hemisphere Shorebird Reserve Network 2009) would likely help attain these objectives. The Western Hemisphere Shorebird Reserve Network is an international conservation strategy established in 1986 to protect key shorebird habitats. In eastern North America, along the West Atlantic flyway (also known as the Atlantic Americas flyway or Atlantic flyway), it includes Delaware Bay and two sections of the Upper Bay of Fundy. These sites are considered among the most important for shorebird conservation in the Americas. Expansion of the Western Hemisphere Shorebird Reserve Network is considered as the importance of other major candidate sites would be properly assessed and recognized (Western Hemisphere Shorebird Reserve Network 2009). Thus, our objective was to document timing of migration and abundance of southbound shorebirds using the St. Lawrence River Estuary to expand the knowledge base needed to assess the ecological value of the St. Lawrence River Estuary for their conservation. Here, we present the results of the most intensive shorebird survey ever conducted in the St. Lawrence River Estuary during fall migration.

### Study Area

This study was conducted on the southeast shore of the St. Lawrence River Estuary, approximately 100 km northeast of Quebec City, along a 150 km stretch of shoreline between St-Jean-Port-Joli (47.189°N, 70.296°W) and St-Simon-sur-Mer (48.205°N, 69.082°W), Quebec, Canada (Figure 1). The St. Lawrence River Estuary exhibits a strong salinity gradient west to east (Fradette and Bourget 1980; Saucier et al. 2009). This gradient is reflected by major changes in riparian and intertidal vegetation (Gauthier 2000) as well as in benthic invertebrate communities (Bourget 1997). Within the study area, water circulation is dominated by semi-diurnal tides that can reach over 5 m in height (Fisheries and Oceans Canada 2016). The intertidal zone may reach more than 3 km at its widest points (e.g., Ste-Anne Bay and Kamouraska Islands) according to marine charts (Natural Resources Canada 2016). Intertidal substrates are highly variable, ranging from mud-

![Figure 1](image-url). The study area on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 and 2012. Light grey areas represent the intertidal zone.
flats adjacent to American Bulrush (*Schoenoplectus americanus* (Persoon Volk ex Schinz & R. Keller) or cordgrass (*Sporobolus* spp.) marshes in protected bays, to boulders and bare rock at exposed sites. Peregrine Falcons (*Falco peregrinus*) and Merlins (*Falco columbarius*), two important shorebird predators (Dekker *et al*. 2011), nest in and migrate through the study area. Attacks on migrating shorebirds by these predators were witnessed regularly during this study (see also Turcotte *et al*. 2013).

**Methods**

**Shorebird Surveys**

We established 30 survey sites 5 km apart along the shoreline. Each survey site corresponded to a 600 m stretch of shoreline measured with a handheld GPS at the higher high water mean tide level (the average of all higher high waters; Fisheries and Oceans Canada 2016). The higher high water mean tide level coincides with the upper limit on the shore of, depending on water salinity, American Bulrush or Smooth Cordgrass (*Sporobolus alterniflorus* (Loiseleur-Deslongchamps) P. M. Peterson & Saarela; Gauthier 2000). Thus, a total of 18 km of shoreline were covered per survey. Survey sites included all adjacent shorebird habitats above and below the shoreline (marshes, beaches, rocky shores, and tidal flats). The location of a first survey site was randomly selected to the nearest meter along a longitudinal axis within the study area. The other sites were thereafter positioned progressively every 5 km along the shoreline (systematic random sampling). In some cases, survey sites were relocated in similar habitat type, as close as possible from the selected site when, chiefly due to duck hunting activity, observer safety could have been compromised.

Based on radiotelemetry studies conducted during the non-breeding season, we assumed that this spacing would on the one hand, reduce, though certainly not eliminate, the likelihood that shorebirds would be counted in more than one survey site on a given day (see Conklin and Colwell 2007; Sprague *et al*. 2008; Obermuenemann *et al*. 2013; Turcotte *et al*. 2013), while providing, on the other hand, as much as possible a representative coverage of the study area in order to properly describe the structure of the shorebird community. Thus, abundance values presented here should be interpreted cautiously because some “double counting” (i.e., birds counted in more than one nearby [5–15 km] survey sites not visited simultaneously) likely occurred. Conversely, “double missing” (i.e., birds missed in all nearby survey sites not visited simultaneously) would have occurred as well, counterbalancing, in an unknown proportion, double counting bias. Costly aerial surveys would have eliminated this problem. However, for most species, they would not have provided, unless supported by ground surveys, information on age class.

Surveys were conducted in 2011 and 2012 from late June/early July through late November, corresponding to the migration period of all species potentially present in the study area. Surveys were conducted every week in 2011 (21 survey weeks). In 2012, surveys were conducted every other week (11 survey weeks). During 30 min, one or two observers (same observers in both years) walked the entire 600-m survey site to ensure complete visual coverage. Shorebirds were identified with >60 spotting scopes. Age class (juveniles or adults) of shorebirds on ground was determined according to Hayman *et al*. (1986) and Paulson (2005), whenever conditions permitted (distance, light conditions, flock density, and behaviour). We surveyed sites in different tidal conditions (tidal flat covered and most birds roosting or tidal flat partly uncovered and most birds foraging) during consecutive weekly or bi-weekly surveys. Thus, it took four or five days per survey week to visit all 30 sites in requested tidal conditions. As a result, double counting and double missing were likely unavoidable.

**Statistical Analyses**

Statistical analyses were carried out using R version 3.3.1 (R Development Core Team 2016). Values reported are abundance (number of individuals detected) and relative abundance (%) per age class (calculated from the total number of known-age individuals detected per year). Abundance values were tested for normality (Shapiro-Wilk test; the statistical test of the null hypothesis of normality with the highest power; Ruxton *et al*. 2015) and homoscedasticity ($F$ test). Square-root-transformation ($0.5$ added to data before transformation due to the presence of a value equal to 0), a transformation frequently applied to count data (Sokal and Rohlf 1995; Gotelli and Ellison 2004), was used to meet $t$-test assumptions. A Pearson’s Chi-square test was utilized to assess the association between categorical variables.

**Results**

**Timing of Migration**

Considering the entire shorebird community, abundance of individuals peaked in early September (Tables 1 and 2, Figure 2). Shorebird juveniles initiate migration later than adults (Warnock *et al*. 2002; van de Kam *et al*. 2004). Therefore, raw values such as those appearing in Tables 1 and 2 may limit our understanding of shorebird migration dynamics. Thus, for species in which the less abundant age class included at least 2% of known age individuals (Table 3), Figure 3 (2011: weekly survey) and Figure 4 (2012: bi-weekly survey) illustrate relative abundance and timing of migration per age class. We only present species for which we were able to determine age class for at least one fourth of all individuals detected, represented by a conservative sample size (250 or more known age individuals). We thus reduced the risk of potential bias hampering...
TABLE 1. Shorebird abundance per weekly survey during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011. Numbers in brackets are survey week order given a 21 consecutive week schedule.

<table>
<thead>
<tr>
<th>Species</th>
<th>1 July (1)</th>
<th>2 July (2)</th>
<th>3 July (3)</th>
<th>4 July (4)</th>
<th>5 July (5)</th>
<th>6 July (6)</th>
<th>7 July (7)</th>
<th>8 July (8)</th>
<th>9 July (9)</th>
<th>10 July (10)</th>
<th>11 July (11)</th>
<th>12 July (12)</th>
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<th>15 July (15)</th>
<th>16 July (16)</th>
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<th>19 July (19)</th>
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The Canadian Field-Naturalist
TABLE 2. Shorebird abundance per bi-weekly survey during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2012. Numbers in brackets are survey week order given a 21 consecutive week schedule.

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FIGURE 2. Shorebird abundance during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 (weekly survey) and 2012 (bi-weekly survey). Survey week order as in Tables 1 and 2.
Table 3. Relative abundance per age class of known-age shorebirds during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 and 2012.

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**Between-year Differences in Abundance**

We observed a 64% decrease in mean shorebird abundance per survey week between 2011 (n = 21 weeks, 2442 birds) and 2012 (n = 11 weeks, 892 birds). Considering the entire migration period, when 2011 and 2012 shorebird abundances are compared on a weekly basis, this decrease was significant at the 0.05 level (paired t-test, t_{10} = 2.35, P = 0.02). Moreover, Figure 2 suggests that shorebird abundance from late August through October differed greatly between years, corresponding with a less abundant arrival of juveniles in 2012 than in 2011 (Table 3) and the departure of adults from our study area.

**Discussion**

**Timing of Migration and Abundance**

As expected, peak abundance occurred earlier for adults than for juveniles. The relative abundance of Semipalmated Sandpipers in the total shorebird community (46% and 22% in 2011 and 2012, respectively) was much lower than what had been reported for the Bay of Fundy (95% of all shorebirds; Hicklin 1987), a major shorebird fall staging site in eastern North America along the West Atlantic flyway. The abundance of Black-bellied Plover adults and juveniles during several weeks is also worth mentioning. The presence of numerous Black-bellied Plovers has been previously
Figure 3. Relative abundance of some shorebird species per age class (calculated from the total number of known-age individuals detected per year; sum of all bars = 100%) during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 (weekly survey). Solid and light grey bars represent adults and juveniles, respectively.
noted near our study area during fall migration (Maison-neuve et al. 1990).

We do not know length of stay for most species in the St. Lawrence River Estuary. Because we consider that double counting some individuals in the survey sites between consecutive weekly or bi-weekly surveys was inevitable, it would be hazardous to extrapolate abundance values presented here to the 150 km long shoreline of our study area. Indeed, to estimate population size, survey site raw abundance values such as ours need to be corrected to take into account turnover of migrant birds between surveys (Clark et al. 1993; Cohen et al. 2009), before being extrapolated to an entire study area. Nevertheless, as shoreline covered during each survey (18 km) represented approximately 12% of total shoreline within our study area (150 km), we consider it likely that, during years of high nesting success such as 2011, a few hundred thousand shorebirds would use the study area.

Semipalmated Plover is however the only species for which published results for this study area during fall migration are available. In this species, minimal length of stay of juveniles is, on average, 12.5 days ($n = 8$; Turcotte et al. 2013). Based on this value and abundance of Semipalmated Plover juveniles (estimated from values in Tables 1, 2, and 3), we consider that, because survey sites were randomly selected, approximately 11,800 and 10,600 Semipalmated Plover juveniles used our study area during fall migration in 2011 and 2012, respectively. These rough estimates would represent about 5% of the estimated world population (200,000; Andres et al. 2012).

### Abundance per Age Class

When compared to 2011, the lower relative abundance of juveniles in 2012 suggests lower breeding success on the breeding grounds for that year. Breeding output of tundra nesting birds is affected by weather conditions. Low temperatures and precipitation can af-
fect breeding density, timing of breeding, and survival of juveniles (Melothe et al. 2007; Robinson et al. 2014). Furthermore, pulsed resources such as rodent cycles can strongly affect nesting success (proportion of nests fledging at least one young). During low rodent abundance years, predators such as Arctic Fox (Vulpes lagopus), Glaucous Gull (Larus hyperboreus), and jaegers (Stercorarius spp.) rely more on alternative prey such as terrestrial bird nests and flightless juveniles (Mckinnon et al. 2014). Most birds migrating through the St. Lawrence system likely nest at higher latitudes along the West Atlantic flyway (Van de Kam et al. 2004; Winn et al. 2013; Brown et al. 2017). Information on nesting success at source locations within this flyway could help understand what we observed in our study area. Such data are available for 2011 and 2012 for a few study sites in the eastern Arctic, all located in Nunavut and Churchill (58.7°N, 81.7°W), Nunavut, and Churchill (58.7°N, 93.8°W), Manitoba (Arctic Shorebird Demographics Network 2015). Though anecdotal, it is noteworthy that nesting success at these three sites was lower in 2012 (35%, n = 220) than in 2011 (52%, n = 175; \( \chi^2 = 10.9, P = 0.001 \)). Moreover, particularly detailed information is available for the Bylot Island study site for both years on arctic weather conditions, rodent abundance, and terrestrial bird nesting success (Gauthier et al. 2013). On Bylot Island, after two years of high density, Brown Lemming (Lemmus trimucronatus) populations crashed in 2012 (Gauthier et al. 2013; Fauteux et al. 2016). Furthermore, 2012 was the wettest summer since 1995, contrasting with warm and sunny conditions encountered in 2011 (Gauthier et al. 2013). These factors likely contributed to the particularly low nesting success of shorebirds on Bylot Island in 2012 (13%) as compared to 2011 (75%; Lamarré et al. 2012).

**Between-year Differences in Abundance**

To determine whether the between-year differences we observed were a local phenomenon or a general trend in northeastern North America between 2011 and 2012, we compared our results with data corresponding to our survey weeks available from eBird (Table 4), an online citizen-science project repository for bird observation (Sullivan et al. 2009). We used eBird weekly average counts (average number of birds detected when encountered; eBird 2016) for coastal eastern Canada (Quebec [excluding our data], Newfoundland and Labrador, Prince Edward Island, New Brunswick, and Nova Scotia) and coastal New England (Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut). For this comparison, we only considered species for which at least 1000 individuals were detected in our study area in 2011, our high abundance reference year. Six species met this criterion, representing 90% of all individuals detected in 2011.

Data in the eBird repository are not collected following a constant effort protocol as ours nor do they present age class information. They should therefore be interpreted cautiously. Nevertheless, for most species, the decline we observed along the St. Lawrence River Estuary between 2011 and 2012 appears to have been general across both coastal eastern Canada and coastal New England (Table 4).

**Ecological Value of the St. Lawrence River Estuary for Shorebird Conservation**

We found that, for most species, juveniles largely outnumbered adults in the St. Lawrence River Estuary during fall migration (Table 3). For Semipalmated Sandpiper, the most abundant species in northeastern North America during fall migration, the situation reported here (~ 98% juvenile and ~ 2% adult birds) appears to differ from what is observed at two major staging sites, James Bay (Morrison 1984) and the Bay of Fundy (Hicklin 1987). James Bay and the Bay of Fundy are located approximately 1000 km northwest and 400 km southeast of the St. Lawrence River Estuary, respectively. In James Bay, Semipalmated Sandpiper juveniles are also more abundant overall than adults (juvenile peak population size in August 1982, 10 055 individuals [Morrison 1984]; adult peak population size

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**Table 4. Mean abundance in some shorebird species per survey week on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada (this study), coastal eastern Canada, and coastal New England (eBird), 2011 and 2012.**

<table>
<thead>
<tr>
<th>Species</th>
<th>St. Lawrence River Estuary</th>
<th>Coastal eastern Canada</th>
<th>Coastal New England</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2011</td>
<td>2012</td>
<td>Change (%)</td>
</tr>
<tr>
<td>Black-bellied Plover (Pluvialis squatarola)</td>
<td>300.5</td>
<td>339.5</td>
<td>13</td>
</tr>
<tr>
<td>Semipalmated Plover (Charadrius semipalmatus)</td>
<td>166.6</td>
<td>143.2</td>
<td>−14</td>
</tr>
<tr>
<td>Sanderling (Calidris alba)</td>
<td>50.5</td>
<td>10.5</td>
<td>−79</td>
</tr>
<tr>
<td>Dunlin (Calidris alpina)</td>
<td>421.4</td>
<td>33.5</td>
<td>−92</td>
</tr>
<tr>
<td>White-rumped Sandpiper (Calidris fuscicollis)</td>
<td>196.5</td>
<td>12.1</td>
<td>−94</td>
</tr>
<tr>
<td>Semipalmated Sandpiper (Calidris pusilla)</td>
<td>1068.5</td>
<td>187.9</td>
<td>−82</td>
</tr>
</tbody>
</table>
in July 1982, ~3570 individuals, estimated from Figure 13 in Morrison [1984]). By contrast, in the Bay of Fundy, the vast majority of staging birds, including Semipalmated Sandpipers, are adults (Hicklin 1987; Morrison et al. 1994). This suggests different migration strategies between southbound adult and juvenile birds.

The St. Lawrence River Estuary may be skipped by many adult Semipalmated Sandpipers and adults from most species, thus reducing the risk of predation when moving to an additional stopover (Ydenberg et al. 2002), because their body condition can take them further. In contrast, the St. Lawrence River Estuary may represent a mandatory staging site for lean juveniles trying to avoid fatal body reserve depletion before reaching the Atlantic coast. Indeed, early in their migration period, many Semipalmated Sandpiper and Semipalmated Plover juveniles weigh less than estimated mean fat-free mass at their arrival in the St. Lawrence River Estuary (Turcotte et al. 2013). That could be especially true for birds confronted en route with unpredictable winds (Shamoun-Baranes et al. 2010). Moreover, the St. Lawrence River Estuary may represent the last staging site for many juveniles able to accumulate sufficient body reserves to fly directly to their winter range (Hicklin 1987; Turcotte et al. 2013).

Based on the evidence presented here (abundance of birds [Tables 1 and 2], relative abundance of juvenile birds [Table 3]) and elsewhere (Maisonneuve et al. 1990; Turcotte et al. 2013), we recommend that, given its importance as a staging site for juvenile birds and therein, its conservation value, the St. Lawrence River Estuary, or sections of it, should be included within the Western Hemisphere Shorebird Reserve Network.

Acknowledgements
We are grateful to J.-É. Joubert and C. Pomerleau for their help in the field. M.-J. Gibson, J. R. Foote, and two anonymous reviewers improved the quality of the manuscript by their comments. We acknowledge the cooperation of several landowners for graciously allowing us land access. Y.T. received support from Fonds de recherche du Québec – Nature et technologies (FRQNT), Environnement et Changement climatique Canada (contract K2C55-12-2053), Comité Z.I.P. du Sud-de-l’Estuaire and Cégep de La Pocatière. J.-F.L. and J.B. received support from Fonds de recherche du Québec – Nature et technologies, Conseil de recherches en sciences naturelles et en génie du Canada (CRSNG/NSERC), and Université du Québec à Rimouski.

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Diet of Grey Wolves (Canis lupus) During Calving in a Moose–Caribou System in Northern Ontario

ROB FOUND1, 3, 4, ASHLEY A. D. MCLAREN1, ARTHUR R. RODGERS2, and BRENT R. PATTERSON1

1Ontario Ministry of Natural Resources and Forestry, Wildlife Research and Monitoring Section, Trent University, DNA Building, 2140 East Bank Drive, Peterborough, Ontario K9J 7B8 Canada
2Ontario Ministry of Natural Resources and Forestry, Centre for Northern Forest Ecosystem Research, 103—421 James Street South, Thunder Bay, Ontario P7E 2V6 Canada
3Current address: Parks Canada, Elk Island National Park, 1-54401, R.R. 203, Fort Saskatchewan, Alberta T8L 0V3 Canada
4Corresponding author: robert.found@pc.gc.ca


Grey Wolves (Canis lupus) are a leading proximate cause of declining populations of Woodland Caribou (Rangifer tarandus) across their shared ranges (Festa-Bianchet et al. 2011). The ultimate cause may be anthropogenic disturbance, seen as the proliferation of roads and other linear features and expansion of industrial forestry (Dyer et al. 2001). These landscape modifications can improve habitat structure for Moose (Alces americanus; Schneider and Wasel 2000; Bjorneraas et al. 2011) and wolves (Dyer et al. 2001; Apps and McLelland 2006) leading to increases in densities of both species (Seip 1992; Wittmer et al. 2007). Although wolves may target Moose as their primary prey, greater wolf density can lead to an increased frequency of incidental encounters with secondary or tertiary prey (Bergerud 1988; Seip 1992; James et al. 2004). The impact of this incidental predation may be negligible when the prey in question is highly productive, such as American Beaver (Castor canadensis) or Snowshoe Hare (Lepus americanus), but can be serious for caribou, which occur in naturally low densities, reproduce slowly, and whose inherent sensitivity to human disturbance increasingly limits their distribution (Cumming et al. 1996; Wittmer et al. 2007).

The potential use of caribou by wolves in northern Ontario, Canada, is of particular interest because the Woodland Caribou Boreal population is listed as “threatened” both nationally (SARA Registry 2014) and provincially (COSSARO 2007). The southernmost range of Woodland Caribou in Ontario has been retreating northward, and now approximates the northern extent of commercial forestry in the province (Schaef er 2003; Vors et al. 2007). As in other jurisdictions, human disturbance and commercial forestry activities in this mixed coniferous–deciduous forest has changed the seral composition and forest structure (Bowman et al. 2010) and the area now supports moderate densities of Moose and wolves, but low caribou density (Avgar et al. 2015).

Our objective was to determine the diversity and portions of prey selected by wolves during the ungulate calving season in a region of Ontario where Moose, beaver, and caribou were expected to be the major prey. In particular, we wished to document the extent of wolf consumption of both adult and neonatal caribou and Moose and explore the potential for wolf predation to be a limiting factor for caribou in this area. Because of their relatively high density, we expected Moose would be the main prey item found in wolf scats. However, because of the density and prevalence of wolves across the study area, we expected caribou and beaver to be important alternative prey.

Methods

Our study focused on the Ogoki-Nakina forest in Ontario (centroid: 87.7°W, 50.5°N). Human disturbance in this area is high, with 41 km of road per 100 km² and commercial logging across 28% of the region (Thompson et al. 2014). The area now supports moderate densities of Moose (11.8/100 km²) and wolves (0.67/100 km²; Kittle et al. 2015) and a low density of caribou (minimum 0.50/100 km²; MNRF 2014). The region is
also populated by Snowshoe Hare, beaver, and other small mammals representing potential prey items for wolves.

We determined the diversity and relative proportion of prey items in wolf diets by examining scat samples and calculating percentage biomass of prey consumed (Floyd et al. 1978; Ciucci et al. 1996; Klare et al. 2011). We collected scats opportunistically along roads and trails between 23 May and 19 June 2012 (n = 31) and 2013 (n = 70). Scats were also collected from the territories of up to 13 wolf packs using the study area, but, because road and trail access was not equal across the entire study area, we opportunistically encountered more scats in certain areas. We minimized pseudo-replication by using both spatial and temporal separation of sampling events to reduce the likelihood of collecting multiple scats from the same individual. We analyzed only the first scat found at any location where multiple scats were deposited on the same day. Scats were located while driving along multiple roads and walking multiple trails each day and collected on 16 days. Of seven scats ultimately found to contain caribou, six were collected on different days, and all seven were also from different locations. We pooled the results from both years into a single data set (n = 101), to exceed the minimum (n = 59) recommended by Trites and Joy (2005) for inferring population-wide dietary trends.

We rinsed boiled scats in water for 2–3 minutes and air-dried them overnight. Dried, undigested matter was spread onto a grid sheet divided into 20 cells, which allowed estimates of relative proportions of diet components (i.e., coverage of one cell = 5% of scat). We expected wolves to feed mostly on mammalian prey, which are best identified using hairs found in scats (Lockie 1959; Korschgen 1980). We identified hairs visually, either unaided or microscopically, from either cuticular impression mounts or whole mounts, using a reference guide for mammalian hair in Ontario (Adorjan and Kolenosky 1969). This guide also allowed us to differentiate between calves and adults of ungulate species.

To quantify dietary variation, we recorded the frequency of occurrence of each dietary item and the percentage it contributed to total scat volume. Because increasing prey body size results in an increasing ratio of digestible to indigestible mass, the proportion of prey in scat is not representative of the relative amount of prey originally consumed (Klare et al. 2011). Smaller prey tend to be over-represented in scats based on volume, particularly in diets of predators whose main prey include a mix of large and small prey. Using controlled feeding trials on wolves, Weaver (1993) derived a formula to correct biases in the diets of wolves whose main prey include both very large (e.g., Moose) and smaller prey (e.g., beaver). We used that equation — mass of prey per collectable scat = 0.439 + (0.008)* (body mass of prey) — to correct for biases in prey body size and convert percentage scat volume to percentage biomass in the diet. Because the formula was validated in wolf diets containing prey ranging in size from Snowshoe Hare to Moose, we calculated percentage biomass only for Moose, caribou, beaver, and hare. As data for the Weaver formula, we used the following literature-derived average body masses: Moose adult 475 kg (Quinn and Aho 1989) and calf 24 kg (at 3 weeks; Addison et al. 1994); caribou adult 130 kg (Kelsall 1984) and calf 10 kg (at 3 weeks; Kojola 1993); beaver, 18 kg (Hoover and Clarke 1972); and Snowshoe Hare 1.5 kg (Bennett et al. 2005). We calculated separate percentage biomasses for ungulate adults and calves then combined them to derive the overall percentage biomass for each ungulate species.

Results
Wolves consumed 12 identifiable dietary items, of which eight were animal and four vegetable. All scats contained some animal matter, while 38.6% contained vegetable matter. The most frequently occurring item was Moose, which was found in 51.5% of all scats, followed by beaver (38.6%), grasses (18.8%), Snowshoe Hare (9.9%), and caribou (6.9%; Figure 1). By proportion of total scat volume, Moose (44.9%) and beaver (34.4%) remained the top two dietary items, followed by caribou (6.5%), then Snowshoe Hare (6.2%). By volume, all other dietary items contributed less than 1.5% each to the total wolf diet. Total grass consumption by volume was only 1.3%, making it disproportionately frequent in scats compared to the relatively small amount of grass present. Diet items whose frequency of occurrence is relatively larger than their percentage volume may be important only in low quantities, but may also represent smaller units of prey representing incomplete meals for wolves. Black Bear (Ursus americanus) made up 1% of total scat volume, but this was the result of a single scat containing the only occurrence of bear. Just over half (50.5%) of all scats contained a single dietary item, 31.7% contained two dietary items, 14.9% contained three dietary items, and just 2.0% and 1.0% contained four and five dietary items, respectively.

We were able to differentiate between hairs of ungulate adults and calves and found that 15 of 52 occurrences of Moose in scats were calves (30.7% of total Moose biomass) and four of seven occurrences of caribou were calves (69.5% of total caribou biomass). Based on these biomass values, wolves consumed mostly Moose (82.7%), followed by beaver (10.9%), caribou (3.1%), and Snowshoe Hare (1.5%; Figure 2). By biomass, only 6.0% of total Moose consumption consisted of calves, but 45.2% of caribou consumption consisted of calves.

Discussion
Moose were the dominant item in the spring diet of wolves in our study area, while smaller proportions of caribou (3.1%) and beaver (10.9%) indicated that they
were of less importance to wolves. These results are similar to those of other studies of spring–summer wolf diet results which ranked Moose as the main diet item, followed distantly by beaver and caribou as important alternate food sources (May–June, Ballard et al. 1987; May–October, Tremblay et al. 2001; Latham et al. 2011).

Selection of ungulates by wolves may correspond directly to the availability of that prey (Spaulding et al. 1998), but it may also be a function of increased effort and risk to wolves from hunting larger prey (Smith et al. 2000). For example, in Alaska, caribou remained the primary prey even when Moose were twice as abundant (Dale et al. 1993). A study of wolf predation during years of changing deer density in Quebec found that Moose was the primary spring–summer prey, but deer was the primary winter prey even when they were at a much lower density than Moose (Potvin et al. 1988). In contrast, in our system, wolves favoured the largest ungulate available, perhaps because the ease of finding abundant Moose offset the extra effort and risk required to kill them.
Although we expected the timing of our study to be optimal for detecting consumption of ungulate calves, it may also have been optimal for predation on beaver. We found a relatively large amount of beaver in wolf diets, possibly because our study period immediately followed ice-out for beavers (when surface ice on ponds and rivers thaws enough to allow beavers to resume movement between water and land), which occurs in late April through May. Beaver are nutrition stressed at this time, which drives increased foraging activity both in and out of the water and, subsequently, increases their risk of predation (Kallemeyn et al. 2003). An example of this was found in northeast Alberta, where despite the availability of deer, Moose, and caribou calves, beaver were the primary prey of wolves during May and June (Latham et al. 2013). Wolves may also have been targeting beavers during our study.

Half of all the wolf scats we examined contained only one diet item; this is expected in diets dominated by large prey, which typically provide complete or even multiple meals for multiple wolves. Although nearly half the scats we examined contained multiple prey items, we expect that this spring–early summer prey diversity would decline with the onset of winter, with reduced availability of vegetative matter and access to prey such as beavers. Among scats containing Snow-shoe Hare, all but two also contained Moose or beaver, suggesting that wolves did not rely on such small prey, but likely ate them opportunistically while targeting larger prey. Opportunism was also evident in the presence of anthropogenic garbage in one scat and Black Bear hair in another single scat. Conversely, grasses were found in low volumes (1.3%) but high frequency (18%), suggesting that they are an important dietary supplement (Ciucci et al. 1996). Consumption of grasses and herbs by canids is intentional and likely a way to acquire vitamins or self-treat for intestinal parasites (Mech 1970).

Moose calves made up nearly a third of all Moose biomass consumed by wolves during our study, but caribou calves made up over two-thirds of all caribou biomass consumed, which is four times what would be expected based on estimated caribou density compared with Moose density in the area. Our study period overlapped ungulate calving season, when the young are most vulnerable and generally targeted by predators (Pimm 1974; Fritts and Mech 1981), but our results suggest that caribou calves, in particular, may have been targeted by wolves at this time. Latham et al. (2013) found low predation rates by wolves on caribou calves, but also greater selection by wolves of caribou-preferred habitats during calving season, which also suggested caribou calves were being specifically targeted. Results from scats collected in Alaska during May–June from wolf territories with low caribou and Moose densities showed 89.5% of total Moose consumption consisted of Moose calves, but only 15% of total caribou consumption consisted of caribou calves (Ballard et al. 1987); these results were based on 40 scats collected from a single denning site. Further complicating the risk to caribou, wolves are likely not the only predators on caribou calves, as Black Bears were common in our study area. In a similar highly managed landscape in the neighbouring province of Quebec, 57% of caribou calves were killed by Black Bears, while only 4.3% were killed by wolves (Pinard et al. 2012).

Because wolves adjust their search images and strategies to target primary prey, secondary prey are usually hunted only incidentally (Carbyn 1987). However, when landscape changes enhance habitat for primary prey and wolf populations increase in response, rates of incidental predation on secondary prey can also increase, and mortality rates can be highest where that prey’s densities are lowest (e.g., Bergerud 1988; Hayes et al. 2000; James et al. 2004).

Although caribou represented only 3.1% of the biomass consumed by wolves in early summer, given the typical low rate of increase of caribou populations, low density relative to wolf density in this system, incidental predation of caribou, and consumption of caribou calves, this may still have serious conservation implications when combined with other stressors (Wittmer et al. 2013; Beauchesne et al. 2014).

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**Note**

**Observations of Long-distance Post-release Dispersal by Reintroduced Bison (Bison bison)**

**THOMAS S. JUNG**<sup>1, 3</sup> and NICHOLAS C. LARTER<sup>2</sup>

<sup>1</sup>Department of Environment, Government of Yukon, P.O. Box 2703, Whitehorse, Yukon Y1A 2C6 Canada  
<sup>2</sup>Department of Environment and Natural Resources, Government of Northwest Territories, P.O. Box 240, Fort Simpson, Northwest Territories X0E 0N0 Canada  
<sup>3</sup>Corresponding author: thomas.jung@gov.yk.ca


Key objectives of wildlife reintroduction projects should include encouraging post-release site fidelity and high survival rates of founding individuals. Yet, few studies empirically evaluate these performance metrics for released individuals. Bison (Bison bison) restoration is receiving renewed interest by wildlife managers. To inform new bison reintroduction projects, we provide an observation of a 375-km (straight-line distance) post-release movement of three bison bulls from a release site in Yukon, Canada, in 1988. In addition, we note 250-km and 155-km post-release movements of bison in the Northwest Territories, Canada, in 1980 and 1998, respectively. These observations demonstrate the dispersal ability of bison encountering new environments. Wildlife managers planning for new bison reintroductions should consider means to enhance post-release site fidelity to limit long-distance dispersal and mortality and maximize initial population growth.

**Key Words:** Bison; Bison bison; dispersal; movements; post-release; reintroduction; Yukon

The universal goal of reintroduction projects is to establish a viable population in the wild. As such, key objectives should be to encourage post-release site fidelity and high survival rates of founding individuals. Field studies (e.g., Spinola et al. 2008; Ryckman et al. 2009; Yott et al. 2011) and simulation modeling (Mihoub et al. 2011) have both demonstrated that post-release survival is negatively correlated with dispersal distance for species capable of long-distance movements. Banks et al. (2002) found the opposite for species with limited dispersal ability. For species with high dispersal ability, ensuring post-release site fidelity may be challenging because founding individuals lack experience with their new environment (Stamps and Swaisgood 2007) and lack resident conspecifics to encourage social attraction to a new range (Mihoub et al. 2011). A primary method used to increase post-release site fidelity is a soft release, where individuals are temporarily held in an in situ enclosure before release, in an effort to acclimatize, familiarize, and bond them to their new range. In contrast, a hard release entails releasing individuals directly onto the landscape.

Here, we report an observation of long-distance post-release dispersal among reintroduced bison (Bison bison) of the Aishihik population (Jung et al. 2015a,b) that were soft released in Yukon, Canada, during 1988–1993, and note other occurrences from the adjacent Nahanni population, which were hard released in 1980 and 1998 (Larter and Allaire 2007).

Most bison reintroductions occurred during the 1980s and early 1990s; however, there is currently renewed interest in further restoring the species to their native range (Freese et al. 2007; Sanderson et al. 2008). For example, bison were reintroduced to Alaska in March 2015 (C. T. Seaton, personal communication) and Banff National Park in February 2017 (Steenweg et al. 2016; K. Heuer, personal communication). As such, historical observations of long-distance post-release dispersal may be informative for wildlife managers working on, or planning, the establishment of new bison populations.

On 17 March 1988, 20 adult bison (11 male, 9 female) were released from an enclosure 55 km west of Carmacks, Yukon, Canada (62.089°N, 136.289°W), where they had been held in situ since they were yearlings (1 year old in 1984) to acclimatize to local environmental conditions. This was the first release of bison into southwestern Yukon and constituted the founding of the Aishihik population (Jung et al. 2015a,b). Included in the inaugural release of Aishihik bison were three adult (5 year old) male bulls that were each equipped with a VHF radio-collar (Telomics, Mesa, Arizona, USA) and an individually numbered yellow ear tag (#82, #83, and #85). Their relatedness was unknown.

On 11 May 1988, the three bulls were observed together in an alpine area during an aerial telemetry flight, about 45 km west of their release site (Figure 1; P. J. Merchant, personal communication). The bulls were next seen together on 20 June 1988 about 20 km south of Beaver Creek, Yukon, on the verge of the Alaska Highway. This movement was approximately 140 km northwest of their last known location. This was the last record of #85, which was rumoured to have been killed illegally (D. R. Drummond, personal communication). During the winter of 1988–1989 the remaining two bulls, recognizable from their ear tags, were ob-
Although not as well documented, similar long-distance post-release dispersals of bison from the Nahanni population apparently occurred in 1980 and 1998. In 1980, eight of 28 bison released to found the population reputedly dispersed from the release site near Nahanni Butte, Northwest Territories, southward to near Fort Nelson, British Columbia—a distance of approximately 250 km (Harper et al. 2000). In 1985, caribou harvesters from Trout Lake, Northwest Territories, came across tracks from what were believed to be bison on a winter road about 150 km east of the 1980 release site (Larter and Allaire 2007). In April 1998, 59 bison were released near Fort Liard, Northwest Territories, to augment the small Nahanni population, and 17 of these 59 animals also dispersed to near Fort Nelson, British Columbia, after release—a distance of approximately 155 km (Larter and Allaire 2007). The 1980 initiative was a hard release; that in 1998 was meant to be a soft release to reduce the potential for the long-distance dispersal observed in 1980, but the animals escaped from the pen shortly after arrival. The fate of these long-distance dispersing bison is unknown.

These observations are of value because they point to the extraordinary dispersal ability of post-release bison. Bison may be nomadic and, when they have not yet established their range, they may disperse to areas not anticipated by wildlife managers. As remarkable as maximum recorded post-release dispersal distances of 375 km and 250 km for Aishihik and Nahanni bison may be, this behaviour is not unique to bison. For example, Yott et al. (2011) documented a maximum post-release dispersal distance of 142 km for reintroduced Elk (Cervus canadensis) in Ontario and reported other incidents involving reintroduced Elk apparently dispersing more than 300 km in Ontario-Quebec, and over 600 km in Alberta.

In addition, these observations emphasize that long-distance dispersal is risky (Bartoń et al. 2012; Jung 2017) and may result in losses that may be costly to the viability of small, reintroduced populations. Similarly, Yott et al. (2011) reported that long-distance dispersal by post-release Elk was also associated with high mortality rates, which may contribute to slow population growth. Although only a few individuals may make extreme post-release dispersals, their impact on the growth of founding populations may be pronounced. For Nahanni bison, the functional loss of eight of the founding 28 individuals likely created a lag in growth of the new population (Larter and Allaire 2007). However, long-distance dispersal is important for the long-term viability of reintroduced populations because it may facilitate range expansion into vacant habitats (Larter et al. 2000; Jung 2017) and gene flow among neighbouring populations.

In conclusion, anticipated bison restoration projects (e.g., Freese et al. 2007; Sanderson et al. 2008; Steenweg et al. 2016) should consider the post-release dis-

![Figure 1. Release site (closed square), immediate post-release movements (solid lines with arrows), and subsequent translocation (dashed line) of three, then two, adult bison (Bison bison) bulls in Yukon and Alaska, from March 1988 to September 1989.](image-url)
persal capability of bison and plan accordingly, partic-
ularly where dispersing bison may conflict with people
and compromise reintroduction objectives. As suggest-
ed for Elk, wildlife managers planning bison reintro-
ductions should consider means to enhance post-release
site fidelity to limit long-distance dispersal and mor-
tality and maximize initial population growth (Yott et
suggested that post-release site fidelity may be im-
proved for species with long-distance dispersal ability
by an extended conditioning period before release (i.e.,
soft releases). Post-release conditioning, such as supple-
mental feeding over the first year or so, may also help to
bond animals to a new range. even with efforts to pre-
vent long-distance dispersal, managers should be pre-
pared with protocols in place to address such move-
ments and the conflicts with humans that may ensue
when bison move into areas where they are not wanted
(Clark et al. 2016; Jung 2017). Finally, to help improve
the science of reintroduction biology (Seddon et al.
2007; Armstrong and Seddon 2008), projects involving
the release of bison onto the landscape should strive to
learn more about the relationship between post-release
dispersal distances, survival, and initial population
growth.

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O bservations of Notable Parental Behaviours of Northern Spotted Owls (*Strix occidentalis caurina*)

JESSE M. ALSTON 1,2,6, JANET E. MILLARD 1, JESSICA A. RICK 1,3,4,5, BRANDON W. HUSBY 1, and LAUREL A. MUNDY 1

1Okanogan-Wenatchee National Forest, United States Forest Service, United States Department of Agriculture, 600 Sherbourne Street, Leavenworth, Washington 98826 USA
2Department of Zoology and Physiology, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA
3Biodiversity Institute, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA
4Department of Botany, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA
5Program in Ecology, University of Wyoming, 1000 E University Avenue, Laramie, Wyoming 82071 USA
6Corresponding author: jalston@uwyo.edu

Northern Spotted Owl (*Strix occidentalis caurina*) is a medium-sized forest owl of conservation concern in the Pacific Northwest of North America. We report two sightings of previously unreported parental behaviour: a Northern Spotted Owl feeding avian nestlings to its young and a Northern Spotted Owl defending its fledgling against a Black Bear (*Ursus americanus*). Further research may be warranted on the influence of brood size and habitat quality on dietary breadth. Although Black Bears have not been previously documented as Northern Spotted Owl predators, we suggest that they should be considered potential predators of nestling and fledgling owls.

Key Words: Nest predation; nest defense; diet; Northern Spotted Owl; *Strix occidentalis caurina*; Black Bear; *Ursus americanus*

Northern Spotted Owl (*Strix occidentalis caurina*) is a medium-sized owl native to western portions of northern California, Oregon, Washington, and southern British Columbia. It primarily inhabits mature forests with complex canopy structure (Forsman *et al.* 1984, 2015; LaHaye 1988; Solis and Gutierrez 1990) and preys primarily on medium-sized nocturnal rodents, such as Bushy-tailed Woodrats (*Neotoma cinerea*), Northern Flying Squirrels (*Glaucomys sabrinus*), and Red Tree Voles (*Arborimus longicaudus*; Thomas *et al.* 1990; Forsman *et al.* 2004).

In the United States, Northern Spotted Owl has been listed as “threatened” under the *Endangered Species Act* since 1990, largely because of habitat loss, and it is currently under review for increased protection because of competition with invasive Barred Owls (*Strix varia*) and other emerging threats, including disease and climate change (USFWS 2015). It has been listed as “enangered” since 2000 (COSEWIC 2008) under Canada’s *Species at Risk Act* (SARA Registry 2017) for the same reasons. United States federal agencies conduct regular monitoring of Northern Spotted Owls in areas that may be altered by management activity under a protocol established by the United States Fish and Wildlife Service (USFWS 2012). In this note, we report two observations of previously unreported parental behaviours recorded during sanctioned nest monitoring activities: a Northern Spotted Owl feeding avian nestlings to its young and a Northern Spotted Owl defending its fledgling against a Black Bear (*Ursus americanus*).

On 26 June 2014, we observed a Northern Spotted Owl feeding avian nestlings to its young. The observation occurred when we followed an adult male Northern Spotted Owl to an active nest site about 15 km south of Leavenworth, Washington, on the Wenatchee River Ranger District of Okanogan-Wenatchee National Forest. Several passerines were mobbing the owl when we located it at 1925. At 1940, the owl took a mouse from us and led us to its mate and two fledglings. From 1940 to 2045, the pair of owls took four mice from us, delivering two of them to the fledglings, eating one, and caching the other. The male owl also brought two avian nestlings to the fledglings from outside our field of view (one at 2006, the other at 2020). The fledglings had difficulty eating the mice — repeatedly dropping them and requiring piece-by-piece feeding by the female after an hour spent attempting to eat them whole on their own — but had no difficulty eating the nestlings. This could indicate familiarity with avian prey, but it could also simply be a function of the nestlings’ size and frailty compared with mice.

The nestlings could have been retrieved from a cache or taken directly from an active nest, but they were not alive by the time they entered our view. They appeared to be in an early stage of development. Neither nestling had yet developed feathers. Both were approximately
the size of the mice we were using to document nest status. Based on the vegetation composition of the nest stand, the size of the nestlings, and the bird songs we have heard in the area, we believe nestlings may have been American Robins (Turdus migratorius) or Hermit Thrushes (Catharus guttatus).

Northern Spotted Owls are known to feed on avian species, but these species make up only a small part of their diet: 1.4–2.8% (Hamer et al. 2001), 4.4–6.4% (Forsman et al. 2001), 4.4–5.6% (Forsman et al. 2004). Researchers have witnessed Northern Spotted Owls feeding on avian species (S. G. Sovern, personal communication), but, to our knowledge, Northern Spotted Owl predation on avian nestlings had not been directly observed previously. This observation indicates that avian nestlings, which are much more easily captured than adult birds, make up some portion of these owls’ avian prey and are potentially a seasonally valuable resource. It is impossible to know from one observation whether this was opportunistic or selective behaviour. In either case, however, broadening of the owls’ diet may have been driven in part by the increased energetic needs of owls with two nearly fledged owlets. Further research on the role of brood size in diet selection may be warranted.

This behaviour may have been driven by marginal availability of preferred prey in the breeding territory. Northern Spotted Owls have been found to prey predominantly on Bushy-tailed Woodrats and Northern Flying Squirrels in the eastern Washington Cascades (Forsman et al. 2001). In this area, woodrat abundance has been found to correlate well with the abundance of large snags, mistletoe brooms, and downed logs (Lehmkuhl et al. 2006a), while flying squirrel abundance has been found to correlate positively with canopy cover (Lehmkuhl et al. 2006b). We believe that this breeding territory, which has relatively little canopy or ground structure and a fairly open canopy, is unlikely to support high densities of either of these prey species. Despite the apparent unsuitability as woodrat and flying squirrel habitat, this breeding territory has been occupied (often with successful reproduction) for over a decade, indicating that either some unaccounted-for factor allows for continued high woodrat and/or flying squirrel densities or that the owls in this territory rely on other prey species.

On 7 June 2016, while visiting a different active nest site in the same area, we observed a female Northern Spotted Owl defending its fledgling from a Black Bear. We arrived at the nest site and located a fledgling owl at 2010. It was in a large Ponderosa Pine (Pinus ponderosa Douglas ex Lawson & C. Lawson) within 30 m of the nest, at roughly nest level (15 m above the ground). Although it was no longer in the nest, it appeared that it could not yet fly. An adult male owl arrived at 2013, and an adult female arrived shortly thereafter. At 2040, before either of the adult owls took a mouse, a Black Bear walked through the drainage below the nest tree. The female immediately flew down toward the bear and dove to harass it. The bear continued moving down the drainage and past the nest tree to an opening downhill of it, where the bear spotted us and ran out of the stand. Although brush obscured our view of both the owl and the bear in the drainage, we saw the owl dive at the bear at least once. The female followed the bear down the drainage, roosting low enough to continue harassing the bear. She returned to the nest area only after the bear had departed the area.

Nest defense by Northern Spotted Owls has been documented in response to humans climbing nest trees or approaching owlets that had left the nest but could not fly, as well as against Common Ravens (Corvus corax) and Cooper’s Hawks (Accipiter cooperii; Forsman et al. 1984). Researchers have also witnessed defensive behaviour against domestic dogs (J. Reid and D. Herter, personal communication) and bobcats (S. Greml, personal communication). We found no evidence in the literature or through communication with other Northern Spotted Owl researchers that Black Bears are Northern Spotted Owl nest predators, but the female’s aggressive behaviour indicates that she recognized the bear as a potential predator, and Black Bears are known predators of other young raptors (McKelvey and Smith 1979) and cavity-nesting birds (Fisher and Wiebe 2006; Tozer et al. 2009), even accounting for about 10% of predation events in one study of cavity-nest predation in Washington (Kozma 2011). Large, vocal owlets with limited mobility could certainly be attractive prey for foraging Black Bears. Although we believe predation on nestling and fledgling Northern Spotted Owls by Black Bears is likely uncommon, our observation coupled with known predation on the young of other raptors and cavity nesters suggests that Black Bears should, nevertheless, be considered potential predators of these young owls.

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Northern Snakes Appear Much More Abundant in Old Fields than in Forests

FRANCISCO RETAMAL DIAZ1, 2, 3 and GABRIEL BLOUIN-DEMERS1

1Department of Biology, University of Ottawa, 30 Marie-Curie, Ottawa, Ontario K1N 6N5 Canada
2Current address: Department of Wood and Forest Sciences, Laval University, 2405 Terrasse Street, Québec, Quebec G1V 0A6 Canada
3Corresponding author: francisco.retamal-diaz.1@ulaval.ca


Temperature is one of the most important factors regulating habitat selection by ectotherms. Through behavioural thermoregulation, reptiles maintain preferred body temperatures and thereby maximize fitness. At northern latitudes, small colubrids appear to use forest habitat rarely because of thermal constraints. In cool environments, open habitats such as old fields offer more favourable thermal conditions than forest. We studied two northern colubrid snakes, Red-bellied Snake (Storeria occipitomaculata) and Common Gartersnake (Thamnophis sirtalis), in Gatineau Park, Quebec, Canada, to test the hypothesis that small northern snakes are more abundant in open than in closed habitats because open habitats provide better opportunities for thermoregulation. Snakes were sampled using large arrays of tin and plywood coverboards. Snakes were indeed much more abundant in old fields than in forest, and fields offered more favourable thermal conditions. Most snakes were captured in spring and summer (May to August) when temperatures were highest. Storeria occipitomaculata preferred tin over plywood coverboards. We confirmed an apparent strong preference for open habitats in northern snakes.

Key Words: Habitat selection; behavioural thermoregulation; Common Gartersnake; Thamnophis sirtalis; Red-bellied Snake; Storeria occipitomaculata; population density; Gatineau Park

Introduction

Species face different environmental conditions across their geographic ranges, and these environmental conditions limit their distribution and abundance. The abundant centre hypothesis states that a species’ abundance is highest at the centre of its geographic distribution and gradually decreases toward the edges (Brown 1984; Sagarin et al. 2006). At higher latitudes, abiotic factors, such as temperature and sunlight, are believed to limit abundance and distribution of terrestrial species, whereas at lower latitudes biotic factors are believed to be the main limit (Dobzhansky 1950; MacArthur 1972).

The spatial distribution of reptiles is influenced by numerous factors, such as prey density (Madsen and Shine 1996), availability of hibernation sites (Reinert and Kodrich 1982), and proximity to retreat sites (Martino et al. 2011). For the Squamata, temperature is considered to be one of the most important factors regulating habitat selection (Reinert 1993). In ectothermic animals, the necessity to maintain an adequate body temperature is vital for physiological and developmental processes (Peterson et al. 1993). Indeed, body temperature affects physiological, reproductive, and ecological performance (Huey 1982). By adjusting microhabitat selection and timing of activity, ectotherms can thermoregulate effectively (Huey et al. 1989; Krohmer 1989).

In northern latitudes, colubrids appear to use forest rarely, probably because of thermal constraints (Chandler and Gregory 1995; Halliday and Blouin-Demers 2016). Black Ratsnakes (Elaphe obsoleta) prefer edges of open habitats because they provide the best opportunities for thermoregulation (Blouin-Demers and Wehrenhead 2001). Milksnakes (Lampropeltis triangulum) also prefer open habitats with high thermal quality (Row and Blouin-Demers 2006a). Habitats with high thermal quality have a minimal difference between the operative environmental temperature and the preferred body temperature of individuals. Because forest vegetation is dense and does not allow sufficient exposure to sunlight, snakes are expected to use open habitats so that they can bask and achieve preferred body temperatures (Row and Blouin-Demers 2006b).

We tested the hypothesis that small northern snakes are more abundant in open than in closed habitats because open habitats provide better opportunities for thermoregulation. More specifically, we tested the prediction that the number of captures of Common Gartersnakes (Thamnophis sirtalis) and Red-bellied Snakes (Storeria occipitomaculata), both small northern snakes, should be significantly higher in old fields than in forest. We monitored the abundance of small snakes in arrays of coverboards in old fields and in forest in Gatineau Park, Quebec, during their active season in 2015.

Coverboards are effective for sampling snakes (Grant et al. 1992; Houze and Chandler 2002; Ryan et al. 2002), particularly cryptic species (Halliday and Blouin-Demers 2015). Coverboards of different sizes (Hecnar and Hecnar 2011) and materials (Engelsoft and Ovaska 2000) can attract different species based on their microhabitat preferences (Hyde and Simons 2001). Coverboards can provide protection from predation as well as thermal benefits (Cooper et al. 1999; Goldsbrough et al. 2006). Coverboards are often made of tin or plywood.
Tin was more effective than plywood for sampling Common Gartersnakes, Western Terrestrial Garter-snakes (Thamnophis elegans), and Sharp-tailed Snakes (Contia tenuis) in British-Columbia (Engelstoft and Ovaska 2000). Coverboards are preferred over traps because they are economical and safe (Ryan et al. 2002). A secondary objective of our study was to quantify the efficacy of tin and plywood coverboards at attracting small snakes.

**Methods**

We sampled snakes at four sites in Gatineau Park (45.50°N, 76.00°W), Quebec, in summer 2015. All sites were less than 25 km apart. Although Red-bellied Snake, Common Gartersnake, Smooth Greensnake (Lioclithospermum vernalis), Ring-necked Snake (Diadophis punctatus), and Milksnake (Lampropeltis triangulum) were all captured, we only obtained sufficient captures for analysis of Common Gartersnake and Red-bellied Snake. At each of the four sites, we set up 200-m transects with pairs of coverboards (one roofing tin, one ½-inch [2-cm] plywood, both 90 × 60 cm) installed every 10 m, for a total of 320 coverboards. At each site, the transects were parallel to and 50 m from the edge between old field and forest, one transect in the field and one transect in the forest. The plant community in the old fields consisted mainly of Aster sp., Rhamnus sp., Asclepias sp., Cirsium sp., and Poa spp. All forests were mostly composed of White Birch (Betula papyrifera Marshall), Sugar Maple (Acer saccharum Marshall), and American Beech (Fagus grandifolia Ehrhart). Detailed site descriptions and photographs are available in Appendix S1.

We sampled snakes weekly from 14 May to 16 November 2015. The four sites were visited on the same sunny day between 0800 and 1800 with a weekly rotation in the order in which sites were visited so that they were visited at different times of day. Snakes were hand captured from under the coverboards and each individual was marked by branding one ventral scale with a medical cauterity unit (Bovie Aaron Low-Temp Reusable Cautery Unit, Clearwater, Florida, USA; Winne et al. 2006). The date, time, air temperature (at about waist height), temperature under the coverboard, coverboard type (tin or plywood), and habitat type (forest or old field) were recorded for each capture. Individuals were then released immediately at their point of capture. We placed 18 temperature data loggers (iButton thermometer, model DS1921L, Dallas, Sunnyvale, California, USA) under coverboards of both materials and in both habitats at the four sites. The loggers were programmed to measure temperature on the hour between 0800 and 1800 for two periods: from 12 May to 30 July and from 10 September to 23 October.

For both species, we compared the total number of snakes captured (including recaptures) in forest with the total number of snakes captured under tin with those captured under plywood using generalized linear mixed-effects models with a Poisson distribution in R (R Core Team 2012; package lme4; function glmer; family Poisson; Bates et al. 2012). We used a Poisson distribution because the data were zero inflated. Month, habitat, time of capture, ambient temperature, coverboard material, and all interactions were fixed effects, and site identity was a random effect. We compared maximum temperature under tin and plywood coverboards in forest and old field using a linear mixed-effects model in R (package lme; function lme; Pinheiro et al. 2012). Habitat, cover type, and all interactions were fixed effects and site identity was a random effect.

**Results**

We captured 353 snakes (including recaptures) of five species during the 25 weekly visits. Captures remained constant from May until late August and then decreased slowly until November. Common Garter-snakes (n = 90) and Red-bellied Snakes (n = 242) were the two most abundant species. Rarer species included Smooth Greensnake (n = 2), Ring-necked Snake (n = 2), and Milksnake (n = 17). Total unique captures comprised two Ring-necked Snakes, two Smooth Greensnakes, 13 Milksnakes, 57 Common Gartersnakes, and 171 Red-bellied Snakes.

Controlling for the effects of month, site, and time of capture, we captured significantly more Common Gartersnakes (z = 4.47, P < 0.001) and Red-bellied Snakes (z = 9.196, P < 0.001) in the field than in forest (Figure 1). In fact, only one Common Gartersnake and seven Red-bellied Snakes were captured in forest. We also captured more snakes in mid-season (June to July) than in early (May) and in late season (September to November): Common Garter snake: z = 2.42, P = 0.016; Red-bellied Snake: z = 2.875, P = 0.004 (Figure 2). Whereas Common Gartersnakes did not seem to have a preference between tin and plywood coverboards (z = 0.11, P = 0.91; Figure 1), we captured more Red-bellied Snakes under tin than plywood coverboards (z = 5.78, P < 0.001; Figure 1).

Temperature did not vary significantly between plywood and tin coverboards (t = 0.16, P = 0.87; Figure 3). Temperature varied significantly between coverboards in forest and those in fields only during the warmer months (May, June, and July). During these months, temperatures under coverboards in fields were on average 8.8°C higher than under coverboards in forest (t = 3.46, P < 0.001; Figure 3). Coverboards in forests never warmed to the preferred temperature range of either Red-bellied Snakes (about 26.5°C; Brattstrom 1965) or Common Gartersnakes (24.5°–30.7°C, Peterson et al. 1987; 25.5 ± 0.4°C [SE] to 27.4 ± 0.3°C, Halliday and Blouin-Demers 2016; Figure 3).
Figure 1. Number of captures of Red-bellied Snakes (*Storeria occipitomaculata*; *n* = 242) and Common Gartersnakes (*Thamnophis sirtalis*; *n* = 90) under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 14 May to 16 November 2015. Each bar represents mean daily captures across four study sites. In each graph, means with the same letter are not significantly different, and error bars represent the standard error.

Figure 2. Number of captures by month of Red-bellied Snakes (*Storeria occipitomaculata*; *n* = 242) under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 14 May to 16 November 2015. Each bar represents mean monthly captures across all four study sites. In each graph, means with the same letter are not significantly different, and error bars represent the standard error.
Discussion

Both Common Gartersnakes and Red-bellied Snakes strongly preferred old field over forests, a pattern also observed in previous studies of other snakes (Charland and Gregory 1995; Row and Blouin-Demers 2006b; Kapfer et al. 2008; Lagory et al. 2009; Halliday and Blouin-Demers 2016). Old fields offered significantly higher temperatures than forests, particularly in May, June, and July. These patterns are consistent with the hypothesis that northern snakes are more abundant in open habitats because of their high thermal quality. Halliday and Blouin-Demers (2016) demonstrated that Common Gartersnakes prefer open habitats and that open habitats offer the best thermal conditions and the greatest fitness in terms of reproductive output and growth rate. Similarly, Black Ratsnakes use open habitats to increase fitness (measured by locomotor performance; Blouin-Demers and Weatherhead 2008). It is important to note that, although open habitats are preferred by many snake species, forest can still be important. For example, Eastern Massasauga Rattlesnakes (Sistrurus catenatus) prefer forest for hibernation (Harvey and Weatherhead 2006).

Most Common Gartersnakes and Red-bellied Snakes were captured from May to August with a peak in June and July, which corresponds with the highest maximum temperatures. Because body temperature directly affects physiological, reproductive, and ecological performance (Huey 1982), it is likely that the high number of captures during warmer months results from favourable thermal conditions. From May to August, high solar radiation heated the coverboards in old fields rendering them useful for behavioural thermoregulation.

It is worth noting that this study took place in a challenging thermal environment for ectotherms, where thermal quality is expected to be a strong predictor of habitat selection. In more southern and tropical locations, snakes often use forest (Luiselli and Capizzi 1997; Baxley et al. 2011; Steen et al. 2012), suggesting that thermal quality may not be a strong predictor of habitat selection in warmer areas. In Illinois, a less thermally challenging environment, Black Ratsnakes use forest more and forest edges less than populations of the same species in Ontario (Carfagno and Weatherhead 2006). Similarly, Five-lined Skink (Plestiodon fasciatus) uses open habitats in the northern part of its...
range (Quirt et al. 2006; Brazeau 2016), whereas it is found in forests in the southern part of its range (Watson and Gough 2012). Therefore, although northern populations of species, such as Common Gartersnake and Red-bellied Snake, prefer open habitats because of their thermal needs, southern populations of the same species may prefer different habitats for other reasons, such as prey density (Madsen and Shine 1996; Wasko and Sasa 2012).

Another possible explanation for the preference of northern snakes for open habitats is that coverboards act as refuges reducing predation risk associated with open habitats. Cover serves both as a resting place to avoid detection (Webb and Whiting 2005) and as a refuge for individuals that have been detected in open habitats (Martin and Lopez 2015). In fact, small snakes are found more frequently under cover in open habitats than large snakes, most likely because small snakes use cover as protection from predators (Gregory and Tuttle 2016).

Tin was preferred over plywood coverboards by Red-bellied Snakes, as also observed in some other snakes (Engelstoft and Ovaska 2000; Halliday and Blouin-Demers 2015). Although Engelstoft and Ovaska (2000) believed this was because tin is a better thermal conductor than plywood, we did not detect a significant difference between temperatures under tin and plywood coverboards. Furthermore, Common Gartersnakes did not prefer tin coverboards, but this may be a result of fewer captures (90 Common Gartersnakes versus 242 Red-bellied Snakes) and, thus, less power to detect a preference. The intriguing preference for tin over plywood coverboards in several snakes warrants further study.

In conclusion, Common Gartersnakes and Red-bellied Snakes were more abundant in old fields than in forest, confirming the preference of northern snakes for open habitats, likely because such habitats facilitate behavioural thermoregulation. However, an important caveat must be made: snakes were sampled exclusively with coverboards, and coverboards may be more attractive to snakes in open habitats than in closed habitats. For instance, we showed that coverboards in fields became warmer than coverboards in forest because they received more solar radiation. In fact, coverboards in forest never reached the preferred body temperature range of small northern snakes. Therefore, it is possible that coverboards in fields are more attractive to snakes because of their superior thermal attributes and, thus, are used more than coverboards in forest. If this is the case, the number of captures under coverboards may not be an accurate reflection of the relative density of snakes in the two habitats. This potential bias clearly deserves further study using different sampling methods.

Acknowledgements
We are grateful to William Halliday and James Paterson for their help with analyses. We are indebted to Caroline Gagné of the Nature Conservancy of Canada, to Isabelle Beaudoin-Roy, Catherine Verreault, and Joce-lyne Jacob of the National Capital Commission, and to the Natural Sciences and Engineering Research Council of Canada for financial support. We thank Audrey Paquette and Mélanie Routh of the National Capital Commission for providing detailed descriptions of the study sites. We also thank Simon Pelletier, Pierre-André Bernier, and Sylvain Giguère for their help in setting up the coverboards.

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**SUPPLEMENTARY MATERIAL:**

**Appendix S1:** Detailed descriptions of the study sites, provided by Audrey Paquette and Mélanie Routh under the supervision of Jocelyne Jacob, National Capital Commission, Gatineau Park.
Note

Side to Side Swaying as a Defensive Behaviour in the Dekay’s Brownsnake (*Storeria dekayi*)

DAVID L. LeGROS

Algonquin Provincial Park, P.O. Box 219, Whitney, Ontario K0J 2M0 Canada; e-mail: david.legros@ontario.ca


When discovered by humans, Dekay’s Brownsnake (*Storeria dekayi*) exhibits a range of defensive behaviours that are likely used to cope with a variety of potential predators. After being handled, a brownsnake at Rondeau Provincial Park, Ontario, Canada, was observed to coil the anterior portion of its body and to sway the coil from side to side as it attempted to flee. Swaying has rarely been documented in Dekay’s Brownsnake and may be a tactic to distract or confuse a visually oriented predator.

Key Words: Dekay’s Brownsnake; Northern Brownsnake; *Storeria dekayi*; defensive behaviour; swaying; Rondeau Provincial Park; Ontario

Dekay’s Brown snake (*Storeria dekayi* (Holbrook, 1836)), is a small, terrestrial snake found throughout much of eastern North America, although its Canadian distribution is limited to southern and central Ontario and extreme southwestern Quebec (Cook 1984; Rowell 2012). Dekay’s Brown snake may be common to abundant in appropriate habitat (Catling and Freedman 1980), such as meadows and forest edges, where it preys on invertebrates, primarily terrestrial snails, slugs, and worms (Freedman and Catling 1978; Ernst and Ernst 2003; Rowell 2012; Gray 2014a). The small size of this species makes it vulnerable to predation by a variety of wildlife, including mammals, birds, other snakes, and even arachnids (Bittner 2003; Ernst and Ernst 2003).

When faced with a predator, Dekay’s Brownsnake may respond to both visual and tactile stimuli by demonstrating a suite of defensive postures and behaviours (Ernst and Ernst 2003; Gray 2014b, 2015). Here, I present an observation of defensive behaviour that combines the more commonly observed dorso-ventral flattening with swaying of the body, as described by Gray (2014b), in a free-ranging, surface-active Dekay’s Brown snake, near the northern limit of the species’ range. Some defensive behaviours may vary geographically or by population (B. S. Gray, personal communication, 2016), with Ontario’s Dekay’s Brownsnakes possibly being an intergrade between two subspecies: *S. d. dekayi* and *S. d. wrightorum* (Rowell 2012).

On 20 May 2016, at approximately 1800, I encountered an adult female Dekay’s Brown snake, about 25 cm total length, crossing the Marsh Trail at Rondeau Provincial Park, southwestern Ontario (42°17’N, 81°51’W). Although I did not record temperature at the time of the observation, the maximum daily temperature was 16.7°C, and approximately 15.9°C at 1800 (Environment Canada 2016). As I approached the snake, intending to remove it from the trail, it remained still and flattened its body dorso-ventrally. When grasped, the snake voided the contents of its cloaca. I placed the snake back on the trail, fully outstretched, to take photographs. After a minute, it began to exhibit the well documented defensive behaviour (Gray 2014b,c, 2015) of coiling the anterior portion of its body to form a large, open loop flattening its body dorso-ventrally to reveal the checkered pattern on the expanded skin of the coil (Figure 1).

Soon afterward, I observed a novel behaviour: the snake began to move forward while maintaining the defensive position, slowly swaying the coil from side to side, approximately 1 cm to the left and right, slightly raised over the ground. The snake was allowed to escape after photos were taken.

Many small natricine snakes exhibit a great variety of anti-predator responses, often a greater repertoire than some larger snakes (Gray 2015; Gregory 2016). In the case of Dekay’s Brown snake, a wide range of responses to predation attempts has been documented. These include non-intimidating defensive behaviours, such as fleeing, head-hiding, remaining still, and smearing cloacal contents on its own body or on the captor; escalated responses, such as biting, open- and closed-mouth striking; and defensive posturing, such as creating an S-shaped curve with the anterior portion of the body and dorso-ventral flattening of the body, presumably to appear larger (Gray 2015). Defensive reactions of Dekay’s Brownsnakes may include a combination of these behaviours and postures (Ernst and Ernst 2003; Rowell 2012; Gray 2014c, 2015). Tactile contact with the animal is required to elicit many defensive responses (Gray 2014b, 2015).

The brown snake I observed displayed several typical and well-documented responses to discovery (Gray 2014b, 2015). However, my observation of the snake slowly moving forward in an attempt to flee and swaying an anterior coil appears to have not been previously...
reported. Gray (2014b; personal communication, 2016) mentions the swaying behaviour of an exceptionally cold (−0.6°C) Dekay’s Brownsnake that was uncoiled and restrained in hand. Snakes that exhibit a variety of responses to potential predators may be limited by suboptimal temperatures to stationary responses, such as gaping, death feigning, and flattening (Keogh and DeSerto 1994; Gerald 2008; Gray 2015). The slow crawl, featuring the defensive S-curve of the Dekay’s Brownsnake in my observation may have been related to the moderate ambient temperature (roughly 16°C), as snakes that are warmer may flee from predators faster, limiting their time of exposure to a threat (Gray 2015).

Dekay’s Brownsnakes exhibit bimodal seasonal activity; thus, encounters with people peak in spring and autumn and snakes may be observed in the open during the day in these seasons (Rowell 2012; Gray 2014a). Presumably, many snakes tend to avoid open areas and potential exposure to predators; however, they may respond either by moving quickly to reduce exposure time or by moving very slowly to draw minimal attention to themselves (Gregory 2016). Because of the secretive nature of Dekay’s Brownsnake, most formal research on this species is conducted by sampling cover objects (Hecnar and Hecnar 2010; Gray 2014a,b,c, 2015). As a result, snakes that are encountered are typically under cover and not active on the surface, allowing few opportunities to study their defensive behaviour.

Small snakes that are actively moving during the day, such as Dekay’s Brownsnake, are exposed to many kinds of visual predators that forage in the leaf litter. I speculate that ground-foraging birds might be the predators that elicit the behaviour I observed. Ernst and Ernst (2003) cite American Robin (Turdus migratorius) and Brown Thrasher (Toxostoma rufum) as confirmed predators of this snake, and Blue Jay (Cyanocitta cristata) has also been observed attempting to prey on this species (B. S. Gray, personal communication, 2016). My observation coincided with the end of spring migration of birds through Rondeau Provincial Park, and both American Robins and Brown Thrashers were abundant, both as migrants and residents in late May (eBird 2016; personal observation, 2016). Many birds prefer small or juvenile snakes to large or adult individuals (Bittner 2003), and Dekay’s Brownsnake is rather small and inoffensive. Swaying possibly serves to confuse visual predators, such as birds, increasing time for escape. Swaying may also make it more difficult for a predator to strike accurately. Contrary to a swaying tail
display, which diverts attention away from vital organs and body parts (Greene 1997), swaying of the anterior region may draw attention to this vulnerable region, and, thus, the exact function of this display remains unclear. Despite the difficulty of studying the defensive behaviour of free-ranging snakes (Gray 2015; Gregory 2016), opportunistic field observations, such as this one, may contribute to our understanding of such behaviour.

Acknowledgements
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Psychrotolerant Microfungi Associated with Deer Mice (Peromyscus maniculatus) in a White-nose Syndrome Positive Bat Hibernaculum in Eastern Canada

KAREN J. VANDERWOLF1, 2, 3, 4, DAVID MALLOCH1, and DONALD F. MCALPINE1

1Department of Natural Science, New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5, Canada
2Canadian Wildlife Federation, 350 Michael Cowpland Drive, Kanata, Ontario K2M 2W1 Canada
3Current address: Department of Pathobiological Sciences, University of Wisconsin, 1656 Linden Drive, Madison, Wisconsin 53706 USA
4Corresponding author: kjsanderw@gmail.com


With the exception of recent work on bats, no reports on the fungi present on live mammals in underground habitats have been published. We cultured psychrotolerant fungi from the external surface and faeces of live Deer Mice (Peromyscus maniculatus), and from the intestinal contents of a single freshly killed P. maniculatus, overwintering in a white-nose syndrome positive bat hibernaculum and from adjacent forest in eastern Canada. A low diversity of psychrotolerant fungi was cultured from P. maniculatus compared with that found in previous studies of the mycoflora of bats and arthropods occupying bat hibernacula in the region. Although the grooming habits of P. maniculatus may reduce the accumulation of a diverse psychrotolerant fungal assemblage on their external surface, we demonstrate that active eutherian mammals in underground habitats can carry viable spores of psychrotolerant fungi, both externally and internally. Small rodents using cave habitats may also play a role in dispersing psychrotolerant fungi between caves and suitable low-temperature habitats (i.e., burrows) in adjacent forest.

Key Words: Pseudogymnoascus destructans; Deer Mouse; Peromyscus maniculatus; cave fungi; cave mycota; cold-tolerant fungi; fungal dispersal; white-nose syndrome

Introduction

Mammals introduce organic matter, including fungal spores, into underground habitats, where nesting material, food caches, scat, carcasses, and shed hair and skin serve as substrates for various fungi (Nelson and Smith 1976; Jurado et al. 2010). The introduction to North American caves and cave-like habitats (i.e., mines; hereafter we include such habitats under the generic term “caves”) of the psychrotolerant (cold-tolerant) fungus Pseudogymnoascus destructans, causative agent of the lethal bat disease, white-nose syndrome (WNS; Lorch et al. 2011), has prompted increased interest in the mycology of caves. However, with the exception of recent work focusing on bats (Johnson et al. 2013; Vanderwolf et al. 2013, 2016a; Lorch et al. 2015), no reports on the fungi present on live mammals in caves have been published. In addition, the literature on how psychrotolerant fungi might be dispersed from cave habitats is limited (Stephenson et al. 2007; Vanderwolf et al. 2016a, b).

Deer Mice (Peromyscus maniculatus Wagner, 1845) are a common and widespread North American small rodent that may reside in small numbers in caves, where available, during the winter (Trevor-Deutsch 1973). During the warmer months, this species disperses into surrounding woodland, staying relatively close to cave entrances in spring and early summer and ranging farther afield in late summer (Fenton 1970; Trevor-Deutsch 1973). Here we report on psychrotolerant fungi associated with overwintering P. maniculatus using cave habitat in eastern Canada, where overwintering bat populations were severely reduced after the 2011 arrival of the fungus Pseudogymnoascus destructans to the area (McAlpine et al. 2011). As a comparison, during the summer months, we also sampled fungi on mice from forest adjacent to this cave habitat.

Methods

Winter Sampling

Peromyscus maniculatus were live-trapped in Dorchester Mine, an abandoned copper mine and bat hibernaculum near Sackville, New Brunswick, 11–14 March 2014 (42 trap nights). Two trap sizes were used: 5.1 × 6.4 × 16.5 cm and 7.7 × 8.9 × 22.9 cm (H. B. Sherman Traps, Inc., Tallahassee, Florida, USA). All traps were soaked in fungicide and rinsed prior to sampling. Traps were baited with a mixture of peanut butter and oats, furnished with cotton nesting material, checked daily, and re-baited as required. Traps were placed on the floor and on ledges along the walls adjacent to a mouse nest (1–2 m above the floor; Figure 1A), approximately 45–80 m from the mine entrance. The temperature in Dorchester Mine was measured using ibuttons (model DS1920-F5, Maxim Integrated Products Inc., Sunny-
vale, California, USA) in the manner of Vanderwolf et al. (2012).

Each trapped mouse was transferred to a fresh plastic bag for swabbing by inverting the trap over the bag. Two swabs per mouse were taken using a new, sterile, dry, cotton-tipped applicator for each swab. The swabs were rubbed over the fur both dorsally and ventrally. After swabbing, the applicator was immediately streaked across the medium surface in a petri plate. Three diluting streaks were completed in the mine within 1 h of the initial streak, after which plates were sealed in situ with parafilm (Pechiney Plastic Packaging, Chicago, Illinois, USA). Two media types were inoculated for each mouse: dextrose–peptone–yeast extract agar (DPYA) and Sabouraud–dextrose agar (SDA), both of which were infused with the antibiotics chlortetracycline (30 mg/L) and streptomycin (30 mg/L). Mice were not directly handled or marked during any part of the procedure and were immediately released after sampling. One mouse was removed from the mine after swabbing of its external surface (New Brunswick Museum specimen 12946), euthanized using isoflurane, and the contents of its stomach, small intestine, and large intestine were spread on separate petri plates containing DPYA medium with no dilution.

Faeces produced by mice held in bags were transported to the lab for processing. Faeces (~3 pellets per mouse) were suspended in 100 mL of autoclaved water and vigorously shaken for 10 minutes. The sample was then serially diluted five times, with 10 mL of each successive solution mixed with 90 mL of water. For each of the five dilutions, plus the undiluted sample, 10 mL were spread over the surface of separate petri plates containing hardened DPYA medium.

**Summer Sampling**

On the night of 27 August 2014, mice were trapped with live traps (100 trap nights) baited with bird seed adjacent to the entrance of Dorchester Mine. All traps were soaked in fungicide and rinsed the day before use. Mice were processed using the methods described above, except that faeces and intestinal contents were not collected. Three mice were swabbed twice, with one swab inoculated on DPYA medium and the other on SDA medium. For all other mice, only one swab was taken and inoculated on DPYA medium because of contamination issues with the SDA medium.

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**Figure 1.** A. Deer Mouse (*Peromyscus maniculatus*) nesting material (a source and substrate for fungal spores) and a live trap in place on a wall ledge in Dorchester Mine near Sackville, New Brunswick. B. In winter, *P. maniculatus* were active in the dark zone on wall ledges and the floor of the mine. Photos: K. J. Vanderwolf.
**Fungal Culturing and Data Analysis**

In the laboratory, samples were incubated, inverted, in the dark at 7°C in a low-temperature incubator (Model 2015, VWR International, Mississauga, Ontario, Canada) to approximate the subterranean environment and target psychrotolerant fungi. Samples were monitored over four months until either no new cultures had appeared for three weeks, or the plate had become overgrown with hyphae. Once fungi began growing on the plates, each distinct colony was subcultured to a new plate. DPYA without oxgall and sodium propionate was used for maintaining pure cultures (Figure 2). Identifications were carried out by comparing the micro- and macro-morphological characteristics of the microfungi to those traits appearing in the taxonomic literature and compendia (Domsch et al. 2007; Seifert et al. 2011) and by comparing isolates to a reference collection of fungi assembled from previous studies in underground habitats in the region, which were identified using a mix of morphological and molecular methods (Vanderwolf et al. 2013, 2016a,b). Permanent desiccant-dried vouchers of the collected fungi are deposited in the New Brunswick Museum mycological collection (NBM numbers F-05152–05155, 05161, 05163–05169, 05246–05256, 05359, 05364–05370, 05394–05400, 05521, 05626).

The numbers of fungal taxa per mouse were not normally distributed and subsequently were square-root transformed. A two-sample t-test was used to compare the number of fungal taxa per mouse for winter mice versus summer mice using Minitab software (Minitab Inc., Pennsylvania State University, Pennsylvania, USA).

**Results**

**Winter Sampling**

Six *P. maniculatus* were captured (two per night) during three days of sampling in Dorchester Mine. Nine fungal taxa and one sterile morph were cultured from the fur of mice sampled in the mine, with a mean of 2.83 fungal taxa per individual (standard deviation [SD] 0.75, range 2–4, n = 6 mice). The second swab contributed 0.67 fungal taxa (SD 0.82, range 0–2) that were not detected with the first swab. The most common fungal taxa were *Pseudogymnoascus pannorum sensu lato* (100% of mice; this fungal taxon is polyphyletic, S. Hambleton, personal communication to K.J.V.) and *Penicillium* spp. (50%), while all other taxa were isolated from a single mouse each (Table 1). Most fungal taxa were obtained from the undiluted sample and the first dilution; the fifth dilution produced no cultures. Seven fungal taxa plus one sterile morph were isolated from mouse gut contents.

The mean temperature in Dorchester Mine during the sampling period, March 2014, was −0.98°C (SD 1.24) in the twilight zone and 6.63°C (SD 0.00) in the dark zone. The twilight zone ibutton was located 3 m inside the entrance. The mean temperature outside the mine, approximately 20 m from the entrance and above snow cover, was −2.49°C (SD 5.31). Mice were generally observed on wall ledges and the floor deeper in the mine (Figure 1B) where air temperatures were warmer, and where they were subsequently captured.

**Summer Sampling**

Twenty-two fungal taxa plus five sterile morphs were cultured from 15 mice, with a mean of 4.87 fungal taxa per mouse (SD 2.13, range 2–8). Female mice (n = 8) carried a mean of 4.75 (SD 2.31) fungal taxa and males (n = 5) carried 4.6 (SD 2.30). Two mice escaped before sex was determined. The second swab contributed two fungal taxa (SD 2, range 0–4, n = 3 mice) that were not detected with the first swab. The most common fungal taxa were *Mucor* sp. (87% of mice), *Penicillium* sp. (87%), *Cladosporium* sp. (80%), *Pseudogymnoascus pannorum sensu lato* (47%), *Scopulariopsis* sp. (20%), *Thysanophora* sp. (20%), *Alternaria* sp. (13%), and *Microascus* sp. (13%), while all other taxa were isolated from a single mouse each (Table 1). Summer mice captured outside the cave carried a significantly higher number of fungal taxa per individual than winter mice sampled inside the cave (t1,18 = −2.48, P = 0.024). The mean temperature in Dorchester Mine during August 2014 was 13.65°C (SD 0.76) in the twilight zone and 6.59°C (SD 0.00) in the dark zone. The mean temperature outside of the mine, approximately 20 m from the entrance, was 18.12°C (SD 4.21).

**Discussion**

Mice sampled during our study carried few fungi capable of growing at typical eastern Canadian dark zone cave temperatures, although summer mice carried a higher diversity of psychrotolerant fungi compared with mice swabbed during the winter. The psychrophilic *Pseudogymnoascus destructans* was not detected on mice, but isolates of a closely related species complex, *Pseudogymnoascus pannorum sensu lato*, was cultured from all mice sampled during the winter and on half the mice sampled during the summer. Although only two bats (either Little Brown Myotis [Myotis lucifugus] or Northern Long-eared Myotis [M. septentrionalis]) were present in Dorchester Mine during the winter 2014 sampling period, viable *P. destructans* was present and was cultured from both walls (Vanderwolf et al. 2016c) and arthropods (Vanderwolf et al. 2016b) in the mine.

*Pseudogymnoascus pannorum* is commonly found on various substrates in caves, including hibernating...
FIGURE 2. Representative psychotolerant fungi in pure culture from the winter (W) and summer (S) fur (FU), faeces (FE), and gut contents (GC) of Deer Mice (Peromyscus maniculatus) associated with a white-nose syndrome positive bat hibernaculum in eastern Canada. All cultures on DPYA without oxgall and sodium propionate. A. Alternaria sp. (S-FU); B. Arthrinium phaeospermum (S-FU); C. Arthoderma silverae (W-FU, W-GC); D. Microascus caviarformis (W-FU, W-FE, W-GC); E. Oidiodendron cf. state of Myxotrichium emodense (S-FU); F. Penicillium thomii (S-FU); G. Pseudogymnoascus roseus (W-FE); H. Scopulariopsis candida (S-FU); I. Talaromyces sp. (W-FU); J. Thysanophora canadensis (S-FU). Photos: K. J. Vanderwolf.
bats (Johnson et al. 2013; Vanderwolf et al. 2013), and has been isolated from the fur of wild voles, shrews, mice, and rabbits outside caves (Hubalek et al. 1979; Chabasse 1988), as well as scat from Arctic Ground Squirrel (Spermophilus parryii; Kobayasi et al. 1967). Pseudogymnoascus pannorum appears to be a common component of the mycobiome of mammalian fur. However, P. pannorum is polyphyletic and the resolution of the species complex may reveal different ecological patterns.

Outside caves, the fungal diversity detected on mammals has generally been low. For example, the number of fungal isolates per Persian Squirrel (Sciurus anomalus; n = 60) varied from 0 to 4 (mean 2.6, SD 0.83) with 23 fungal species from 17 genera isolated overall (Rostami et al. 2010). Sierra et al. (2000) studied fungi on the fur of 85 Domestic Cats (Felis catus) and found the number of fungal genera per cat varied from 1 to 9 (mean 3.2). Dermatophytes, such as Arthroderma benhamiae, A. quadriridium, A. persicolor, and Chrysosporium sp. have previously been isolated from P. maniculatus fur (Knudtson and Robertstad 1970; Hubalek 2000).

A greater diversity of fungi was cultured from mouse faeces than mouse fur and, paired with fungi cultured from mouse intestinal contents, demonstrate that mice

### Table 1. Psychrotolerant fungi cultured from the external surface of Deer Mice (Peromyscus maniculatus) captured inside a bat hibernaculum in winter 2014 and outside adjacent to the hibernaculum entrance in summer 2014, New Brunswick, Canada.

<table>
<thead>
<tr>
<th>Fungus</th>
<th>Winter (no. mice)</th>
<th>Summer (no. mice)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fur (n = 6)</td>
<td>Faeces (n = 4)</td>
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</tr>
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<tr>
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<td>Cladosporium sp.</td>
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<tr>
<td>Leuconeurospora capsici</td>
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<td>0</td>
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<td></td>
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<tr>
<td></td>
<td>Microascus sp.</td>
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are capable of transporting viable spores of psychrotolerant fungi internally. These spores may be acquired during feeding and grooming, as five of the fungal genera cultured from faeces were also found on fur. Although faeces collected from the traps may have acquired spores from the environment, Kohl et al. (2015) found no significant difference in the microbiome between Desert Woodrat (Neotoma lepida) faeces collected aseptically and faeces collected from live traps.

Macrofungi and mycorrhizal fungi are part of the omnivorous diet of P. maniculatus, and viable spores of these fungi are frequently detected in their faeces and stomach contents outside caves (Maser and Maser 1987; Pyare and Longland, 2001; Frank et al. 2006; D’Avla et al. 2007; Meyer et al. 2015). It is thought that P. maniculatus and other rodents play a role in dispersing fungal spores across the landscape, which is of particular importance with regard to mycorrhizal inoculum (Maser and Maser 1987; Pyare and Longland 2001; Frank et al. 2006; D’Avla et al. 2007; Meyer et al. 2015). However, mice are unlikely to transport fungal spores great distances internally, as Cork and Kenagy (1989) found that the mean retention time of Elaphomyces granulatus spores was 12.0 h (standard error 2.4) in P. maniculatus.

Nevertheless, evidence suggests that mice opportunistically feed on fungi growing in caves, such as those growing on live and dead bats, decaying leaf litter, and woody debris, or consume spores concomitant with other cave food sources such as arthropods (Peck 1988) and bats (Trevor-Deutsch 1973). Therefore, mice likely play a role in fungal dispersal in underground environments. For example, we observed Microascus caviariformis growing in Dorchester Mine, and we subsequently isolated viable spores of this fungus from mouse faeces and from the gut contents. This fungus has rarely been isolated, and never outside caves (Malloch and Hubart 1987; Vanderwolf et al. 2013, 2016a).

It is noteworthy that a full 33% of the summer isolates from mice were members of the genus Microascus, including related asexual anamorphs assigned to Scopulariopsis spp. Species of Microascus lack the forcible discharge of ascospores common to most ascomycetes and occur in habitats where access to freely flowing air currents is limited. For species of Microascus, such habitats include stored grains, soil, dung, and caves (Barron 1961; Vanderwolf et al. 2013; Sandovaldenis et al. 2016).

Once P. maniculatus leave caves in the spring and disperse into the outside environment (Trevor-Deutsch 1973), they may carry spores of psychrotolerant fungi with them, both internally and externally, to woodland burrow systems. Winter and summer burrow temperatures of Peromyscus spp. across a diversity of habitats in North America fall within the range of temperatures at which psychrotolerant fungi will grow, e.g., mean of 10–15°C during summer and 0–6°C during winter in British Columbia, depending on habitat (Hayward 1965). Burrow microclimate may have contributed to the diversity of psychrotolerant fungi we cultured from the fur of mice during the summer.

Several of the fungal genera we isolated from faeces are coprophilous, such as Cephalotrichum stemonitis, Thelebolus spp., and Arthroderma silvareae (Currah et al. 1996; Domsch et al. 2007). Other fungal taxa, especially those we isolated from mice during the summer, such as Alternaria spp., Arthrinium phaeospermum, and Thysanophora spp., are often associated with plants (Domsch et al. 2007). Genera such as Mucor, Cladosporium, and Penicillium are ubiquitous in the outside environment (Domsch et al. 2007) and were more commonly isolated from mice sampled outside the mine than inside.

The relatively low psychrotolerant fungal diversity found on mice during this study is in marked contrast to the diverse fungal assemblage isolated from bats hibernating in caves in the region (Vanderwolf et al. 2013, 2016a) and even arthropods at the same site (Vanderwolf et al. 2016b). For example, using similar methods, a mean of 8.3 (SD 3.2) fungal taxa per individual were cultured from Harvestmen (Nelima elegans; n = 9) overwintering in Dorchester Mine.

Peromyscus maniculatus remain active throughout the winter and hence do not undergo a drop in body temperature, unlike hibernating bats. This may decrease the diversity of psychrotolerant fungi on the external surface of Peromyscus. Perhaps more important, rodents are effective groomers (Murray 1961; Hallman et al. 1993), and P. maniculatus overwintering in caves are likely to groom more frequently than hibernating bats. Mammals that regularly groom are able to limit ectoparasites (Murray 1961) and may also be able to limit the mycoflora they carry on their fur, including dermatophytes and psychrotolerant fungi.

Although the sample size of mice available to us was small, this study demonstrates that eutherian mammals occupying caves can carry a variety of viable spores of psychrotolerant fungi, both externally and internally. Small rodents using cave habitats may also play a role in dispersing psychrotolerant fungi between caves and suitable low-temperature habitats (i.e., burrows) in adjacent forest.

Acknowledgements

We thank John Klymko and Sarah Robinson for assisting with winter fieldwork and S. Hambleton (Agriculture Canada, Ottawa, Ontario, Canada) for discussions on fungal taxonomy. Howie Huynh kindly assisted with summer fieldwork. Research funding was provided by the New Brunswick Wildlife Trust Fund, Crabtree Foundation, New Brunswick Environmental Trust Fund, New Brunswick Department of Natural Resources, and Parks Canada. We also thank the Department of Energy and Resource Development for approving our request to euthanize a single Deer Mouse and to live-trap more generally in Dorchester Mine.
Literature Cited


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**Fabronia ciliaris**, a Moss New to Canada from Southeastern Manitoba

**RICHARD T. CANERS**

Royal Alberta Museum, 9810 103A Avenue, Edmonton, Alberta T5J 0G2 Canada, and Department of Renewable Resources, University of Alberta, Edmonton, Alberta T6G 2H1 Canada; email: Richard.Caners@gov.ab.ca


*Fabronia ciliaris* (Fabroniaceae, Bryophyta) was recently discovered in the Great Lakes–St. Lawrence forest region in southeastern Manitoba. This collection represents the first record of the species in Canada and the northernmost extent of the species in North America.

Key Words: Bryophyta; distribution; *Fabronia ciliaris*; *Fabronia pusilla*; Fabroniaceae; Great Lakes; Manitoba; moss; phyto-geography; St. Lawrence; Whiteshell Provincial Park

**Introduction**

In North America, the moss family Fabroniaceae contains a single genus, *Fabronia* Raddi (Fabroniaceae, Bryophyta), that is represented (McIntosh 2014) by only two species: *F. ciliaris* (Bridel) Bridel (Fabronia Moss) and *F. pusilla* Raddi (Silver Hair Moss). Several previously recognized taxa are now considered to be synonymous with *F. ciliaris*, including *F. ciliaris* var. *polycarpa* (Hooker) W. R. Buck, *F. ciliaris* var. *wrightii* (Sullivan) W. R. Buck, *F. ravenelii* Sullivant, and *F. wrightii* Sullivant (McIntosh 2014; for additional synonyms see Tropicos.org 2017).

The genus *Fabronia* in North America comprises diminutive, sparsely branched, perennial plants that often form thin and silky whitish-green mats (Buck 1994; McIntosh 2014). Leaves are tiny (0.4–0.9 mm long), mostly ovate-lanceolate, loosely appressed when dry, and terminate in linear apical cells. Leaves also have single, short costae that extend to about half of the leaf length, rhomboidal laminar cells, and quadrate to short-rectangular basal cells. Plants are autoicous, with female and male reproductive structures on the same shoots. Plants regularly contain sporophytes, with erect, ovoid to pyriform capsules that have sinuose cells in their outer walls (exothecia). *Fabronia ciliaris* is distinguished from *F. pusilla* in having acute or acuminate leaf apices and low-dentate (sometimes entire) leaf margins with teeth of one cell each. *Fabronia pusilla* has acute to long-acuminate leaf apices and ciliate-dentate leaf margins with teeth often composed of more than one cell.

*Fabronia ciliaris* is known in North America from the United States and Mexico (Figure 1). In the United States, the species has a wide distribution, occurring mainly from the northeast to the southwest (Arizona, Arkansas, California, Colorado, Georgia, Indiana, Kansas, Kentucky, Louisiana, Michigan, Minnesota, Missouri, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, and Wisconsin) based on McIntosh (2014). Worldwide, the species is also known from the West Indies, Central America (Guatemala), South America, Europe, eastern Asia (Japan), Pacific Islands (Hawaii, New Zealand), and Australia (McIntosh 2014). *Fabronia ciliaris* has not been reported previously for Canada. The species was not included for Canada in the Bryophyte Flora of North America (McIntosh 2014) or in the 2015 list of the General Status of Species in Canada (CESCC 2016). There are no known Canadian specimens in the digitally accessible Consortium of North American Bryophyte Herbaria (CNABH 2017) or BRYOQUEL (Faubert et al. 2017) databases, and, based on personal communications, there are no known Canadian specimens at multiple Canadian herbaria (ALTA, CAFB, CANM, MMMN, PMAE, UADB, UBC, WIN; refer to Thiers 2017 for standardized, stable herbarium abbreviations) or United States herbaria with substantial Canadian bryophyte collections (F, FH, MO, NY, US). Also, Grout (1928–1940) and Crum and Anderson (1981) do not list the species for any Canadian jurisdiction.

A specimen from the University of British Columbia herbarium (UBC B56875), collected by W. B. Schofield (59600) on 27 March 1976, from “Sumas Mountain escarpment near Chilliwack”, was labelled *F. ciliaris*, but was subsequently annotated to *F. pusilla* by T. T. McIntosh in January 2008. A collection from the Pacific Northwest Herbarium at Western Washington University (WWB B-2535) by J. S. Martin (4985) on 23 July 1975, from Algoma District in northeastern Ontario, found growing on granitic rock, near Brownlee Lake, about 9.5 km east of Thessalon, was labelled “*Fabronia ciliaris* (?) (Brid.) Brid.”. However, on examination by the author, the specimen was determined to be *Hypnum pallescens* (Hedwig) P. Beauvois. *Fabronia ciliaris* is not included in the list of bryophytes for Ontario and is not ranked or tracked by the Ontario Natural Heritage Information Centre (David Bradley, personal communication, 13 January 2017).

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Methods

Surveys to document bryophyte diversity in southeastern Manitoba were conducted in late September 2016. One survey was held on 27 September 2016 at Hunt Lake in Whiteshell Provincial Park, Manitoba (49°44'N, 95°10'W; 343 m elevation) under Manitoba Sustainable Development, Parks and Protected Spaces permit no. PP-PHQ-16-026. The park is situated in the Great Lakes–St. Lawrence forest region (Rainy River section) of Canada, which extends across southern and eastern Canada, from the St. Lawrence River in Quebec to its western limits in southeastern Manitoba (Rowe 1972). Climate in the vicinity of the study site has an annual daily average temperature of 2.5°C and total annual precipitation of 630.8 mm, with 506.8 mm falling as rain (data from Indian Bay meteorological station, Manitoba; 49°37'N, 95°12'W; 327 m elevation; Environment and Climate Change Canada 2017).

Results

The survey at Whiteshell Provincial Park revealed the moss *Fabronia ciliaris* (Figure 1). The species was growing on a forested, calcareous rock outcrop close to the lake shore (Figure 2). The tree canopy was dominated by Eastern White-cedar (*Thuja occidentalis* L.), Balsam Fir (*Abies balsamea* (L.) Miller), and Paper Birch (*Betula papyrifera* Marshall). The cliff face supported numerous microhabitats that ranged from xeric on exposed vertical rock faces to mesic in sheltered rock crevices. *Fabronia ciliaris* was growing on a dry, vertical rock face among shoots of *Orthotrichum anomalum* Hedwig, as several scattered gametophytes containing sporophytes, over an area of several square centimetres. A collection of the species was made from this area to confirm its identity. Extended searches for the species in the vicinity were not conducted. Although the cliff face had a northwest aspect overall, the specimen was collected on a segment of the cliff that was south facing. Morphological characteristics of the specimen were typical of other collections from the northern United States (Figures 3–5; see Specimens Examined). The collection (R. T. Caners 7994) has been deposited at the Royal Alberta Museum herbarium (PMAE accession no. C16.3.1).
Discussion

The Great Lakes–St. Lawrence forest region in southeastern Manitoba hosts a distinctive bryophyte flora and supports a number of bryophyte species that are almost certainly restricted to this portion of the province (personal observation). The discovery of *Fabronia ciliaris* within this forest region in southeastern Manitoba represents the first record of the species in Canada and the northernmost occurrence in North America. The closest known occurrence of *F. ciliaris* is Taylors Falls, Minnesota (see Specimens Examined), more than 500 km to the southeast, where the species was first collected by J. M. Holzinger in 1895 (MO 90065179; CNABH 2017) and has been collected multiple times over the past century. In Manitoba, the species was growing on calcareous rock, a substrate type that has been reported for the species in other parts of its range in the United States (CNABH 2017; see Specimens Examined). Calcareous rock outcrops occur in the Thunder Bay region and along the north shore of Lake Superior, and these areas are closer to Taylors Falls, Minnesota, than to the Manitoba site. However, the species is also reported frequently on the bark of trees and other rock types, including granite (e.g., see

**Figure 2.** Rock outcrop in Whiteshell Provincial Park, Manitoba, where *Fabronia ciliaris* was collected. Photo: Richard Caners, 27 September 2016.

**Figure 3.** Several shoots of *Fabronia ciliaris* growing among *Orthotrichum anomalum*. The length of the scale bar represents 1.0 mm. Photo: Richard Caners.
Specimens Examined for Taylors Falls, Minnesota), substrates that are widespread throughout the Great Lakes–St. Lawrence forest region in Canada. *Fabronia ciliaris* appears to become less frequent at the most northerly latitudes in the eastern United States. This may be because of increasingly harsh growing conditions or, perhaps, because of slow expansion of the species into northern regions following the retreat of the Laurentide Ice Sheet at the end of the Wisconsin glaciation. Indeed, there are few records of the species to the north of the maximum extent of glacial ice. Rapid retreat of ice began after about 14 000 $^{14}$C years ago (Mickelson and Colgan 2003) and was markedly faster in the area to the west of the Great Lakes compared with areas further east (Dyke 2004, 2005). This could have provided more time for the species to expand into southeastern Manitoba from Minnesota and Wisconsin. *Fabronia ciliaris* is autoicous and produces sporophytes frequently (McIntosh 2014), suggesting that it may be able to disperse over long distances by its small spores.

**Figure 4.** Representative stem leaves of *Fabronia ciliaris* collected in southeastern Manitoba. The length of the scale bar next to each leaf represents 0.1 mm. Photos: Richard Caners.
The lack of records in Canada to date suggests that the Great Lakes could possibly represent a barrier to expansion into northern regions. There have been relatively more collectors in southern Ontario than in many other parts of the country (personal observation), providing opportunity for _F. ciliaris_ to have been reported from this area in the past. However, there still remain large areas of under-surveyed habitat within the Great Lakes–St. Lawrence forest region, especially to the west of Lake Superior and the northernmost part of the forest region, suggesting there may be other undiscovered colonies in the region.

The only other species of _Fabronia_ in North America is _F. pusilla_. This species occurs mostly in the west, where it is known in the United States from Arizona, California, Colorado, Idaho, Oregon, and Washington State, and in Mexico from Baja California Sur (Metcalf 2014). In Canada, _F. pusilla_ is known from a single site on sandstone in south-central British Columbia, where it reaches the northern extent of its range in North America (COSEWIC 2002, 2012; British Columbia Recovery Team 2007) and is listed as endangered under the federal _Species at Risk Act_ (SARA Registry 2017). _Fabronia ciliaris_ may similarly reach its presumed northernmost extent in southeastern Manitoba, but surveys are needed to assess its distribution in Canada. _Fabronia ciliaris_ risks being overlooked because of its small size; however, the survey that first detected this species in Canada was not a targeted survey.

**Fabronia ciliaris** Specimens Examined

UNITED STATES: KANSAS. Cherokee County: 5 miles (8 km) east of Baxter Springs, on trunk of bur oak, oak-hickory ravine, 29 July 1969, *R. R. Ireland* 22595 (ALTA 044458). MINNESOTA. Chicago County: Taylors Falls, St. Croix River, on granite rock, 24 August 1966, *D. H. Vitt* 409 (ALTA 044441). MISSOURI. Barry County: cedar glade just south of Roaring River State Park on Hwy. F, beneath limestone ledge, 23 May 1973, *P. L. Redfearn, Jr.* 28483 (ALTA 044442); Greene County: wooded east-facing slope above James River just below Lake Springfield Dam, alt. ca. 1300 feet (400 m), common on trunks of red cedar, 1 November 1985, *P. L. Redfearn, Jr.* & *A. Rushing* 33569 (ALTA 044456); Pike County: Louisiana, Stark Brothers Nursery retain building, on large tree trunk in commercial nursery area, 30 May 1994, *D. H. Vitt s.n.* (ALTA 044451); Vernon County: 3 miles...
(4.8 km) west of El Dorado Springs, north along county line road, on trunk of dead deciduous tree, 26 August 1966, R. R. Ireland 9815 (PMAE C95.1.19021). NEBRASKA. Jefferson County: 5 miles (8 km) south of Fairbury on Hwy 15 and 1/4 mile (0.4 km) east, 1/2W, Sec.14, T1N, R2E, upland tributary, moss on trunk of Ulmus, 0–2.5 feet (0–0.8 m) on NE-side, 1 October 1975, S. P. Churchill 6845 (PMAE C95.1.19025). OKLAHOMA. Payne County: Stillwater, southeast of OSU campus, 8 feet (2.4 m) high on bark of elm tree, 16 January 1959, C. D. Bird 2920 (PMAE C95.1.19020).

Acknowledgements

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River Otter (*Lontra canadensis*) Killed by Wolves (*Canis lupus*) during Winter in Northern Minnesota

THOMAS D. GABLE¹, ², STEVE K. WINDELS¹, and IAN C. RAUTIO¹

¹Voyageurs National Park, 360 Highway 11 E, International Falls, Minnesota 56649 USA
²Corresponding author: thomasd.gable@gmail.com


Few accounts exist of Gray Wolves (*Canis lupus*) killing small sympatric mammalian predators. In January 2017, we observed a River Otter (*Lontra canadensis*) that had been killed by wolves on the ice in Voyageurs National Park, Minnesota. This is one of only a few documented instances of wolves killing otters.

Key Words: River Otter; Gray Wolf; predation; kill site; Minnesota; *Canis lupus*; *Lontra canadensis*

Gray Wolves (*Canis lupus*) predominantly hunt, kill, and consume ungulates and small mammalian prey, such as beavers (*Castor* spp.) and hares (*Lepus* spp.; Mech et al. 2015; Gable et al. 2016; Newsome et al. 2016). Wolves will also kill medium to large sympatric predators, such as bears (*Ursus* spp.), Cougars (*Puma concolor*), and Coyotes (*Canis latrans*) possibly to eliminate competition for resources (Rogers and Mech 1981; Ballard et al. 2003; Berger et al. 2008). However, there are anecdotal accounts of wolves killing small sympatric mammalian predators (primarily mustelids) with whom they do not directly compete (White et al. 2002; Palacios and Mech 2010). Such accounts are rare, but they provide information about causes of natural mortality in small predator populations as well as the effect of wolves as predators on small predator communities (Ballard et al. 2003).

On 30 January 2017, we found a River Otter (*Lontra canadensis*) carcass on the ice near the southern shore of Rainy Lake in Voyageurs National Park, Minnesota (48°30′N, 93°50′W). The otter carcass was frozen and had not been consumed, but appeared to have been killed recently. Several wolf tracks were present in the snow around the carcass, and we found no evidence of other predators nearby; we could not determine how many wolves were involved because of the concentration of tracks. We followed the wolf tracks, drag marks (presumably from the wolves moving the carcass), and general disturbance in the snow (i.e., snow packed down from wolves) from the otter carcass to where the encounter appeared to have started (~15 m from the carcass). We did not find any blood or hair in this area, which is not surprising given the cause of death (see below) and that wolves did not consume the carcass. We also could not determine the activities of either the wolves or otter before the encounter, for example, whether a chase had occurred, because of the trampled snow. The beginning of the encounter was not near any visible opening in the ice, and we suspect the otter was likely moving across the frozen lake when wolves found and killed it. When searching this area, we also found a recent (< 3 days) wolf-killed White-tailed Deer (*Odocoileus virginianus*) < 1.5 km from the location of the otter carcass. Wolves had consumed most of the deer carcass.

We conducted a field necropsy of the otter carcass to determine cause of death. We did not see any visible external injuries except for two 1-cm holes on the back right leg and anus where we assume birds had picked at the carcass. Once we removed the hide, we found severe hemorrhaging and trauma on the right side of the abdomen and rib cage, confirming that these wounds occurred while the otter was alive. We found two puncture wounds on the abdomen which were about 4 cm apart — roughly the spread of wolf canines, 3.5–5.0 cm ([Elbroch 2006](https://doi.org/10.22621/cfn.v131i3.1913)) — and several ribs had been crushed. We also found two puncture wounds in the hide that corresponded to the puncture wounds on the abdomen. In addition, the proximal portion of the cranium (parietal, temporal, and occipital bones) had been crushed and there was a laceration/puncture wound (3 cm × 2 cm), which had not been visible during external examination, on the right proximal side of the cranium. However, we are unsure whether this wound was from a wolf canine entering from the outside or from shattered skull bone puncturing the muscle tissue from the inside. We found no other evidence of injury and concluded that the otter likely died from blunt force trauma because its cranium and rib cage were crushed.

Based on necropsy results and wolf sign at the otter carcass, we are confident that wolves killed the otter. Wolves are likely the only predator during winter in Voyageurs National Park that possess the bite strength necessary to crush an otter skull. Few reports exist of wolves killing otters even though the two are sympatric throughout much of northern North America (Mech and...
Boitani 2010; Serfass et al. 2015). For example, Stenlund (1955) stated that he occasionally found wolf-killed otters in northern Minnesota during the winter, but provided no additional information about these kills. Furthermore, previous work in Voyageurs National Park documented a radio-tagged otter that was killed and partly consumed by a wolf in early September (Route and Peterson 1991). How frequently wolves kill otters is unknown, as the natural mortality of River Otters is not well documented or understood (Gorman et al. 2008). Interestingly, otter fur has not been found in any of the > 4000 wolf scats collected in Voyageurs National Park during intensive wolf diet studies conducted from 1988 to 1989 (Gogan et al. 2004) and from 2012 to 2016 (Chenaux-Ibrahim 2015; Gable et al. 2017; Voyageurs National Park, unpublished data). However, if wolves do not consume otters after killing them, as we observed, then scat-based wolf diet estimates would not reflect the frequency of wolf predation on otters.

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**Literature Cited**


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Note

Adult Snapping Turtle (Chelydra serpentina) Feeding on Goldeneye Embryos of Pumpkinseed (Lepomis gibbosus) in Defended Nests

ALEXANDER J. BUSE1, MEGHAN A. DOUGLAS1, THOMAS N. GIGUÈRE1, and BEREN W. ROBINSON1, 2

1Department of Integrative Biology, University of Guelph, Guelph, Ontario N1G 2W1 Canada
2Corresponding author: berenrob@uoguelph.ca


Rarely observed predatory behaviour of adult Snapping Turtles (Chelydra serpentina) was recorded using remote video technology. We observed turtles inspecting and, in one case, apparently feeding on goldeneye stage embryos (<3 mm) from defended nests of Pumpkinseed (Lepomis gibbosus). This novel behaviour was limited to nests in a secluded bay and was not observed at nests located along exposed shorelines or on shallow shoals in the deep open water habitat of an inland oligotrophic lake. The benefit of feeding on small prey is likely enhanced by embryos being clustered in nests and by an abundance of sunfish nests. Low-cost and low-intrusion video technology provides excellent opportunities, even in aquatic systems, to document novel predator and prey behaviours.

Key Words: Remote video recording; predator–prey interaction; fish embryos; nesting Pumpkinseed; Lepomis gibbosus; Snapping Turtle ram-feeding; Chelydra serpentina

Snapping Turtle (Chelydra serpentina) originated 40 million years ago (Van Devender and Tessman 1975) and has one of the largest geographic ranges of any freshwater turtle in the Americas (Ernst and Lovich 2009). It swims and walks along the bottom in a variety of lentic and slow-moving lotic waters. A diverse foraging ecology may contribute to its evolutionary persistence and extensive range. Fish, birds, anurans, crayfish, and many small benthic invertebrates can all occur in their diet (Herrel et al. 2002; Spotila and Bell 2008; Lawrence and Peterson 2010). Although direct evidence in the field is rare, adults are thought to use sit-and-wait ambush tactics to capture live fish (Punzo 1975; Spotila and Bell 2008; Ernst and Lovich 2009), but they also scavenge dead prey (Schneider 1998; Spotila and Bell 2008). Vegetation frequently appears in the diet (Ernst and Lovich 2009), particularly when animal prey are rare and vegetation is abundant (Moldowan et al. 2015) and more frequently in the southern part of the range (Spotila and Bell 2008). However, ingesting vegetation may also occur when feeding on high densities of attached invertebrates (Harper and Bolen 1996). In large adults, it is unclear whether the eggs of fishes, salamanders and frogs, tiny aquatic insect larvae, benthic invertebrates, and duckweed (Lemnaceae) are ingested as a consequence of feeding on gravid females, on the benthos, or in some other habitat that concentrates these items (Ratz et al. 1999; Spotila and Bell 2008). Recent advances in digital cameras can provide opportunities to observe active predation by such elusive animals to clarify their feeding behaviour.

Snapping Turtles capture their prey solely with their mouths, but have a variety of specializations that permit a diverse diet, including a strong biting force (Herrel et al. 2002), rapid prey strike (Lauder and Prendergrast 1992), and rapid protein digestion (Spotila and Bell 2008). Prey cannot be consumed out of water, although it can be captured there (Summers et al. 1998; Ernst and Lovich 2009). The feeding kinematics of turtles is challenging to assess (Bels et al. 2008), but in water, Snapping Turtles predominantly use a ram-feeding mode (Lauder and Prendergrast 1992; Summers et al. 1998) contrary to earlier theories suggesting that suction feeding dominates (Lagler 1943; reviewed in Ernst and Lovich 2009). Ram feeding is typically characteristic of predators that feed on elusive prey that can detect and escape rapid predator strikes, whereas suction feeding is often used to capture smaller prey in water (Wainwright et al. 2001). Thus, a ram-feeding mode raises questions about how and why Snapping Turtles may feed on small prey.

Diet diversity in Snapping Turtles is enhanced by the ability to modulate ram-feeding kinematics depending on the prey (Lauder and Prendergrast 1992), although strike performance is also affected by temperature (Vervust et al. 2011). For large predators, the energetic and opportunity costs of feeding on small and dispersed prey increasingly outweigh the nutritional gain and, thus, the profitability of small prey can be enhanced when prey are aggregated, such as egg masses of frogs and salamanders (Spotila and Bell 2008; Moldowan et al. 2015), or have a high local density, such as blooms of duckweed (Kadlec 1962).

Here, we report field observations made via remote videotaping of adult Snapping Turtles inspecting the defended nests of Pumpkinseed (Lepomis gibbosus) and
Observations of Snapping Turtles and nesting Pumpkinseeds were made in Ashby Lake (45°05'N, 77°21'W) in the Addington Highlands of Ontario, Canada, a 259-ha oligotrophic Canadian Shield lake with a maximum depth of 36.6 m (Jastrebski and Robinson 2004) as part of ongoing studies of the reproductive biology of Pumpkinseeds. Waterproof ‘Gideon’ action sports camcorders by Wasp cameras (Cedar Electronics, Chicago, Illinois, USA) attached to bricks were deployed for 4 h on the lake bottom, about 1 m from nest-guarding male Pumpkinseeds whose nests contained either fertilized eggs or hatched goldeneye-stage embryos based on inspection by a skin diver. In this and other post-glacial lakes, Pumpkinseeds males construct, maintain, and defend nests in the littoral habitat of secluded bays, along more open shorelines exposed to deeper open-water lake habitat, and on shallow submerged rocky shoals in deep open-water habitat (Jastrebski and Robinson 2004). Cameras in littoral and open shoreline habitats were positioned on the shoreward side of each nest facing toward deeper water for the largest field of view of potential aquatic predators. Approximately 600 h of video capturing 125 nesting Pumpkinseeds from three lake habitats were obtained between 1 June and 25 July 2015.

We define nest inspection by a Snapping Turtle as its presence at a Pumpkinseed nest with at least one head-down posture within a few centimetres of the substrate inside the nest perimeter. This is consistent with either visual or olfactory searching behaviour. We also recorded Snapping Turtles in the field of view but not visiting the focal nest. Turtles were not marked or otherwise handled in this study. Observations followed animal care and use guidelines at the University of Guelph developed in accordance with the standards of Good Animal Practice certification by the Canadian Council on Animal Care.

Snapping Turtles appeared in ten of the 125 recordings. Nine sightings occurred in 49 recordings made in a single 1-ha bay (one sighting 10 June, four on 25 June, four on 7 July); one sighting in 37 recordings from open shoreline nests (11 June); and none in 39 recordings of nests on shoals in open waters. Turtles could be clearly seen in seven recordings and were in the background in the other three.

At least two different adult turtles were involved in the greatest number of nest inspections in the bay: one could be identified by a distinct deformation on the second claw on its front left leg (see Video S1). This individual was observed in three recordings (involving two nest inspections and one swim-by, all on 25 June). One or more individuals without obvious distinguishing features were observed at close proximity in three additional recordings, all involving nest inspections (one on 10 June and two on 7 July). The individual observed in a recording of the nest in the open shoreline habitat could also be distinguished by a prominent white patch on top of its head (not observed elsewhere); it swam in close proximity to the sunfish nest, but did not inspect it.

The turtles observed were large, with carapace lengths equal to or exceeding the diameter of the Pumpkinseed nests, which are typically 25–40 cm in diameter. The frequency of nest visits by turtles did not depend on time of day (six observations in the morning versus four in the afternoon, 1-sample \( z = 0.63, P = 0.74 \)) and the time spent inspecting a nest varied from 5 s to 14:32 min:s (mean duration of five visits = 3:59 min:s, SE 2:47). None of the nest-guarding male Pumpkinseeds permanently abandoned its nest after any turtle inspection. Sunfish also did not engage in “mobbing” behaviour in response to Snapping Turtles as reported for Bluegills (Lepomis macrochirus; Dominey 1983).

Active inspection of a sunfish nest occurred in five out of ten recordings. In one of these, we observed a turtle making a very long inspection and apparently feeding on goldeneye embryos in a nest at a water depth of about 1 m (Video S1). We estimate the anterior carapace width of this turtle to be 25–30 cm (based on an \( \text{in situ} \) estimate of the size of the nest-guarding male sunfish by a diver). The animal remained submerged and in view for 14:32 min:s, where 13:32 min:s was spent inside the perimeter of the focal sunfish nest. The turtle came into view from deeper water and stopped at a distance of 2–3 m, after which it changed direction and approached the nest. The turtle stopped with its front legs resting inside the nest perimeter and directed its head to bite at the substrate in the nest centre. It raised its head up in a forward-facing position, made gulping actions, and wriggling embryos escaped from its nostrils and rapidly sank to the nest substrate. At this point, the guarding male sunfish darted at the head of the turtle and retreated over an interval of less than 0.25 s. The turtle jerked its head downwards two more times at the nest substrate during the time inside the nest, but it was not clear whether embryos were taken in or escaped from its nostrils during these additional actions. During the 810 s the turtle was inside the nest, it spent only 134 s “nosing” at the nest bottom and swallowing (17% of total time); during the remainder of the time, it raised its head to a forward position and remained still. At high playback speeds, its eyes can be seen following the nest-guarding male and other Pumpkinseeds hovering nearby until it leaves.

Predator–prey interactions are difficult to observe because they are unpredictable in time and space and often occur over short intervals (Lawrence and Peterson 2010). We confirm the utility of remote cameras for observing undiscovered or rare behaviour in aquatic...
habitats by providing the first direct observations of adult Snapping Turtles visiting and inspecting active Pumpkinseed nests and, in one case, apparently feeding on the clustered embryos there. Large turtles feeding on very small prey demonstrates the diverse feeding repertoire of adult Snapping Turtles.

Sunfish embryos could be a valuable source of nutrients for Snapping Turtles, especially in this oligotrophic lake with its low density of aquatic plants. Sunfish males typically construct nests in shallow inshore habitats well within the diving range (< 2 m) of these turtles. Eggs and embryos are rich in fat and usually aggregate in the centre of a nest depression where they are defended from predators (Scott and Crossman 1998). From 500 to 5000 embryos can be available in a nest over a 3–5-day interval before larvae disperse (Scott and Crossman 1998). Nests are spatially and temporally predictable and, thus, could be visited repeatedly by a nest predator over the 2-month spawning season (starting when waters reach 20°C and ending here in early August). Pumpkinseed nests are common: 30–50 active nests were present in the 1-ha bay where turtle activity was highest and well within the summer home range size of 2–10 ha reported for adult Snapping Turtles elsewhere (Pettit et al. 1995). These features reduce the costs to a Snapping Turtle of foraging for embryos, particularly as the abundance of active sunfish nests increases.

This predatory behaviour may be rare, as we observed a feeding attempt at only one of the five nests inspected among 49 nests recorded in the shallow bay. It is also not clear what factors influence whether a turtle will feed on larvae during a nest inspection or why larvae leaked from the turtles nostrils after being taken in. A forward-facing camera attached to the carapace of a Snapping Turtle could be used to estimate the prevalence of this foraging behaviour and, possibly, reveal other novel interactions between Snapping Turtles and nest-guarding male Pumpkinseed that affect whether fish larvae are consumed.

Acknowledgements

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SUPPLEMENTARY MATERIAL:

VIDEO S1. A mature Snapping Turtle (Chelydra serpentina) inspects a Pumpkinseed (Lepomis gibbosus) nest in the littoral habitat of Ashby Lake (Addington Highlands region, Ontario, Canada) where it apparently feeds on goldeneye-stage sunfish larvae. https://www.youtube.com/watch?v=gNOVM30q_Cc.
Range Extensions of 35 Bryophyte Species in the Black Spruce–Feather Moss Forest of Western Quebec, Canada

MARIoN BARBé1, 4, LOUIS DUBoIS2, JEAN FAUBERT3, MARTIN LAVoIE2, YVES BERGERON1, and NICoLE J. FENTON1

1Université du Québec en Abitibi-Témiscamingue, Institut de recherche sur les forêts, 445, boul. de l’Université, Rouyn-Noranda, Quebec J9X 4E5 Canada
2Université Laval, Département de géographie, 2405, rue de la Terrasse, Québec, Quebec G1V 0A6 Canada
3Société québécoise de bryologie, 47, 4ème Rang Est, Saint-Valérien-de-Rimouski, Quebec G0L 4E0 Canada
4Corresponding author: marion.barbe@uqat.ca


Although the North American bryophyte flora are relatively well known, bryophytes of the Black Spruce–feather moss forest in the Nord-du-Québec administrative region, especially its southern portion (49–51°N, 74–79°W), remain under-sampled. Here, we report 169 bryophyte taxa for this region, of which 35 (14 true mosses, 20 liverworts, one sphagnum) represent noteworthy records, including 20 taxa new for the region. These new occurrences close several gaps in distribution in the study area and, more broadly, in the boreal Black Spruce (Picea mariana) forest of adjacent Ontario. Microhabitat preferences of the species are also documented. This work represents a substantial contribution to knowledge of the bryophyte flora, which will help define protection priority ranks of species of Quebec and Labrador.

Key Words: Boreal forest; bryoflora; bryo-geography; liverwort; true moss; sphagnum; northern Quebec

Malgré une bonne connaissance globale de la bryoflore nord-américaine, la pessière noire à mousses de certaines régions telles que le Nord-du-Québec et notamment sa partie méridionale (49–51°N, 74–79°W) demeure sous-échantillonnée. Nous rapportons 169 taxons bryophytiques dans cette région, dont 35 (14 mousses, 20 hépatiques et une sphaigne) représentent des ajouts substantiels à la flore, incluant même 20 nouveaux taxons pour le territoire considéré. Ces récoltes permettent de relier les aires de répartition jusque-là disjointes de plusieurs taxons en pessière noire à mousses au Québec, mais aussi dans la province jouxtante de l’Ontario. Les préférences des espèces en termes de microhabitats sont aussi décrites. Ce travail contribue à améliorer les connaissances sur la bryoflore et permettra de redéfinir les rangs de priorité pour la conservation des espèces au Québec et Labrador.

Mots-clés: aire de répartition; bryoflore; bryo-geography; liverwort; true moss; sphagnum; Nord-du-Québec

Introduction

Bryophytes (liverworts, true mosses, and sphagnum), along with lichens, dominate the coniferous boreal forest in terms of biomass, species richness (Turetsky et al. 2012), and net primary productivity (Bisbee et al. 2001; Proctor 2011). They form a continuous carpet several centimetres thick and inhabit a variety of microhabitats (Dynesius and Hylander 2007). Bryophytes represent 25% of the plant diversity of Quebec (Faubert et al. 2010). In 2016, the database of the bryophytes of Quebec–Labrador listed 231 species of liverworts, 582 species of mosses, and 62 species of Sphagnum (Faubert et al. 2014+). However, the distributional ranges of some species are only partly defined, and the bryophyte flora is unknown in certain areas (Faubert and Gagnon 2013).

This is the case for the administrative region of Abitibi-Témiscamingue and the adjacent southern portion of the Nord-du-Québec administrative region, which have been neglected in terms of bryophyte sampling compared with other regions. Understanding the frequency and distribution of species is of primary importance in establishing conservation plans and in implementing resource management practices in these regions, where boreal forests are disturbed both by natural wildfires and anthropogenic exploitation (forest harvest, mining, hydroelectric development). These cumulative disturbances of the landscape threaten species that are ill-adapted to anthropogenic environments, including many bryophytes (Fenton and Frego 2005; Hylander et al. 2005; Caners et al. 2013).

Since the publication of the Catalogue des bryophytes du Québec et du Labrador (Faubert 2007), the number of bryophyte species documented in Quebec and Labrador has continued to grow (Gauthier 2011; Moisan and Pellerin 2011; Faubert et al. 2012; Faubert and Gagnon 2013). New occurrences are continuously being compiled in the online database of the bryophytes of Quebec–Labrador (Faubert et al. 2014+), contributing to continuous updating of the bryophyte flora (Faubert 2012–2014). The current study contributes to our understanding of bryophyte distributional ranges at the scale of the boreal Black Spruce (Picea mariana (Miller) Britton, Sterns & Poggenburgh) forest of Quebec–Labrador. We describe the bryophyte community of this forest bioclimatic domain, including microhabitat preferences, which may permit better forest development practices and bryophyte conservation.
Study Area

The study area covers 73,197 km² (48°83’N to 50°71’N and 74°50’W to 79°69’W) in the southern portion of the Nord-du-Québec administrative region of western Quebec (Figure 1). After the retreat of the Laurentide Ice Sheet, the area was covered by the proglacial lakes Barlow and Ojibway, which existed 11,500 and 7900 radio carbon years before present, respectively (Vincent and Hardy 1977). Sedimentation in the lakes generated a layer of clay 10–60 m thick that forms the soils of the “clay belt” of northeastern Ontario and northwestern Quebec. There is little topographic variation in the region, with elevations ranging from 200 to 300 m above sea level.

The study area is located in the Black Spruce–feather moss forest bioclimatic domain that extends over 154,184 km² in Quebec (Grondin 1996). Forest stands are dominated by Black Spruce, Jack Pine (Pinus banksiana Lambert), Trembling Aspen (Populus tremuloides Michaux), Balsam Fir (Abies balsamea (L.) Miller), and Paper Birch (Betula papyrifera Marshall). The understory is dominated by ericaceous shrubs on a ground cover of bryophytes (Saucier et al. 2009). The natural dynamics of these forests are driven primarily by stand-replacing wildfires. The fire cycle has been estimated at 398 years (Bergeron et al. 2004), and the average age of the forest is over 150 years. Average annual temperature and precipitation (1981–2010) are 1°C and 928 mm,
Methods

Bryophyte Sampling

Bryophytes were sampled within the footprints of six natural wildfires (Figure 1b) varying in age, size, and origin and used for a study on post-fire residual forest patches (Barbé et al. 2016, 2017). Within each wildfire footprint, we identified five residual patches (unburned forest areas) and three burned areas for a total of 30 residual patches aged 36–3400 years (time since last wildfire) and 18 burned matrices aged 10–44 years (time since last wildfire). The age of the patches was estimated by coring 10 dominant trees; if the 10 dominant trees were approaching their maximum lifespan (> 180 years old for Black Spruce; Simard et al. 2007) the age of the patch was determined by 14C dating of charcoal particles extracted from the mineral soil. Age of burned areas corresponds to time since the last fire determined from Société de protection des forêts contre le feu digital maps (SOPFEU 2011). All residual patches were chosen based on the following criteria: Black Spruce dominance, accessibility (< 600 m from the logging road), flat topography, and no complete submergence of the soil except in local depressions (waterholes). No bogs or fens were sampled, but post-fire residual patches located in paludified areas (i.e., natural succession to peatland; Crawford et al. 2003) Black Spruce forests were included. Consequently, we sampled sites encompassing the range of natural Black Spruce forest succession: from recently burned to paludified areas. Patches varied in size (0.05–11.1 ha) and forest structure (e.g., 7.4–109 m³/ha of coarse woody debris). More details about the characteristics of the patches are presented in Babé et al. (2017).

Rectangular plots (50 m²) were used to sample the bryophyte communities in each residual patch and burned area. At each location, a north–south linear transect was established that included the burned zone, edge, and core positions (Figure 1c). In patches smaller than 1 ha, five plots were placed along the transect: two in the surrounding burned zone, two straddling each edge of the patch, and one in the core. In patches over 1 ha, a second core plot was added. Plots were 10–200 m apart. In each wildfire footprint, three additional 50-m² plots of burned area were placed 200–850 m from residual patches. Size, number, orientation, and placement of sampling plots were chosen to include all microhabitats at each site, from more humid and cold microhabitats found at the northern edge and in residual patch cores, to warmer and drier microhabitats found at the southern edge and in burned areas. In total, the bryophyte community was sampled over 9300 m²: 108 plots in 30 residual patches (48 cores and 60 edges) and 78 plots in burned areas (2 × 30 residual patches plus 3 × 6 wildfires). The four corners of each plot were geo-located using a handheld global positioning system receiver (Garmin GPSmap 62, Olathe, Kansas, USA).

In each 50-m² plot, the bryophyte community was sampled using a modified form of “floristic habitat sampling” (Newmaster et al. 2005), which consists of sampling all the bryophytes present in all microhabitats (e.g., coarse woody debris, tree bases, peat mounds, water holes). This method was used to ensure that all small non-visible species were captured. Vouchers of all specimens are stored at the Université du Québec en Abitibi-Témiscamingue (Rouyn-Noranda, Canada). Nomenclature follows Faubert et al. (2014+) except for Sphagnum subtile (Russ.) Warnst. (Flora of North America Editorial Committee 2007).

All samples were dried and later identified to species level using a stereomicroscope and a compound light microscope following the specimen preparation and identification method described in Faubert (2012). Damaged, senescent, or immature specimens were identified only to genus level. The microhabitat in which each species was found was qualitatively compared with data from Flore des Bryophytes du Québec–Labrador (Faubert 2012–2014; herein shortened as “Flora”) to determine whether a species was specific to certain microhabitats in the study area.

Distribution Maps

Provincial distribution maps were generated for species found in this study whose ranges differed from those previously known in Quebec. New occurrences were compared with those detailed in the open-access BRYOQUEL participative online database of the bryophytes of Quebec–Labrador (Faubert et al. 2014+). New occurrences were also compared with documented occurrences from the neighbouring province of Ontario (Ireland and Ley 1992; Ley and Crowe 1999; CNALH 2017). Maps were generated using the geographic information system, ArcGIS 10.3.1 (Environmental Systems Research Institute [ESRI], Redlands, California, USA). Original map layers were from the GéoIndex+ platform of the Geographic and Statistical Information Centre (GéoStat Centre) of the Université Laval created with data from Statistics Canada, geographic division, DMTI Spatial Inc. (Richmond Hill, Ontario, Canada), and ESRI. The projection used for all maps was NAD83 CSRS MTM 10.

Data Analyses

Provincial occurrences, extracted from Faubert et al. (2014+), are “previously documented occurrences” and were classified into four categories: rare (< 5 occurrences), infrequent (5–10), uncommon (11–30), and common (> 30; Table 1). There was no minimum distance between occurrences. The local occurrences from this study were treated as “new occurrences”. Local occurrences refer to the record of one species in a residual patch or a burned area. Indeed, even though a species was found several times in the same residual patch or burned area (i.e., several records in the same 50-m²
plot), only one occurrence was drawn on the map (one cross) to avoid overloading maps with superimposed crosses. Local occurrences followed the same categories as provincial ones but were based on the number of plots where the species was found: rare (recorded in < 5 plots), infrequent (5–10 plots), uncommon (11–30 plots), and common (> 30 plots). Local occurrences were used to refine species occurrences in Quebec. For example, a species represented by 28 provincial occurrences plus 10 new local occurrences was updated from uncommon to common in Quebec. Each occurrence (provincial as well as local) was presented regardless of plot and site location. Species were grouped by their provincial and local occurrences: group 1: locally uncommon/infrequent species already recorded near the study area; group 2: provincially common to rare species only recorded sporadically near the study area; group 3: species that were new occurrences for the study area.

Microhabitats of species in the study area were compared with those documented in Flora (Faubert 2012–2014), which were compiled from an exhaustive list of preferential microhabitats found in the literature (Schuster 1966–1992; Crum and Anderson 1981; Ireland 1982) plus additional microhabitats from specimens collected in Quebec. Thus, we compared species’ microhabitat preferences between boreal Black Spruce forest and habitats in the rest of the province and the species’ Canadian distribution to identify differences in microhabitat preferences in the Black Spruce forest of western Quebec. Microhabitats were classified as humus (T: terricolous species living on soil and litter), peat (B: species living among sphagna or on exposed peat in paludified areas), dead wood (DW: facultative or obligate epixyls), epiphyte (EP: epiphytic or corticolous species on living trees and shrubs), and rock (R: saxicolous species).

Results

Bryophyte Community and Species Distribution

Bryophytes were sampled in 11 036 microhabitats, each containing on average four species (range 0–20) for a total of 169 species encountered (61 liverworts, 90 mosses, and 18 sphagna; Appendix S1). Locally, 118 species (70% of all species) were common (found in more than 30 plots); the remaining species occurred more sporadically over the sampling area.

Post-fire residual patches were dominated by the feather mosses, Hlyocodium splendens (Hedw.) Schimp., Pleurozium schreberi (Willd. ex Brid.) Mitt., and Ptilidium ciliare (Hedw.) Hampe. The wettest sites also supported Aulacomnium palustre (Hedw.) Schwägr., Sanonia uncinata (Hedw.) Loeske, and Warnstorfia...
<table>
<thead>
<tr>
<th>Species name</th>
<th>Species group affiliation</th>
<th>Previously documented Quebec occurrences*</th>
<th>New occurrences</th>
<th>Status in Quebec–Labrador and proposed change (→)</th>
<th>Proposed modification to range‡</th>
<th>Closest known Quebec occurrence distributional ranges (km)</th>
<th>Factors possibly explaining modification of ranges</th>
<th>Micronhabitats‡</th>
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<td>P/DW/R/T</td>
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<td>BBSF?</td>
<td>26</td>
<td>&lt; 1 mm/DW/C</td>
<td></td>
</tr>
</tbody>
</table>

Note: Cont. dist. = continuous distribution, ID = identification, BBSF = boreal Black Spruce forest.
*From Faubert et al. (2014+).
†No proposed modification suggests that the new occurrences are too few to extend species distribution. BBSF? = may extend to the whole boreal Black Spruce forest bioclimatic domain in the Quebec–Labrador (based on vegetation zones defined by Payette and Bouchard 2001).
‡Microhabitats previously documented from Faubert (2012–2014); empty boxes indicate that no additional microhabitats were found: C = epiphytic or corticolous; DW = dead wood; NS = not specified; P = peat; R = rock; T = terricolous; W = wet.
§This species was misidentified as Hypnum fertile, absent in Quebec–Labrador; therefore, presenting a map is impossible without revision of the herbarium specimens.
fluitans (Hedw.) Loeske, whereas Ceratodon purpureus (Hedw.) Brid., Polytrichum juniperinum Hedw., and Pohlia nutans (Hedw.) Lindb. were found mainly in burned areas, which were also the driest sites. In addition, deep mats of sphagna (Sphagnum capillifolium (Ehrh.) Hedw., Sphagnum fallax H. Klinggr., Sphagnum magellanicum Brid.) were found, as many of the sites sampled were undergoing paludification (Fenton et al. 2005). Some of the species described as common in the coniferous boreal forests of Quebec in Faubert (2012–2014) were under-represented (≤ 15 occurrences) in our samples (e.g., Barbilophozia hatcheri (A. Evans) Loeske, Bryum capillare Hedw., Tomenthypnum nitens (Hedw.) Loeske).

In addition to these locally common species, 35 species (14 true mosses, 20 liverworts, and one sphagnum) represent noteworthy records (Table 1). of these, four species (group 1) were locally uncommon or infrequent, but were expected to be found because they have already been recorded 25 km from the study area in Quebec and 50–150 km from the study area in Ontario: Calypogeia sphagnicola (Arnell & J. Perss.) Warnst. & Loeske, Fuscocephaloziopsis pleniceps (Austin) Vâňa & L. Söderstr., Lophozia guttulata (Lindb. & Arnell) A. Evans, and Sphenolobus hellerianus (Nees ex Lindenb.) Steph. (Figure 2). Ten other species (group 2), including four true mosses (Brachythecium erythrorhizon Schimp., B. starkei, (Brid.) Schimp., Isopterygiopsis muelleriana (Schimp.) Z. Iwats., Polytrichum commune Hedw. var. perigoniale (Michx.) Hampe and six liverworts (Cephaloziella hampeana (Nees) Schiffn. ex Loeske, Kurzia pauciflora (Dick.) Grolle, Lophozia ascendens (Warnst.) R.M. Schust., L. bicrenata (Schm.) Dumort., Odontoschisma francisci (Hook.) L. Söderstr. & Vâňa, Schistochylopsis laxa (Lindb.) Konstant.) were provincially common to rare, but had been recorded only sporadically near the study area (one to three occurrences 20–115 km; Figure 3). Some of these moss species are found west of the study area, in Ontario (i.e., Brachythecium erythrorhizon, B. starkei, Polytrichum commune var. perigoniale), where they have already been recorded 50–200 km from the provincial border (Ireland and Ley 1992; Ley and Crowe 1999; CNALH 2017).

Finally, 20 species (group 3) are new occurrences for the study area, with range extensions from 75 km to more than 670 km in Quebec–Labrador. These include nine true mosses (Camptothecium protensum (Brid.) Kindb., Dicranum fulvum Hook., Helodium blandowii (F. Weber & D. Mohr) Warnst. var. blandowii, Hypnum curvifolium Hedw., Isopterygiopsis pulchella (Hedw.) Z. Iwats., Pohlia elongata Hedw. var. elongata, P. sphagnicola (Bruch & Schimp.) Broth., Thuidium recognitum (Hedw.) Lindb., Uloeta crispa (Hedw.) Brid.), 10 liverworts (Calypogeia suecica (Arnell & J. Perss.) Müll. Frib., Cephaloziella elachista (J.B. Jack) Schiffn., C. spinigera (Lindb.) Jörg., Chiloscyphus coadunatus (Sw.) R.M. Schust. & J.J. Engel var. rivularis (Raddi)
FIGURE 3. Distributional ranges of species of group 2 (10 in total), comprising provincially common to rare species sporadically recorded in the study area previously: a. *Brachythecium erythrorhizon*, b. *Brachythecium starkei*, c. *Isopterygiopsis muelleriana*, d. *Polytrichum commune var. perigoniale*, e. *Cephaloziella hampeana*, f. *Kurzia pauciflora*, g. *Lophozia ascendens*, h. *Lophozia bicrenata*, i. *Odontoschisma francisci*, j. *Schistochylopsis laxa*. Their presence in the study area was confirmed by numerous newly reported occurrences. Dots show previously documented occurrences; plus signs are new occurrences. The shaded zone represents the boreal Black Spruce–feather moss forest in cases where the new occurrences suggest that the species may be found throughout the whole bioclimatic domain. Asterisks indicate species that are provincially rare according to Faubert et al. (2014+).

*Hypnum fairiei* Cardot was sampled once in the study area. No map was produced for this species because its distribution in the province is unknown as a result of its recent separation from *H. fertile* Sendtn. (Faubert 2014).

**Bryophyte Microhabitat Preferences**

The microhabitat preferences of the 35 species discussed above were more diverse than reported previously in Flora (Faubert 2012–2014; Table 1). For example, two mosses (*Pohlia sphagnicola* and *Calypogea sphagnicola*) and several liverworts were found in a greater variety of microhabitats than the exclusive peat microhabitat mentioned in Flora (Faubert 2012–2014). Eighteen species were recorded on tree or shrub bases in Black Spruce forest, especially *Picea mariana* and *Rhododendron groenlandicum* (Oeder) Kron & Judd (Table 1), although they were not described as corticolous or epiphytic at the provincial scale. Half were associated with only one tree or shrub species, but multiple hosts were also identified for many bryophyte species (e.g., *Pohlia sphagnicola*, *Brachythecium starkei*, *Cephaloziella elachista*; data not shown). Similarly, numerous species not previously identified as epixylics in Flora (Faubert 2012–2014) were found on dead wood (Table 1; e.g., *Brachythecium erythrorhizon*, *Dicranum fulvum*).

**Discussion**

Among the 169 bryophytes species identified, we have documented 20 new species for the study area and increased the understanding of the distributional range for 15 others. Our results suggest that these species may be more common in Quebec–Labrador and especially in the bioclimatic domain of the Black Spruce-feather moss forest, than previous occurrences indicate. We examine here the noteworthy occurrences within groups 1, 2, and 3 as identified above.

**Distributional Ranges Extended to the Entire Boreal Black Spruce Forest Bioclimatic Domain**

Even though already documented in the study area, we extended the known distribution of four species of liverwort (*Calypogea sphagnicola*, *Fuscocephaloziopsis pleniceps*, *Lophozia guttulata*, and *Sphenolobus hellerianus*), with 82 to more than 200 new occurrences for these species. These occurrences, together with those already documented from eastern Quebec, suggest their continuous distributional ranges extend throughout the Black Spruce forest of Quebec–Labrador. Furthermore, the dispersed and numerous locations of these species indicate that they are common but under-sampled in the province. Further extension of their continuous distributional ranges to all of Quebec–Labrador may be possible, but more sampling is needed to determine their true distributions.

Our results also extend to the entire Black Spruce forest domain the known distributions of the liverworts *Cephaloziella elachista*, *C. hampeana*, *C. spinigera*, *Chiloscyphus coadnatus* var. *rivularis*, *Fuscocephaloziopsis loitlesbergeri*, *Kurzia pauciflora*, and *Odontoschisma francisci*, and of the true mosses *Brachythecium starkei* and *Pohlia sphagnicola*. However, some of them (*Cephaloziella elachista*, *C. spinigera*, *Chiloscyphus coadnatus* var. *rivularis*, *F. loitlesbergeri*, *Lophozia silvicola*, and *O. francisci*) have only rarely been recorded in eastern Quebec; further sampling is needed to confirm their presence across the province. In light of the 92 and 56 new occurrences of *B. starkei* and *C. hampeana*, respectively, as well as the 634 new occurrences of *P. sphagnicola*, the status of these species in the province should be changed from uncommon to common. Liverworts, especially *Cephaloziellaceae* and *P. pauciflora*, are minute (<1 mm wide shoots) and especially difficult to detect, which has probably contributed to the underestimation of their frequency and distribution. Directed sampling efforts focusing on these taxa might help distinguish between a lack of sampling versus true rarity in other regions. The distributional ranges of the true mosses *B. starkei* and *P. sphagnicola* are unclear because of past misidentifications (Faubert 2012–2014). Indeed, in the past, the few and confusing diagnostic characters discriminating these species from others of the same genera have led to confusion between *B. starkei* and *B. curtum* (Lindb.) Limpr., *P. sphagnicola* and *P. nutans*, and between *Sphagnum tenerum* and *S. capillifolium*.

*Lophozia bicrenata* also needs attention. This uncommon and minute species, typical of disturbed landscapes, is present in dispersed locations across the entire province. It is possible that this species is found province-wide, but this possibility can only be addressed by additional sampling to discriminate between true rarity and under-collection.

**Distributional Ranges Extended to the North and West**

The few new reported occurrences of *Dicranum fulvum* and *Thuidium recognitum* (three and five, respectively) extend the provincial distribution of these species 135 km to the north and 75 km to the west, respectively. These species are common in the province, but have not been previously recorded in the study area. *Helodium blandowii* var. *blandowii*, *Hypnum curvifolium*, and *Uolta crispa* are also common. However, we do not suggest extension of their continuous distributions be-
FIGURE 4A. Distributional ranges of species of group 3 (20 in total), comprising new occurrences in the study area with range extensions 77 km to > 650 km from their closest previously documented occurrence: a. *Campylium protensum*, b. *Dicranum fulvum*, c. *Huellodium blandowii var. blandowii*, d. *Hypnum curvifolium*, e. *Isopterygiopsis pulchella*, f. *Pohlia elongata var. elongata*, g. *Pohlia sphagnicola*, h. *Thuidium recognitum*, i. *Ulota crispa*, j. *Calypogeia suecica*. Dots show previously documented occurrences; plus signs are new occurrences. The shaded zone represents areas where the species were already known in the province or the boreal Black Spruce–feather moss forest in cases where the new occurrences suggest that the species may be found throughout the entire bioclimatic domain. A gradient in a shaded zone indicates that continuous species distribution in the area is uncertain, given the few occurrences reported in the lighter grey areas; arrows show the direction of range extension. Asterisks indicate species that are provincially rare according to Faubert et al. (2014+).
4b. Distributional ranges of species of group 3 (20 in total), comprising new occurrences in the study area with range extensions 77 km to > 650 km from their closest previously documented occurrence: k. Cephaloziella elachista, l. Cephaloziella spinigera, m. Chiloscyphus coadnatus var. rivularis, n. Fuscocephaloziopsis loitlesbergeri, o. Mesopychia rutheana, p. Lophozia silvicola, q. Mesopychia heterocolpos var. heterocolpos, r. Scapania apiculata, s. Scapania uliginosa, t. Sphagnum tenerum. See Figure 4A for meaning of symbols.
cause only one occurrence of each species was recorded in the study area, and the distance from the rest of their known Quebec range is substantial (325, 270, and 165 km, respectively).

Finally, the few occurrences (generally < 10) of the remaining 14 species do not suggest a continuous distribution of those species, but rather their sporadic presence over the study area. The new occurrences of Brachythecium erythrorhizion, Isopterygiopsis muel leriana, Polytrichum commune var. perigoniale, Lopho phiza ascendens, and L. bicrenata close gaps in their provincial distribution between southern and northern Quebec but also, in the case of B. erythrorrhizion and P. commune var. perigoniale, between eastern Quebec and Ontario. Furthermore, we document the presence of Campylium protensum, Isopterygiopsis pulchella, Polyli a elongata var. elongata, Calypogea suecica, Mesop tychia rutheana, M. heterocolpos var. heterocolpos, Scapania apiculata, and S. uliginosa in the southern portion of Nord-du-Québec, 260–670 km west of their previously documented Quebec occurrences.

Our discoveries of the rare true mosses Campylium protensum and Hypnum fauriei and the rare liverworts Chiloscyphus coadnatus var. rivularis, Odontoschisma francisci, and Schistochylopsis laxa, confirm the importance of bryophyte sampling efforts in the neglected regions of Quebec–Labrador. However, some of the species described here may be misunderstood as a result of under-sampling or taxonomic confusion. Recent changes in species taxonomy have made herbarium specimens unreliable describers of species abundance until they can be re-examined and their identifications confirmed.

Finally, considering a larger geographic perspective, even though our findings represent significant distributional extensions within the province of Quebec, for some species the distance from the adjoining Ontario populations is less substantial (50–200 km, on average, from our study area). However, bryophyte distributions in Ontario are not as well as or as recently documented as in Quebec (Faubert 2012–2014). Therefore, it is difficult to evaluate the exact distances between species occurrences. These species were found in eastern Ontario, in some localities of the Hudson Bay lowlands, and the Clay Belt region. The Clay Belt straddles Quebec and Ontario and its specific soil conditions may explain why the two provinces shared bryophyte assemblages.

Conclusions and Implications for Management and Conservation

This study suggests that numerous bryophytes may be more common than expected in Quebec–Labrador. We present a substantially revised and updated list of the bryoflora of the southern Nord-du-Québec administrative region. The updated ranges documented here can not only be used to redefine the protection priority ranks of these species, but may also aid in predicting the impacts of forest harvest and global climate changes. At the microhabitat level, our results indicate that some species had singular preferences in terms of habitat in the Black Spruce forest compared with other ecosystems across the province. Species found in our study occupied, in general, more diverse microhabitats and particularly more woody ones.

The southern portion of the Nord-du-Québec administrative region is considered by Quebec bryologists to be a “black hole” in terms of knowledge about the distribution of the bryophyte flora, reflecting the paucity of sampling efforts in the region rather than species. Substantial work is still needed to map bryophyte distributions accurately in the province. Furthermore, increased sampling and the consultation of herbarium specimens will be required to fully understand the distribution and microhabitat preferences of bryophytes throughout North America. Efforts should be made in boreal feather moss forests, which may be defined as “bryo-diversity hotspots” in view of the occurrences of uncommon, infrequent, and rare bryophyte species and, therefore, require particular conservation attention.

Acknowledgements

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SUPPLEMENTARY MATERIAL:

APPENDIX S1. Number of plots where bryophyte taxa were found in residual forest patches and burned areas in boreal Black Spruce–feather moss forest in the southern portion of the Nord-du-Québec administrative region, western Quebec, Canada.

2017 BARBÉ ET AL.: BRYOPHYTE RANGE EXTENSIONS IN QUEBEC 269

**LOIS A. HARWOOD**1,6, ELLEN V. LEA2, STEPHEN A. RAVERTY3, PATRICIA A. HALL4, ERIN LINN5, LIANNE POSTMA4, and OLE NIELSEN4

1Fisheries and Oceans Canada, 301 5204 50th Avenue, Yellowknife, Northwest Territories X1A 1E2 Canada
2Fisheries and Oceans Canada, P.O. Box 1871, Inuvik, Northwest Territories X0E 0T0 Canada
3Animal Health Center, British Columbia Ministry of Agriculture, 1767 Angus Campbell Road, Abbotsford, British Columbia V3G 2M3 Canada
4Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba R3T 2N6 Canada
5Golder Associates Ltd., 1721 8th Street East, Saskatoon, Saskatchewan S7H 0T4 Canada
6Corresponding author: lois.harwood@dfo-mpo.gc.ca

Each spring, most Bowhead Whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort (BCB) population migrate to the Canadian Beaufort Sea and Amundsen Gulf for summer feeding. Occasionally, Inuvialuit hunters and others observe beachcast (stranded) or adrift Bowhead Whale carcasses. From 1987 to 2016, 26 such occurrences were recorded. Most (65%) were found by Inuvialuit hunters travelling on the land, with the majority (54%) reported during 2000–2006. Bowhead Whale carcasses were found widely distributed throughout the region, with twice as many in Amundsen Gulf (65%) compared with the southeastern Beaufort Sea (35%). It was possible to measure or estimate standard length for 17 of 26 specimens, and all were either provisional ‘subadults’ (7–9.5 m; n = 10; 59%) or provisional ‘mature adults’ (13–16 m; n = 7; 41%). The cause(s) of mortality was not determined for any of the specimens. Whales in the ‘subadult’ group were likely 1–4 years old, while the ‘mature adult’ group were likely mostly mature animals (~25 y), including some potentially very old (>100 y). There was evidence or direct observation of Polar Bears (*Ursus maritimus*) and/or Grizzly Bears (*U. arctos*) scavenging at 60% of the carcasses for which presence or absence of bears or bear sign (scats and/or tracks) was reported. It is important to continue to record incidental observations of beachcast Bowhead Whales, as this may enable stranding rates to be evaluated.

Key Words: *Balaena mysticetus*; Bowhead Whale; beachcast; stranding; Beaufort Sea; Amundsen Gulf

**Introduction**

Each spring, most Bowhead Whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort (BCB) population migrate to the Canadian portion of the Beaufort Sea and the Amundsen Gulf to feed during the summer (Richardson et al. 1987; Moore and Reeves 1993; Harwood et al. 2010, 2017). They aggregate and forage there during August and September, with most starting their return westward to the Bering Sea wintering areas by mid to late September (Citta et al. 2015; ADFG 2017; Harwood et al. 2017).

The BCB population is listed as Special Concern under Canada’s *Species at Risk Act* (SARA Registry 2017) and endangered under the US *Endangered Species Act* (NOAA 2016). Bowhead Whales have a slow growth rate, a low reproductive rate, a late age of sexual maturity (~25 y; Rosa et al. 2013), and are extremely long-lived (oldest on record is a 14.6 m male, 211 y; George et al. 1999; Lubetkin et al. 2012). Based on the spring 2011 census at Point Barrow, Alaska, the most recent estimate of population size for the BCB population was 16,820 whales (95% CI = 15,376–18,643; Givens et al. 2016), representing an increase over the last decade. Clarke et al. (2013, 2014) reported that calf sighting rates increased during this same period, and George et al. (2015) detected increases in the body condition of whales from 1989–2011, statistically so in sub-adults. Although future trajectories for population size and body condition are not known (George et al. 2015), a suite of indicators are presently showing positive or stable trends (George et al. 2017).

In the western Canadian Arctic, local Inuvialuit hunters, fishers, pilots, researchers, and park staff have observed and reported beachcast or drifting Bowhead Whale carcasses during recent decades. The co-management framework which is now in place with the implementation of the Inuvialuit Final Agreement (IFA; INAC 1986) has fostered and enhanced reporting of unusual occurrences of wildlife in the Inuvialuit Settlement Region (ISR), including beachcast Bowhead Whale carcasses. Our objective was to summarize the location and timing of beachcast Bowhead Whale reports in the western Canadian Arctic, by reviewing available stranding records for 1987 to 2016. Where feasible, our secondary objective was to examine the relative size of beachcast specimens, and examine the records for possible reason(s) for the mortalities. We also note observations of Grizzly Bear (*Ursus arctos*) and Polar Bear (*U. maritimus*) scavenging at beachcast Bowhead Whale carcasses.
Methods

People travelling in coastal areas of the Inuvialuit Settlement Region (i.e., subsistence hunters and fishers, and scientific, enforcement, aviation, and park staff) have made opportunistic observations of beachcast or drifting Bowhead Whale carcasses and reported these to Fisheries and Oceans Canada (DFO). Coastal areas of the ISR used by Inuvialuit harvesters for hunting and travel are extensive and include most coastlines (Figure 1). We do not have empirical records of the number of trips or hours of search effort that were involved in the discovery of the carcasses.

DFO has maintained a database of these incidental observations, including the reported locations, date and source of first observation or report, state of the carcass, and associated notes and photographs. Where practical and when resources and personnel were available, site visits were done to obtain additional photographs and length measurements (standard length, tip of rostrum to notch in tail), and in a few cases, to collect tissue samples and measure blubber thickness. The geographic locations of the carcasses were recorded with global positioning systems (GPS), or reported according to local landmarks and official or local geographic names. Locations where beachcast whales were initially observed were mapped using ArcGIS (Figure 2).

Skin tissue samples were collected from seven carcasses to molecularly determine gender (Table 1). These were preserved either in a salt-saturated 20% dimethyl sulphoxide (DMSO) solution (Seutin et al. 1991), or frozen as soon as possible after collection. These tissues were transferred to fresh salt/DMSO solution in the lab and archived at −20°C to −80°C. Total cellular DNA extractions were performed using DNeasy blood and tissue kit spin columns (Qiagen Hilden, Germany). A polymerase chain reaction (PCR) based method was used for molecular determination of gender following methods described by Rosel (2003) and Shaw et al. (2003). For most of the tissues, these different methods were used in tandem to verify gender assignment.

Results

From 1987 to 2016, 23 beachcast and three drifting Bowhead Whale carcasses were found opportunistically in the western Canadian Arctic and reported to DFO (Figure 2; Table 1). Most were discovered by Inuvialuit harvesters travelling on the land (65%), with the rest reported by others (e.g., pilots, researchers, government staff). Nearly half (47%) of the observations recorded during the 30-year period were from 2000 to 2006 (Table 1). Half of the years (15 of 30) had no occurrences, and the other years had 1–4 observations of beachcast Bowhead Whales per year.

Carcasses were reported from widely distributed locations (Figure 2), in both the southeastern Beaufort Sea (35%) and Amundsen Gulf (65%). The carcasses were clustered in several recurring locations, including Franklin Bay (n = 4), Darnley Bay including Pearce Point (n = 4), along the Yukon coast (n = 5), off the southwest coast of Banks Island (n = 5), and in Prince Albert Sound (n = 3).

Carcasses were generally inaccessible for complete necropsy, due to their remote location, positioning on shore (e.g., portion sunk, buried), prevailing weather conditions, and/or the presence of bears; only one carcass was necropsied by a veterinary pathologist (Figure 3). Carcasses ranged from bone piles (Figure 3) to relatively intact carcasses (Figure 4). It was however possible to estimate or measure standard length of 17 (65%) of the carcasses, measure dorsal blubber thickness (25–30 cm) in three, and determine gender for two using molecular methods (Table 1).

The estimated whale lengths were all in one of two distinct size groupings, referred to here as provisional ‘subadults’ (7.0–9.5 m; n = 10; 59%) and provisional ‘mature adults’ (13–16 m; n = 7; 41%; Table 1) based on suggestions by George et al. (2011). No ‘mature adults’ were found west of Cape Bathurst, and mainly ‘subadults’ were found east of Cape Bathurst (Figure 2; Table 1). Cursory external examination of some carcasses and in some cases archived photos did not yield clues as to the cause of death in any of the specimens. None of the carcasses had any external or obvious indications of predation by Killer Whales (Orcinus Orca; George et al. 2004), or human interactions, such as shipstrike related trauma, or harpoons, floats, or attached ropes that would suggest the whale was struck-and-lost during subsistence hunting.

Of the 15 reports with notes about the presence/absence of bears, nine carcasses had one or more bears, or evidence of scavenging (scats and/or tracks) by Polar Bears and/or Grizzly Bears (Table 1). One carcass on the Yukon coast (no. 2; Table 1) had both bear species feeding on the carcass at the same time. A female Polar Bear with three cubs and three male Polar Bears were simultaneously feeding on a carcass (no. 8; Table 1) in southeastern Franklin Bay. At a relatively ‘fresh’ carcass on the western shores of Franklin Bay in 2000 (no. 7; Table 1), there were ten Grizzly Bears observed feeding at the carcass, and another six fled when the helicopter arrived and were sighted within 2–3 km in the nearby hills. A large male Grizzly Bear was observed at the Bowhead Whale carcass in Franklin Bay in August 2015 (Figure 4).

Discussion

Since 1987, there have been 26 opportunistic reports of beachcast or drifting bowhead carcasses in the western Canadian Arctic, 65% of these reported by Inuvialuit harvesters. The carcasses were widely distributed along the mainland coast and the southwest shores of Banks and Victoria islands in the Inuvialuit Settlement Region, with twice as many found on the shores of Amundsen Gulf (65%; all mature adults) compared with the southeastern Beaufort Sea (35%, mainly subadults). Polar Bears and/or Grizzly Bears were observed...
FIGURE 1. Coastlines in the Inuvialuit Settlement Region (ISR; polygon) self-identified by harvesters as having extreme or particular significance to ISR hunters. We infer these to include hunting and travelling routes that are regularly used (adapted from Community of Aklavik et al. 2008; Community of Inuvik et al. 2008; Community of Paulatuk et al. 2008; Community of Sachs Harbour et al. 2008; Community of Tuktoyaktuk et al. 2008; Community of Ulukhaktok et al. 2008).
at, or inferred to have been scavenging at, 60% of the carcasses. It was not possible to determine the cause(s) of mortality in any of the specimens.

Hunters from the ISR that found these carcasses have self-identified the lands and waters where cultural and renewable resources are of extreme significance and sensitivity (Figure 1), and we infer these to be the most intensely ‘searched’ coastlines during hunting and other traditional travel-based activities. Hunter reports of beachcast animals, ‘accidental’ wildlife sightings, predation accounts, and information on animal behaviour are some of the best examples of “local ecological knowledge” (Noongwook et al. 2007). Additionally, the onshore locations where the carcasses are discovered likely reflect, at least in part, a combination of prevailing winds, currents, and bathymetry that tends to concentrate the carcasses and wash them ashore (Figure 2). Similarly, flight routes used by light commercial aircraft are generally established and consistent, as are the locations where park staff work (airstrips and parks), although deviations from typical routes due to weather, altitude, or destination cannot be discounted.

Despite the limitations and biases associated with the data from beachcast whales, including an inability to quantify search effort, the database is unique in that it provides a long-term record of occurrences.

Our efforts to determine the cause of mortality and establish baseline health parameters were hindered by our inability to access fresh carcasses in a timely manner. None of the carcasses had any obvious evidence of predation or ship strike-related wounds, although most were in an advanced state of decomposition. Length measurements were subject to error due to decomposition, scavenging, access, and positioning of the carcass. Evidence of freeze and thaw cycles in successive winter seasons (Table 1) further confounds the comparison of inter-annual data. The blubber thickness measured on the three specimens was consistent with that for healthy landed bowheads (George 2009), although blubber thickness may not be the best indicator of nutritional state. A more recent study indicates adipocyte size and fibre density may be more informative indicators of body condition (Ball et al. 2015).

Figure 2. Location of beachcast and drifting Bowhead Whale (*Balaena mysticetus*) carcasses discovered in the western Canadian Arctic by hunters and others, 1987–2016 (whale number corresponds to Table 1).
<table>
<thead>
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<th>Whale #</th>
<th>Year</th>
<th>Month</th>
<th>Carcass first observed</th>
<th>On-site inspection of carcass by technical staff</th>
<th>Estimated length (m)*</th>
<th>Size class†</th>
<th>Discovered and/or reported to DFO by</th>
<th>Sex</th>
<th>Blubber thickness (cm)</th>
<th>No. bears observed or evidence of bears, scavenging (scats and/or tracks) at carcass</th>
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<td>9</td>
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<td>9§</td>
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<td>DFO staff</td>
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<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>2</td>
<td>1991</td>
<td>–</td>
<td>no</td>
<td>–</td>
<td>–</td>
<td>Aklavik Hunter</td>
<td>–</td>
<td>–</td>
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</tr>
<tr>
<td>3</td>
<td>1989</td>
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<td>13–14</td>
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<td>Paulatuk Hunter</td>
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<td>4</td>
<td>1995</td>
<td>4</td>
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*Not possible or practical to estimate measurement error.

†Provisional subadult = 7–9.5 m; provisional mature adult = >13 m.

‡GB = Grizzly Bear (*Ursus arctos*); PB = Polar Bear (*Ursus maritimus*).

§State of decomposition suggested whale was beachcast in previous year(s).

¶Female Polar Bear, three cubs, and three male Polar Bears feeding.

*Whale was accessible and necropsied by a veterinary pathologist on 15 July 2005 (Figure 3), > 8 months after stranding. The carcass was in an advanced stage of decomposition.
In cases where fresh carcasses are examined, such as is possible with Alaskan subsistence harvests, very few Bowhead Whales are found with any pathology (George et al. 1999), and blubber thickness and body condition of subadults have been showing a positive trend over the past 20 years (George et al. 2015). Bowheads have a long evolutionary history and are considered to possess protective molecular adaptations relevant to age-related diseases (Keane et al. 2015). Although the only known natural cause of death in a stranded Bowhead Whale was attributed to intestinal volvulus (Heidel and Albert 1994), recent detection of harmful algal (HABs) toxins in harvested and stranded marine mammals in Alaska in 2014 suggest this could be a potential contributing factor to future whale morbidity and loss (Lefebvre et al. 2016). As well, detection of an exotic pathogen, phocine distemper virus in Alaskan Sea Otters (Enhydra lutris), suggests a possible route of intro-
duction via the Northwest Passage (Goldstein et al. 2009). Exposure of Bowhead Whales to other novel pathogens may also be a consideration. Another possible explanation for death would be natural mortality. Despite the above mentioned limitations in measuring carcasses, given the 4 m separation in length between our ‘subadult’ and ‘adult’ age classes, it is unlikely that we would have assigned specimens to the wrong group. George et al. (2015) suspect that Bowhead Whales are most vulnerable to environmental vagaries when standard length is 8–10 m, and this matches with our ‘subadult’ group. Mortalities in this category may reflect early life stage events that coincide with a time of weight loss and growth of baleen racks (George et al. 2016). Our provisional ‘adult’ group most likely consisted of sexually mature whales, some potentially very old, although recently or nearly matured whales may have also been included (Koski et al. 1988, 1993). Mortality in our ‘adult’ group likely includes senescent mortality, but to an unknown extent.

Stable and positive trends observed in this population in recent years (see George et al. 2017) may be linked with enhanced production of the bowhead’s planktonic prey, associated with the changing climate (Moore et al. 2014; Arrigo and van Dijken 2015; George et al. 2015; Moore and Stabeno 2015; Wood et al. 2015). It could also include an increase in whale abundance since the cessation of commercial whaling in the early 1900s (McGhee 1988); population size has shown a strong recovery and has now approached pre-contact estimates of population size (Woodby and Botkin 1993; Brandon and Wade 2006).

Finally, based on the absence of observed harpoons, floats or ropes, or other signs of prior strikes, there was no indication of beachcast Bowhead Whales having been struck-but-lost by harvesters, as reported in Alaska (NOAA 2017a). The only recent subsistence harvests of Bowhead Whales in the western Canadian Arctic were in 1991 (Freeman et al. 1992) and 1994 (Harwood and Smith 2002). Prior to the 1991 harvest, the last recorded landed bowhead in this region was in 1925 (McGhee 1988). The reasons for the concentration of reported mortalities in the mid–early 2000s are not known, but for the reasons above, we do not attribute these to be hunting losses by Canadian hunters.

The geographic separation of carcasses, with ‘sub-adults’ in the Beaufort Sea and ‘adults’ in Amundsen Gulf, matches the segregation of subadults and adults...
that has been observed during photogrammetric, telemetry, and aerial survey studies conducted in these same areas (Cubbage and Calambokidis 1987; Koski et al. 1988; Koski and Miller 2009; Harwood et al. 2010, 2017). In all of these cases, subadults occurred mainly in waters over the continental shelf in the Beaufort Sea, while mature animals used more distant habitats and deeper waters, particularly Amundsen Gulf (Koski and Miller 2009; Harwood et al. 2017). This may explain the propensity for beachcast specimens in the two age groups to be separated geographically.

The prevalence of bears and bear sign at the beachcast carcasses was also notable. There is growing evidence that subsistence-harvested Bowhead Whale carcasses (bone piles left after subsistence hunts in Alaska) are becoming increasingly important in the diet of Polar Bears, particularly because more bears are spending more time close to shore (Miller et al. 2015; Rogers et al. 2015). Although the extent of scavenging at Bowhead Whale bone piles varied among years, there are indications that the contribution of Bowhead Whale to the diet of Polar Bears is increasing (Bentzen et al. 2007; Herreman and Peacock 2013; Rogers et al. 2015).

Emerging and dramatic environmental change in the Arctic marine ecosystem (e.g., Moore and Stabeno 2015), coupled with anticipated increases in shipping traffic in the Arctic (Halliday et al. 2017), prompted us to compile the historical stranding records for the Canadian portion of the BCB Bowhead range. In the Alaskan portion of their range, which includes the western Beaufort Sea, Chukchi Sea, and Bering Sea, beachcast Bowhead Whales are similarly recorded through the Alaska Marine Mammal Stranding Network (NOAA 2017a). Together, these datasets are the most practical means to document occurrences, and may inform managers when considering trends in spatial and temporal stranding records, and often is the only metric available to assess marine mammal mortality events (NOAA 2017b). We urge keeping the database as standard and current as possible.

Acknowledgements

We gratefully acknowledge the many people who reported and/or investigated the beachcast Bowhead Whales in the Inuvialuit Settlement Region. R. Baker, S. Cosens, L. Dahlke, L. Ermaghok, R. Ettagiak, J. Illisiat Jr., N. Robinson, late C. Ruben, F. Pociak, K. Snow, J. Felix Jr., M. Branigan, P. Cott, J. Alikamik, A. Joss, J. Kuptana, N. Perry, J. Lucas, A. Tardiff, E. Raddi, and T. Stein, participated in field sampling (our apologies to anyone we may have missed). Coordinators/field leaders were assisted in the field by numerous hunters and technicians from the communities of Ulukhaktok, Sachs Harbour, Paulatuk, Aklavik, Inuvik, and Tuktoyaktuk, Northwest Territories. Funding was provided by DFO and the Fisheries Joint Management Committee. We are particularly grateful to the Hunters and Trappers Committees from Sachs Harbour, Paulatuk, Tuktoyaktuk, Aklavik, and Ulukhaktok for notifying DFO of these occurrences and assisting with sampling. We thank C. George for providing advice and references relating to these occurrences over many years and in the preparation of this paper and J. Richardson for helpful comments on an earlier version. Figures 1 and 2 were prepared by J. Friesen of DFO, the latter based on an earlier iteration by D. Leonard. Preparation of this article was funded by DFO’s Species at Risk Program. C. George, D. Lee, and T. Jung provided comments that improved this manuscript.

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Lefebvre, K. A., L. Quakenbush, E. Frame, K. Burek Koski, W. R., G. W. Miller, N O A A (N ational O ceanic and A tm ospheric A dm inistration) and


Great Canadian Field-Naturalists

As part of Canada’s 150th birthday celebration, the Ottawa Field-Naturalists’ Club (OFNC) is initiating the formal recognition of Canada’s greatest field naturalists: individuals who made significant contributions to our knowledge of the natural history of Canada. This recognition will include:

i) Developing a Great Canadian Field-Naturalist “Hall of Fame” on the OFNC website, and posting tributes with a description of each naturalist and a summary of his/her accomplishments;

ii) Publishing the tribute in a special section in The Canadian Field-Naturalist (CFN);

iii) Partnering with the Canadian Wildlife Federation and potentially other national conservation organizations, for dissemination through their websites, social media, and/or magazines.

Selection Process:
The selection will be made by a sub-committee of the OFNC Publications Committee. The sub-committee will solicit and accept nominations. The call for nominations will be disseminated broadly, including through publication in CFN, posting on the OFNC website, and through the various channels of communication with partners. Nominations should consist of a few paragraphs outlining the candidate’s accomplishments against the selection criteria and be sent to editor@canadianfieldnaturalist.ca. Previously published Great Canadian Field-Naturalists tributes also should be reviewed for guidance. Nominations will be assessed as they are received. When a nominee is selected, a Great Canadian Field-Naturalist tribute will be prepared, ideally by the person making the nomination. Nomination and selection will be ongoing.

Criteria for Selection:

Potential Candidates:

- Deceased individuals who were Canadian citizens or long-time, including seasonally recurring, residents of Canada;
- Recognition acknowledges lifetime achievement or many years of contribution within the scientific community;
- Contributions can be in either a professional or amateur capacity.

Character of Contributions:

- Significant contributions to our knowledge of the natural history of Canada;
- Contributions predominantly through field biology investigations and analyses within a single (e.g., botany, entomology, or zoology) or multi-disciplinary (e.g., botany and entomology) field and, not predominantly geological, cultural/educational, conservation, or resource management in orientation;
- Activities/contributions predominantly made in Canada and at regional to national geographic scales, rather than a localized scale;
- Contributions were documented in credible literature and/or with fully curated, publicly accessible specimen collections.

OFNC Publications Committee

Great Canadian Field-Naturalists: James Fletcher (28 March 1852–8 November 1908)

James Fletcher (Figure 1) was born in the hamlet of Ashe in southeastern England and privately developed considerable expertise in entomology (Lepidoptera) in this rural landscape. He received no specialized science training but graduated from King’s School, Rochester with a well-rounded liberal education and with a particular proficiency in mathematics. He was initially employed at age 19 as an accounting clerk in England, immigrating to Canada (Montreal) in 1874, and then to Ottawa where he joined the staff of the Parliamentary Library as an accounting clerk in 1876. Under the mentorship of Parliamentary Librarian Alpheus Todd, he was also encouraged to conduct entomological research there. Fletcher was appointed Honourary Dominion Entomologist in 1884 and formally appointed as Dominion Entomologist and Botanist in 1886. He held that position until his untimely death in 1908. He is buried in Beechwood Cemetery in Ottawa, Ontario.

Major Area(s) of Natural History Contribution

Entomology (Lepidoptera, economic entomology, taxonomy); botany (vascular plants); public education; organizational and institutional development; biodiversity documentation.

Historical Summary

James Fletcher is credited with establishing the science of economic entomology as well as establishing the basis for plant pathology investigations in Canada. He is also notable for his establishment, in the absence of significant research resources, of a massive informational network of people engaged in agricultural activities throughout Canada. He maintained

Figure 1. James Fletcher with insect collecting net, Ottawa 1907. Photographer unknown; from Fletcher memorial issue, The Ottawa Naturalist 24(5) 1910.
correspondence with over 400 entomologists alone! Fletcher’s contacts and associates included several internationally acclaimed intellectuals, including Alexander Graham Bell and evolutionist Alfred Russel Wallace.

At the same time, he was deeply involved with and promoted the study of Canadian native biodiversity for its own sake. He collected extensively across the country, ultimately donating these specimens (Figure 2) to form the foundation both for Canada’s largest herbarium, the National Collection of Vascular Plants (DAO), and the largest insect collection in Canada, the Canadian National Collection of Insects (CNCI). Fletcher published extensively on native biodiversity, focusing on the natural history and taxonomy of insects and the control of agriculturally problematic species. He engaged as well in investigations on a wide variety of subjects, such as bird migration, geology, and environmental education. He was much in demand as a speaker and writer across Canada on such topics both in-person and through printed media.

Fletcher established innumerable first records through his personal field efforts and described a number of new insect species from that field work. A new species of dragonfly was named in honour of this work (Figure 3).

His inspiration of individual field naturalists and his pivotal role in the establishment and development of regional, national, and international organizations such as the Ottawa Field-Naturalists’ Club, The Entomological Society of Ontario, the Association of Economic Entomologists, and the Ottawa Horticultural Society, were equally significant contributions. Many of those organizations continue to contribute as he intended. In 1880 he served as the founding editor of the predecessor of The Canadian Field-Naturalist. He was also successful in enhancing the importance of investigations of Canadian natural sciences through his prominent positions and roles within influential national organizations such as the Royal Society of Canada.

All said and done, James Fletcher was likely the premier contributor amongst the group of largely self-taught resident 19th Century naturalists who pioneered the scientific investigation of Canadian biodiversity.

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Great Canadian Field-Naturalists: JOHN MACOUN (17 April 1831–18 July 1920)

John Macoun (Figure 1) was born in Northern Ireland to a farming family and immigrated with his parents and brother to Canada in 1850, to settle on a farm north of Belleville, Ontario. He had little formal education and certainly no academic training in natural sciences. Nonetheless, after brief study in 1859 at the Toronto Normal School (a teacher’s college), he was accredited as an elementary school teacher and taught in several eastern Ontario communities over the following decade. During this period his botanical activities expanded from a casual interest into a serious passion. He largely developed his identification and remarkable field biology skills through contacting an increasingly wide circle of botanical associates in the 1860s.

In 1868 he was appointed Professor of Botany at the newly establishing Albert College in Belleville. He taught there for almost 15 years, also conducting surveys for the Geological Survey of Canada (GSC) and the Canadian Pacific Railway over several summers in the 1870s and early 1880s. Macoun...
was appointed Naturalist (Dominion Field Naturalist, in his words) to the GSC in 1882 and held that position (variously titled, including Assistant Director) until his retirement in 1911. He moved to Sidney, Vancouver Island, British Columbia for the remainder of his life. He is buried in Beechwood Cemetery in Ottawa.

Major Area(s) of Natural History Contribution
- Botany (vascular plants, bryophytes, lichens); fungi; marine algae; ornithology; malacology; biodiversity documentation.

Historical Summary
While best known for his western explorations and discoveries, Macoun is the most significant collector of natural history specimens in more regions of Canada than anyone before or since his time. Perhaps dissuaded by his lack of formal scientific training or simply because of his stated preference for field work, he conducted no taxonomic investigations. Instead, he circulated duplicates of his collections widely to taxonomic authorities in the United States (there were none in Canada through most of his career) and, to a lesser degree, in Europe. Many native plants and at least one insect were named in his honour by these authorities. A number of these have stood the test of time and remain the preferred species name (Figures 2 and 3).

Macoun was an exceptionally perceptive collector with an intuitively keen eye for what was unusual or exceptional within whatever landscape he was exploring. This and the fact that his explorations were frequently conducted in primary growth (original) examples of virtually every significant non-arctic environment in Canada, resulted in the acquisition of innumerable exceptional specimens. A travel bursary of the Canadian Botanical Association is named for him to honour that inspirational performance.

It is almost certain that more plant species are known in Canada solely from Macoun’s collections than from the efforts of any other field naturalist in history. These include the remarkable Macoun’s Shining-moss (*Neomacounia nitida* (Lindberg) Ireland; Figures 4 and 5) an endemic southern Ontario species and genus now believed to be extinct. The total of his collections is not known but even excluding duplicates, they...

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**FIGURE 1.** John Macoun with Geological Survey of Canada associates William Spreadborough (right) and (probably) C. H. Young (left), sorting marine specimens, Vancouver Island, British Columbia, 1908–1909. Photographer unknown.


**FIGURE 3.** Macoun’s Arctic (*Oeneis macounii*) from Bonnchere, Algonquin Park, Nipissing District Ontario, 17 June 1972. Photo: P. M. Catling.

**FIGURE 4.** Macoun’s Shining Moss (*Neomacounia nitida* (Lindberg) Ireland), a species and genus known only from Macoun’s collections near Belleville between 1860 and 1893 and considered extinct as of November 2002 (SARA Registry 2018). Photo: Lyndsey Sharp, Canadian Museum of Nature.
number in the tens of thousands. The Canadian Museum of Nature herbarium (CAN), now the second largest in Canada, is founded upon Macoun’s massive collection of vascular and non-vascular plants. The herbarium housed over 100,000 specimens at the end of his career at the GSC.

As keen as he was on exploring and collecting native Canadian flora and fauna, he conducted virtually no field investigations outside the country. However, he was a prolific chronicler of Canadian biodiversity. His *Catalogue of Canadian Plants* was the first coast-to-coast inventory, covering all vascular and non-vascular species in a series of reports over a 20-year period. Much the same can be said of his *Catalogue of Canadian Birds* produced between 1900 and 1903, although William McIlwraith of Hamilton Ontario, Macoun’s son James, and his long-time field associate William Spreadborough are likely due the major credit for the latter publication.

Macoun emphasised the practical aspects of field explorations (applied science) as opposed to pure research undertaken for its intrinsic contribution to human knowledge. He employed his field botanist insights and discoveries most famously in promoting the agricultural potential of the drylands of the Northwest Territories (today’s Prairie Provinces) in a massive 1882 tome supporting the federal government’s Western expansion policies and its preference for a southern route for the Canadian Pacific Railway.

Macoun was modestly involved in early efforts to generate conservation awareness. He called, for example, for protection of the extraordinary deciduous forest of southwestern Ontario in the area we know today as the Carolinian Zone. In 1893 he bemoaned that “the careless habits of the last generation” were destroying the forests of the Niagara Peninsula “so completely [that] its boasted title of the Garden of Canada would be a misnomer”.

Though largely proven correct in subsequent years, his boosterism for Western development certainly exceeded what a more cautious science-based analysis would have concluded. It likely secured his appointment to his coveted position at the GSC, however, and thus established a uniquely productive career that was to last for more than 30 years. (He was less prescient in applying his field experience in parts of southern Ontario, declaring that the future of Lake Erie’s Pelee Island “is not bound up in the making of wine”!).

Macoun was very physically strong and rarely ill, and many contemporaries spoke of his endurance, tirelessness, and enthusiasm as well as his remarkable memory and workaholic ways. Even with the limitations of a debilitating stroke he suffered in 1912 he continued collecting, amassing a vast collection of marine organisms during his southern Vancouver Island retirement.

John Macoun remains, simply put, the most significant collector of Canadian biodiversity ever.

References


Daniel F. Brunton and Paul M. Catling
Upcoming Meetings and Workshops

The Alberta Chapter of the Wildlife Society Conference

Entomological Society of America, Eastern Branch Meeting
The 89th annual meeting of the Eastern Branch of the Entomological Society of America to be held 17–19 March 2018 at the Westin Annapolis Hotel, Annapolis, Maryland. Registration is currently open. More information is available at http://www.entsoc.org/eastern/2018-branch-meeting.

Entomological Society of America, North Central Branch Meeting
The 73rd annual meeting of the North Central Branch of the Entomological Society of America to be held March 18–21 March 2018 at the Madison Marriott West Hotel, Madison, Wisconsin. Registration is currently open. More information is available at http://www.entsoc.org/northcentral/2018-branch-meeting.

Entomological Society of America, Southwestern Branch Meeting

US Regional Association of the International Association for Landscape Ecology Annual Meeting
The annual meeting of the US Regional Association of the International Association for Landscape Ecology (US-IALE) to be held 8–12 April 2018 at the Palmer House Hilton, Chicago, Illinois. Registration is currently open. More information is available at http://www.usiale.org/annual-meeting.html.

American Ornithology Meeting 2018

2018 Northeast Natural History Conference

Annual Northeast Fish & Wildlife Conference
The 74th annual Northeast Fish & Wildlife Conference to be held 15–17 April 2018 at the Hilton Burlington Hotel, Burlington, Vermont. The theme of the conference is: ‘Leading with Science for Conservation’. Registration is currently open. More information is available at http://www.neafwa.org/conference.html.
James Fletcher Award Established

Late in 2017, inspired by the historical reflections all around us in this 150th anniversary year of Canadian Confederation, the Publications Committee of the Ottawa Field-Naturalists’ Club (OFNC) established an award to acknowledge and celebrate excellent contemporary contributions to The Canadian Field-Naturalist (CFN) while also honouring the historic roots of the journal. The award is named in honour of OFNC founder James Fletcher (1852–1908), who was the founding editor of the CFN’s earliest iteration, the Transactions of the Ottawa Field-Naturalists’ Club, and who also served as editor of its succeeding journal, The Ottawa Naturalist (later, CFN), for over a decade.

The James Fletcher Award recognizes the best paper published in CFN in a particular volume, commencing with volume 130 (2016). “Best” is often a subjective and perhaps not always fair term, especially considering the diversity of research subjects and approaches reported within a typical CFN volume. Accordingly, the ultimate choice is made from a selection of up to three finalists, all deemed particularly excellent contributions in their own right.

A subcommittee of the Publications Committee recommended suitable choices to the full committee. The full Publications Committee made the final selection.

Three finalist papers were identified for the James Fletcher Award for CFN Volume 130 (2016):


Robert G. Forsyth, Paul Catling, Brenda Kostiuk, Sheila McKay-Kuja, and Allen Kuja. Pre-settlement snail fauna on the Sandbanks baymouth bar, Lake Ontario, compared with nearby contemporary faunas. Canadian Field-Naturalist 130(2): 152–157. https://doi.org/10.22621/cfn.v130i2.1839; – a combination of contemporary field work and forensic lab analysis compares snail diversity detected within a deposit of 1000+ year old specimens against the current diversity at this lakeshore sand dune site;

Peter B. Mills and Duncan J. E. Hill. Ancient lake maxima and substrate-dependent riverine migration have defined the range of the Mudpuppy (Necturus maculosus) in southern Ontario following the Wisconsinan glaciation. Canadian Field-Naturalist 130(2): 158–163. https://doi.org/10.22621/cfn.v130i2.1840; – a large body of data gathered co-operatively through the Ontario Herpetological Atlas is combined with regional geographic/biogeographic information to hypothesize probable post-glacial migration routes.

The paper “Distribution and ecology of a new species of water-lily, Nymphaea loriana (Nymphaeaceae), in Western Canada” was selected from these finalists as the first recipient of The James Fletcher Award. It represents foundational research on a new taxonomically important species and will be referred to for decades to come.

Congratulations to authors Robson, Wiersema, Hellquist and Borsch, who have been sent personal copies of the award certificate (Figure), and to the other finalists. We are pleased to take this opportunity as well to express our appreciation of all authors who chose to share their valuable field-based research findings with the readers of The Canadian Field-Naturalist Volume 130.

Daniel F. Brunton and Jeffery M. Saarela
OFNC Publications Committee
When early explorers from Europe came to Canada they found not only a new land, but also a new flora comprised of many plants they had never seen or heard of before. During these early explorations plants were sent back to Europe so that botanists could study them or grow them for food or medicine. For these first modern botanists it meant making many new discoveries. Some more adventurous botanists even made the trip across the ocean in the hope of finding new species. The native people who inhabited the land centuries before taught the newcomers about many useful plants, and even saved their lives by showing them how to use a mysterious plant potion they called Annedda to cure them from scurvy. However, early botanists wanted to describe and name the new plants according to the botanical knowledge of their scientific culture. The difference between traditional and scientific plant knowledge as well as the science of botany, which was still at its infancy, sets the scene for many fascinating stories.


By Alain Asselin, Jacques Cayouette, and Jacques Mathieu. 2014, 2015, 2017. Septentrion. 288, 328, 312 pages, 44.95, 49.95, 49.95 CAD, Paper.

Curieuses histoires de plantes du Canada is a series of books describing interesting botanical and historical facts of Canadian plants. Many botanical discoveries were made during important historic events that defined Canada. These events are recounted in these books with emphasis on plants or plant particularities that were discovered contemporaneously. The three recently published volumes are divided according to important milestones in Canadian history. The first volume contains stories spanning the time frame from the first Viking explorations to around the beginning of the Hudson Bay Company. Volume two takes place during the French rule period, while the third volume takes place during the British rule period until the time of confederation. Each volume is divided into multiple short stories presented in chronological order. Each story provides the reader with the necessary historical context at the time of these botanical discoveries and describes what was known about the plants at that time. The stories also highlight specific points about the people and circumstances leading to the discoveries.

It is interesting to see how botanical knowledge evolved through time. Of frequent interest to readers may be the historical medicinal values and other beneficial properties of plants. One example is Bloodroot (Sanguinaria canadensis) which was once used as toothpaste and mouthwash. It was proven that Bloodroot does not have any effects against dental plaque or gingivitis but there may be antimicrobial and antitumor properties that have yet to be discovered. Another interesting story explains an easy recipe which was used to test for food adulterants in flour. By placing a small quantity of flour in a glass of water and adding sulphuric acid, it was possible to evaluate for impurities. If the flour was pure, the sulphuric acid would consume all of it. Adulterants would have been clearly visible after 10 minutes because they would not have been consumed. In addition, materials such as lime would cause the mixture to fizz. Some other stories relate interesting anecdotes behind plant names. Some stories convey information on the persons who named the plants and others on who they were named after. One example is the story about Sir Joseph Banks, a famous English naturalist with connections to the Canadian railway system. As a matter of fact, Pinus banksiana was named in honour of his legacy and it happens to be one of the most commonly used timber in the production of railway ties in Canada. These books contain many more stories, all sharing with the reader curious and intriguing facts about plants.

This book series is both pleasant and interesting to read. It is beautifully edited and includes many appealing botanical and historical drawings of great aesthetic and scientific value. Numerous text boxes provide more detail on various aspects present in the stories. Extensive references are also included to encourage readers to learn more about the plants and their uses.
Entomology

The Secret Life of Flies


When was the last time you really, truly looked at a fly? Admired the shimmery blues and greens of a Housefly (Musca domestica) before swatting it away from your dinner? Gawked at the Stalk-Eyed Fly (Achias rothschildi) as it swallows air to inflate its own eyes (think bicycle pump)? Step inside the brain of Erica McAlister, the Senior Curator for Diptera at the Natural History Museum in London, United Kingdom, and you will see flies for what they are: an order of species with astonishing diversity, usefulness, and beauty.

Imagine the most enthusiastic teacher you’ve ever had, and you get close to the experience of reading this book. The writing is liberally peppered with exclamatory points, and it is infectious! There are enough jaw-dropping fly facts in here to catch the attention of any reader who wants to know more about the natural world. Truly, Diptera are lucky to have such a passionate advocate in McAlister. As she rightly points out, too often are flies, and insects in general, ignored by “mainstream conservationists” in their campaigns to protect the charismatic macro-fauna. Where, she argues, is the campaign to save the endangered Bee Louse (Braula coeca) that has not been seen in the United Kingdom for years? When was the last time you expressed concern for the Rhino Bot Fly (Gyrostigma rhinocerontis), which may be one of the most threatened species of animal on the planet? If we will only conserve what we love and only love what we know, then let this book become your guide to giving flies the respect they are due.

Flies are often underappreciated, but they are essential to our daily lives. They pollinate many economically and culturally important crops (thank a fly from the Forcipomyia genus the next time you enjoy chocolate!), control other insects that are agricultural pests, are a food source for animals that we enjoy watching, such as birds, and do an excellent job of decomposing plant and animal waste.

However, McAlister does not spend all her time trying to convince the reader that flies are only worthy of our attention because of their usefulness to humans. She constantly regales us with descriptions of how fascinating these animals are as objects of scientific study. The Gray Bee Fly (Anastoechus melanohalteralis) is “possibly the cutest animal on the planet” (p. 205); horse flies often have “the most spectacular bands, squares, triangles, circles and wiggles on their eyes” (p. 216), and parasitic flies “are some of the most extreme in terms of modifications from the basic plan, which of course leaves even the most experienced of dipterists with feelings of childlike pleasure” (p. 211). These descriptions made me simultaneously feel like...
I was missing out by not being a dipterist, and glad that I had been pulled along for the ride in this joyful written book.

McAlister has divided her book into 10 chapters based on functional feeding type, such as the Pollinators, the Coprophages (the eaters of animal waste), the Vegetarians, the Parasites, and the Sanguivores (bloodsuckers like mosquitoes and black flies). Within these chapters McAlister nimbly jumps among species and anecdotes that connect flies to history, medicine, agriculture, forensic science, conservation, and even pop culture. One of my favourite passages is a rant about the use of a dinosaur-DNA-filled adult crane fly in the opening scene of the original Jurassic Park movie. Adult crane flies, as I learned, do not possess the mouthparts to pierce the skin and would therefore never be filled with another animal’s blood. So egregious is the error that “many a performance must have been disrupted due to excessive tutting by indignant dipterists” (p. 129), and now you too can join in the indignation. It is precisely this commitment to connecting flies to our daily lives in a way that inspires an “Oh neat!” rather than an “Oh gross!” that makes this book so engaging and worthwhile.

Entomology is a huge topic and this, as are Stephen Marshall’s previous books, is a huge book. The numbers above say as much, but here’s another one: it weighs just over three kilograms! Clearly not a field guide, but very much a guide to the fields explored by naturalists. And if you want an entomology course—guide, but very much a guide to the fields explored by naturalists. And if you want an entomology course—


The roadmap may be the same, but the landscape it guides us through is changing: new species, introduced inadvertently or deliberately and often invasive, have become established; extinction rates are too high and rising; climate change increasingly forces ecological change. Meanwhile, we do not know enough to describe and evaluate these changes accurately. And so, Marshall aims this edition at naturalists, in the hope that while exploring our locales, we will gather and share information about the changes we witness: his explicit call for engagement in citizen science is reiterated at various places throughout.

The Introduction provides an overview of the definition of an insect and its general morphology plus the “tree” of insect life. The 11 chapters forming the body of the book are organized around the common names of several insect orders, bracketed by Chapter 1 on the earliest insects and Chapter 13 on other arthropods, such as spiders and millipedes. A final chapter provides an excellent, succinct overview of “Observing, Collecting and Photographing Insects”. Each chapter consists of text organized around the families under discussion, followed by copious photos illustrating the many species within these families. The photos—an integral, essential part of the book—are a reasonable size, 44 × 58 mm, and usually nine to a page. Organized like the text, but in more taxonomic detail, the photos and their

Here’s something to ponder the next time you’re getting chewed on by mosquitoes in a bog: did you know that there are species of mosquito whose larvae live inside the water body (the phytotelma) of pitcher plants? Older plants produce less of the digestive enzyme needed to break down insect material. The mosquito larvae, in the midst of their feeding frenzy in the belly of the pitcher plant, leave behind finely shredded insect remains that are more accessible to the smaller supply of enzymes available in older plants. At the very least, reading this book will leave you with many such neat facts for your next nature hike or cocktail party.

I hope The Secret Life of Flies will bring you more than fodder for small talk. It has the power to inspire you to pay closer attention to all the small things around us, like the mosses, plankton, insects, bacteria, and fungi that collectively make the world work in ways we don’t understand. As naturalists, ecologists, and conservationists, we should strive to learn as much as we can about all life, and McAlister’s engaging look into the world of flies is a great place to start.

EMMA BOCKING
St. John’s, NL, Canada
captions—which contain additional details on the size, range, habitat, and behaviour of the species pictured—both illustrate and supplement the main text. Marshall is a prolific photographer and this edition is, in part, a celebration of the advances in digital photography, “the game changer” for “most naturalists” (p. 7). He started using photos in his courses 30 years ago in the days of slide film; many new photos in this edition are digital. The photos were taken over several decades of travel and concentrate mainly on northeastern North America.

Chapter lengths vary with the size of the orders discussed. Thus, Chapter 3 on Stoneflies is a mere six pages, Chapter 8 on Caddisflies is 10. Similarly, the chapters on the five largest orders, Hemiptera, Lepidoptera, Coleoptera, Diptera, and Hymenoptera, are long and involved. The longest is 11, “Flies, Scorpions and Fleas”, at 167 pages, a mere summary of his 2012 volume, Flies: The Natural History and Diversity of Diptera (Firefly Books). A description of the order is followed by its main subcategories, generally down to family and sometimes genus. It seems every page is punctuated by fascinating details of insect characteristics and behaviour, recounted in his approachable style, leavened by his sense of humour. Only a brief sample can be mentioned here. Did you know that owlet moths can detect the clicks of bats, and that the mites that live in these moths’ ears choose only one ear so as to enable the moths to continue evading the bats, protecting both the moth and mite (p. 175)? Or that our single species of bess beetle (Passalidae) has 14 distinct calls (p. 269); that male dance flies provide nuptial gifts to prospective mates (p. 399); an ingredient for secret ink was first found in oak galls (p. 524); or how maggots are like whales (p. 401)? Didn’t think so!

Retaining so much of the original text makes sense for several reasons, but a light editorial hand could have checked, for example, all the unchanged uses of the word ‘recent’ and similar expressions, or updated occasional time-based references, such as a canoe trip 30 years ago mentioned in both editions. Occasional more important updates have been made, for example, predicted dates for mass appearances of cicadas (pp. 102–103). And, while I’m quibbling anyway, one large family appears in the photos, but not the text (Lepidoptera: Notodontidae, the Prominents; pp. 225–229). These are minor points, however, for most readers aren’t going to check both volumes and the second edition text doesn’t sound or feel dated.

The back matter remains relatively unchanged from the first edition: website information has been updated (for the most part), including note of the invaluable work in the open, online Canadian Journal of Arthropod Identification (http://biologicalsurvey.ca/ejournal), with which, he modestly omits to say, he is heavily involved. Several references have been added to the bibliography; two new “simplified” picture keys have been added to the original two dozen: one on insects that hurt and one on species found indoors. The picture keys are an important part of the book, illustrated by sketches and generally using familiar terms. Three indexes are provided, to the photographs by genus and species, to common family names, and a general, largely taxonomic, index; its updates reflect, of course, the many taxonomic changes. That might seem like overkill, but there is a lot to navigate in this book!

The simple statistics of the book indicate how impossibly large the field of entomology is. Scientists can spend entire careers collecting and organizing chosen families of insects. Stephen Marshall has made heroic efforts in this and previous publications to distill this extensive knowledge into a useful, accessible format. While the book is far too big and heavy to cart into the field, it is invaluable in the home office—preferably on a lectern!—for anyone interested in learning more about these fascinating animals. While the first edition was produced initially as a text for his third-year entomology course, the second adds another purpose: to not only teach insect identification, but also to encourage potential citizen scientists to contribute to their own as well as a broader understanding of entomology. This is a never-ending task, and the sheer number of people Marshall acknowledges (p. 677) as helping along the way is another measure of its enormity. This book, then, is in a sense an iterative process: it accumulates much of what is known, comments on how little that really is, and encourages the expansion of knowledge. If it’s successful, the second edition will necessitate its replacement by further editions as well as, we can hope, more specialized off-shoot volumes, such as Flies, for other large orders. We’re behind in Canada compared to other countries. We may never catch up, but we can at least be inspired to get into the game.

Insects: Their Natural History and Diversity is a great source of such inspiration.

BARRY COTTAM
Ottawa, ON, Canada

ORNITHOLOGY

Raptors: The Curious Nature of Diurnal Birds of Prey


Reading this book on raptors was like reading Lady Diana’s biography. We have seen the pictures and much of the text before. Pulling all the many reports together in one place provides a clarifying perspective on a very complex subject. This is the case with Raptors. I have heard much—but not all—of the information before,
in bits and pieces and separated by years. Bildstein has done a great job of combining all the information into one volume. The author has excellent credentials for this undertaking. He is the Sarkis Acopian Director of Conservation Science at Hawk Mountain Sanctuary in Pennsylvania. He organises the conservation and education programs and runs the graduate, international, and visiting scientist programs. He has authored many peer-reviewed publications including several books on raptors.

Many years ago, I was confused by the question of what is a raptor? Is it a meat eater? American Robin (Turdus migratorius) and Golden Eagle (Aquila chrysaetos) eat meaty worms. Mergansers and Osprey (Pandion halaetus) eat fish. Clearly robins and mergansers are not raptors. How about birds that catch prey in their talons? Where does this leave vultures? I am relieved to note I am not the only one confused. Even the mighty taxonomists seem to be in a quandary. This author notes that the American Ornithological Society (AOS) lists woodpeckers, falcons, and parrots in sequence. However, he says it should be tyrant flycatchers, parrots, and falcons. Similarly, the AOS has hawks, owls, and trogons together, while the author quotes molecular research as grouping owls, North American vultures, and the Cuckoo Roller (Leptosomus discolor). Our own Turkey Vulture (Cathartes aura) is another enigma. It is not a buzzard and is not related to the raptors of Europe, Africa, and Asia. While the New World vultures look like their old-world counterparts and perform the same ecological role, it is the result of convergent evolution, not family ties. Taxonomists seem to have difficulty deciding who the Turkey Vulture’s closest relatives are: ibis, owls, or the enigmatic Cuckoo Roller; no wonder I am confused. I will stay happy to count all the hawk-like birds as raptors.

For me the author has two achievements. Aside from bringing an over-arching outlook, he also brought a global perspective. He does a really fine job of covering raptor biology, at least what we know so far. He has researched how a raptor is put together and the effect on feeding, breeding, flight, distribution, and migration. He notes the many deficiencies in our knowledge and the possible ways we can fill the gaps (with webcams, satellite tracking, miniature transmitters, etc.).

I thought I understood migration, but Bildstein shows it is way more complex than we ever knew. The recently-discovered meanderings of Turkey Vultures are confusing. The amazing migration of Amur Falcons (Falco amurensis) is truly startling. I have seen these delightful little raptors breeding in Mongolia and wintering in Africa without realising how tough they are.

There is a small section of photographs. While they are good quality, I suspect they were chosen to illustrate a point rather than provide heart-stopping photos.

I found the chapter on “Raptors and People” the most enlightening and disturbing. The list of offences, both deliberate and unthinking, we have committed against these birds makes for unsettling reading. It is remarkable how they have survived this onslaught, but they still need our help. Despite taking four trips to India, I have seen just over 150 vultures of all species in a country where there used to be 40–50 million birds. In North America, the number of times bounties have been paid for raptor heads is horrifying. We are still not over the anti-raptor hurdle and it is comforting to know there are still people working to save these magnificent birds.

While most avid birders will be in familiar territory, the book reveals some interesting twists. It is easy to read, yet still maintains a very high level of scientific objectivity. I learned a lot, as well as refreshing some of the grey zones in my aging brain. Most importantly, I enjoyed reading this book.

The Australian Bird Guide


Technically, I had been to Australia in 2013. My single day on Macquarie Island in 2013, over 2000 km south of Melbourne, did not prepare me for the overwhelming barrage of new species and genera when I reached the mainland in 2017. What better to assist me to plough through this confusion than a brand-new field guide. And what a guide!

Australia, plus its offshore territories, has a list approaching 900 species, almost half of which are endemic. This new guide has around 4700 colour illustrations depicting over 900 species and covers all the distant islands. The authors include everything, from full coverage of vagrants to remote island territories and species known only as washed up bodies. Each species has illustrations of adults, juveniles, females, dark and light morphs, and summer and winter plumage as appropriate. When necessary, birds are shown in flight. These depictions are not just accurate, they are beautiful. It is very useful to have the variation in plumages depicted, especially for a novice. So often the bird you see does not quite “fit” the book. Having multiple choices helps when you find a bird like a cuckoo-shrike. There are four similar species of cuckoo-shrike and having minor details helps narrow the choice. Also, the Australasian Figbird (Specotheerus vielioti) has two subspecies (S. v. vielioti and S. v. ashbyi), both accurately depicted, and I saw both. My notes are such that if the taxonomists split these two into full species I will be able to count an armchair tick.

The illustrations are accompanied by text that is more informative and expansive than a typical guide. This comes at a price. The book is 18 × 25 × 3.3 cm
ZOOLOGY

Wolves of the Yukon


Wolves of the Yukon was an engaging and highly enjoyable, easy read with a simple but most accurate book title. While I have never been to the Yukon, this paperback put it on the map as one of my bucket list destinations. It is an area that is pure wilderness, with Moose (Alces americanus) and Caribou (Rangifer tarandus) outnumbering people 10 to one and one Gray Wolf (Canis lupus) for every five humans (p. 125). My basic research on the Canadian Territory (i.e., Googling it) showed that today there are about 35 000 people living there and given that there are 5000 wolves inhabiting the region (pp. 102, 118, 126, 170, 251), the ratio is now more like seven to one. Nonetheless, this Territory is about as pristine as a large area gets with an amazing lack of people living in “the very last remaining mountain wilderness of North America” (p. 10). It is an area dominated by many of the large mammal inhabitants which have been there since the Pleistocene over 10 000 years ago.

Bob Hayes researched wolves in the Yukon for nearly 20 years from 1982–2000. He radio-collared hundreds of wolves, pioneering research on the kill rate by wolves of Moose, Dall’s Sheep (Ovis dalli), and woodland and migratory Caribou. He also studied the effects of wolf control on wolf and prey populations, guiding original research on non-lethal ways of controlling predation. He came to understand many aspects of wolf biology, including pack dynamics, reproduction, food habits, kill rates, dispersal, den selection, scavenger competition, and cause and rate of mortality (p. 247).

Using a combination of narratives and easy-to-follow essays, Hayes traces the history of the Yukon wolf from the end of the Ice Age to the present day. Each chapter begins with a vignette or field experience that relates to the theme of the chapter. In the first couple of chapters, which starts 20 000 years ago on the Mammoth Steppe, we learn about some now extinct animals such as the Giant Short-faced Bear (Arctodus simus), Woolly Mammoth (Mammuthus primigenius), and Yukon Horse (Equus lambei; a perfect prey item for wolves back in that epoch), among others, that lived in Beringia, a vast treeless plain or steppe resembling the high grassland...
Chapter 1 painted the scene of a pre-historic pack of wolves hunting Caribou and losing their carcass to an enormous Giant Short-faced Bear. It was highly captivating. The first seven chapters, all in the section “History”, started with fictional events but were based on real-world experiences that the author has had with modern-day wolves which haven’t changed much since the Pleistocene (p. 20). The chapters then described ecological conditions since the most recent glaciation and include the relation between ancient and modern native people and wolves. Chapter 5 is set in the late 1800s and here we learn about the importance of Jack London’s and Robert Service’s writing and the linking of wolves and wilderness, especially the Yukon region. I thought that the first section of the book did a great job of setting the stage for the second—and longer—section.

The second of the two parts of *Wolves of the Yukon*, “Understanding”, included nine chapters on Bob Hayes’ research. The beginning chapter stories in this section were based on his or his colleagues’ field notes and explored his original investigations into wolf relations to Moose, Caribou, Mountain Sheep (*Ovis canadensis*), Ravens (*Corvus corax*), Grizzly Bears (*Ursos arctos*), and human hunters. Hayes does an admirable job of describing the importance of radio-telemetry to studying wolves and gives many engaging accounts of him darting wolves from helicopters (pp. 154–164). He described finding uncollared wolves as searching for the proverbial needle in a haystack (p. 163). I couldn’t stop reading that chapter (9)! Using radio-telemetry, Hayes found that, despite humans killing them liberally, wolves were the number one cause of death of other wolves (p. 163). In section two, we discover that Moose are the “perfect prey” (Chapter 10) and that wolf numbers throughout the Yukon most closely parallel Moose distribution with abundance and pack sizes being bigger (> 10) in areas with increased Moose densities (p. 137). In fact, Yukon wolves are some of the largest in the world because of their reliance on this large prey item (pp. 56, 171). I also learned that, although wolves mostly kill young and old (i.e., not prime-aged) Moose, most are healthy and in good condition (p. 177).

Chapter 11 describes many exciting encounters between wolves and Dall’s Sheep in highly remote, pristine, mountainous regions. However, neither Hayes nor his associates ever witnessed an actual sheep kill by wolves (p. 189). And because sheep live in steep and dangerous areas, wolves have little effect on their populations (p. 194). In fact, wolves that rely on sheep live in small, unstable packs (p. 195). The next chapter (12) describes some very interesting behavioural observations of wolves in the Arctic region of the Yukon. There they are vagabonds and have no fixed territory because of the migratory nature of their main prey, Caribou (p. 201). This behaviour remains the norm for northern wolf packs until one goes south and into the taiga region where the presence of Moose provides a food-base for wolves to live year-round on territories (p. 203).

In the remaining chapters (13–15), also highly absorbing, we learn that Muskrat (*Ondatra zibethicus*) and other small animals are important summer foods (pp. 214–215) and that fish, even in the winter, are important to some packs (pp. 215–217), which can have the added benefit of taking pressure off Moose and Caribou. Ravens are easily the most important scavengers of wolf kills (pp. 223–225), especially for small packs or pairs where the birds can remove impressive amounts of meat from a carcass (pp. 225–228). There was a fascinating description of Ravens aggressively attacking a pair of wolves even while Hayes was trying to dart the wolves for collaring purposes (pp. 230–231). And, what would a book about wolves in the far north be without including a chapter (15) on bear-wolf relations? While they are mutual enemies, it is rare for them to kill each other, although it does happen, as Hayes vividly describes (pp. 238–240).

The last chapter of *Wolves of the Yukon* tells why broad-scale killing of wolves to increase game should ultimately end. Hayes believes that it is cost inefficient and biologically and morally wrong and, ultimately, short term in nature as wolves recover quickly from control actions (pp. 249–251). Here we learn that fertility control works best in reducing predation pressure and is a much more publicly accepted, non-lethal wolf management technique (pp. 253–255). He raises profound arguments about how to value and conserve the largest remaining tract of complete wilderness on the continent, poignantly stating that “Despite the constant challenges the wolf has faced since the Pleistocene it has endured and succeeded in becoming the primary force shaping the Yukon wilderness today. It has survived prey extinctions since the ice age… In the last hundred years the Yukon timber wolf has recovered from trapping, hunting, bounties, poison, and aerial control campaigns. Despite this persecution the wolf has endured… with as many wolves ranging through the Yukon today as thousands of years ago” (pp. 258–259). To this end, Hayes can be credited for contributing to the *Yukon Wolf Conservation and Management Plan* (2012, Environment Yukon), which assures that wolves have a right to live in the Yukon and that hunting laws value wolves as a big game animal, and for researching non-lethal methods to control wolf numbers (p. 253).

I really enjoyed this book. Despite being 278 pages, it was a relaxed and quick read. Because it was self-published, I did notice a dozen or more errors, but these were all very minor and easy to interpret (and ultimately to fix with a potential new edition). There was no index at the end of the book which prevented searching for specific information unless you kept notes (which I did), but there was a nice bibliography including many of his papers. I found it interesting that Hayes often referred to wolves in the Yukon as timber wolves which I thought was a term for wolves well to the south. There were many maps throughout the book including a pull-out on the cover insert and at least one per chapter. I found these immensely helpful in relating to a region that I have yet to visit. Kudos to Bob Hayes, who had a
great 20-year research career and gave the world a gift by putting in the effort to make this self-published book available for all who want to learn about wolves living in one of the most remote regions of the world. Well done!

OTHER

Rise of the Necrofauna: The Science, Ethics and Risks of De-Extinction


This book is about the recreation of extinct species through genetic engineering. It addresses how it might be done, what species might be targetted, and the various practical problems entailed. It also reviews at some length why we would want to do it, and the various pros and cons of such resurrections. The book grew out of a couple of radio broadcasts the author had created on the same topic and I realised, after starting to read it, that I had heard one of them, on the CBC “Ideas” programme, a year or so back and had been very impressed with the open, but quizzical, way in which the host (the author) had addressed the topic.

In the introduction, the author quotes the biologist, Stan Temple, as saying de-extinction is “…a game-changer for the conservation biology movement”, because it overturns one of the main driving forces behind species conservation, “extinction is forever” (p. 6). The author suggests that there is a danger we might reduce our concerns about species extinction if we feel we can resurrect them when conditions improve. She quotes Stuart Pimm as calling it a “moral hazard” (p. 72). Unsurprisingly, scientists working on projects related to de-extinction do not feel that way.

The field of de-extinction studies is not a huge one right now. This is because (a) the technical problems in species resurrection are formidable, (b) many species have disappeared because we destroyed the ecosystems they were part of, and there seems little point in resurrecting them unless we can simultaneously restore their native habitat, and (c) large fierce animals, which are charismatic enough to attract the necessary funding, often threaten other interests (farmers, foresters, the public at large) and their resurrection may not be greeted with universal enthusiasm.

Wray devotes much text to two cases where de-extinction has been mooted: the Passenger Pigeon (Ectopistes migratorius) and the Woolly Mammoth (Mammuthus primigenius). Passenger Pigeons were the most abundant birds in North America in the pre-European period. They fed principally on tree seeds and must have had a huge impact on forest ecology at the time. Woolly Mammoths trampled and cropped the tundra ecosystems of the Pleistocene and it has been argued that their efforts were crucial in maintaining grasslands. Hence, both species were probably essential to their ecosystems, and their resurrection and spread might help to restore many aspects of early ecosystems that have been lost. Certainly, the idea of restoring either or both has a huge emotional appeal.

As in her radio programme, Wray is skeptical about the true value of de-extinction in this book. She feels that the techniques developed may be more useful in preventing extinction of still extant species than in creating “necrofauna”. Is this a topic that we, naturalists and conservationists, should be deeply concerned about? That is not the message of the book. Rather, the author uses the concept of restoring extinct species as a basis for discussing a variety of conservation choices. Should you read it? All seven reviews currently on Amazon give it five stars. The writing is engaging and there is lots of interesting information, but I did not get the feeling that this is something the thinking conservationist must know about. No doubt at some stage in the future some species will be resurrected, if only because of the fame that will attach to their re-creator, but right now there are probably much more important problems out there to be wrestled with.

TONY GASTON
Ottawa, ON, Canada

The Magnificent Nahanni: The Struggle to Protect a Wild Place


Most of us have seen images of the Nahanni River region, of the Rabbitkettle tufa mounds, Virginia Falls, canyon walls towering over rafts and canoes, or the jagged peaks of the Cirque of the Unclimbables. While Gordon Nelson’s The Magnificent Nahanni includes a few excellent photos (30) of these icons, this is neither a coffee table photo book nor a guidebook. But if you are looking for a comprehensive history of the four-decade struggle to protect this biologically and culturally rich area, then this is the right book.
The book is separated into three parts, each of which has two to four chapters. Those are followed by two appendices (one a note on sources and the other a list of traditional place names in the Dene language), 21 pages of chapter-by-chapter notes, 15 pages of references, and an index. Fifteen maps of various scales were appropriately chosen. Nelson brings a scholarly approach to his subject, having published numerous papers, reports, and books in the fields of land use, environment, and planning, with special emphasis on national parks. However, his writing style is mostly very approachable. Interestingly, although he has been involved with the area since the early 1970s (at that time he was president of the National and Provincial Parks Association, precursor to the Canadian Parks and Wilderness Society), Nelson did not do a Nahanni River trip until 2013!

Nelson begins Part I with a brief introduction to the natural wonders of the Nahanni area (expanded upon in Chapter 2), introducing the reader to Raymond Murray Patterson, a young Englishman who trapped and prospected in the lower valley in the late 1920s and much later wrote *The Dangerous River: Adventures on the Nahanni* (George Allen and Unwin), first published in 1954. Patterson was the first person to propose conservation of the area, and Nelson refers to Patterson’s observations throughout the book. After setting the wild stage, Nelson does a rather abrupt segue to discussing the prevailing concept of wilderness being pristine, uninhabited land, which left First Nations out of early park discussions, and their recent involvement in park expansion. In the early 1970s there were two fundamental policies to creation of a national park: that the federal government should ultimately own all the land in the park, and that it should be planned and managed as “pristine”, i.e., devoid of past or present human activity: both policies led to indigenous opposition.

The formation of the small core area as a national park reserve in 1976 indicated postponement of the ownership question until settlement of aboriginal land claims by the Dehcho and Sahtu First Nations. In Chapter 3 Nelson outlines the 30-year struggle to expand the park. Changes in the field of ecology, with new concepts in biodiversity, landscape ecology, conservation biology, and population viability, made it possible to better understand, plan, and manage wildland ecosystems. On-the-ground research involving radio-telemetry showed that Grizzly Bears (*Ursus arctos*), Caribou (*Rangifer tarandus*), and Dall’s Sheep (*Ovis dalli*) were all undertaking seasonal movements that took them well beyond the boundaries of the small reserve. New park concepts of ecological integrity, the idea of “inhabited wilderness”, and a shift from top-down to co-operative management with First Nations were also fundamental to the expansion of the reserve in 2009 to include most of the Nahanni River watershed.

In Part II (“Why and How the Natural Qualities of the Nahanni were Conserved in the Past”), Nelson goes back in time to explore the impacts of the 19th-century fur trade on the First Nations and wildlife of the Nahanni region, setting it within the context of broader activities in northwestern North America. The First Nations of the Nahanni region were already linked to an extensive native trade network through the regions we know as Yukon, British Columbia, and Washington, as well as to the Russian fur traders in present-day Alaska. While the local First Nations did not seem to be as involved or interested in trading furs as those in some other areas, the competition among incoming traders did reduce the number of fur-bearers, and local game populations (e.g., Moose [*Alces americana*]) that were previously relied on by indigenous people for food. Nelson’s reliance on scholarly research material led him to extrapolate local First Nations’ historical use of resources from those of peoples in the Yellowstone area and Alaska; I would have thought there would have been more relevant local traditional knowledge that he could have referenced. By the early 1900s, with the fur trade gone, there were sporadic searches for gold in the Nahanni Valley. By the 1930s individual prospectors were replaced by companies and corporations more capable of financing the search for, and development of, mineral resources. There was even a proposal to build a dam at Virginia Falls to provide power for mining companies. Through the roughly 200 years of fur trading and mining, the difficult terrain, harsh climate, uneven distribution of resources, conflict and competition with rivals, and changes in markets or economic and political conditions, inadvertently conserved the ecological integrity of the Nahanni.

Nelson looks to future challenges and opportunities in Part III (“The Struggle Continues”). He lumps the challenges into two groups: those that mostly affect the natural diversity and ecological integrity of the watershed, and those that mainly relate to the indigenous people in the protected area. Foremost in the first group is a zinc mine on Prairie Creek, a tributary to the Nahanni, that is surrounded by park reserve. It was approved in 2011 over considerable shortcomings in the environmental assessment and stated opposition by environmental groups and First Nations. If developed the mine could significantly affect the aquatic ecosystem. On the opportunity spectrum is the possibility of the park becoming a centre for indigenous culture and learning, youth education, and Traditional Ecological Knowledge research. In the final chapter, Nelson wraps up his case study by looking at the significance of cooperation in research, planning and management of protected areas by government, non-governmental organizations, and indigenous people with examples from around the world.

The Nahanni River is not the longest (only about 500 km) nor the hardest river to paddle, but it slices through the heart of a region that abounds in grandeur and natural diversity, and this book will help the reader appreciate it all the more.

**Cyndi M. Smith**
Canmore, AB, Canada
Coexistence: The Ecology and Evolution of Tropical Biodiversity


Coexistence: The Ecology and Evolution of Tropical Biodiversity is a fascinating chronology and reconstruction of the history of the science of tropical ecology in the Western Hemisphere. The book is framed as a history of the Smithsonian Tropical Research Island (STRI) on Barro Colorado Island in the Lago Gatun of the Panama Canal, but it also provides a broad history of the theories, debates, and research surrounding the evolution and maturing of tropical ecology. The author skillfully weaves in the development and evolution of theories related to tropical diversity (forests and corals) and why so many species can coexist in tropical ecosystems. At its essence, the debate is about how 50% of the global plant and animal species diversity can coexist on only 2% of the planet’s area. At one level, the book would seem narrowly focussed on essentially how scientists attempted to explain how many species could occupy the same habitat in tropical ecosystems (both tropical forests and marine coral reefs). But at another level the book is a fascinating chronology of the development and maturing of science through the proposal and subsequent refuting of many competing hypotheses. The establishment and development of the STRI is used as a template for explaining the much broader evolution of tropical forest and marine ecology.

While both scientists and lay readers may now accept tropical ecology as a given and accepted sphere of ecology, this was not always the case. At one time it was assumed that principles of temperate forest ecology, where the earliest scientific strides had been made, would directly apply to the tropics. It is interesting how much of the early field of ecology was based upon research in temperate regions, and how strongly that influenced initial theories of tropical ecology.

The initial tropical research station in the isolated Panamanian rainforest which became the STRI was the first one established for the express purpose of studying tropical natural history rather than applied agricultural research. Major marine research on both Atlantic and Pacific marine coral ecosystems also evolved out of this research initiative. This provided the unique opportunity to study fish community structure and ecology in two totally different marine ecosystems, separated by major geologic events in the past and yet only 65 km apart.

A dizzying and competing sequence of theories has been developed to explain tropical biodiversity. The author has done a masterful job of explaining the scientific complexities of the various theories of tropical ecology and evolution that led to the establishment of the research station, and how those theories and concepts evolved through time in a manner true to the science and yet understandable and interesting to the lay person. Like a skilful mystery writer, the author leads us from one potential hypothesis to another, building up the basis for the theory, the subsequent research to prove or disprove the hypothesis, the scientific debates and arguments, and the inevitable refinement and alternative hypothesis that took its place, leading to the book’s final analysis and conclusions.

The author has an impressive grasp of scientific literature from a diverse range of fields and portrays an amazing understanding of scientific principles and processes. As one example, his grasp of biological, evolutionary, and geological history was evident in the succinct summary of processes leading to the mass extinction of marine species that resulted from the geological closure of the seaway and the creation of the Panamanian isthmus.

While the title may suggest a book with a rather limited target audience, it is a fascinating and very compelling story of interest to scientists and lay readers alike. The author obviously did a great deal of meticulous research, scrutinizing scientific publications, letters, research notes, chronicled archives of the research institute, popular articles, and personal interviews. These are skilfully and seamlessly woven into a fascinating chronology of the parallel evolution of the Barro Colorado Island field station and tropical ecology as a scientific field. In its 275 pages, 50 devoted to scientific references. Almost every fact noted has an accompanying reference. I found myself repeatedly flipping back to the reference section simply out of curiosity to see what the source could be of yet another interesting nugget of tropical science history.

Some of the early history is especially fascinating, detailing the vision, boldness, and courage that brought the concept of the Barro Colorado reserve to life. There are fascinating stories of the early unique research scientists and their often-fractious relationships. The stories are accompanied by grainy black and white photos that add to the historical perspective. The impacts of history and politics on science, sometimes in totally unforeseen ways, provided interesting insights. These included the role of construction of the Panama Canal on the stimulation of interest in tropical research, and the effects of the American invasion of Panama. The book provides fascinating insights into the canal’s history, such as the very serious proposal to use nuclear devices to create a sea-level canal rather than a series of freshwater locks, and the kidnapping of marine research scientists during the Panamanian invasion.

There are many interesting elements to the gradual maturing of tropical ecology as a scientific discipline, which the author carefully researched and clearly and succinctly described. Tropical research innovated and initiated the use of canopy towers to study all manner of scientific questions without disturbing the flora or fauna, eventually leading to a global network of tropical canopy towers. Another initiative was the develop-
ment of large, permanent study plots which, despite all the debate about the source and status of tropical diversity, no one had previously thought to establish. This eventually led to the creation of a global, interlinked network, which is proving useful to current research on the effects of climate change.

As well as detailing the development and evolution of the research station, and almost as an aside, the book objectively and without comment describes the parallel evolution of growing gender parity on the island over the decades. In the early years women were not permitted on the island, for fear of proving a distraction, and children and families were discouraged. Eventually female scientists came into their own, initially assisting with their husbands’ research, often as unpaid research assistants, and later as fully independent and autonomous research scientists.

Author Jan Sapp is a Professor of Biology and History at Toronto’s York University, but, not surprisingly, this book on tropical ecology has few references to Canada. References I noted related to the Welland Canal, which allowed Sea Lamprey (*Petromyzon marinus*) into the upper Great Lakes, an example of ecological implications with parallels to what was proposed in Panama, and a reference to a McGill biologist’s reviewing of Stephen Hubbell’s book on neutral theory.

*Coexistence* provides a fascinating and comprehensive overview of the evolution of tropical forest and marine ecology and their rapidly expanding research sphere. For the most part it is tightly researched and edited, and almost no distracting typographic or spelling errors were noted. However, it does suffer from a few minor inconveniences at the micro scale. The need to convert between Imperial and metric measures was a minor annoyance. The first hint that the book was losing its tight editorial focus came in Chapter 9, when three references in as many pages were made to the pending canal treaties that would terminate the Canal Zone in 1979. A few other duplicate references to historical facts were scattered throughout the text, where notable facts appeared to have been collected and inadvertently inserted twice. Unfortunately, the same level of detail that went into the research and writing did not go into making optimal use of the interesting and informative historical photos. While these black and white photos helped the reader to envision the historical period, their placement and use was at times distracting and almost haphazard. The figure was often not placed with the first reference to the subject matter, and often the content of the photo and the textual reference were only tangentially related.

This is a meaty book that cannot be read quickly but must be contemplated and absorbed. Although it is focussed primarily on tropical ecology, it is also a fascinating chronology of a detailed and skillfully researched scientific history that both scientists and lay readers can learn from and enjoy.

TED ARMSTRONG
Thunder Bay, ON, Canada

The Eye of the Sandpiper: Stories from the Living World


This book is a thoughtful journey exploring the natural world, the ongoing research into it, while questioning our relationship with it. Based on the cover and title I expected this to be a book full of shorebird research, and so was surprised to read about a variety of life from birds to fish. Keim does a wonderful job choosing stories that capture the audiences’ interest and leaves us wanting to know more.

These short stories are organized into thematic sections including: Dynamics, Inner Lives, Intersections, and Ethics.

The first theme draws on evolution and ecological dynamics of the natural world. In this section we read about Cane Toads (*Rhinella marina*), chickadees, Monarch Butterflies (*Danaus plexippus*), and more. He explored stories about the deep sea, challenged how we think about Sea Lamprey (*Petromyzon marinus*), and reminded us to listen, literally, to the natural world.

The second theme expands on the inner lives of animals. Keim draws on research that many may consider anthropomorphic topics, such as empathy, self-awareness, language, mental-time travel, and emotions. It was fascinating to read some of the research being conducted on species we may see around us daily, such as honeybees, mice, rats, and birds.

The third theme, Intersections, is full of stories about people who are applying our knowledge to the world. These stories provide the book with views of hope through the passion people have and the direct changes they can make.

The final theme, Ethics, centres on humanity’s role in the future of nature. Human activities have influenced the earth so much that Keim delves into the idea of the Anthropocene throughout this chapter. Topics raised include the ideas of wilderness and wilderness, bringing back extinct species, and non-native species.

Chapters were very well written, but I often found myself wishing that they were not so short. Some controversial topics, such as the removal of invasive species such as Mute Swans (*Cygnus olor*) or feral cats, were presented with points of view from both sides. Environmental problems can often be a depressing topic; however, Keim’s stories approach them in a way that is interesting and instills a sense of hope. I appre-
ciated that this book was not only well researched and thought provoking, but Keim’s curiosity for the natural world was contagious.

Books like this play an important role as they help communicate research to the public. The primary audience of this book is likely already those who read science articles; however, many of the stories and interesting facts could reach a broader audience interested in the natural world. The wide variety of subjects allowed me to learn about species and topics I may not have sought out otherwise.

Throughout this book I found an overarching call to become aware of my surroundings and to learn to act in ways that nourish the life around me, both human and non-human. Perhaps if we pay more attention and further appreciate and respect the non-human world, we will care more about the place we call home and those we share it with.

TIA NNA BURKE
Parry Sound, ON, Canada

NEW TITLES
Prepared by Barry Cottam

Please note: Only books marked † Available for review or * Assigned have been received from publishers. All other titles are listed as books of potential interest to subscribers. Please send notice of new books – or copies for review – to the Book Review Editor.

†Available for review *Assigned

Currency Codes – CAD Canadian Dollars, USD US Dollars, EUR Euros, AUD Australian Dollars, GBP British Pound.

BOTANY


†Carnivorous Plants: Physiology, Ecology, and Evolution. Edited by Aaron Ellison and Lubomir Adamec. 2018. 544 pages, 125.00 CAD, Cloth. Also available as an E-book.


*Identification of Trees and Shrubs in Winter Using Buds and Twigs. By Bernd Schulz. 2018. Royal Botanic Gardens, Kew; distributed by University of Chicago Press. 368 pages, 45.00 GBP, 80.00 USD, Cloth.


ENTOMOLOGY

The Moths of America North of Mexico. Fascicle 9.5: Pelochrista Lederer of the Contiguous United States and Canada (Lepidoptera: Tortricidae: Eucosmini). By Donald J. Wright and Todd M. Gilligan. 2017. The Wedge Entomological Research Foundation. 376 pages, 168 species accounts, 48 plates with 720 colour photos, and 70 plates with 945 black and white line drawings, 90.00 USD, Cloth.


Ornithology


Zoology

Are We Smart Enough to Know How Smart Animals Are? By Frans de Waal. 2017. W. W. norton. 352 pages, 27.95 USD, Cloth, 16.95 USD, Paper.


†Evolutionary Ecology of Marine Invertebrate Larvae. Edited by Tyler Carrier, Adam Reitzel, and Andreas Heyland. 2018. Oxford University Press. 368 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

Essential Fish Biology: Diversity, Structure, and Function. By Derek Burton and Margaret Burton. 2017. Oxford Univer-
sity Press. 416 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

**Immersion: The Science and Mystery of Freshwater Mus

**Marine Ecosystem-Based Management in Practice: Dif
terent Pathways, Common Lessons.** By Julia Wondollec
and Steven Yaffee. 2017. Island Press. 288 pages, 70.00 USD, Cloth, 35.00 USD, Paper or E-book.

†**Marine Fishes of Arctic Canada.** Edited by Brian W. Coad and James D. Reist. 2017. University of Toronto Press. 632 pages and 200 illustrations, 74.96 CAD, Cloth or E-book.


**Biological and Conservation of Musteloids.** Edited by David W. Macdonald, Chris Newman, and Lauren A. Harrington. 2018. Oxford University Press. 672 pages, 125.00 CAD, Cloth, 60.00 CAD, Paper. Also available as an E-book.


**Mimicry, Cryptis, Masquerade and other Adaptive Re


**Sustaining Lake Superior: An Extraordinary Lake in a Changing World.** By Nancy Langston. 2017. Yale University Press. 312 pages, 35.00 USD, Cloth.


**Heart Waters: Sources of the Bow River.** By Kevin Van Tighem. Photography by Brian Van Tighem. 2015. Rocky Mountain Books. 240 pages, 40.00 CAD, Cloth.


*Islands of Grass. By Trevor Herriot. Photography by Bran-


Editors’ Report for Volume 130 (2016)

Mailing dates for the four issues in volume 130 are as follows: 17 June 2016; 30 September 2016; 16 December 2016; 21 April 2017. Summaries of the distribution of memberships in the Ottawa Field-Naturalists’ Club, who all receive access to The Canadian Field-Naturalist, and subscribers to The Canadian Field-Naturalist for 2016 are provided in Table 1, along with comparison numbers for volume 129. Institutional subscribers potentially represent many thousands of users. The number of Articles and Notes in volume 130 is summarized in Table 2 by topic. Totals for book reviews and new titles are given in Table 3, and the distribution of content by page totals per issue is provided in Table 4. Sixty-nine manuscripts were submitted to The Canadian Field-Naturalist in 2016: only 25 of these were submitted by email with all those after July submitted using the Online Journal System. Of the 69 submissions, 57 (82.6%) were accepted for publication and either published or undergoing further revision and review, nine were not accepted upon initial submission or review, two were not accepted upon revision, and one was withdrawn. A total of 30 Articles, 20 Notes, and two Tributes were published in 2016.

Dwayne Lepitzki began the transition to Editor-in-Chief from Carolyn Callaghan with issue 2. Amanda Martin, Assistant Editor, edited content, proofread galleys, compiled the “Upcoming Meetings and Workshops” section of the News and Comments, and sent and received author order and transfer of copyright forms. Sandra Garland and, beginning with issue 4, John Wilmhurst proofed and copy edited manuscripts. Wendy Cotie typeset galleys, provided corrections for page proofs, and created pdfs. Roy John and, beginning with issue 3, Barry Cottam requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings. Ken Young assumed the duties for managing subscriptions and page charge invoices from Eleanor Zurbrigg with issue 2. William Halliday, Journal Manager and Webmaster, provided digital content to subscribers, posted tables of contents, abstracts, and pdfs on The Canadian Field-Naturalist website, and prepared the Index. Our Associate Editors managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. The Publication Committee, chaired by Jeff Saarela and consisting of Annie Béclair, Dan Brunton, Carolyn Callaghan, Paul Catling, Barry Cottam, Tony Gaston (resigned late in 2016), William Halliday, Diane Kitching, Dwayne Lepitzki, Amanda Martin, Karen McLachlan Hamilton, Frank Pope, and David Seburn effectively guided the operation of the journal. We are indebted to our very dedicated team.

### Table 1. The 2016 (2015) circulation of The Canadian Field-Naturalist. Compiled by Ken Young from the subscription list for 130(4).

<table>
<thead>
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<th>Subscriber Type</th>
<th>Canada</th>
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### Table 2. Number of research articles and notes published in The Canadian Field-Naturalist, Volume 130 (Volume 129), by major field of study.

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<tr>
<th>Subject</th>
<th>Articles</th>
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<tr>
<td>Mammals</td>
<td>9 (7)</td>
<td>10 (6)</td>
<td>19 (13)</td>
</tr>
<tr>
<td>Birds</td>
<td>4 (7)</td>
<td>5 (5)</td>
<td>9 (12)</td>
</tr>
<tr>
<td>Amphibians and Reptiles</td>
<td>4 (2)</td>
<td>0 (3)</td>
<td>4 (5)</td>
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<tr>
<td>Fishes</td>
<td>4 (4)</td>
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<td>Plants</td>
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<tr>
<td>Insects</td>
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<tr>
<td>Non-insect</td>
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<td></td>
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<tr>
<td>Invertebrates</td>
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<td>2 (1)</td>
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<td>Total</td>
<td>30 (28)</td>
<td>20 (19)</td>
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### Table 3. Number of reviews and new titles published in the Book Review section of The Canadian Field-Naturalist, Volume 130 (Volume 129), by topic.

<table>
<thead>
<tr>
<th>Reviews</th>
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<tr>
<td>Zoology</td>
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<tr>
<td>Botany</td>
<td>3 (3)</td>
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<tr>
<td>Miscellaneous</td>
<td>9 (14)</td>
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<tr>
<td>Total</td>
<td>22 (35)</td>
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The following Associate Editors managed, assessed, and reviewed manuscripts published in volume 130: P. M. Catling, Agriculture and Agri-Food Canada, Ottawa ON (4 manuscripts); F. Chapleau, University of Ottawa, Ottawa ON (4); F. R. Cook, Emeritus Research Associate, Canadian Museum of Nature, Ottawa ON (5); J. Foote, Algoma University, Sault Ste. Marie ON (4); G. Forbes, University of New Brunswick, Fredericton NB (1); A. J. Gaston, Environment Canada (emeritus), Ottawa ON (4); T. Jung, Yukon Government, Whitehorse YT (3); D. F. McAlpine, New Brunswick Museum, Saint John NB (5); G. Mowat, government of British Columbia, Nelson BC (3); D. W. Nagorsen, Mammal Biological Consulting, Victoria BC (7); M. Obbard, Ontario Ministry of Natural Resources and Forestry, Peterborough ON (3); C. Renaud, Canadian Museum of Nature, Ottawa ON (2); J. M. Saarela, Canadian Museum of Nature, Ottawa ON (3); J. Skevington, Agriculture and Agri-Food Canada, Ottawa ON (2).

The following referees reviewed manuscripts published in volume 130 (number of manuscripts reviewed >1 in parenthe-
TABLE 4. Number of pages per section published in The Canadian Field-Naturalist, Volume 130 (Volume 129), by issue.

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<thead>
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<th>Issue</th>
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<th>2</th>
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<td>Editorials/Editor’s Report</td>
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<td>0 (0)</td>
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<td>73 (66)</td>
<td>43 (44)</td>
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<td>4 (10)</td>
<td>9 (14)</td>
<td>11 (4)</td>
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<td>3 (2)</td>
<td>4 (2)</td>
<td>10 (16)</td>
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<td>Reports†</td>
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<td>4 (0)</td>
<td>15 (13)</td>
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<td>19 (18)</td>
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<tr>
<td>Index</td>
<td>– (–)</td>
<td>– (–)</td>
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<td>Total</td>
<td>90 (114)</td>
<td>100 (104)</td>
<td>84 (104)</td>
<td>120 (104)</td>
<td>394 (426)</td>
</tr>
</tbody>
</table>

*Includes reviews and new titles.
†Includes Annual Business Meeting Minutes, Annual Committee Reports, Financial Statements, Awards.

INDEX

CAROLYN CALLAGHAN, Editor-in-Chief;
AMANDA MARTIN, Assistant Editor

THE CANADIAN FIELD-NATURALIST
Vol. 131

NEALE, Fisheries and Oceans Canada; Dianne R. Nelson, East Tennessee State University; Erica Newton, Ontario Ministry of Natural Resources and Forestry; Martyn Obbard, Ontario Ministry of Natural Resources and Forestry (retired); Colleen Offenbuttel, North Carolina Wildlife Research Commission; Ken Otter, University of Northern British Columbia; Kristiina Ovaska, Victoria BC; Brent Patterson, Ontario Ministry of Natural Resources and Forestry / Trent University (2); Tim Pearce, Carnegie Museum of Natural History (2); Bruce Pond, Ontario Ministry of Natural Resources and Forestry; Paul Pratt, Wheatley ON; Tanya Pulfer, Ontario Nature; Randall Reeves, Hudson QC; Darryl Reynolds, British Columbia Ministry of Forests, Lands and Natural Resource Operation; Tony Reznick, University of Michigan; Jim Richards, Nunavut Bird Checklist; Mark Ridgway, Ontario Ministry of Natural Resources and Forestry; Forestry; Mike Rodway, Gold Bridge BC; Rick Rosatte, Ontario Ministry of Natural Resources and Forestry; Dolph Schluter, University of British Columbia; Fred Schueler, Bishop Mills ON; Helen Schwantje, British Columbia Ministry of Forests, Lands and Natural Resource Operations; Spencer Sealy, University of Manitoba; David Seburn, Ottawa ON; Dale Seip, British Columbia Ministry of Environment; Philipp Semenchuk, University of Tromso; Tamara Smith, US Fish and Wildlife Service; Tyler Smith, Agriculture and Agri-Food Canada; Stuart Slattery, Ducks Unlimited Canada; Michael Steele, Wilkes University; Tom Sullivan, University of British Columbia; Heidi Swanson, University of Waterloo; Tara Szeku- 

The journal was printed at Gilmore Printers, Ottawa. Thanks to Guyalaine Duval of Gilmore Printers for overseeing production and printing. We are grateful to The Ottawa Field-Naturalists’ Club President Fenja Brodo and the club’s Board of Directors for their support of the journal. We are 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, field biology, and ecology. Finally, we thank our families/partners for being patient and supportive throughout many long days, evenings, and weekends of working on the journal.
News and Comment

Great Canadian Field-Naturalists 280

Great Canadian Field-Naturalists: James Fletcher 280

Great Canadian Field-Naturalists: John Macoun 281

Upcoming Meetings and Workshops


James Fletcher Award Established 285

Book Reviews


ZOOLOGY: Wolves of the Yukon 291


NEW TITLES 297

Editors’ Report 301

Mailing date of the previous issue 131(2): 1 December 2017
Annual and seasonal variation in shorebird abundance in the St. Lawrence River estuary during fall migration

Diet of Grey Wolves (Canis lupus) during calving in a Moose–Caribou system in northern Ontario

Observations of long-distance post-release dispersal by reintroduced bison (Bison bison)

Observations of notable parental behaviours of Northern Spotted Owls (Strix occidentalis caurina)

Northern snakes appear much more abundant in old fields than in forests

Side to side swaying as a defensive behaviour in the Dekay’s Brownsnake (Storeria dekayi)

Psychrotolerant microfungi associated with Deer Mice (Peromyscus maniculatus) in a white-nose syndrome positive bat hibernacula in eastern Canada

Fabronia ciliaris, a moss new to Canada from southeastern Manitoba

River Otter (Lontra canadensis) killed by wolves (Canis lupus) during winter in Northern Minnesota

Adult Snapping Turtle (Chelydra serpentine) feeding on goldeneye embryos of Pumpkinseed (Lepomis gibbosus) in defended nests

Range extensions of 35 bryophyte species in the Black Spruce–feather moss forest of western Quebec, Canada


(continued on inside back cover)