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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 Bêty, pages 203–214. Photo: Jonathan Frenette, August 2009.

The Canadian Field-Naturalist

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Annual and Seasonal Variation in Shorebird Abundance in the St. Lawrence River Estuary during Fall Migration

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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

Plusieurs espèces d'oiseaux de rivage étant en déclin, il importe d'identifier les sites d'importance fréquentés annuellement afin de concevoir des plans de conservation. Nous avons voulu documenter certains aspects nécessaires à l'évaluation de la valeur écologique de l'estuaire du Saint-Laurent pour ces espèces. Nous présentons les résultats de l'inventaire le plus intensif à ce jour pour l'estuaire du St-Laurent au cours de la migration automnale. Les inventaires ont été réalisés de St-Jean-Port-Joli à St-Simon-sur-Mer, Quebec, Canada, en 2011 et en 2012, de la fin juin/début juillet jusqu'à la fin novembre, soit pendant la période migratoire des espèces présentes dans l'aire d'étude. Le bécasseau semipalmé (*Calidris pusilla*) était l'espèce la plus abondante en 2011, suivie par le bécasseau variable (*Calidris alpina*) et le pluvier argenté (*Pluvialis squatarola*). En 2012, le pluvier argenté était l'espèce la plus abondante, suivie par le bécasseau semipalmé. Considérant l'ensemble des espèces, l'abondance des individus culminait en début septembre. L'abondance maximale des adultes précédait celle des juvéniles. Chez la plupart des espèces, les juvéniles était plus abondants que les adultes. Les juvéniles étaient relativement moins abondants en 2012 qu'en 2011. Cette tendance était générale dans le nord-est de l'Amérique du Nord. Cela pourrait signifier que le succès reproducteur était inférieur en 2012. Considérant son importance pour les juvéniles (l'aire d'étude pouvant être fréquentée annuellement par quelques centaines de milliers d'individus) et donc, sa valeur pour la conservation, nous proposons que l'estuaire du St-Laurent soit intégré au Réseau de réserves pour les oiseaux de rivage de l'hémisphère occidental.

Mots-Clés: Bécasseau semipalmé; *Calidris pusilla*; chronologie de la migration; conservation; écologie; estuaire du fleuve St-Laurent; halte migratoire; inventaire; migration automnale; oiseaux de rivage

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 (Bélanger *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 Québec 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 semidiurnal 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-

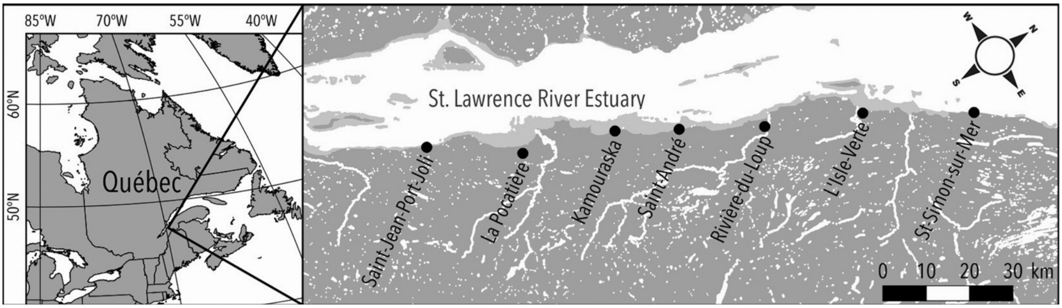

FIGURE 1. The study area on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 and 2012. Light grey areas represent the intertidal zone.

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; Obernuefemann *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.

	Survey week																					
Species	1 July (1)	8 July (2)	15 July (3)	22 July (4)	29 July (5)	5 Aug. (6)	12 Aug. (7)	19 Aug. (8)	26 Aug. (9)	2 Sep. (10)	9 Sep. (11)	16 Sep. (12)	23 Sep. (13)	30 Sep. (14)	7 Oct. (15)	14 Oct. (16)	21 Oct. (17)	28 Oct. (18)	4 Nov. (19)	11 Nov. (20)	18 Nov. (21)	Total
Nesting in the study area																						
Killdeer (*Charadrius vociferus*)	3	9	1	5	8	5	5	3	0	1	1	0	0	0	0	0	0	0	0	0	0	41
Spotted Sandpiper (*Actitis macularius*)	0	0	9	6	20	17	10	14	11	12	4	4	5	4	4	1	2	1	0	0	0	124
Wilson's Snipe (*Gallinago delicata*)	0	0	0	1	0	0	1	2	0	0	0	0	2	1	1	1	2	1	3	0	0	15
Migrating through the study area																						
Black-bellied Plover (*Pluvialis squatarola*)	0	1	0	0	5	99	718	1269	1256	626	220	60	651	533	414	92	177	136	51	2	1	6311
American Golden-Plover (*Pluvialis dominica*)	0	0	0	0	0	0	0	0	0	0	4	12	4	3	3	0	0	0	0	0	0	26
Semipalmated Plover (*Charadrius semipalmatus*)	0	0	0	36	191	206	163	349	375	643	680	211	231	104	84	114	109	2	1	0	0	3499
Solitary Sandpiper (*Tringa solitaria*)	0	0	0	0	1	1	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	9
Greater Yellowlegs (*Tringa melanoleuca*)	0	0	0	0	0	13	39	9	9	12	21	5	25	15	8	6	18	7	3	0	0	190
Lesser Yellowlegs (*Tringa flavipes*)	0	0	1	1	3	42	67	14	47	11	6	0	1	0	0	0	3	1	0	0	0	197
Whimbrel (*Numenius phaeopus*)	0	0	0	6	6	60	20	1	4	18	39	0	2	2	1	0	0	0	0	0	0	159
Hudsonian Godwit (*Limosa haemastica*)	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0	7
Ruddy Turnstone (*Arenaria interpres*)	0	0	0	0	0	1	3	49	11	64	57	48	22	30	7	0	1	10	0	0	0	303
Red Knot (*Calidris canutus*)	0	0	0	0	0	0	2	17	32	54	7	0	85	48	84	0	5	0	0	0	0	334
Stilt Sandpiper (*Calidris himantopus*)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sanderling (*Calidris alba*)	0	0	0	0	0	2	1	21	45	78	153	186	81	31	59	71	144	117	40	30	1	1060
Dunlin (*Calidris alpina*)	0	0	0	0	0	0	0	0	0	9	11	126	4155	3589	463	82	212	167	35	0	0	8849
Baird's Sandpiper (*Calidris bairdii*)	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	6
Least Sandpiper (*Calidris minutilla*)	1	18	20	28	49	53	229	184	169	174	41	16	3	0	1	0	0	0	0	0	0	986
White-rumped Sandpiper (*Calidris fuscicollis*)	0	0	0	0	0	53	86	12	5	4	16	44	5	529	1768	635	504	351	47	67	0	4126
Pectoral Sandpiper (*Calidris melanotos*)	0	0	0	0	0	0	0	0	0	5	11	1	3	18	4	13	13	0	0	0	0	68
Semipalmated Sandpiper (*Calidris pusilla*)	0	0	0	24	72	86	78	180	3337	8059	7085	3007	391	68	12	29	10	0	0	0	0	22 438
Short-billed Dowitcher (*Limnodromus griseus*)	0	0	1	0	0	0	1	3	4	5	0	0	0	0	0	0	0	0	0	0	0	14
Yellowlegs (*Tringa* spp.)	0	0	0	0	0	30	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	36
Unidentified shorebirds	0	0	0	0	54	140	40	623	801	439	169	30	32	122	6	15	0	0	0	0	0	2471
All species	4	28	32	107	409	808	1463	2752	6106	10 222	8534	3752	5698	5103	2919	1060	1200	793	180	99	2	51 271

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.

	Survey week											
Species	29 June (1)	13 July (3)	27 July (5)	10 Aug. (7)	24 Aug. (9)	7 Sep. (11)	21 Sep. (13)	5 Oct. (15)	19 Oct. (17)	2 Nov. (19)	16 Nov. (21)	Total
Nesting in the study area												
Killdeer (*Charadrius vociferus*)	1	5	3	3	13	0	0	0	0	1	0	26
Spotted Sandpiper (*Actitis macularius*)	2	2	7	10	16	11	0	0	0	0	0	48
Wilson's Snipe (*Gallinago delicata*)	0	0	0	1	1	0	0	1	0	1	0	4
Migrating through the study area												
Black-bellied Plover (*Pluvialis squatarola*)	0	1	11	835	34	2060	627	65	30	72	0	3735
American Golden-Plover (*Pluvialis dominica*)	0	0	0	1	0	0	2	1	0	0	0	4
Semipalmated Plover (*Charadrius semipalmatus*)	0	0	71	185	238	605	251	97	125	3	0	1575
Solitary Sandpiper (*Tringa solitaria*)	0	0	0	5	2	0	0	0	0	0	0	7
Greater Yellowlegs (*Tringa melanoleuca*)	0	0	0	3	1	18	4	6	7	17	0	56
Lesser Yellowlegs (*Tringa flavipes*)	0	1	0	18	3	19	3	0	0	0	0	44
Whimbrel (*Numenius phaeopus*)	0	5	27	28	8	10	9	0	0	0	0	87
Ruddy Turnstone (*Arenaria interpres*)	0	0	1	24	6	15	24	5	2	4	0	81
Red Knot (*Calidris canutus*)	0	0	0	24	2	220	68	0	1	0	0	315
Sanderling (*Calidris alba*)	0	1	0	0	6	58	45	2	1	2	0	115
Dunlin (*Calidris alpina*)	0	0	0	0	0	47	50	24	31	216	0	368
Baird's Sandpiper (*Calidris bairdii*)	0	0	0	1	0	0	0	0	0	0	0	1
Least Sandpiper (*Calidris minutilla*)	20	66	41	281	104	28	3	0	0	0	0	543
White-rumped Sandpiper (*Calidris fuscicollis*)	0	0	6	2	1	1	0	2	51	70	0	133
Pectoral Sandpiper (*Calidris melanotos*)	0	0	0	0	6	26	59	10	11	0	0	112
Semipalmated Sandpiper (*Calidris pusilla*)	0	0	24	259	398	1188	142	30	26	0	0	2067
Short-billed Dowitcher (*Limnodromus griseus*)	0	0	0	1	0	4	0	0	0	0	0	5
Unidentified shorebirds	0	0	9	130	82	182	42	0	25	15	0	485
All species	23	81	200	1811	921	4492	1329	243	310	401	0	9811

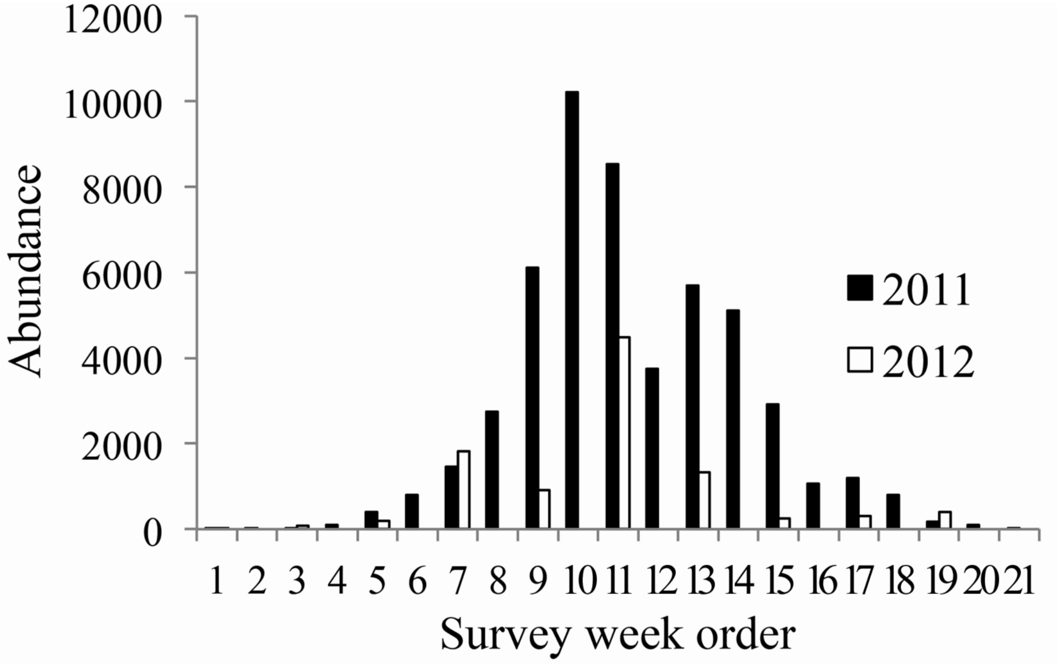

FIGURE 2. Shorebird abundance during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011(weekly survey) and 2012 (bi-weekly survey). Survey week order as in Tables 1 and 2.

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.

	2011			2012		
	n	Adults (%)	Juveniles (%)	*n*	Adults (%)	Juveniles (%)
Nesting in the study area						
Killdeer (*Charadrius vociferus*)	1	100.0	0.0	6	66.7	33.3
Spotted Sandpiper (*Actitis macularius*)	24	16.7	83.3	19	0.0	100.0
Wilson's Snipe (*Gallinago delicata*)	–	–	–	1	100.0	0.0
Migrating through the study area						
Black-bellied Plover (*Pluvialis squatarola*)	5188	65.7	34.3	2959	92.8	7.2
American Golden-Plover (*Pluvialis dominica*)	15	6.7	93.3	4	25.0	75.0
Semipalmated Plover (*Charadrius semipalmatus*)	2666	19.1	80.9	1408	19.1	80.9
Solitary Sandpiper (*Tringa solitaria*)	2	0.0	100.0	–	–	–
Greater Yellowlegs (*Tringa melanoleuca*)	69	18.8	81.2	27	14.8	85.2
Lesser Yellowlegs (*Tringa flavipes*)	35	34.3	65.7	6	0.0	100.0
Whimbrel (*Numenius phaeopus*)	86	65.1	34.9	69	82.6	17.4
Hudsonian Godwit (*Limosa haemastica*)	1	0.0	100.0	–	–	–
Ruddy Turnstone (*Arenaria interpres*)	285	17.9	82.1	79	32.9	67.1
Red Knot (*Calidris canutus*)	321	1.6	98.4	302	1.0	99.0
Stilt Sandpiper (*Calidris himantopus*)	–	–	–	–	–	–
Sanderling (*Calidris alba*)	906	0.2	99.8	43	2.3	97.7
Dunlin (*Calidris alpina*)	62	6.5	93.5	13	15.4	84.6
Baird's Sandpiper (*Calidris bairdii*)	2	0.0	100.0	1	0.0	100.0
Least Sandpiper (*Calidris minutilla*)	333	15.6	84.4	192	17.2	82.8
White-rumped Sandpiper (*Calidris fuscicollis*)	1202	2.2	97.8	49	22.4	77.6
Pectoral Sandpiper (*Calidris melanotos*)	17	0.0	100.0	11	0.0	100.0
Semipalmated Sandpiper (*Calidris pusilla*)	8758	2.0	98.0	964	2.5	97.5
Short-billed Dowitcher (*Limnodromus griseus*)	2	0.0	100.0	–	–	–
All species	19 975	21.6	78.4	6153	51.7	48.3

interpretation. Six species and three species met these criteria in 2011 and 2012, respectively.

Abundance

In 2011, a total of 51 271 shorebirds belonging to 22 species were detected in the 30 survey sites during the 21 weekly surveys (Table 1). In 2012, a total of 9811 shorebirds belonging to 20 species were detected in these survey sites during the 11 bi-weekly surveys (Table 2).

Semipalmated Sandpiper, one of the most abundant shorebird species in eastern North America during migration (Hicklin and Gratto-Trevor 2010), 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; Tables 1 and 2).

Abundance per Age Class

Age class of 39% and 66% of shorebirds could be determined in 2011 and 2012, respectively. With the exception of Whimbrel (*Numenius phaeopus*) and Black-bellied Plover, juveniles outnumbered adults in species migrating through the study area (Table 3). Considering all species, juveniles were relatively less abundant in 2012 (48% of known-age birds) than in 2011 (78% of known-age birds; Table 3; $\chi^2_1 = 2080.1$, $P < 0.0001$).

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, one-tailed, $t_{10} = 2.35$, $P = 0.02$). 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

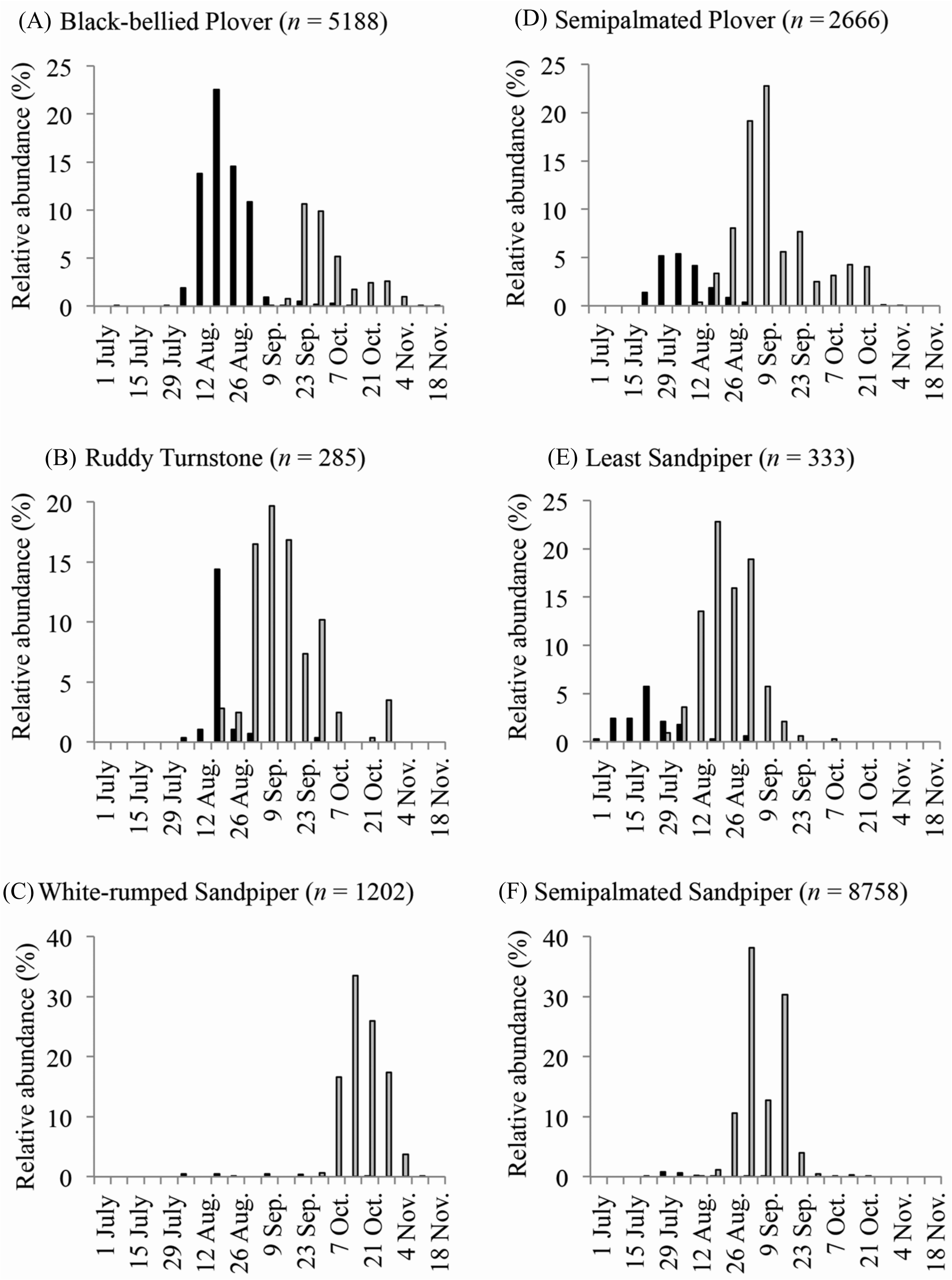

FIGURE 3. Relative abundance of some shorebird species per age class (calculated from the total number of known-age individuals detected per year; sum of all bars = 100%) during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2011 (weekly survey). Solid and light grey bars represent adults and juveniles, respectively.

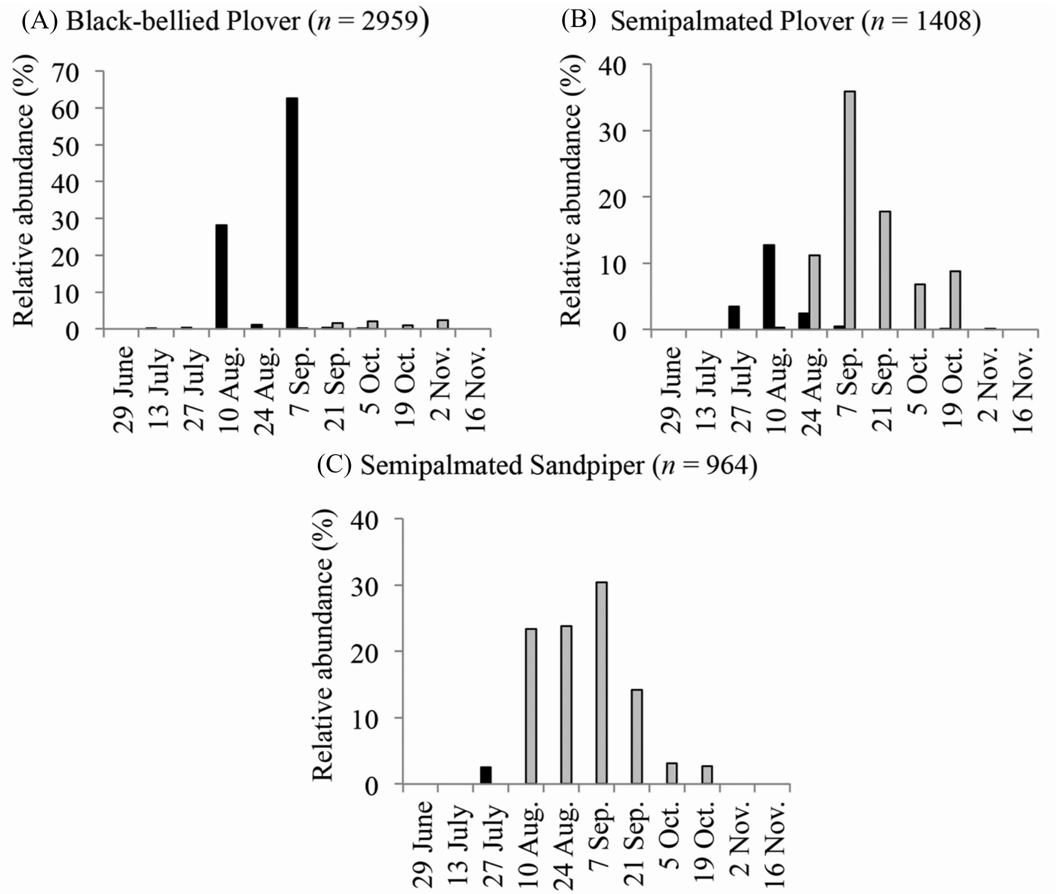

FIGURE 4. Relative abundance of some shorebird species per age class (calculated from the total number of known-age individuals detected per year; sum of all bars = 100%) during fall migration on the southeast shore of the St. Lawrence River Estuary, Quebec, Canada, 2012 (bi-weekly survey). Solid and light grey bars represent adults and juveniles, respectively.

noted near our study area during fall migration (Maisonneuve *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 affect breeding density, timing of breeding, and survival of juveniles (Meltofte *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 Canada: Bylot Island (73.2°N, 80.0°W) and East Bay (64.0°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%, $n = 175$; $\chi^2_1 = 10.9$, $P = 0.001$). 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%; Lamarre *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

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 2016), 2011 and 2012.

	St. Lawrence River Estuary			Coastal eastern Canada			Coastal New England		
Species	2011	2012	Change (%)	2011	2012	Change (%)	2011	2012	Change (%)
Black-bellied Plover (*Pluvialis squatarola*)	300.5	339.5	13	15.9	12.4	−22	31.7	31.1	−2
Semipalmated Plover (*Charadrius semipalmatus*)	166.6	143.2	−14	21.8	24.7	13	32.7	27.7	−15
Sanderling (*Calidris alba*)	50.5	10.5	−79	33.0	25.9	−22	74.9	67.1	−10
Dunlin (*Calidris alpina*)	421.4	33.5	−92	23.7	11.2	−53	33.6	22.0	−34
White-rumped Sandpiper (*Calidris fuscicollis*)	196.5	12.1	−94	19.5	12.5	−36	7.1	4.1	−42
Semipalmated Sandpiper (*Calidris pusilla*)	1068.5	187.9	−82	506.1	182.6	−64	85.1	71.5	−16

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.

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Note

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

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Grey Wolves (*Canis lupus*) are a leading proximate cause of declining populations of Woodland Caribou (*Rangifer tarandus*), a threatened species. Although predation on adult caribou has been well documented, less is known about predation on neonatal calves. We used scat analysis to examine the diet of wolves in an area of Ontario overlapping the receding southern limit of caribou occurrence. Wolves consumed mostly Moose (*Alces americanus*; 82.7%), followed by American Beaver (*Castor canadensis*; 10.9%), caribou (3.1%), and Snowshoe Hare (*Lepus americanus*; 1.5%). This low use of caribou is consistent with other evidence suggesting that caribou are a minor dietary component of wolves in this system; however, because most caribou consumption consists of calves, the impact on this slowly reproducing species may still be significant.

Key Words: Grey Wolf; *Canis lupus*; canids; Woodland Caribou; *Rangifer tarandus*; Moose; *Alces americanus*; American Beaver; *Castor canadensis*; diet; scat; predation; human disturbance; prey selection; northern Ontario

Introduction

Grey Wolves (*Canis lupus*) are a 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 McLellan 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 it 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 (Schaefer 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 proportions 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 km^2 and commercial logging across 28% of the region (Thompson *et al.* 2014). The area now supports moderate densities of Moose (11.8/100 km^2) and wolves (0.67/100 km^2; Kittle *et al.* 2015) and a low density of caribou (minimum 0.50/100 km^2; 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

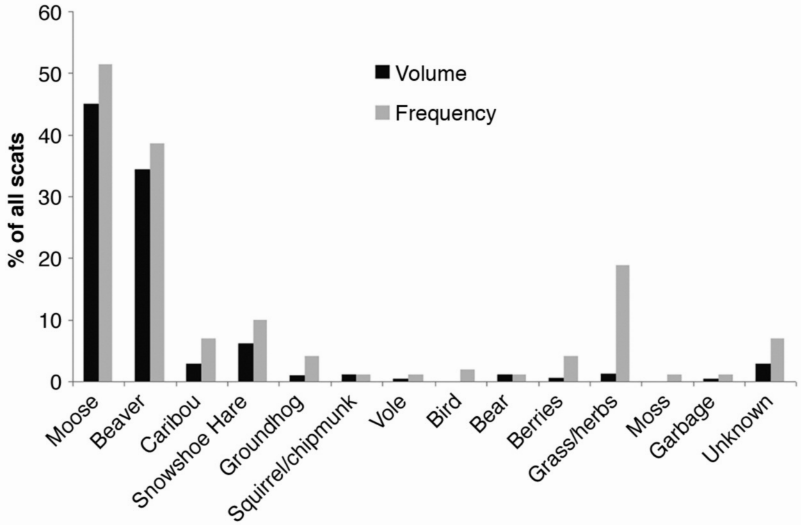

FIGURE 1. Volume and frequency of occurrence of various prey items in Grey Wolf (*Canis lupus*) scats collected in northern Ontario from late May to late June, 2012 and 2013 ($n = 101$). Differences between frequency and volume for a prey item tell us, for example, that wolves eat grass often, but not much of it. Grasses are almost always part of mixed-species scats as either a supplemental food or incidental consumption. In contrast, the biomass and frequency of caribou are similar, indicating that it is a major prey item found more often in single-prey-item scats.

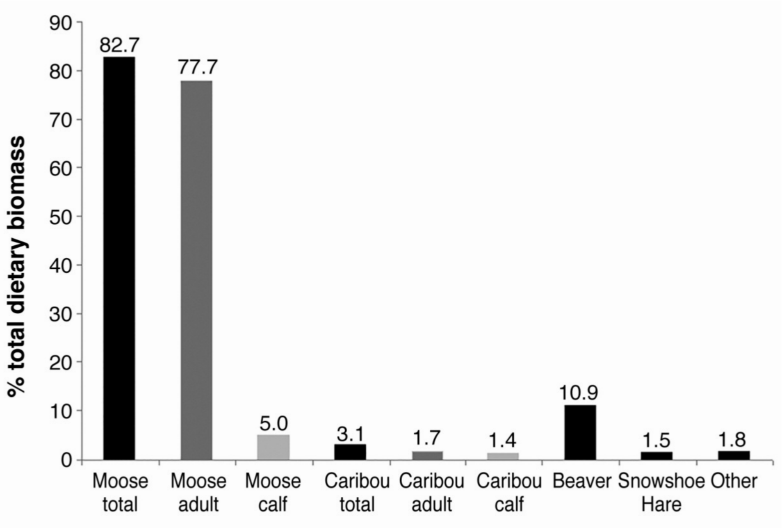

FIGURE 2. Proportion of various prey species consumed by Grey Wolves (*Canis lupus*) in northern Ontario from late May to late June, 2012 and 2013, based on calculated percentage of biomass in scat ($n = 101$).

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 Snowshoe 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 (Pimlott 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 targetted. 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 compounding 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*)

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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 (Telonics, 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-

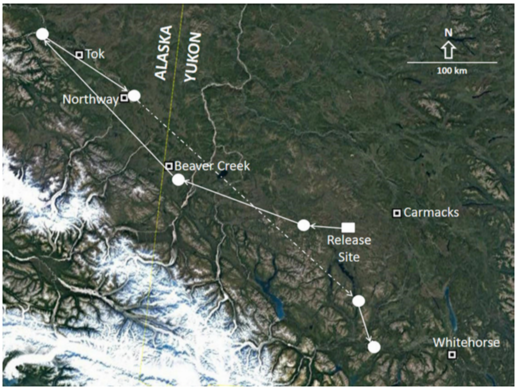

FIGURE 1. Release site (closed square), immediate post-release movements (solid lines with arrows), and subsequent translocation (dashed line) of three, then two, adult bison (*Bison bison*) bulls in Yukon and Alaska, from March 1988 to September 1989.

served variously along the Alaska Highway between the communities of Northway Junction and Tok, Alaska. During this time, they were observed by Alaskan wildlife officials as far from the release site as 45 km west of Tok (Figure 1; D. G. Kellyhouse, personal communication). Subsequently, the bulls moved back eastward along the Alaska Highway toward Northway Junction. The longest recorded straight-line distance of the bulls from their release site was about 375 km (Figure 1), which they traversed in about 6 months post-release.

While wintering near Northway Junction, the two bulls remained close to a highway roadhouse and were a concern to local residents. In late April 1989, one of the bison killed a pet dog in Northway Junction, and Alaskan wildlife officials asked their counterparts in Yukon to retrieve the two bulls. On 4 May 1989, Yukon wildlife officials captured the bulls (via chemical immobilization) in Northway Junction and transported them by truck to a release site 115 km northwest of Whitehorse, Yukon, and approximately 42 km north of the Alaska Highway (Figure 1; P. J. Merchant, personal communication). Bison #82 was last seen with #83 on 12 May 1989, near the translocation site. On 22 August 1989, #83 was seen on the Alaska Highway with a group of about 20 other bison of various sex and age classes. This bison group remained on, or adjacent to, the roadside verge for several weeks, posing a threat to highway travellers. On 13 September 1989, an adult female from the group was killed on the highway in a bison-vehicle accident. The next day, #83 was shot by wildlife officials because he would not leave the accident scene and posed a collision hazard and in an attempt to deter the rest of the group from loitering on the roadside verge (D. R. Drummond, personal communication).

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 long distances 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 dispersal capability of bison and plan accordingly, particularly where dispersing bison may conflict with people and compromise reintroduction objectives. As suggested for Elk, wildlife managers planning bison reintroductions should consider means to enhance post-release site fidelity to limit long-distance dispersal and mortality and maximize initial population growth (Yott *et al.* 2011; Bleisch *et al.* 2017). Ryckman *et al.* (2009) suggested that post-release site fidelity may be improved for species with long-distance dispersal ability by an extended conditioning period before release (i.e., soft releases). Post-release conditioning, such as supplemental feeding over the first year or so, may also help to bond animals to a new range. Even with efforts to prevent long-distance dispersal, managers should be prepared with protocols in place to address such movements 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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Note

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

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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 a 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 "endangered" 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

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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. Gremel, 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

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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 (Charland 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 Weatherhead 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 Gartersnakes (*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 (*Liochlorophis 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 two 200-m transects with pairs of coverboards (one roofing tin, one ¾-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 cautery 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 thermochron, 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 those captured in field and 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 nlme; 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 Gartersnakes (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 Gartersnake: 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).

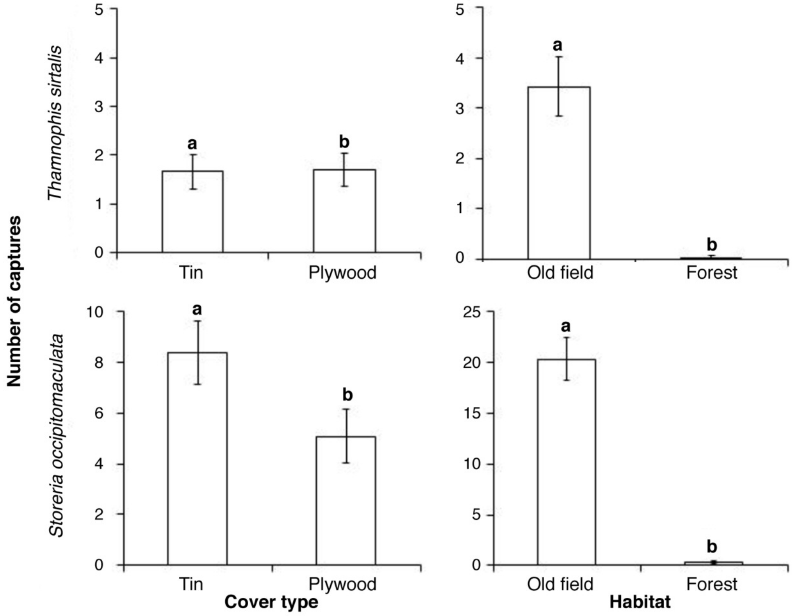

FIGURE 1. Number of captures of Red-bellied Snakes (*Storeria occipitomaculata*; $n = 242$) and Common Gartersnakes (*Thamnophis sirtalis*; $n = 90$) under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 14 May to 16 November 2015. Each bar represents mean daily captures across four study sites. In each graph, means with the same letter are not significantly different, and error bars represent the standard error.

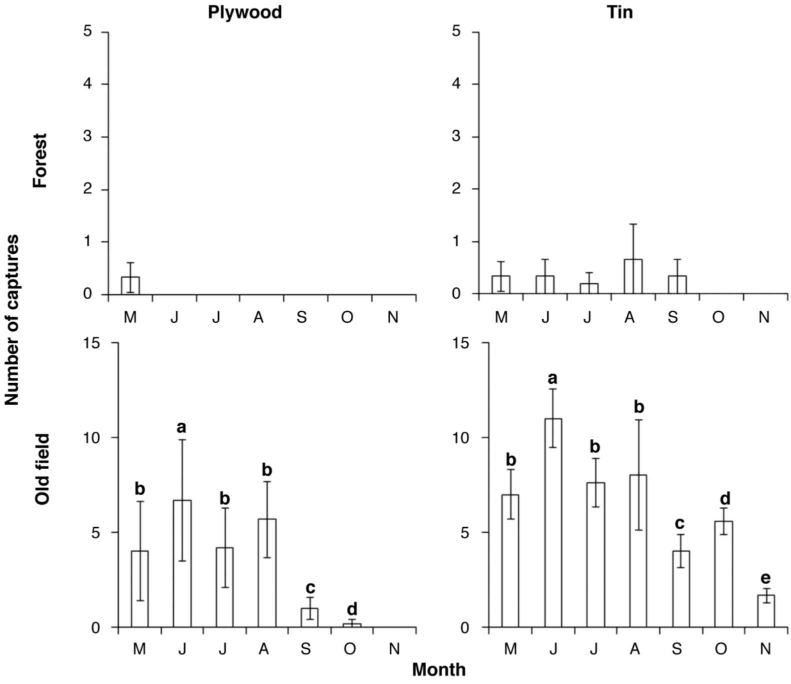

FIGURE 2. Number of captures by month of Red-bellied Snakes (*Storeria occipitomaculata*; $n = 242$) under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 14 May to 16 November 2015. Each bar represents mean monthly captures across all four study sites. In each graph,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

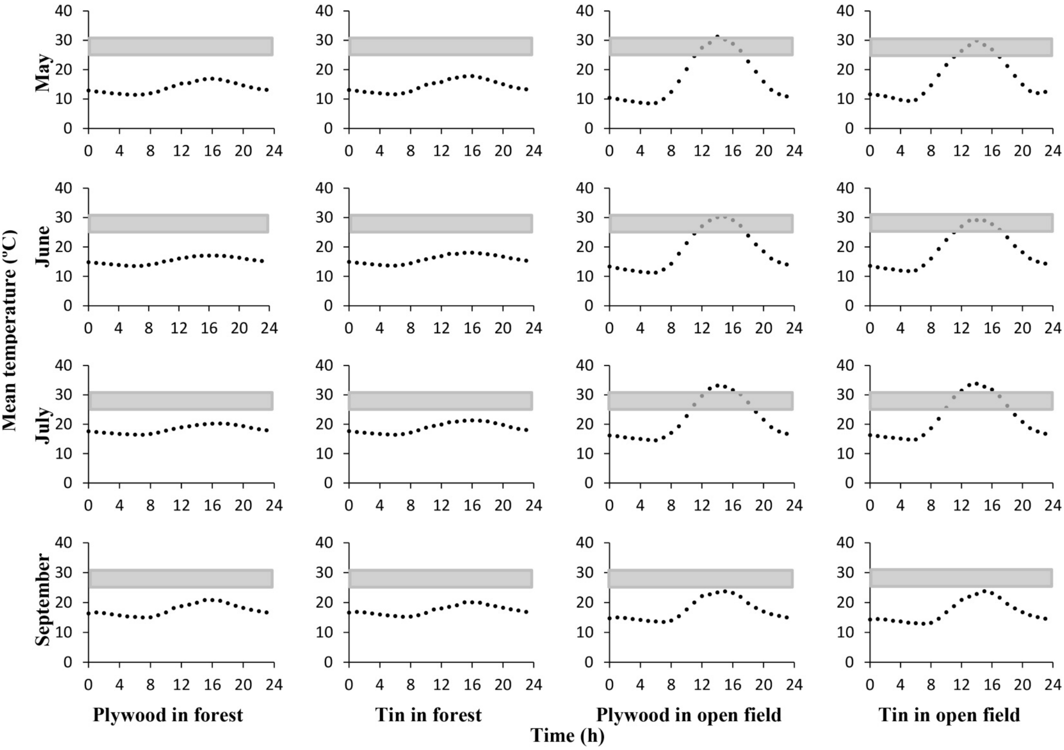

FIGURE 3. Mean temperature profiles under plywood and tin coverboards in old field and forest in Gatineau Park, Quebec, Canada, 2015. The grey rectangle represents the mean preferred temperature of Common Gartersnakes (*Thamnophis sirtalis*): 24.5–30.7°C (Peterson 1987).

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.

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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*)

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LeGros, David L. 2017. Side to side swaying as a defensive behaviour in the Dekay's Brownsnake (*Storeria dekayi*). Canadian Field-Naturalist 131(3): 235–237. https://doi.org/10.22621/cfn.v131i3.1897

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 Brownsnake (*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 Brownsnake 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 Brownsnake, 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 Brownsnake, 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 Brownsnake, 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 brownsnake 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

FIGURE 1. Dekay's Brownsnake (*Storeria dekayi*) exhibiting dorso-ventral flattening and a defensive coil, which was swayed side to side as the snake slowly fled, 20 May 2016, Rondeau Provincial Park, Ontario. Photo: D. LeGros.

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.

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

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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 summer 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 euthermic 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., Sunnyvale, 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.

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 senso 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).

Twelve fungal taxa and multiple sterile morphs were isolated from faeces collected from four mice, with a mean of 6.0 fungal taxa per individual (SD 2.83). Two mice did not produce scat before release. The most common fungal taxa cultured from feces were *Mucor* spp. (100% of mice, *n* = 4), *Pseudogymnoascus pannorum senso lato* (75%), *Penicillium* spp. (75%), *Cephalotrichum stemonitis* (50%), *Thelebolus crustaceus* (50%), and *Leuconeurospora capsici* (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 senso 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 ($t_{1,18} = -2.48$, $P = 0.024$). 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 senso 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

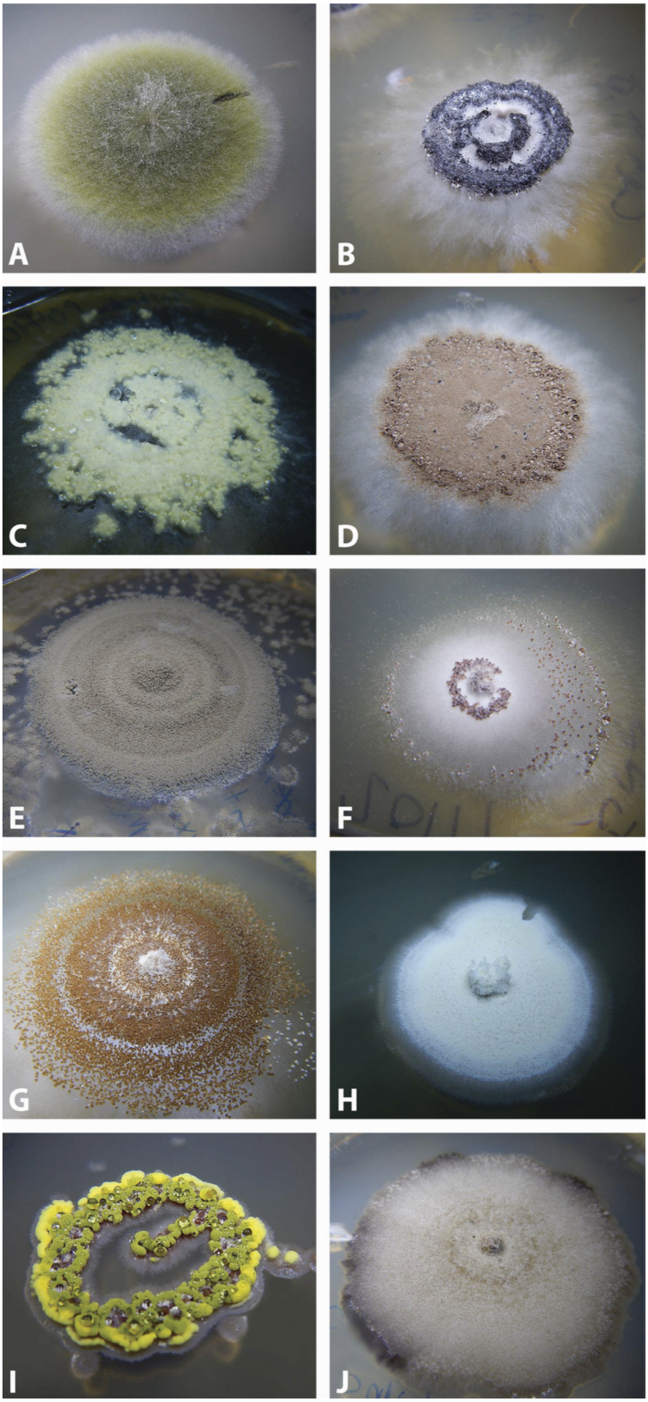

FIGURE 2. Representative psychotolerant fungi in pure culture from the winter (W) and summer (S) fur (FU), faeces (FE), and gut contents (GC) of Deer Mice (*Peromyscus maniculatus*) associated with a white-nose syndrome positive bat hibernaculum in eastern Canada. All cultures on DPYA without oxgall 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.

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.

Fungus	Winter (no. mice)			Summer (no. mice)
	Fur (*n* = 6)	Faeces (*n* = 4)	Gut contents (*n* = 1)	Fur (*n* = 15)
Ascomycota				
Acremonium sp.	0	0	0	1
Alternaria sp.	0	0	0	2
Arthrinium phaeospermum (Corda) M.B. Ellis	0	1	0	1
Arthroderma silverae Currah, S.P. Abbott & Sigler	1	0	1	0
Cephalotrichum stemonits (Pers.) Link	0	2	0	0
Cladosporium sp.	0	0	0	12
Leuconeurospora capsici (J. F. H. Beyma) Malloch, Sigler & Hambleton	0	2	0	0
Leuconeurospora polypaeciloides Malloch, Sigler and Hambleton	0	0	0	1
Microascus sp.	0	1	1	2
Microascus caviariformis Malloch & Hubart	1	1	1	0
Myxotrichum sp.	0	0	0	1
Oidiodendron cf. state of Myxotrichum emodense	0	0	0	1
Oidiodendron cf. hughesii, cf. myxotrichoides	0	0	0	1
Paecilomyces sp.	1	0	0	0
Penicillium sp.	3	3	1	13
Penicillium thomii Maire	0	0	0	1
Pseudogymnoascus pannorum senso lato (Link) Minnis & D.L. Lindner	6	3	1	7
Pseudogymnoascus roseus Raillo	0	1	0	0
Sarcinomyces sp.	0	0	0	1
Scopulariopsis sp.	1	0	0	1
Scopulariopsis candida Vuill.	0	0	0	2
Talaromyces sp.	1	0	0	0
Thelebolus sp.	0	1	0	0
Thelebolus crustaceus (Fuckel) Kimbr	0	2	0	0
Thysanophora canadensis Stolk & Hennebert	0	0	0	2
Thysanophora penicillioides (Roum.) W. B. Kendr.	0	0	0	2
Trichoderma sp.	0	0	0	1
Trichophyton sp.	0	0	1	0
Basidiomycota				
Unidentified Basidiomycete	0	0	0	1
Trichosporon sp.	0	1	0	0
Zygomycota				
Mortierella sp.	1	0	0	1
Mucor sp.	1	4	1	13
Umbelopsis isabellina (Oudem.) W. Gams	0	0	0	1
Sterile morph	1	1	1	5

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. quadrifidum, 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 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 *Scopulariosis* 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; Sandoval-Denis *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 silverae* (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 mycobiome 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 euthermic 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.

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Fabronia ciliaris, a Moss New to Canada from Southeastern Manitoba

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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; phytogeography; 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* (Sullivant) 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 extent to about half the leaf length, rhomboidal laminal 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, UADBG, 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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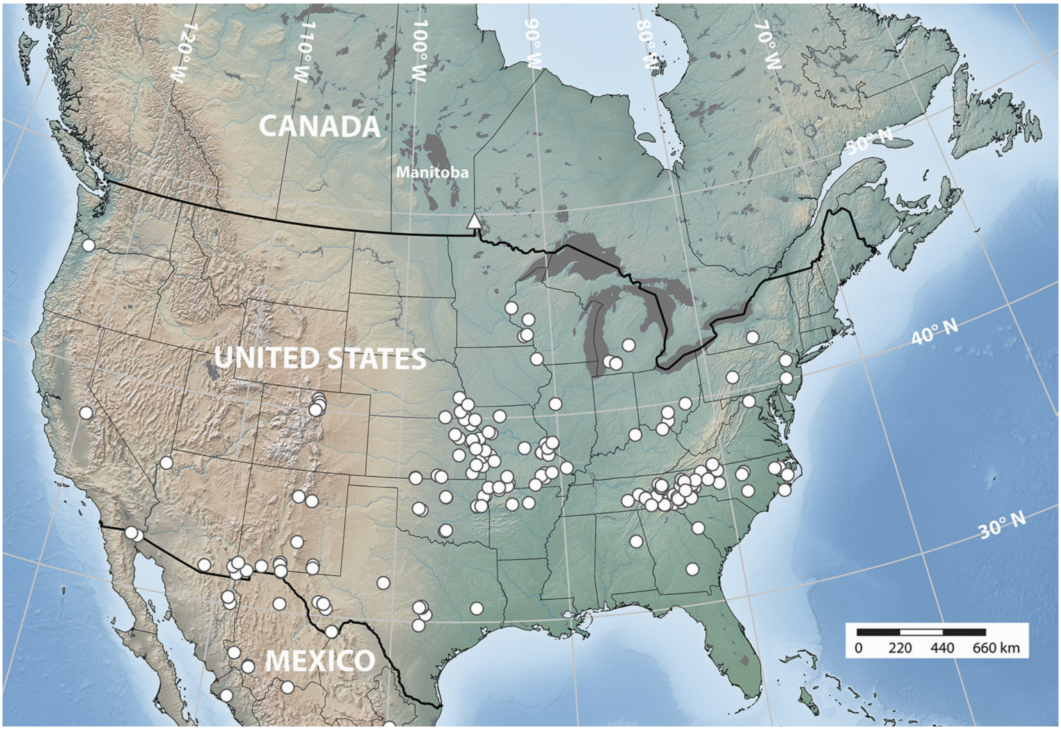

FIGURE 1. Distribution of *Fabronia ciliaris* in North America based on search results from the Consortium of North American Bryophyte Herbaria (CNABH 2017) database. Map generated and modified from SimpleMappr (Shorthouse 2010). The triangle depicts the new collection from Whiteshell Provincial Park in southeastern Manitoba, the first record for Canada. Specimens associated with data points have not been verified by the author and represent the approximate distribution for the species only.

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).

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

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

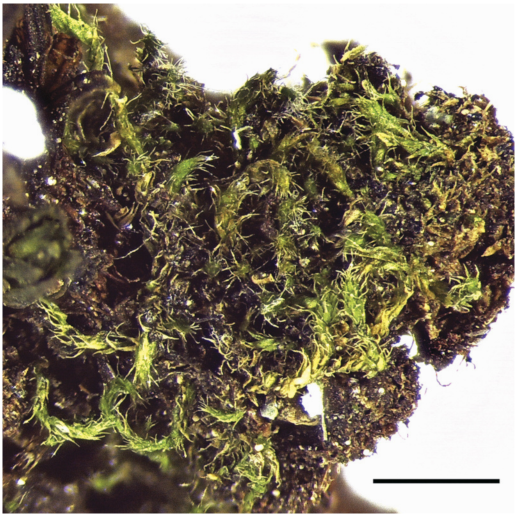

FIGURE 3. Several shoots of *Fabronia ciliaris* growing among *Orthotrichum anomalum*. The length of the scale bar represents 1.0 mm. Photo: Richard Caners.

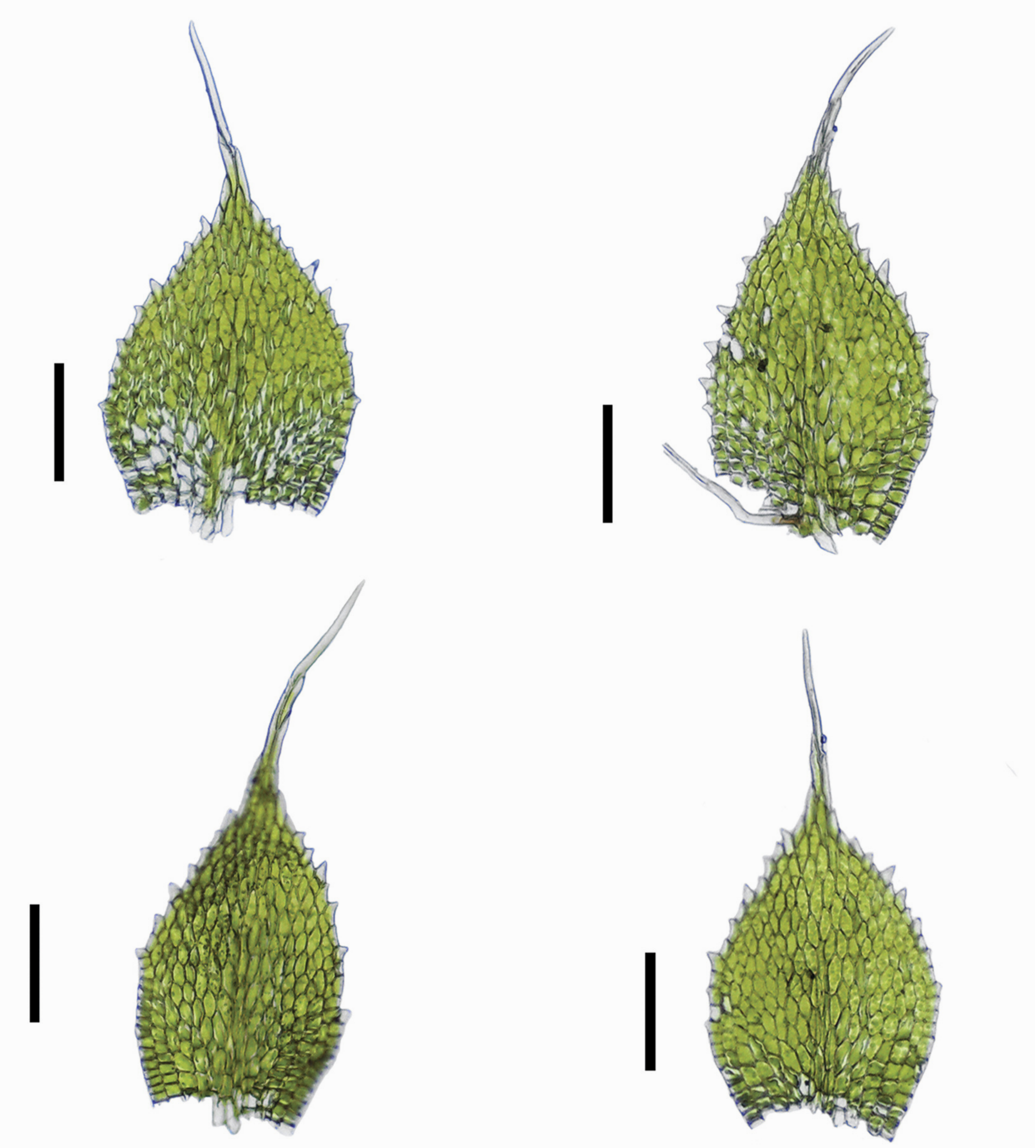

FIGURE 4. Representative stem leaves of *Fabronia ciliaris* collected in southeastern Manitoba. The length of the scale bar next to each leaf represents 0.1 mm. Photos: Richard Caners.

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

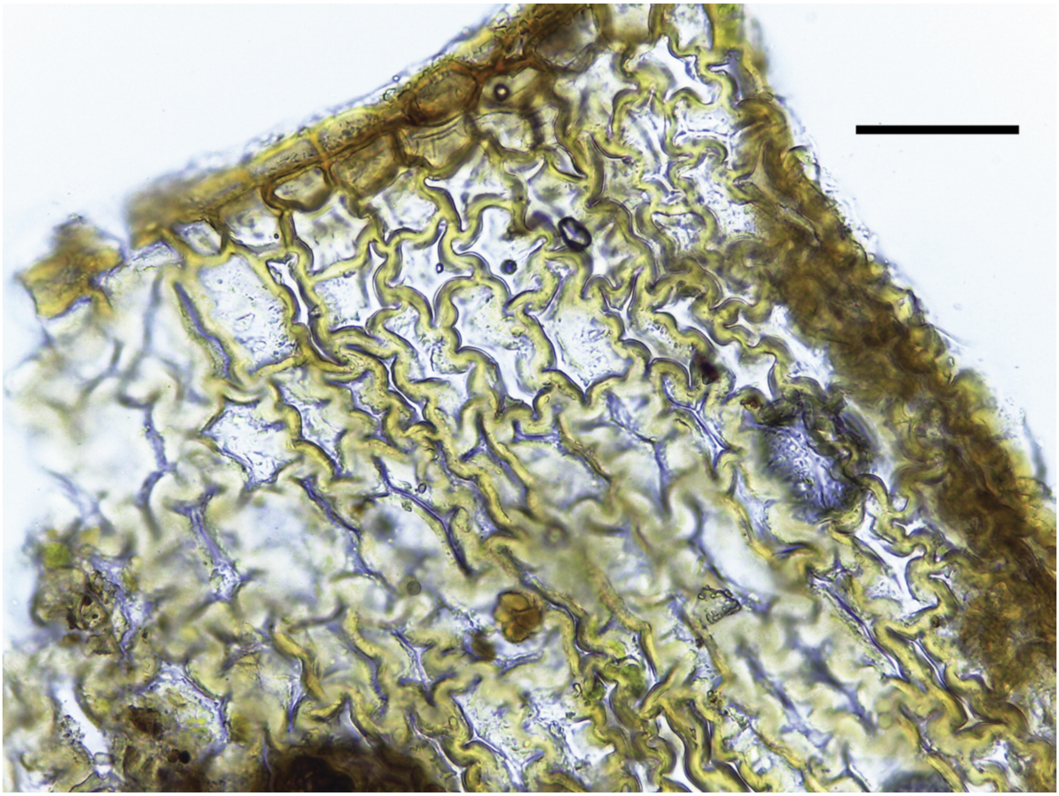

FIGURE 5. Exothecial cells from a sporophyte capsule of *Fabronia ciliaris* collected in southeastern Manitoba. The length of the scale bar represents 0.1 mm. Photo: Richard Caners.

(9–15 µm; Lawton 1971). 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 (McIntosh 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 targetted 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).

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Note

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

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Gable, Thomas. D., Steve K. Windels, and Ian C. Rautio. 2017. River Otter (*Lontra canadensis*) killed by wolves (*Canis lupus*) during winter in Northern Minnesota. Canadian Field-Naturalist 131(3): 252–253. https://doi.org/10.22621/cfn.v131i3.1913

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) — 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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Note

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

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Buse, Alexander J., Meghan A. Douglas, Thomas N. Giguère, and Beren W. Robinson. 2017. Adult Snapping Turtle (*Chelydra serpentine*) feeding on goldeneye embryos of Pumpkinseed (*Lepomis gibbosus*) in defended nests. Canadian Field-Naturalist 131(3): 254–257. https://doi.org/10.22621/cfn.v131i3.1859

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 in one case apparently feeding on goldeneye-stage embryos (i.e., non-mobile post hatch "free" embryos, < 3 mm total length, with yolk sacs, that have not yet started to feed exogenously; Auer 1982). This is the first time this feeding behaviour has been reported in adult Snapping Turtles.

Observations of Snapping Turtles and nesting Pumpkinseed 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 Pumpkinseed. 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, Pumpkinseed 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 Pumpkinseed 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 *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.

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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

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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 refine protection priority ranks of species of Quebec and Labrador.

Key Words: Boreal forest; bryoflora; bryo-geography; liverwort; true moss; sphagna; 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; forêt boréale; hépatiques; mousses; sphaignes; Nord-du-Québec

Introduction

Bryophytes (liverworts, true mosses, and sphagna), 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 understorey 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,

FIGURE 1. a. Location of the study area (white square) in the Nord-du-Québec administrative region of western Quebec, Canada, within the boreal Black Spruce (*Picea mariana*) forest bioclimatic domain (dark grey). b. The six wildfires sampled (dark grey shapes) in Black Spruce forest bioclimatic domain (light gray zone; adapted from Payette and Bouchard 2001). Triangles represent main cities. c. Black rectangles represent sample plots of 50 m² located along a transect crossing the residual patch (light grey) from burned area (B) to edge (E) and core (C).

respectively (Environment Canada 2017). The region is characterized by long winters, with 313 cm of snowfall annually, and a short growing season of 140–160 days.

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 ^{14}C 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 (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 m^3/ha of coarse woody debris). More details about the characteristics of the patches are presented in Barbé *et al*. (2017).

Rectangular plots (50 m^2) 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-m^2 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 m^2: 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 geolocated using a handheld global positioning system receiver (Garmin GPSmap 62, Olathe, Kansas, USA).

In each 50-m^2 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 Statistic 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-m^2

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 epixylics), 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, *Hylocomium splendens* (Hedw.) Schimp., *Pleurozium schreberi* (Willd. *ex* Brid.) Mitt., and *Ptilium crista-castrensis* (Hedw.) De Not., with frequent occurrences of the acrocarp species, *Dicranum fuscescens* Turner and *Polytrichum commune* Hedw. var. *commune*, and of the liverworts, *Lophozia ventricosa* (Dicks.) Dumort, *Ptilidium ciliare* (L.) Hampe, and *Ptilidium pulcherrimum* (Weber) Hampe. The wettest sites also supported *Aulacomnium palustre* (Hedw.) Schwägr., *Sanionia uncinata* (Hedw.) Loeske, and *Warnstorfia*

TABLE 1. The 35 species of bryophytes with range extensions in the south of the Nord-du-Québec administrative region, western Quebec, Canada. Significant additions to the flora of Quebec–Labrador are bolded. Species group affiliations are: 1, locally uncommon/infrequent already recorded near the study area; 2, provincially common to rare only recorded sporadically near the study area; and 3, new occurrences for the study area.

	Species group affiliation	Previously documented Quebec occurrences*	New occurrences	Status in Quebec–Labrador and proposed change (→)	Proposed modification to range†	Closest known Quebec occurrence (km)	Factors possibly explaining modification of distributional ranges	Microhabitats‡	
								Previously documented	Newly observed
MOSSES									
Brachythecium erythrorrhizon	2	25	4	Uncommon	—	115		T/R	DW
Brahythecium starkei	2	13	92	Uncommon → common	—	110	ID confusion	T	C/DW
Campylium protensum	3	19	19	Rare → uncommon	Extended west	605	ID confusion	W	C/DW
Dicranum fulvum	3	Cont. dist.	3	Common	Extended north	135		R	DW
Helodium blandowii var. *blandowii*	3	Cont. dist.	3	Common	Extended west	325		P	C/T
Hypnum curvifolium	3	Cont. dist.	2	Common	Extended west	270		NA	DW
Hypnum fauriei		–	1	?§	—		ID confusion	C/DW/R/T	
Isopterygiopsis muelleriana	2	32	9	Common	—	100		R	DW
Isopterygiopsis pulchella	3	48	3	Common	Extended west	550		C/DW/R/T	
Pohlia elongata var. *elongata*	3	20	2	Uncommon	Extended west	260		NA	T
Pohlia sphagnicola	3	18	634	Uncommon → common	—	300	ID confusion	P	C/EP/T
Polytrichum commune var. *perigoniale*	2	25	12	Uncommon	Extended west	60		T	C

TABLE 1. *(continued)*

	Species group affiliation	Previously documented Quebec occurrences*	New occurrences	Status in Quebec–Labrador and proposed change (→)	Proposed modification to range†	Closest known Quebec occurrence (km)	Factors possibly explaining modification of distributional ranges	Microhabitats‡	
								Previously documented	Newly observed
Thuidium recognitum	3	Cont. dist.	5	Common	Extended north	75		C/DW/R	
Ulota crispa	3	Cont. dist.	16	Common		165		C	DW/T
LIVERWORTS									
Calypogeia sphagnicola	1	12	151	Uncommon → common	BBSF?	25		P	C/DW/R/T
Calypogeia suecica	3	15	6	Uncommon	Extended west	300	< 2 mm	C	
Cephaloziella elachista	3	10	20	Infrequent → uncommon	—	365	< 0.5 mm Under sampled	P	C/DW/T
Cephaloziella hampeana	2	16	56	Uncommon → common	—	20	Under sampled	P/DW/R	C/T
Cephaloziella spinigera	3	10	10	Infrequent	—	360	Under sampled	P	C/DW/T
Chiloscyphus coadunatus var. *rivularis*	3	17	29	Rare → uncommon	—	550		R	C/DW
Fuscocephaloziopsis loitlesbergeri	3	10	100	Infrequent → common	—	490	0.6–0.8 mm Under sampled	P	C/DW/T
Fuscocephaloziopsis pleniceps	1	29	219	Uncommon → common	BBSF?	25		P/DW	C/R
Kurzia pauciflora	2	18	3	Uncommon	—	65	Under sampled	P	DW/T
Lophozia ascendens	2	30	20	Uncommon	—	35	0.8–1.3 mm	DW	C
Lophozia bicrenata	2	25	14	Uncommon	—	45	Under sampled	T	DW/R
Lophozia guttulata	1	21	82	Uncommon → common	BBSF?	27	1–1.8 mm	P/DW	C/R/T
Lophozia silvicola	3	3	77	Infrequent → common	Extended west	350	ID confusion	DW/R	C/P/T
Mesoptychia heterocolpos var. *heterocolpos*	4	67	2	Common	—	670		DW/R	
Mesoptychia rutheana	3	15	1	Uncommon	—	450	3–5 mm	P	
Odontoschisma francisci	2	18	19	Rare → uncommon	—	80		P/T	C/DW
Scapania apiculata	4	6	3	Infrequent	Extended northwest	360		DW	P
Scapania uliginosa	4	9	1	Infrequent	Extended west	465	< 4 mm	R	
Schistochilopsis laxa	2	3	2	Rare	—	35	1.5–2 mm	P	T
Sphenolobus hellerianus	1	38	92	Uncommon → common	BBSF?	26	< 1 mm Under sampled	DW	C
SPHAGNUM									
Sphagnum tenerum	4	7	29	Infrequent → uncommon		350	ID confusion	NA	P/DW/R/T

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.

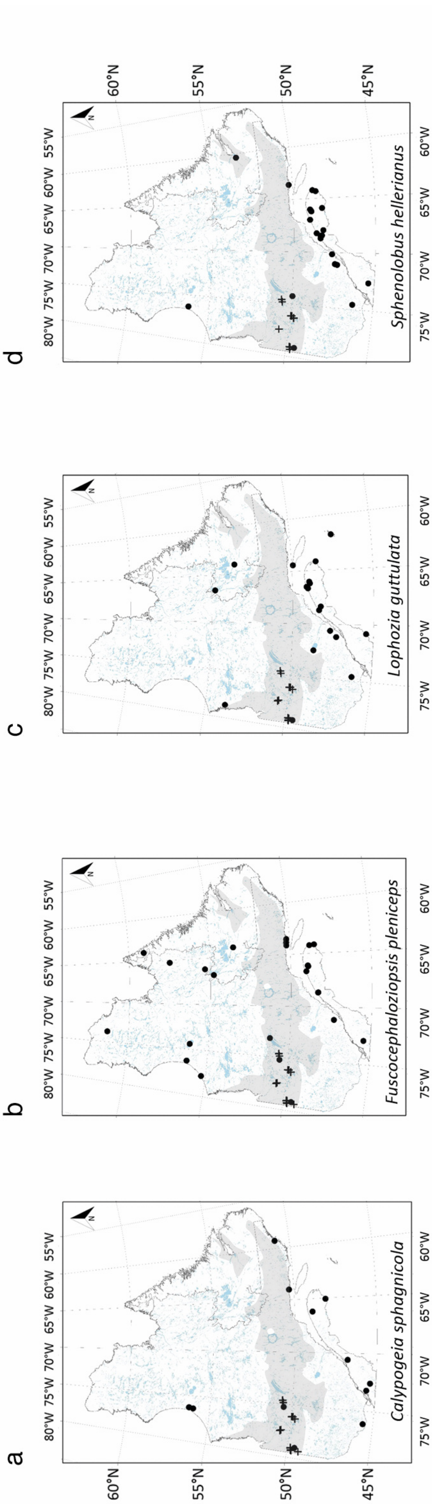


FIGURE 2. Distributional ranges of the four species of group 1, comprising provincially uncommon or infrequent species previously recorded 26–32 km from the study area: a. *Calypogeia sphagnicola*, b. *Fuscocephaloziopsis pleniceps*, c. *Lophozia guttulata*, d. *Sphenolobus hellerianus*. Dots show previously documented occurrences; plus signs are new occurrences. The shaded area represents the boreal Black Spruce–feather moss forest where the species likely occur.

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) Váňa & 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 erythrorrhizon* 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* (Dicks.) Grolle, *Lophozia ascendens* (Warnst.) R.M. Schust., *L. bicrenata* (Schmidel) Dumort., *Odontoschisma francisci* (Hook.) L. Söderstr. & Váňa, *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 erythrorrhizon*, *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 (*Campylium 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., *Ulota 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)

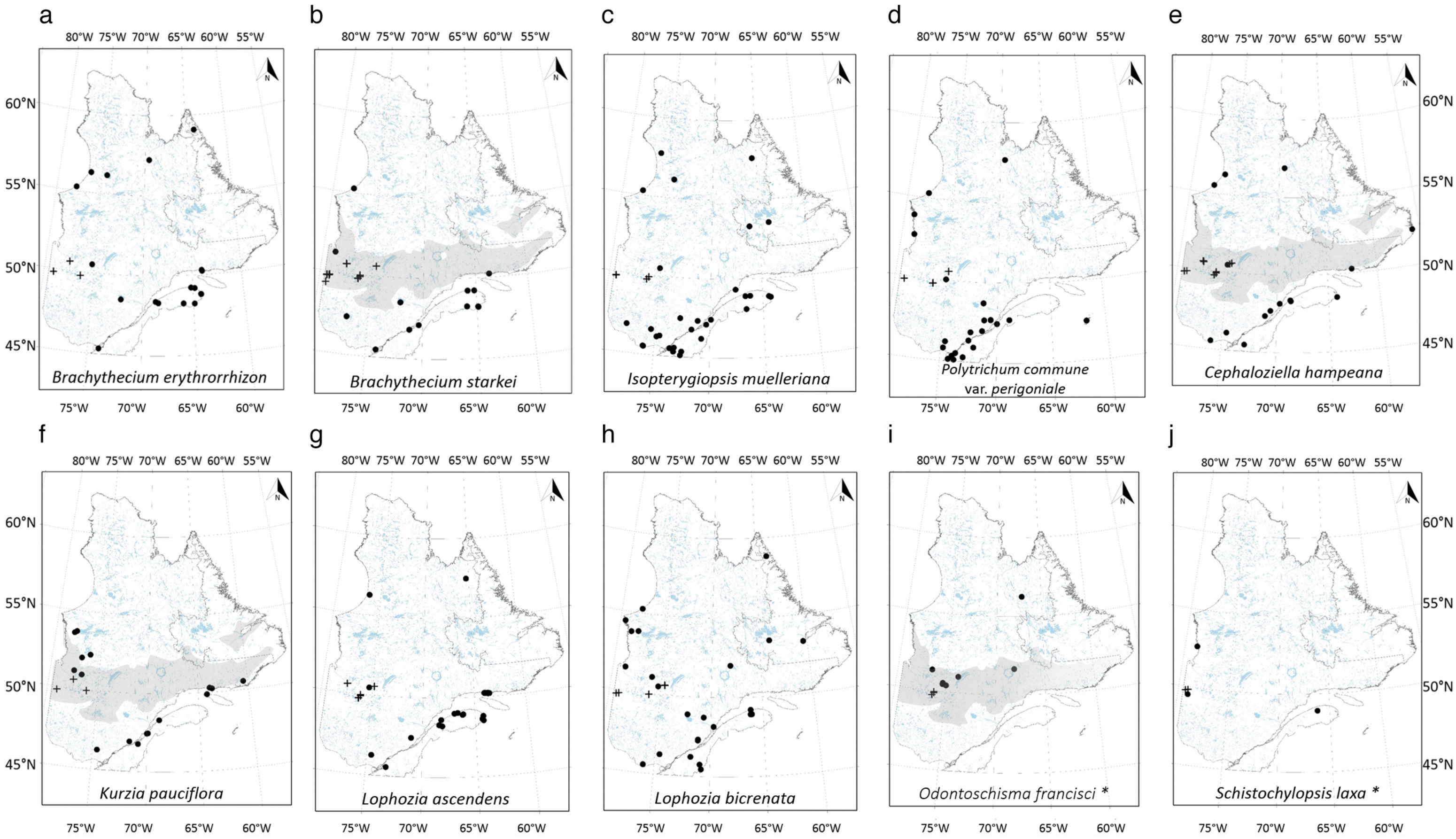


FIGURE 3. Distributional ranges of species of group 2 (10 in total), comprising provincially common to rare species sporadically recorded in the study area previously: a. *Brachythecium erythrorrhizon*, b. *Brachythecium starkei*, c. *Isopterygiopsis muelleriana*, d. *Polytrichum commune* var. *perigoniale*, 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+).

Frisvoll, Elvebakk, Flatberg & Okland, *Fuscocephaloziopsis loitlesbergeri* (Schiffn.) Váňa & L. Söderstr., *Lophozia silvicola* H. Buch, *Mesoptychia heterocolpos* (Thed. *ex* Hartm.) L. Söderstr. & Váňa var. *heterocolpos*, *Mesoptychia rutheana* (Limpr.) L. Söderstr. & Váňa, *Scapania apiculata* Spruce, *S. uliginosa* (Lindenb.) Dumort.), and one sphagnum (*Sphagnum tenerum* Sull. & Lesq. *ex* Sull.; Figure 4). Considering occurrences from Ontario, we report a 50–200 km eastward extension of the distributional range of *Helodium blandowii* var. *blandowii*, *Isopterigiopsis pulchella*, *Pohlia sphagnicola*, and *Thuidium recognitum* (Ireland and Ley 1992; CNALH 2017).

Hypnum fauriei 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 *Calypogeia 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 erythrorrhizon, 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 (*Calypogeia 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 *K. 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 *Ulota crispa* are also common. However, we do not suggest extension of their continuous distributions be-

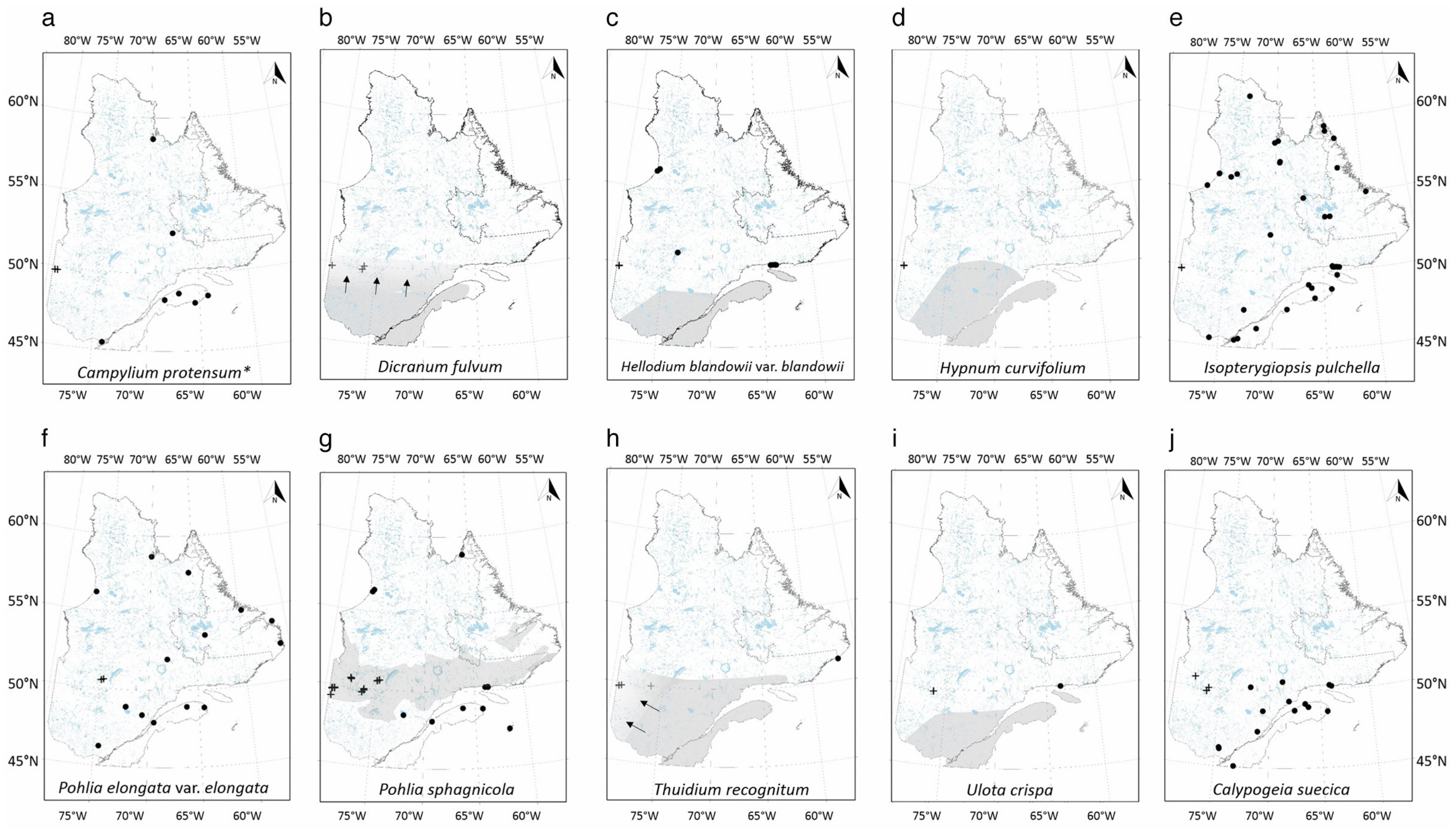
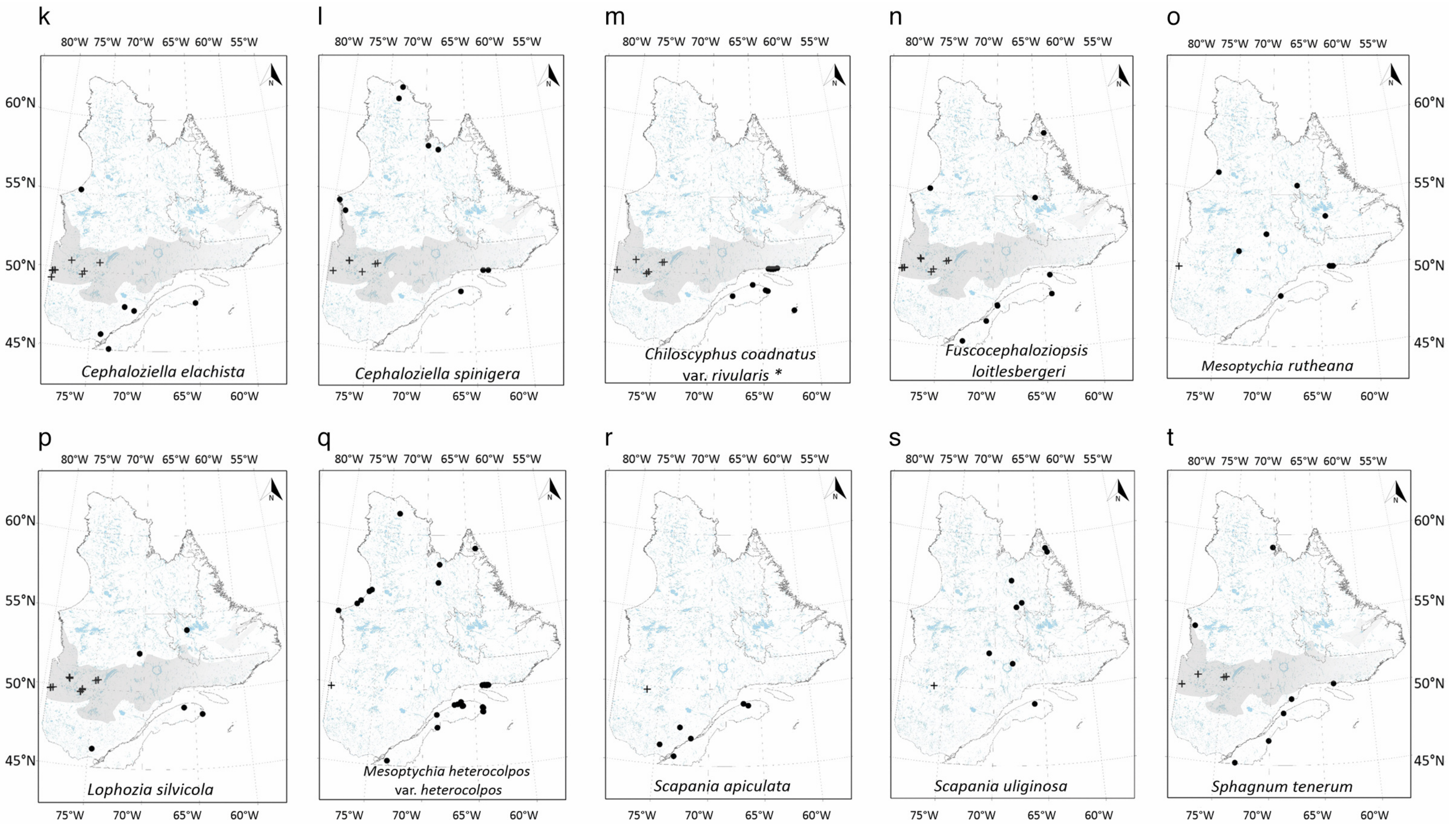


FIGURE 4A. Distributional ranges of species of group 3 (20 in total), comprising new occurrences in the study area with range extensions 77 km to > 650 km from their closest previously documented occurrence: a. *Campylium protensum*, b. *Dicranum fulvum*, c. *Hellodium blandowii* var. *blandowii*, d. *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. *Mesoptychia rutheana*, p. *Lophozia silvicola*, q. *Mesoptychia 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 erythrorrhizon, Isopterygiopsis muelleriana, Polytrichum commune* var. *perigoniale, Lophozia ascendens,* and *L. bicrenata* close gaps in their provincial distribution between southern and northern Quebec but also, in the case of *B. erythrorrhizon* and *P. commune* var. *perigoniale*, between eastern Quebec and Ontario. Furthermore, we document the presence of *Campylium protensum*, *Isopterygiopsis pulchella*, *Pohlia elongata* var. *elongata, Calypogeia suecica, Mesoptychia 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 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.

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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.

Observations of Beachcast Bowhead Whales (*Balaena mysticetus*) in the Southeastern Beaufort Sea and Amundsen Gulf, 1987–2016

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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 = 15 176–18 643; 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 subadults. 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 ship-strike 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

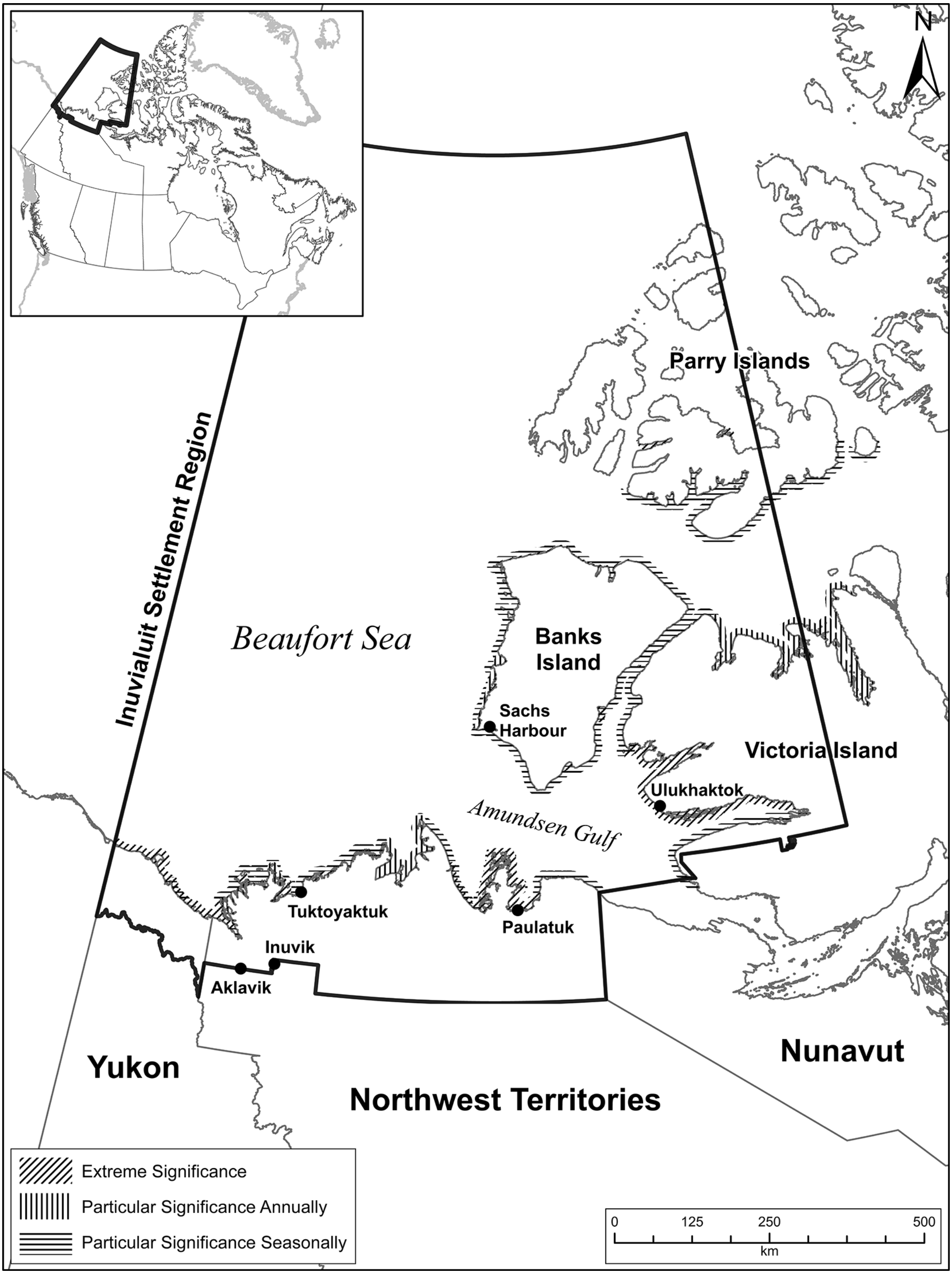

FIGURE 1. Coastlines in the Inuvialuit Settlement Region (ISR; polygon) self-identified by harvesters as having extreme or particular significance to ISR hunters. We infer these to include hunting and travelling routes that are regularly used (adapted from Community of Aklavik *et al*. 2008; Community 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).

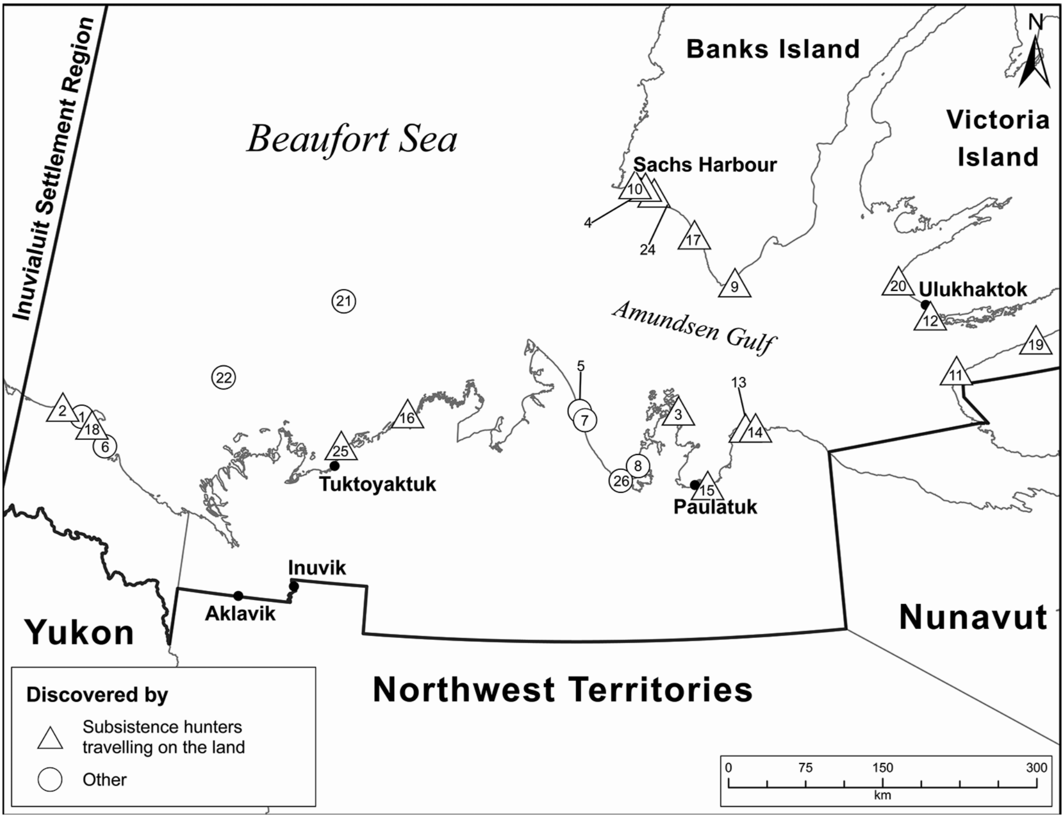

FIGURE 2. Location of beachcast and drifting Bowhead Whale (*Balaena mysticetus*) carcasses discovered in the western Canadian Arctic by hunters and others, 1987–2016 (whale number corresponds to Table 1).

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).

TABLE 1. Beachcast and adrift Bowhead Whale (*Balaena mysticetus*) carcasses observed in the southeast Beaufort Sea and Amundsen Gulf, from 1987 to 2016, as recorded by, or reported to, Fisheries and Oceans Canada (no data = –).

Whale #	Carcass first observed: Year	Carcass first observed: Month	On-site inspection of carcass by technical staff	Estimated length (m)[*]	Size class[†]	Discovered and/or reported to DFO by	Sex	Blubber thickness (cm)	No. bears[‡] observed or evidence of bears, scavenging (scats and/or tracks) at carcass
1	1987	9	yes	9[§]	subadult	DFO staff	–	–	–
2	1991	–	no	–	–	Aklavik Hunter	–	–	3 (GB) + 1 (PB)
3	1989	7	no	7	subadult	Paulatuk Hunter	–	–	–
4	1993	8	no	13–14	mature adult	Sachs Harbour HTC/hunters	–	–	–
5	1995	4	yes	16[§]	mature adult	pilot report	–	–	scavenged
6	1996	8	yes	9	subadult	parks crew	male	–	–
7	2000	9	yes	8.9	subadult	pilot report	–	25–30	10 (GB)
8	2000	9	yes	14	mature adult	unknown	–	–	7 (PB)[‖]
9	2003	4	no	–	–	Sachs Harbour hunters	–	–	–
10	2003	7	yes	14	mature adult	parks crew	female	30	no
11	2003	8	yes	14	mature adult	Ulukhaktok hunters	–	–	scavenged
12	2003	9	no	–	–	Ulukhaktok hunters	–	–	no
13	2004	8	no	14	mature adult	Paulatuk hunters	–	–	4 (GB)
14	2004	8	no	9.5[§]	subadult	Paulatuk hunters	–	–	–
15	2004	8	yes	14	mature adult	Paulatuk hunters	–	30	no
16[¶]	2004	12	yes	8	subadult	Tuktoyaktuk hunters/wildlife officers	–	–	scavenged
17	2005	7	yes	8.2[§]	subadult	Sachs Harbour hunters	–	–	–
18	2005	–	no	–	–	Tuktoyaktuk hunters	–	–	–
19	2006	8	no	–	–	Ulukhaktok hunters	–	–	–
20	2006	–	no	–[§]	–	Ulukhaktok hunters	–	–	
21	2009	10	no	8	subadult	Coast Guard ship	–	–	no
22	2009	10	no	–	–	Coast Guard ship	–	–	no
23	2010	8	no	9	subadult	parks crew	–	–	–
24	2014	8	no	–[§]	–	Sachs Harbour hunters	–	–	scavenged
25	2015	8	yes	9.2	subadult	Tuktoyaktuk hunters	–	–	no
26	2015	9	no	–	–	canoeists reported to Paulatuk HTC	–	–	1 (GB)

[*] 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-

FIGURE 3. Veterinary pathologist, assisted by technical staff from Fisheries and Oceans Canada and the community of Tuktoyaktuk, Northwest Territories, conducting a necropsy of a highly decomposed 'subadult' beachcast Bowhead Whale (*Balaena mysticetus*) carcass, Atkinson Point, Northwest Territories, Canada (no. 16, Figure 2). Photo: E. Linn.

FIGURE 4. Bowhead Whale (*Balaena mysticetus*) ‘adult’ carcass at Franklin Bay with Grizzly Bear (*Ursus arctos*) scavenging (no. 26, Figure 2). Photo: B. Orkin.

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 ‘subadults’ 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.

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News and Comment

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 Kings'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, focussing 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.

FIGURE 2. Voucher specimen of regionally rare Aquatic Beggarsticks (*Bidens beckii*) collected by James Fletcher, W. H. Harrington, and H. Groh in Dows Lake, Ottawa, 7 September 1908 (DAO), likely the last plant specimen he collected. Image courtesy of Gisèle Mitrow, Agriculture and Agri Research Canada.

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).

FIGURE 3. Fletcher's Dragonfly (*Williamsonia fletcheri*) perched on a field naturalist's hand, Alfred Bog, Ontario, 3 September 1984. Photo: Donald Cuddy.

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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DANIEL F. BRUNTON

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

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.

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.

FIGURE 2. Macoun's Gentian (*Gentianopsis macounii* (Holm) Iltis) Jurra Creek, Bow Valley, Alberta, 19 September 2009. Photo: D. F. Brunton.

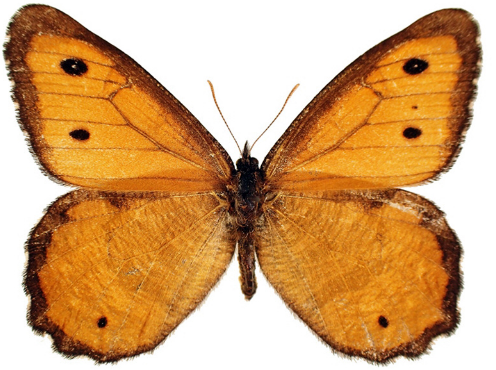

FIGURE 3. Macoun's Arctic (*Oeneis macounii*) from Bonnchere, Algonquin Park, Nipissing District Ontario, 17 June 1972. Photo: P. M. Catling.

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

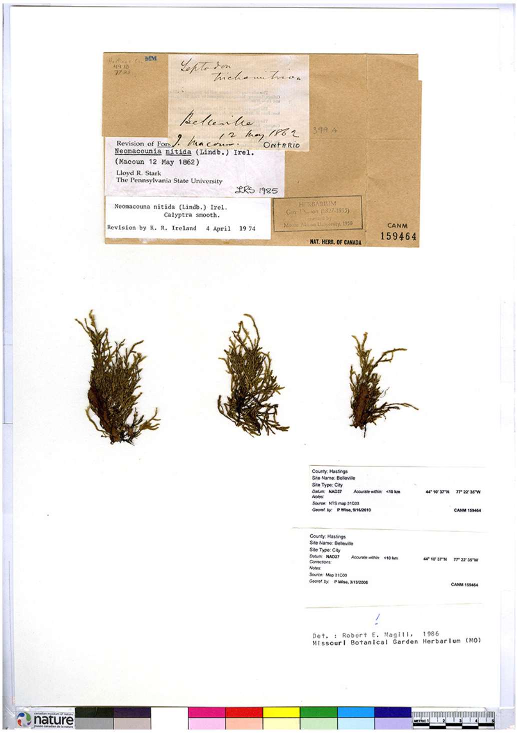

FIGURE 4. Macoun's Shining Moss (*Neomacounia nitida* (Lindberg) Ireland), a species and genus known only from Macoun's collections near Belleville between 1860 and 1893 and considered extinct as of November 2002 (SARA Registry 2018). Photo: Lyndsey Sharp, Canadian Museum of Nature.

FIGURE 5. Magnified image of Macoun's Shining Moss (*Neomacounia nitida* (Lindberg) Ireland). 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.

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DANIEL F. BRUNTON and PAUL M. CATLING

Upcoming Meetings and Workshops

The Alberta Chapter of the Wildlife Society Conference

The Alberta Chapter of the Wildlife Society Conference to be held 9–11 March 2018 at the Lethbridge Lodge, Lethbridge, Alberta. The theme of the conference is: 'A Future with Renewable Energy: Implications for Wildlife Conservation with a Special Symposium: Globalization and Invasive Species'. More information is available at https://www.actws.ca/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

The annual meeting of the Southwestern Branch of the Entomological Society of America to be held 25–29 March 2018 at the Hotel Albuquerque, Old Town, Albuquerque, New Mexico. More information is available at http://entsoc.org/event-calendar/esa-southwestern-branch-2018-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

The 36th annual meeting of American Ornithology and the 2nd annual meeting of the American Ornithological Society to be held 9–14 April 2018 at the Hilton Tucson El Conquistador, Tucson, Arizona. The theme of the conference is: 'Celebrating Connections: Birds Across Borders'. Registration is currently open. More information is available at https://amornithmeeting2018.org/.

2018 Northeast Natural History Conference

The 18th Northeast Natural History Conference to be held 13–15 April 2018 at the Hotel Burlington and Conference Center, Burlington, Vermont. Registration is currently open. More information is available at https://www.eaglehill.us/NENHC_2018/NENHC2018.shtml.

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):

Diana Bizecki Robson, John H. Wiersema, C. Barre Hellquist, and **Thomas Borsch.** Distribution and ecology of a new species of water-lily, *Nymphaea loriana* (Nymphaeaceae), in Western Canada. Canadian Field-Naturalist 130(1): 25–31. https://doi.org/10.22621/cfn.v130i1.1787;

– an extensive field investigation of the distribution and ecology of a newly described aquatic plant species endemic to the Prairie Boreal Region of Canada;

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;

The Ottawa Field-Naturalists' Club
Publications Committee
takes great pleasure in presenting the

James Fletcher Award

to

Diana Bizecki Robson, John H. Wiersema,
C. Barre Hellquist, and Thomas Borsch

for the best paper in *The Canadian Field-Naturalist*
Volume 130, Year 2016:
Distribution and ecology of a new species of water-lily, *Nymphaea loriana* (Nymphaeaceae),
in Western Canada. *The Canadian Field-Naturalist* 130(1): 25-31

James Fletcher
(1852-1908)

Dwayne Lepitzki
Dr. Dwayne Lepitzki
Editor-in-Chief, CFN

Dr. Jeffery Saarela
Chair, OFNC Publications Committee

Date: 13 December 2017

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

Book Reviews

Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well as books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

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

BOTANY

Curieuses histoires de plantes du Canada. Tome 1: 1000-1670, Tome 2: 1670-1760, Tome 3: 1760–1867

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

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.

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 botanical and historical research documents each story and references are provided either at the end of every story or even at the end of each text box. Recent scientific literature references are also used to provide a contrast with the knowledge of our ancestors, or in some cases to confirm their beliefs and findings. Because nomenclature has changed a lot through time, the authors use modern nomenclature to identify the organisms in the books; the plants are referred to with their original names and verified with those now accepted in VASCAN (data.canadensys.net). Looking back in time, some plants were initially thought to be something completely different from what is known today. However, we must also admit that how information on plants is now captured has evolved greatly, though sometimes at the expense of ancestral knowledge about the plants with whom we coexist. The stories narrated in these books help revive countless facts that are generally overlooked in botanical textbooks.

I recommend reading the books if you are interested in plants and you enjoy history. Furthermore, it is an essential read for anyone wishing to learn more about the cultural aspects of Canadian plants. Because all the books contain short stories, it is easy to take breaks between stories and continue later. As well, I think that readers who don't read French books can cope with the challenge of reading these books. The effort of understanding the text is worth it. One can also learn many things just by flipping through the books, reading the titles, and looking at the illustrations. These books have synthesized centuries of historical knowledge relevant to plant sciences from a vast array of sources, and it is ultimately worth reading them in detail. The three currently published volumes constitute a very good reference on early botanical science. The books are easily searchable, whether one is looking for information on a particular plant, on medicinal properties, on a specific locality, or on a botanist, via a very detailed index. For anyone doing research on Canadian plants or wishing to learn more about them, these books provide subtle details that allow one to enrich their existing knowledge of these plants. I am looking forward to the next book(s) in the series to learn how contemporary botanists have contributed to botanical science and what twists the authors will take to make the more recent plant stories interesting to read.

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ENTOMOLOGY

The Secret Life of Flies

By Erica McAlister. 2017. Firefly Books. 248 pages, 29.95 CAD, Cloth.

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 exclamation 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 joyfully 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 mosquitos 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.

Here's something to ponder the next time you're getting chewed on by mosquitos 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
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Insects: Their Natural History and Diversity: With a Photographic Guide to Insects of Eastern North America, Second Edition, Revised and Updated

By Stephen A. Marshall. 2017. Firefly Books. 736 pages and 4000 colour photographs, 95.00 CAD, Cloth.

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—something that is increasing difficult to find, given the decline in the number of courses—without the bother of attending classes, then this is your book. Marshall has been teaching entomology in the University of Guelph's Department of Environmental Biology since 1982 and the two editions of *Insects* are the distillation of that experience. In fact, as he explains in the new preface, their text varies little, with this edition primarily updating the ever-shifting taxonomy of the insect world. Marshall describes the decade following the first edition as "tumultuous" and the taxonomy as "transformed by … application of new molecular tools…" (p. 7). However, his "tree of six-legged life" remains unchanged, for "the main phylogenetic roadmap … has been substantiated, not redrawn" (p. 7). If you already own the first edition, there may not be enough difference here to justify the expense of the second, so long as you don't mind being out of date on the taxonomy and missing out on the new photos. But if you don't own the first, then your entomological library won't be complete without this one.

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 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 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.

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ORNITHOLOGY

Raptors: The Curious Nature of Diurnal Birds of Prey

By Keith Bildstein. 2017. Cornell University Press. 336 pages, 52.50 USD, Cloth.

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 haliaetus*) 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.

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The Australian Bird Guide

By Peter Menkhorst, Danny Rogers, Rohan Clarke, Jeff Davies, Peter Marsack, and Kim Franklin. 2017. CSIRO Publishing. 576 pages, 49.95 AUS, Paper.

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 (*Specotheres vielloti*) has two subspecies (*S. v. vielloti* 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 and weighs a whopping 1458 g. It is not a field guide. My copy of the 2004 *Field Guide to the Birds of Australia* by Simpson and Day is 80% lighter and fits my coat pocket. With the text are clear, readable range maps. These combine to provide better insight into the identification choices you can make.

I was with a non-birder companion when she said the call we had just heard was a wattlebird. I searched and had a very good look at a mid-size, streaky bird. I looked in the new guide for "wattlebird" and could not find an entry. I vaguely remembered that wattlebirds were close to miners, but there was no entry for miners either. By page flicking I found my bird: a Little Wattlebird (*Anthochaera chrysoptera*). I then realised the index does not group birds in the classical fashion (Wattlebirds —, Western Little, Red and Yellow). You need to know the full name—Little Wattlebird—before you can use the index. I found this both confusing and strange.

We continued our walk and saw a large flock of black-coloured cormorants with a single black and white bird in the group. This time, knowing there was a species called "Pied Cormorant", I easily found the cormorant page. I had four choices. I eliminated one by range. Neighbouring birds gave me a good idea of length. Yet the authors do not include length, only weight. I cannot estimate weights in the field. (Remember a Great Horned Owl [*Bubo virginianus*] is 30% shorter than a Great Grey Owl [*Strix nebulosa*], but 30% heavier). In frustration I returned to my old copy of Simpson and Day. I identified my bird as a Little Pied Cormorant (*Microcarbo melanoleucos*).

I continued to use Simpson and Day out in the field. Each evening I would read up in Menkhorst *et al.*, as it provided more information. Sometimes, however, I wondered about the text. I spent a glorious day with a woman who was working hard on her Australia list. She had been to out-of-the-way (expensive) places like Macquarie and Heard Islands. Heard is the best place to find the resident Black-faced Sheathbill (*Chionis minor*), an endemic species. Yet Menkhorst *et al.* list it as a very rare vagrant with only one record. In contrast, they accept the tiny breeding colony of Common Redpoll (*Acanthis flammea*) on Macquarie as a resident species.

After I reached home I discovered there was a quick reference to bird families on page vi. This was very useful as I identified my photographs. I wish I had noticed it in the field. There was a visual quick reference on the inside cover. I could not use this effectively as I did know many of the bird shapes.

Overall, this is a wonderful book. The information and superb illustrations make it a tremendous contribution to the world's bird books. Adding an index that would work well, editing some of the odd text, and relabelling it a "handbook" would turn it into the true triumph it ought to be.

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Literature Cited

Simpson, K., and **N. Day**. 2004. Field Guide to the Birds of Australia, 7th Edition. Princeton University Press, Princeton, New Jersey, USA.

ZOOLOGY

Wolves of the Yukon

By Bob Hayes. 2010. Wolves of the Yukon Publishing. Druckerei Fritz Kriechbaumer. 278 pages, 27.99 CAD, Paper.

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 plateaus of Mongolia today (p. 21). The beginning of 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 admiral 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!

JONATHAN (JON) WAY
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OTHER

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

By Britt Wray. 2017. Greystone Books/David Suzuki Foundation. 288 pages, 26.95 CAD, Cloth.

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
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The Magnificent Nahanni: The Struggle to Protect a Wild Place

By Gordon Nelson. 2017. University of Regina Press. 304 pages, 34.95 CAD, Paper.

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 (*Ursos 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 americanus*]) 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 co-operation 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
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Coexistence: The Ecology and Evolution of Tropical Biodiversity

By Jan Sapp. 2016. Oxford University Press. 275 pages, 49.95 USD, Cloth.

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 skillfully 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 development 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 portending 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

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The Eye of the Sandpiper: Stories from the Living World

By Brandon Keim. 2017. Cornell University Press. 266 pages, 23.98 CAD, Paper.

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 wildness 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 instils a sense of hope. I appreciated 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.

TIANNA BURKE
Parry Sound, ON, Canada

NEW TITLES

Prepared by Barry Cottam

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BOTANY

Diversity and Phylogeny of the Monocotyledons: Contributions from Monocots V. Memoirs of The New York Botanical Garden Volume 118. Edited by Lisa Campbell, Jerrold I. Davis, Alan W. Meerow, Robert F. C. Naczi, Dennis W. Stevenson, and W. Wayt Thomas. 2017. New York Botanical Garden Press. 172 pages, 89.99 USD, Cloth.

Plant Life: A Brief History. By Frederick B. Essig. 2015. Oxford University Press. 280 pages, 74.00 CAD, Cloth. Also available as an E-book.

Grasses of the Great Plains. By James Stubbendieck, Stephan L. Hatch, and Cheryl D. Dunn. 2017. Texas A&M University Press. 736 pages, 50.00 USD, Cloth.

Plants of the World: An Illustrated Encyclopedia of Vascular Plant Families. By Maarten J. M. Christenhusz, Michael F. Fay, and Mark W. Chase. 2017. Royal Botanic Gardens, Kew/University of Chicago Press. 816 pages and 3000 colour plates, 95.00 USD, Cloth or E-book.

***Catalogue of the Vascular Plants of New York State. Memoirs of the Torrey Botanical Society Volume 27.** By David Werier. 2017. Torrey Botanical Society. 543 pages, 35.00 CAD, Cloth. Also available as an E-book.

Fortress Plant: How to Survive When Everything Wants to Eat You. By Dale Walters. 2017. Oxford University Press. 320 pages, 29.95 CAD, Cloth. Also available as an E-book.

The Cabaret of Plants: Forty Thousand Years of Plant Life and the Human Imagination. By Richard Mabey. 2017. W.W. Norton. 384 pages, 17.95 USD, Paper.

†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.

Plants That Kill: A Natural History of the World's Most Poisonous Plants. By Elizabeth A. Dauncey and Sonny Larsson. 2018. Princeton University Press. 224 pages, 29.95 USD, Cloth.

The Long, Long Life of Trees. By Fiona Stafford. 2017. Yale University Press. 296 pages, 18.00 USD, Paper.

***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.

***Flora of Florida, Volume IV: Dicotyledons, Combretaceae through Amaranthaceae**. By Richard P. Wunderlin, Bruce F. Hansen, and Alan R. Franck. 2017. University Press of Florida. 400 pages, 69.95 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.

***The Green Menace: Emerald Ash Borer and the Invasive Species Problem.** By Jordan D. Marché II. 2017. Oxford University Press. 320 pages, 69.95 USD, Cloth.

Bees: An Identification and Native Plant Forage Guide. By Heather Holm. 2017. Pollination Press LLC. 224 pages, 29.95 CAD/USD, Paper.

Listening to the Bees. By Mark Winston and Renée Sarojini Saklikar. 2018. Harbour Publishing. 192 pages, 24.95 CAD/USD, Cloth.

Ant-Plant Interactions: Impacts of Humans on Terrestrial Ecosystems. Edited by Paulo S. Oliveira and Suzanne Koptur. 2017. Cambridge University Press. 452 pages, 84.99 USD, Cloth, 68.00 USD, E-book.

Garden Insects of North America: The Ultimate Guide to Backyard Bugs, Second Edition. By Whitney Cranshaw and David Shetlar. 2017. Princeton University Press. 704 pages and 3300 colour photos, 35.00 USD, 27.95 GBP, Paper.

A Swift Guide to Butterflies of Mexico and Central America, Second Edition. By Jeffrey Glassberg. 2018. Princeton University Press. 304 pages and 3250 colour photos and maps, 39.95 CAD, Paper. Also available as an E-book.

Hidden Kingdom: The Insect Life of Costa Rica. By Piotr Naskrecki. 2017. Comstock Publishing Associates/Zona Tropical Publications. 216 pages and 900 photos and illustrations, 34.95 USD, Paper.

ORNITHOLOGY

Bird Migration Across the Himalayas: Wetland Functioning Amidst Mountains and Glaciers. Edited by Herbert H. T. Prins and Tsewang Namgail. Foreword by The Dalai Lama. 2017. Cambridge Oxford University Press. 458 pages, 75.00 GBP, Cloth.

The Sensory Ecology of Birds. By Graham R. Martin. 2017. Oxford University Press. 320 pages, 95.00 CAD, Cloth. Also available through Oxford Scholarship Online.

Gulls of the World: A Photographic Guide. By Klaus Malling Olsen. 2018. Princeton University Press. 488 pages and 600 photos, 45.00 USD, Cloth.

At Sea with the Marine Birds of the Raincoast. By Caroline Fox. 2016. Rocky Mountain Books. 224 pages, 40.00 CAD, Cloth, 12.99 CAD, E-book.

Far from Land: The Mysterious Lives of Seabirds. By Michael Brooke. Illustrations by Bruce Pearson. 2018. Princeton University Press. 272 pages, 29.95 USD, Cloth.

The Seabird's Cry: The Lives and Loves of Puffins, Gannets and Other Ocean Voyagers. By Adam Nicolson. Illustrations by Kate Boxer. 2017. William Collins (Harper Collins imprint). 228 pages, 16.99 GBP, Cloth, 9.99 GBP, Paper or E-book.

Project Puffin: The Improbable Quest to Bring a Beloved Seabird Back to Egg Rock. By Stephen W. Kress and Derrick Z. Jackson. 2015 (Cloth), 2017 (Paper). Yale University Press. 365 pages, 30.00 USD, Cloth, 20.00 USD, Paper.

Seabirds Beyond the Mountain Crest: The History, Natural History and Conservation of Hutton's Shearwater. By Richard Cuthbert. 2017. Otago University Press. 220 pages, 45.00 NZD, Paper.

†The Birds at My Table: Why We Feed Wild Birds and Why It Matters. By Darryl Jones. 2018. Comstock Publishing Associates/Cornell University Press. 352 pages, 19.95 USD, Paper.

National Geographic Field Guide to the Birds of North America, Seventh Edition. By Jon L. Dunn and Jonathan Alderfer. Illustrations by Paul Lehman. 2017. National Geographic Society. 592 pages, 29.99 USD, Paper.

Birds of Nicaragua: A Field Guide. By Liliana Chavarria-Duriaux. 2018. Cornell University Press. 346 pages, 29.95 USD, Paper.

Woodpecker. By Gerard Gorman. 2017. Reaktion Books. 224 pages, 19.95 USD, Paper.

The Enigma of the Owl: An Illustrated Natural History. By Mike Unwin and David Tipling. Foreword by Tony Angell. 2017. Yale University Press. 288 pages and 200 colour illustrations, 40.00 USD, Cloth.

One More Warbler: A Life with Birds. By Victor Emanuel with S. Kirk Walsh. 2017. University of Texas Press. 295 pages, 29.95 USD, Cloth.

The Meaning of Birds. By Simon Barnes. 2018. Pegasus Books. 208 pages, 26.95 USD, Cloth. Also available as an E-book.

Those of the Gray Wind. *The Sand Hill Cranes*, New Edition. By Paul A. Johnsgard. With a new preface and afterword by the author. 2017. University of Nebraska Press. 174 pages, 14.95 USD, Paper.

Vanished and Vanishing Parrots: Profiling Extinct and Endangered Species. By Joseph Forshaw. Illustrations by Frank Knight. 2017. Comstock Publishing Associates. 344 pages, 95.00 USD, Cloth. Also available as an E-book.

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.

Carnivore Minds: Who These Fearsome Animals Really Are. By G. A. Bradshaw. 2017. Yale University Press. 360 pages, 35.00 USD, Cloth.

Following Fifi: My Adventures Among Wild Chimpanzees: Lessons from our Closest Relatives. By John Crocker. Foreword by Jane Goodall. 2017. Pegasus Books. 272 pages, 27.95 USD, Cloth. Also available as an E-book.

†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 Universitysity Press. 416 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

Immersion: The Science and Mystery of Freshwater Mussels. By Abbie Gascho Landis. 2017. Island Press. 256 pages, 30.00 USD, Cloth or E-book.

Marine Ecosystem-Based Management in Practice: Different Pathways, Common Lessons. By Julia Wondolleck 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.

The Marine World: A Natural History of Ocean Life. By Frances Dipper. Foreword by Mark Carwardine. 2017. Comstock Publishing Associates. 544 pages, 59.95 USD, Cloth.

Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts. Edited by Daniel Pauly and Dirk Zeller. 2016. Island Press. 520 pages and 612 illustrations, 160.00 USD, Cloth, 80.00 USD, Paper, 59.99 USD, E-book.

Whales: Their Biology and Behavior. By Phillip Hammond, Sonja Heinrich, Sascha Hooker, and Peter Tyack. 2017. Cornell University Press. Comstock Publishing Associates. 144 pages, 19.95 USD, Paper.

Wildlife of the Arctic. By Richard Sale and Per Michelsen. 2018. Princeton University Press. 304 pages and 800 photos, 19.95 USD, Paper.

On the Wing: Insects, Pterosaurs, Birds, Bats and the Evolution of Animal Flight. By David E. Alexander. 2015. Oxford University Press. 224 pages, 31.95 CAD, Cloth.

†**Great Plains Bison.** Discover the Great Plains Series. By Dan O'Brien. 2017. University of Nebraska Press, Bison Books. 144 pages, 14.95 USD, Paper.

Handbook of the Mammals of the World, Volume 7. Rodents II. By Don E. Wilson, Thomas E. Lacher, Jr., and Russell A. Mittermeier. Illustrations by Toni Llobet. 2017. Lynx Edicions in association with Conservation International and IUCN. 1008 pages, 160.00 EUR, Cloth.

Biology 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.

Chimpanzees and Human Evolution. Edited by Martin N. Muller, Richard W. Wrangham, and David R. Pilbeam. 2017. Belknap Press/Harvard University Press. 794 pages, 55.00 USD, Cloth.

Mimicry, Crypsis, Masquerade and other Adaptive Resemblances. By Donald L. J. Quicke. 2017. Wiley-Blackwell. 576 pages, 114.00 CAD, Cloth, 91.99 CAD, E-book.

Biochemical Adaptation: Response to Environmental Challenges from Life's Origins to the Anthropocene. By George N. Somero, Brent L. Lockwood, and Lars Tomanek. 2017. Sinauer Associates, an imprint of Oxford University Press. 572 pages, 112.95 CAD, Cloth. Also available as an E-book.

Venom: The Secrets of Nature's Deadliest Weapon. By Ronald Jenner and Eivind Undheim. 2017. CSIRO Publishing. 208 pages, 29.95 AUD, Paper.

Where the Animals Go: Tracking Wildlife with Technology in 50 Maps and Graphics. By James Cheshire and Oliver Uberti. 2017. W. W. Norton. 192 pages, 39.95 USD, Cloth.

The Pipestone Wolves: The Rise and Fall of a Wolf Family. By Günther Bloch. Photography by John E. Marriott. Foreword by Mike Gibeau. 2016. Rocky Mountain Books. 224 pages, 40.00 CAD, Cloth.

Leaving the Wild: The Unnatural History of Dogs, Cats, Cows, and Horses. By Gavin Ehringer. 2017. Pegasus Books. 336 pages, 27.95 USD, Cloth. Also available as an E-book.

OTHER

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

Journeys Through Paradise: Pioneering Naturalists in the Southeast. By Gail Fishman. 2017. University Press of Florida. 328 pages, 24.95 USD, Paper.

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.

***Searching for Mary Schäffer.** Mountain Cairns: A Series on the History and Culture of the Canadian Rocky Mountains. By Colleen Skidmore. 2017. University of Alberta Press. 376 pages, 34.95 CAD, Paper, 27.99 CAD, E-book.

Orange Omelettes & Dusky Wanderers: Studies and Travels in Seychelles Over Four Decades. By Chris J. Feare. 2017. Calusa Bay Publications. 342 pages, 13.99 GBP, Paper.

***Islands of Grass.** By Trevor Herriot. Photography by Branimir Gjetvaj. 2017. Coteau Books. 224 pages, 39.95 CAD/USD, Cloth.

Invasion Dynamics. By Cang Hui and David M. Richardson. 2017. Oxford University Press. 336 pages, 115.00 CAD, Cloth, 59.95 CAD, Paper. Also available as an E-book and through Oxford Scholarship Online.

Firestorm: How Wildfire Will Shape Our Future. By Edward Struzik. 2017. Island Press. 272 pages, 30.00 USD, Cloth or E-book.

Costly Fix: Power, Politics, and Nature in the Tar Sands. By Ian Urquhart. 2018. University of Toronto Press. 384 pages, 95.00 CAD, Cloth, 39.95 CAD, Paper, 31.95 CAD, E-book.

Half-Earth: Our Planet's Fight for Life. By Edward O. Wilson. 2017. Liveright Publishing Corporation. 272 pages, 25.95 USD, Cloth, 16.95 USD, Paper.

The Archipelago of Hope: Wisdom and Resilience from the Edge of Climate Change. By Gleb Raygorodetsky. 2017. Pegasus Books. 336 pages, 28.95 USD, Cloth. Also available as an E-book.

Nature's Allies: Eight Conservationists Who Changed Our World. By Larry Neilsen. 2017. Island Press. 272 pages, 21.00 USD, Paper.

What Should a Clever Moose Eat? Natural History, Ecology, and the North Woods. By John Pastor. Foreword by Bernd Heinrich. 2016. Island Press. 336 pages, 30.00 USD, Cloth or E-book.

Essentials of Soil Science: Soil Formation, Functions, Use and Classification (World Reference Base, WRB). By Winfried Blum, Peter Schad, and Stephen Nortcliff. 2017. CSIRO Publishing. 176 pages, 59.95 AUD, Paper.

Big Pacific: An Incredible Journey of Exploration and Revelation. Edited by Rebecca Tansley. 2017. CSIRO Publishing. 240 pages, 49.95 AUD, Cloth.

Enhancing Science Impact: Bridging Research, Policy and Practice for Sustainability. By Peat Leith, Kevin O'Toole, Marcus Haward, and Brian Coffey. 2017. CSIRO Publishing. 216 pages, 59.95 AUD, Paper. Also available as an E-book.

Inheritors of the Earth: How Nature is Thriving in an Age of Extinction. By Chris D. Thomas. 2017. Allen Lane. 320 pages, 20.00 GBP, Cloth.

Wildlife, Land, and People: A Century of Change in Prairie Canada. By Donald G. Wetherell. 2016. McGill-Queen's University Press. 640 pages, 49.95 CAD, Cloth. Also available as an E-book.

The Biology of Ponds and Lakes, Third Edition. By Christer Brönmark and Lars-Anders Hansson. 2017. Oxford University Press, Biology of Habitats Series. 368 pages, 95.00 CAD, Cloth, 45.95 CAD, Paper. Also available as an E-book.

***Exploring the Limestone Barrens of Newfoundland and Labrador.** By Burzynski, M. H. Mann, and A. Marceau. 2016. Gros Morne Co-operating Association. 364 pages, 26.95 CAD, Paper.

†The Inner Life of Animals: Love, Grief, and Compassion — Surprising Observations of a Hidden World. By Peter Wohlleben. Translated by Jane Billinghurst. 2017. Greystone Books. 272 pages, 29.95 CAD, Cloth.

Wild Sex: The Science Behind Mating in the Animal Kingdom. By Carin Bondar. 2016. Pegasus Books. 400 pages, 27.95 USD, Cloth. Also available as an E-book.

Swamp: Nature and Culture. By Anthony Wilson. 2017. Reaktion Books. 248 pages, 24.95 USD, Paper.

Not So Different: Finding Human Nature in Animals. By Nathan H. Lents. 2017. Columbia University Press. 368 pages, 26.00 USD, Paper. Cloth and E-book published in 2016.

The Nature Fix: Why Nature Makes Us Happier, Healthier, and More Creative. By Florence Williams. 2017. W. W. Norton. 272 pages, 26.95 USD, Cloth, 15.95 USD, Paper.

Our Vanishing Glaciers: The Snows of Yesteryear and the Future Climate of the Mountain West. By Robert William Sandford. 2017. Rocky Mountain Books. 224 pages, 40.00 CAD, Cloth.

Our Place: Changing the Nature of Alberta. By Kevin Van Tighem. 2017. Rocky Mountain Books. 376 pages, 25.00 CAD, Paper, 9.99 CAD, E-book.

The Evolution Underground: Burrows, Bunkers, and the Marvelous Subterranean World Beneath our Feet. By Anthony J. Martin. 2017. Pegasus Books. 400 pages, 28.95 USD, Cloth. Also available as an E-book.

The Face of Nature: An Environmental History of the Otago Peninsula. By Jonathan West. 2017. Otago University Press. 388 pages, 49.95 NZD, Paper.

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 Wilmshurst 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 Bélair, 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 2. Number of research articles and notes published in *The Canadian Field-Naturalist*, Volume 130 (Volume 129), by major field of study.

Subject	Articles	Notes	Total
Mammals	9 (7)	10 (6)	19 (13)
Birds	4 (7)	5 (5)	9 (12)
Amphibians and Reptiles	4 (2)	0 (3)	4 (5)
Fishes	4 (4)	2 (2)	6 (6)
Plants	4 (5)	1 (2)	5 (7)
Insects	2 (1)	0 (0)	2 (1)
Non-insect Invertebrates	3 (2)	2 (1)	5 (3)
Total	30 (28)	20 (19)	50 (47)

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.

	Reviews	New Titles
Zoology	10 (18)	45 (26)
Botany	3 (3)	16 (2)
Miscellaneous	9 (14)	32 (19)
Total	22 (35)	93 (47)

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

Subscriber Type	Canada	USA	Other	Total
OFNC Members	58 (61)	3 (3)	1 (1)	62 (65)
Subscriptions:				
Individual	21 (12)	6 (6)	1 (0)	28 (18)
Institutional	84 (107)	116 (158)	13 (19)	213 (284)
Total	163 (180)	125 (167)	15 (20)	303 (367)

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, Volume 130 (Volume 129), by issue.

	Issue				
	1	2	3	4	Total
Editorials/Editor's Report	0 (0)	3 (3)	0 (0)	0 (0)	3 (3)
Articles	63 (59)	73 (66)	43 (44)	59 (72)	238 (241)
Notes	18 (30)	14 (16)	14 (30)	21 (14)	67 (90)
Tributes	0 (7)	0 (0)	0 (0)	18 (0)	18 (7)
Book Reviews*	8 (15)	4 (10)	9 (14)	11 (4)	32 (43)
News and Comment	1 (3)	2 (9)	3 (2)	4(2)	10 (16)
Reports†	0 (0)	4 (0)	15 (13)	0 (5)	19 (18)
Erratum	0 (0)	0 (0)	0 (1)	0 (0)	0 (1)
Index	– (–)	– (–)	– (–)	7 (7)	7 (7)
Total	90 (114)	100 (104)	84 (104)	120 (104)	394 (426)

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

ses): Ray Alisauskas, Environment and Climate Change Canada; Mike Anderson, Ducks Unlimited Canada (emeritus); Carl D. Anthony, John Carroll University; Robin Baird, Olympia WA; Peter Ball, University of Toronto; Shannon Barber-Meyer, US Geological Survey; Erin Bayne, University of Alberta; John Benson, University of Nebraska—Lincoln; Jennifer Bigman, Simon Fraser University; Anne Bjorkman, German Centre for Integrative Biodiversity Research, Leipzi; Gabriel Blouin-Demers, University of Ottawa; Jeff Bowman, Ontario Ministry of Natural Resources and Forestry; Dan Brunton, Ottawa ON (2); Joseph Bump, Michigan Technological University; Jonathan Choquette, Guelph ON; Jonathan Cormier, New Brunswick Department of Natural Resources; Aurélie Cosandey Godin, Dalhousie University; Hugo Cota, University of Saskatchewan; Brenda Dale, Environment and Climate Change Canada; Christina Davey, Trent University; Dick Dekker, Edmonton AB; A. W. Diamond, University of New Brunswick; Mark Edwards, Royal Alberta Museum; Mark Elbroch, Panthera NY; Marco Festa-Bianchet, Université de Sherbrooke; Graham Forbes, University of New Brunswick; Bruce Ford, University of Manitoba; Robert Forsyth, Kamloops BC; Jochen Gerber, The Field Museum; John Gilhen, Nova Scotia Museum of Natural History (2); Scott Gillingwater, Upper Thames River Conservation Authority; Emily Gonzales, Parks Canada; Karen Graham, Foothills Research Institute; Patrick Gregory, University of Victoria; Samuel Haché, Canadian Wildlife Service; Gavin Hawke, Royal British Columbia Museum; Douglas Heard, University of Northern British Columbia; Raymond Hutchinson, Ottawa ON; Louis Imbeau, Université du Québec en Abitibi-Témiscamingue; James Irvine, Fisheries and Oceans Canada; S. J. Iverson, Canadian Wildlife Service; Chris Johnson, University of Northern British Columbia; Tom Johnston, Ontario Ministry of Natural Resources and Forestry/Laurentian University; Tom Jung, Government of Yukon; Ernest Keeley, Idaho State University; Nicola Koper, University of Manitoba; Piia Kukka, University of Alberta; Christopher Kyle, Trent University; Jeffery Larkin, Indiana University of Pennsylvania; Shawn Larson, Seattle Aquarium; Jim Leafloor, Canadian Wildlife Service; Lisa-Marie Leclerc, Government of Nunavut; Weiming Li, Michigan State University; Staffan Lindgren, University of Northern British Columbia; Todd Mahon, Edmonton AB; David Nagorsen, Victoria BC; Nicholas Mandrak, University of Toronto; Nigel Marley, United Kingdom; Catherine Meckleburg, Auke Bay AK; Randall F. Miller, New Brunswick Museum; W. A. Montevecchi, Memorial University of Newfoundland and Labrador; David Murray, University of Alaska; Fraser Neave, 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 Olfenbuttel, 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 Reznicek, University of Michigan; Jim Richards, Nunavut Bird Checklist; Mark Ridgway, Ontario Ministry of Natural Resources and 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 Szkorupa, British Columbia Ministry of Forests, Lands and Natural Resource Operations; Ken Tape, University of Alaska – Fairbanks; Phil Ward, University of California Davis; Doug Watkinson, Fisheries and Oceans Canada; Dave Zanatta, Central Michigan University.

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DWAYNE LEPITZKI and
CAROLYN CALLAGHAN,
Editors-in-Chief;

AMANDA MARTIN, A*ssistant Editor*

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