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The Canadian Field-Naturalist

Diet of cisco (*Coregonus* spp.) in Algonquin Park region lakes: variation among forms

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Abstract

Efforts to conserve cisco (*Coregonus* spp.) diversity in Canadian lakes have been impeded by the unresolved taxonomy of North American ciscoes. When a strictly taxonomic-based approach is not possible, conservation units of infraspecific diversity can be identified using biological, morphological, ecological, and genetic evidence. Distinct cisco forms have been reported from deep oligotrophic lakes within boundaries of the historical outflow of glacial Lake Algonquin. In this study, we described the diet of three cisco forms netted from eight lakes located in or adjacent to Algonquin Provincial Park, Ontario. Opossum Shrimp (*Mysis diluviana*) was the dominant prey of benthic, low gill raker count forms in Trout and White Partridge Lakes, and of a large-bodied, high gill raker count form in Hogan Lake. Zooplankton was the most important prey item of small-bodied, pelagic forms in White Partridge Lake, and Cisco (*Coregonus artedi*) collected from five other Algonquin Park lakes. The diet of Trout Lake Cisco was a broader mix of prey items, including chironomid pupae, Opossum Shrimp, phantom midges (Chaboridae spp.), and zooplankton. Our study provides strong dietary evidence of the special ecological context occupied by cisco forms in White Partridge Lake, and moderate evidence for Trout Lake. Past reports of Shortjaw Cisco (*Coregonus zenithicus*) in six of the study lakes were not supported by our sampling, because low gill raker count forms were not captured.

Key words: Cisco; diet; Opossum Shrimp; zooplankton; shortjaw; blackfin

Introduction

Ciscoes (*Coregonus* spp.) are among the most phenotypically variable group of fishes in North America and sympatric forms have been described over their entire range (Clarke 1973; Scott and Crossman 1998). Ecological and morphological diversity were historically well developed in the Laurentian Great Lakes (Koelz 1929; Smith and Todd 1984) and have also been described in deep, oligotrophic inland lakes located within the extent of former proglacial lakes (Clarke 1973). Across these habitats, cisco diversity has been in decline attributable to over-harvesting, invasive species (e.g., Rainbow Smelt [*Osmerus mordax*]), hybridization among closely related species, and changes to competitive and predation interactions among ciscoes after declines in Lake Trout (*Salvelinus namaycush*; Bronte *et al.* 2010). Efforts to conserve and restore remnant diversity have been impeded by uncertainty surrounding the taxonomy of North American ciscoes (DFO 2013). For inland Canadian lakes, this uncertainty is largely whether potential Shortjaw Cisco (*Coregonus zenithicus*) and Blackfin Cisco (*Coregonus nigripinnis*) populations have a shared phylogenetic history with Laurentian Great Lakes species, or individually represent examples of ecological speciation derived from ancestral Cisco (*Coregonus artedi*).

As shown for the Lake Whitefish (*Coregonus* spp.) species complex, a flexible, evidence-based approach can be used to identify cisco populations that are important representations of Canadian biodiversity when a strictly taxonomic based approach is not possible (Mee *et al.* 2015). In Canada, the designatable unit (DU) approach is used to identify conservation units of infraspecific diversity based on evidence of discreteness and evolutionary significance (COSEWIC 2020). For ciscoes of conservation concern, a DU identification approach focussed on individual lakes and informed by biological, morphological, ecological, habitat, and genetic evidence has been recommended (DFO 2013). In Ontario, inland lakes with multiple cisco forms have been reported from the south-central and northwestern parts of the province (Mandrak and Crossman 1992). Recent genetic and morphology-based research has confirmed the presence of pairs of distinct cisco forms co-existing in four south-central Ontario lakes: Cedar Lake, Hogan Lake, Trout Lake, and White Partridge Lake (Turgeon *et al.* 2016; Piette-Lauzière *et al.* 2019). These deep oligotrophic lakes are found within boundaries of the historical outflow of glacial Lake Algonquin and support several glacial relict species (Dadswell 1974). In Cedar and Hogan Lakes, the two cisco forms (referred to as Cisco and Blackfin Cisco) occupy different trophic positions reflective of diet and habitat use (Ridgway *et al.* 2020).

Past examinations of stomach contents (Anderson and Smith 1971) and recent stable isotope studies (Schmidt *et al.* 2009; Ridgway *et al.* 2020) have illustrated that phenotypic differences among cisco forms in the Laurentian Great Lakes and some inland lakes reflect diet. Specifically, variation in jaw morphology and the number (spacing) and length of gill rakers among ciscoes have been attributed to partitioning of food resources (Smith and Todd 1984). To satisfy the criteria of evolutionary significance, ecological evidence supporting such a linkage between form and function is needed to substantiate proposed cisco DUs (DFO 2013). In this study, we describe and compare the diet of three cisco forms netted from eight lakes located within or adjacent to Algonquin Provincial Park. Based on morphological characteristics, we refer to these forms as blackfin, cisco, and shortjaw (as per Turgeon *et al.* 2016; Ridgway *et al.* 2020). Cisco diet information from these lakes provides important ecological information needed for the identification of conservation units in Ontario lakes.

Study Area

Our research was conducted in eight lakes in the Nipissing District of south-central Ontario. Seven of the lakes are located in Algonquin Provincial Park (Biggar Lake, Grand Lake, Hogan Lake, Kioshkokwi Lake, Manitou Lake, Three Mile Lake, and White Partridge Lake), and the other lake (Trout Lake) is located slightly north, adjoining the city of North Bay (Figure 1). All lakes are inside the boundary of one of the outlets of glacial Lake Algonquin (Dadswell 1974). Study lakes range from 373.3 to 1673 ha in size, with maximum water depths between 32.9 and 69 m (Table 1). In 2009, we attempted to collect ciscoes from North Tea Lake in Algonquin Park (45.9421°N, 79.0376°W). As only two individuals were netted, the lake was not included in the diet study.

Historically, Shortjaw Cisco was reported from these seven Algonquin Provincial Park lakes (Martin and Chapman 1965) and Trout Lake (Clarke 1973). Multiple cisco forms, differing in gill raker counts and jaw morphology, have been described from three of these lakes: Hogan, Trout, and White Partridge (DFO 2013; Turgeon *et al.* 2016; Bell *et al.* 2019; Piette-Lauzière *et al.* 2019; Table 2). The availability of deepwater crustaceans as prey has been hypothesized to have a role in the diversification of cisco forms in deep, oligotrophic, inland lakes (Bell *et al.* 2019). Opossum Shrimp (*Mysis diluviana*, formerly *Mysis relicta*) has been recorded in all eight study lakes and the freshwater amphipod (*Diporeia* spp.) has been recorded in all the lakes except Hogan and Grand (Dadswell 1974; Bell *et al.* 2019).

Methods

Cisco sampling and processing

We collected ciscoes from late spring to early fall in 2007, 2008, 2009, and 2010. Lakes were sampled using multi-mesh, monofilament experimental gill nets (Sandstrom *et al.* 2013) set over a range of water depths (Table 1) below the thermocline. Nets were either suspended in the water column (pelagic) or on the lakebed (benthic). Pelagic nets were 6 m deep and 27.5 m long, with panels of mesh sizes between 6.25 and 55 mm. Benthic nets were 2.4 m deep and 45.6 m long, with panels of mesh sizes between 13 and 64 mm. Nets were set for either two to three hours during the day or left overnight to sample.

We froze ciscoes until processing in the laboratory. Stomach contents were removed from thawed specimens and preserved in 70% ethanol. Under magnification, we identified prey items to the lowest taxonomic level possible (typically order or family) using Lehmkuhl *et al.* (1979), Merritt and Cummins (1996), and Smith (2001) and estimated the volume of each prey item with a gridded (1 cm × 1 cm) petri dish (Gillespie and Fox 2003).

In the laboratory, we classified ciscoes based on jaw morphology, gill raker characteristics, fin colour, and conformance to Great Lakes taxonomic definitions (Koelz 1929; Hubbs and Lagler 2007). Gill raker number and jaw morphology are primary identification characters, which are interpreted to reflect differences in occupied niches among species (Todd and Smith 1992; Zimmerman and Krueger 2009). For example, Shortjaw Cisco has fewer gill rakers (typically <40) than Cisco, an included lower jaw and angled snout, and is associated with deep, benthic habitats (Scott and Crossman 1998; Murray and Reist 2003). White Partridge Lake ciscoes were also grouped based on body size differences of mature individuals (small or normal; Figure 2) and location of capture (pelagic or deep benthic habitats). Classification of forms is supported by the population genetic structure of ciscoes in Hogan, Trout, and

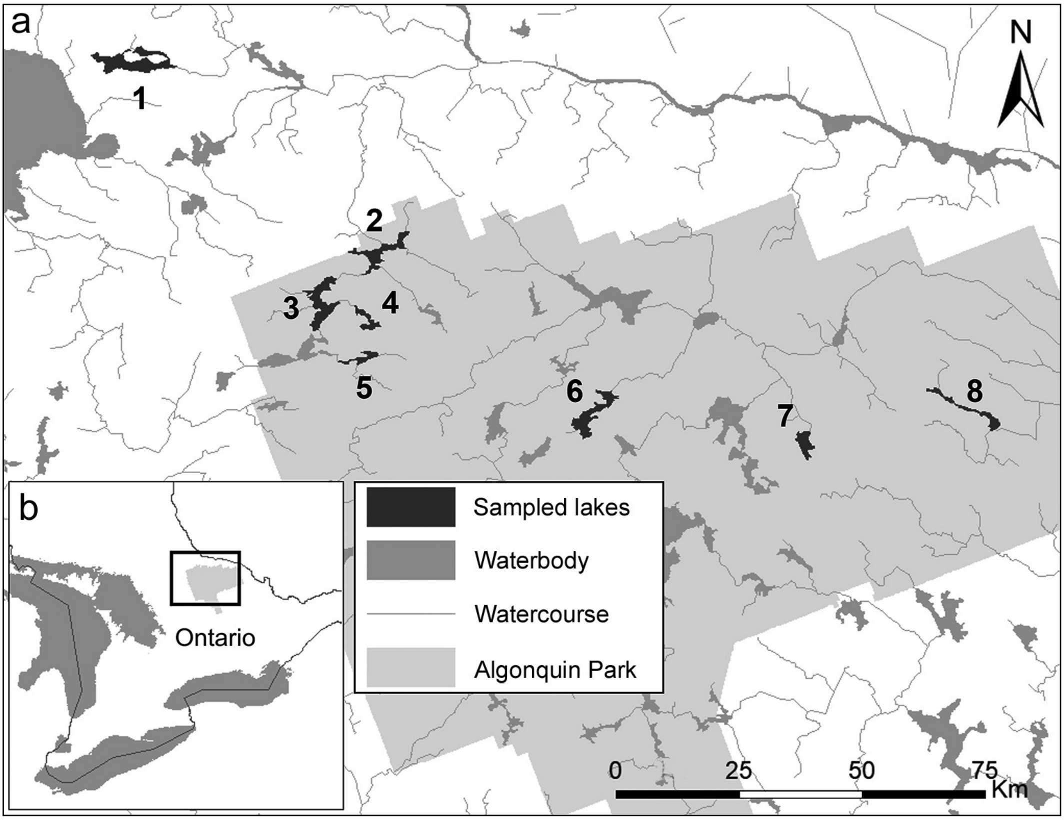

Figure 1. a. Locations of eight study lakes in Algonquin Park region, Nipissing District, Ontario (1 = Trout Lake, 2 = Kioshkiokwi Lake, 3 = Manitou Lake, 4 = Three Mile Lake, 5 = Biggar Lake, 6 = Hogan Lake, 7 = White Partridge Lake, 8 = Grand Lake). Inset map b. provides location of study area within St. Lawrence River–Great Lakes basin.

Table 1. Characteristics of lakes and multi-mesh gill net sampling details for cisco (*Coregonus* spp.) diet study in the Algonquin Park region, 2007–2010.

Lake	Mean lake depth (m)	Maximum lake depth (m)	Area (ha)	Years sampled	Net set depths (m)	Cisco collected (*n*)
Biggar	10.5	32.9	373.6	2008	18–28*	214
Grand	8.6	42.5	752.5	2008	21–35*	79
Hogan	7.4	38.4	1283.5	2009, 2010	13–30*	152
Kioshkokwi	13.8	47.5	1073.7	2008, 2009	14–45*	88
Manitou	13.5	38.6	1381.9	2009	19–37*	100
Three Mile	11.2	41.6	415.0	2008	2–40*	96
Trout	16.8	69.0	1673.0	2010	25–47†	213
White Partridge	16.9	49.3	584.4	2007 to 2009	18–48‡	429

*Pelagic nets were set at depths of 6 to 12 m.
†No pelagic nets were used.
‡Pelagic nets were set at depths of 15 to 35 m.

White Partridge Lakes (Turgeon *et al.* 2016; Piette-Lauzière *et al.* 2019) and growth-trajectory differences between forms in Trout and White Partridge Lakes (DFO 2013).

Data analyses

We described diets using: (i) the frequency of occurrence and volumetric contributions of each prey item, and (ii) the number and diversity of prey items

TABLE 2. Details and summary of stomach content information for ciscoes (*Coregonus* spp.) collected from Algonquin Park region study lakes. Median values and ranges are presented for gill raker counts (LGR = low gill raker; HGR = high gill raker) and length measurements.

Lake	Form	Sample size (*n*)	Gill raker count	Standard length (mm)	Useable stomachs (%)	Prey types (*n*)	Rare diet items (*n*)
Biggar	Cisco	214	44 (39–50)	116.0 (78–143)	61	7	5
Grand	Cisco	79	45 (37–51)	155.5 (123–177)	96	9	4
Hogan	Cisco	53	44 (41–48)	132.5 (114–278)	30	3	0
	HGR*	99	54 (50–61)	253.0 (154–312)	58	7	5
Kioshkokwi	Cisco	88	45 (41–50)	144.0 (86–193)	73	12	12
Manitou	Cisco	100	46 (41–61)	172.0 (150–203)	19	9	0
Three Mile	Cisco	96	45 (41–50)	168.0 (134–195)	59	6	1
Trout	Cisco	142	46 (42–51)	165.0 (85–173)	12	8	0
	LGR†	71	35 (29–39)	180.5 (91–274)	24	7	4
White Partridge	Benthic LGR†	182	31 (26–38)	165.0 (92–234)	68	15	7
	Pelagic LGR	118	35 (28–39)	98.0 (68–147)	43	8	1
	Pelagic HGR	129	41 (40–48)	100.5 (70–121)	40	8	4

Provisional identifications:*blackfin; †shortjaw.

FIGURE 2. a. South end of White Partridge Lake, Algonquin Provincial Park, Ontario. b. Pelagic (upper) and benthic (lower) cisco forms collected with multi-mesh gill nets in 2007. Photo a: Jason Barnucz. Photo b: Scott Reid.

in each stomach. Differences in the prey consumed between cisco forms within and among lakes were tested using an index of niche overlap and multivariate ordination methods.

We calculated prey item diversity for each cisco form using the Shannon-Wiener Diversity Index H′ (Gkenas *et al.* 2019):

$$H' = -\sum_{i}^{s} p_i \ln p_i$$

where p is the proportion of stomach contents of a form made up by prey item type i, and s is the total number prey item types identified in that form.

We calculated the degree of dietary niche overlap between forms in Hogan, Trout, and White Partridge Lakes using Horn's Index of Overlap $\hat{R}o$ (Krebs 1999):

$$\hat{R}o = \frac{\Sigma\,(\hat{p}_{ij} + \hat{p}_{ik})\log(\hat{p}_{ij} + \hat{p}_{ik}) - \Sigma\hat{p}_{ij}\log\hat{p}_{ij} - \Sigma\hat{p}_{ik}\log\hat{p}_{ik}}{2\,log\,2}$$

Where j and k are two distinct forms from the same lake, $\hat{p}_{ij}$ = the proportion of the total stomach contents of form *j* made up by prey type *i*, and $\hat{p}_{ik}$ = the proportion of the total stomach contents of form *k* made up by prey type *i*.

We used ordination methods to visualize diet differences between each form in Hogan, Trout, and White Partridge Lakes, and among ciscoes from all sampled lakes (Gkenas *et al.* 2019). Non-metric dimensional scaling (NMDS) of diet data was done using the Bray-Curtis dissimilarity measure (Oksanen *et al.* 2020). Ordinations used volumetric percent composition data of each prey type. To reduce the influence of both abundant and rare prey items, we square root transformed data and grouped rare prey items (found in <5% of stomachs) with unidentifiable diet items to create an "other" prey item category. Stress values were calculated to evaluate goodness of fit of the NMDS, where values <0.2 indicate a fair fit (Clarke *et al.* 2014).

We used analysis of similarity (ANOSIM) to test if multivariate diet differences between Hogan, Trout, and White Partridge Lake forms were significant (Gandini *et al.* 2014; Gkenas *et al.* 2019). Analysis of similarity results were based on 9999 permutations, and we interpreted *P* values <0.05 to indicate a significant difference between forms. Values of the ANOSIM statistic R close to 1 represent strong dissimilarities between the diets of different cisco morphs, values close to 0 indicate a similar diet, and values below 0 suggest greater dissimilarity among cisco of the same form than between different forms (Buttigieg and Ramette 2014). We used similarity percentages breakdowns (SIMPER) to identify diet items with the greatest contribution to dissimilarity between forms (Gandini *et al.* 2014; Gkenas *et al.* 2019).

All analyses were conducted using R v. 4.0.0 software (R Development Core Team 2020). Bootstrap-based 95% CI were generated using the R "boot" package with 999 permutations (Canty and Ripley 2020). Non-metric dimensional scaling, ANOSIM, and SIMPER were run using the R "vegan" package (Oksanen *et al.* 2020).

Results

A total of 1371 ciscoes were collected from the eight study lakes (Table 1). Multiple forms were identified from samples netted from Hogan, Trout, and White Partridge Lakes; only Cisco was collected from the other lakes (Table 2). Ciscoes from White Partridge Lake were grouped into three forms: a benthic low gill raker count (LGR) form, a small-bodied pelagic LGR form, and a small-bodied pelagic high gill raker count (HGR) form. Trout Lake ciscoes were grouped into a normal form (≥40 gill rakers) and a LGR form. Hogan Lake ciscoes were grouped into a normal form and a HGR form. Gill raker counts across forms/individuals ranged from 26 to 61, with the highest median gill raker count associated with the Hogan Lake HGR form and the lowest with the White Partridge Lake benthic cisco form (Table 2).

Size varied between forms in lakes, and among all lakes, with standard lengths ranging from 68 mm to 312 mm. Small-bodied forms (i.e., dwarf cisco; Shields and Underhill 1993) were netted from both Biggar and White Partridge Lakes. The largest ciscoes were collected from Hogan Lake (Table 2). Low gill raker count forms were provisionally identified as shortjaw and the Hogan Lake HGR form as blackfin. The White Partridge Lake pelagic HGR form and the Hogan and Trout lakes normal forms were provisionally identified as Cisco.

Approximately 54% of ciscoes (n = 746) had useable stomach contents (Table 2). A total of 23 prey item categories were identified from cisco stomachs. Opossum Shrimp and Water Flea (*Daphnia* spp.) were the most frequently occurring prey items, with Opossum Shrimp being the only prey item consumed by all cisco forms across all lakes sampled (Appendix 1).

White Partridge Lake

Approximately 70% of the benthic form and almost half of the two pelagic forms collected had identifiable stomach contents (Table 2). Nearly twice as many prey items were identified from benthic form stomachs than both pelagic forms (Table 2). Despite these differences across White Partridge forms, niche widths were similar: benthic LGR H′ = 1.47 (95% CI 0.39–1.74), pelagic LGR H′ = 1.4 (0.8–2.1), and pelagic HGR H′ = 1.53 (0.88–2.1).

Opossum Shrimp was the dominant prey item of the benthic form but comprised <8% of pelagic cisco stomach contents (Figure 3). Occurring in three-quarters of benthic form stomachs, Opossum Shrimp was also the most frequently identified prey item, over five times more frequently than in pelagic ciscoes (Appendix 1). Bivalves, chironomids (i.e., non-biting midges) larvae, and amphipods were also common benthic form prey items; although each made up <5% of the volume of stomach contents (Figure 3).

Based on frequency of occurrence and volumetric composition, zooplankton (bosminids, *Daphnia* sp., copepods, and unidentified zooplankton taxa) was the dominant pelagic cisco prey item (Figure 3, Appendix 1). Zooplankton represented <1% of benthic LGR form stomach contents. The prevalence and volumetric contribution of different zooplankton taxa were similar between the two pelagic forms. Of identifiable zooplankton taxa, the order of dominance was bosminids, copepods, and *Daphnia* sp. Chironomid pupae were also identified from 10% of pelagic cisco stomachs and comprised 2–6% of stomach content volume (Figure 3, Appendix 1).

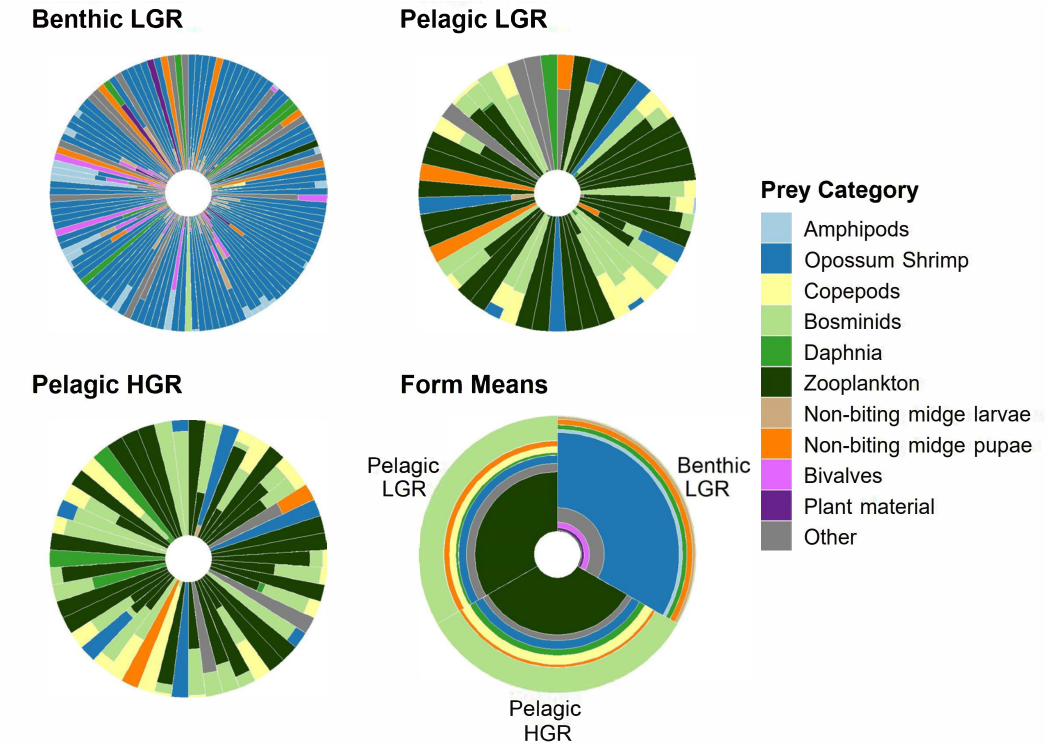

FIGURE 3. Comparison of White Partridge Lake cisco stomach contents based on the relative abundance of prey types for each individual, and on average for each form (LGR = low gill raker; HGR = high gill raker). Cisco forms were identified based on habitat of capture, body size, and gill raker counts.

Ordination of stomach content data clearly illustrated a strong difference between the diets of the benthic and pelagic forms, and substantial overlap between the pelagic forms (Figure 4). Analysis of similarity results indicate that stomach contents for the three morphs were moderately dissimilar (R = 0.43, *P* = 0.001). Subsequent SIMPER analyses identified that prey items with strong contributions to the dissimilarity were Opossum Shrimp and zooplankton (bosminid, copepods, and unidentifiable zooplankton). Similarly, the degree of dietary niche overlap was lowest between the benthic form and either pelagic form ($\hat{Ro} = 0.39$) and greatest between pelagic forms ($\hat{Ro} = 0.97$).

Trout Lake

More than 75% of ciscoes collected had empty stomachs, with only 12% of Cisco and 24% of the LGR form having identifiable stomach contents (Table 2). A similar total number of prey types were identified from stomachs of each form, although rare items were more prevalent in LGR form stomachs (Table 2). Conversely, the niche width of the Trout Lake LGR form (H′ = 0.74, 95% CI 0.00–1.23) was significantly lower than Cisco (H′ = 1.75, 95% CI 1.29–2.49).

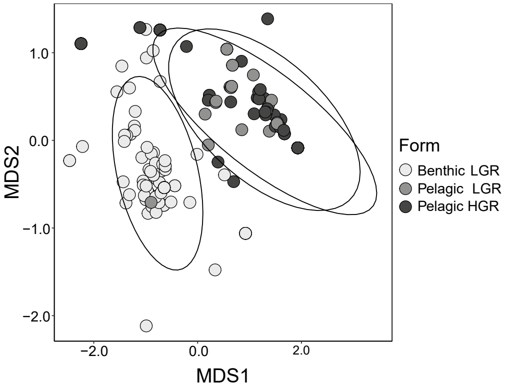

FIGURE 4. Bi-plot of the non-metric multidimensional scaling (NMDS) ordination scores representing the dissimilarity (Bray-Curtis) between stomach contents of White Partridge Lake cisco forms (LGR = low gill raker; HGR = high gill raker). Contour circles outline the spread of the ordination points for each form.

The diet of the LGR form was dominated by Opossum Shrimp (x̄ = 81% of stomach volume). Compared to Cisco stomach contents, Opossum Shrimp was four times more abundant in the LGR form (Figure 5). Opossum Shrimp occurred in almost all LGR form stomachs, but less than a quarter of Cisco stomachs (Appendix 1). Bivalves were consumed by a third of LGR form cisco (Appendix 1), but on average comprised <10% of stomach content volume (Figure 5). Unlike LGR cisco, the volumetric composition of Cisco stomachs was more evenly comprised of pelagic and benthic prey (*Daphnia* sp., chironomid pupae [none-biting midges], and Opossum Shrimp; Figure 5). Other notable, but less abundant prey included bosminids, copepods, and phantom midges (Chaoborid; Appendix I).

Ordination of stomach content data (bi-plot not shown) and subsequent ANOSIM analysis (R = −0.12, *P* = 0.94) indicated a large degree of diet similarity between cisco forms in Trout Lake. Alternatively, dietary niche overlap values indicate moderate dissimilarity between the forms ($\hat{Ro}$ = 0.58).

Hogan Lake

Approximately 30% of Cisco and 60% of HGR form collected had useable stomach contents (Table 2). More than twice as many prey item types were identified in HGR form stomachs than in Cisco stomachs (Table 2). Most prey items in HGR form stomachs were rarely encountered, whereas all Cisco prey items occurred in more than 5% of stomachs (Table 2). Niche widths of the two Hogan Lake forms were similar: Cisco H′ = 1.02 (95% CI 0.27–2.03); HGR H′ = 0.86 (95% CI 0.00–1.34).

For both Hogan Lake forms, Opossum Shrimp was the most frequently occurring prey item and comprised (on average) the majority of stomach content volume. However, Opossum Shrimp was a more important prey item for the HGR form than Cisco. Zooplankton (*Daphnia* sp. and copepods) was present in more than 40% of Cisco stomachs but was rarely found in HGR form stomachs (Appendix 1).

Ordination of Hogan Lake stomach contents (bi-plot not shown), ANOSIM analysis (R = −0.03, *P* = 0.58) and the index of dietary niche overlap ($\hat{Ro}$ = 0.87) all indicated a high degree of diet similarity between the two forms.

Other lakes

Cisco diets in Biggar, Kioshkokwi, Manitou, and Three Mile Lakes were dominated by zooplankton, primarily *Daphnia* sp. and, to a lesser degree, copepods (Appendix 1). Opossum Shrimp was an important prey item of Grand and Three Mile Lake Cisco and was found in two thirds of Grand Lake stomachs and almost 40% of Three Mile Lake stomachs. Other notable prey items were chironomid larvae (Manitou and Kioshkokwi Lakes), amphipods (Manitou and Three Mile Lakes), and phantom midges (Kioshkokwi and Manitou Lakes).

Ordination of stomach content diet from all study

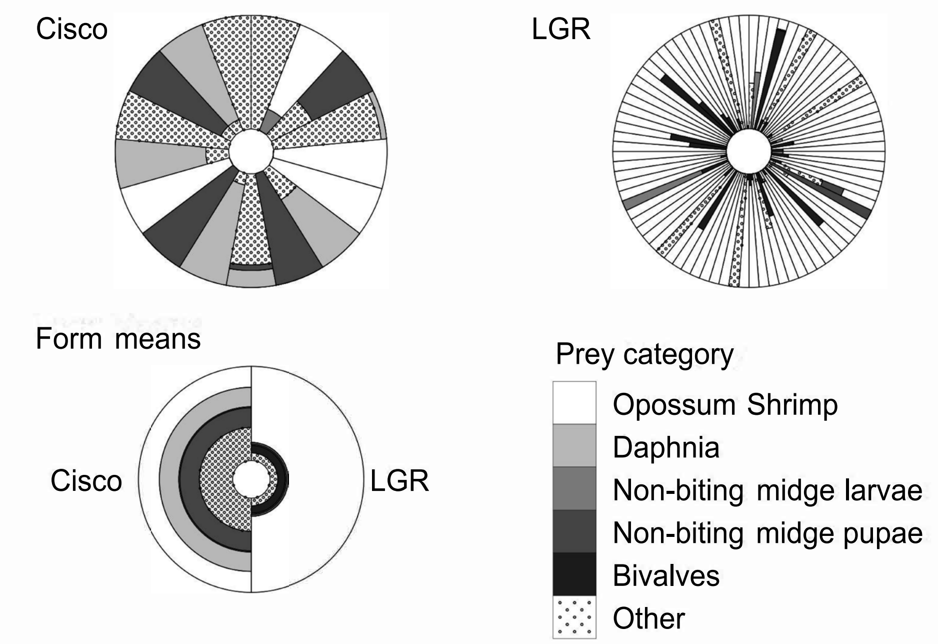

FIGURE 5. Comparison of Trout Lake cisco stomach contents based on the relative abundance of prey types for each individual, and on average for each form (LGR = low gill raker). Cisco forms were identified based on jaw morphology and gill raker counts.

lakes (Figure 6) illustrated the following patterns: (i) a high degree of diet similarity between White Partridge Lake pelagic forms, (ii) a high degree of diet similarity between LGR forms in Trout and White Partridge Lakes, (iii) diets of Grand and Hogan Lake Cisco were similar to LGR forms, and (iv) diets from other Algonquin Park lakes were generally dissimilar from lakes with multiple cisco forms. Variation along the first MDS axis largely reflects differences in the relative importance of Opossum Shrimp and zooplankton to cisco diets, and variation along the second MDS axis reflects the relative importance of different zooplankton taxa.

Discussion

We found large differences in prey consumed by White Partridge Lake cisco forms and moderate differences between Trout Lake forms, while the diet of the two Hogan Lake forms was similar. The diet of the White Partridge Lake benthic form and the Trout Lake LGR form were mostly Opossum Shrimp (a vertically migrating species associated with deep offshore habitats). The diet of the pelagic or HGR forms was comprised largely of smaller prey (zooplankton), which is comparable to Cisco collected from other Algonquin Park lakes (Carl and McGuiness 2006). Such differences have been reported for other lakes with multiple forms of ciscoes or whitefishes. The typical pattern is for HGR count individuals that occupy the pelagic zone to feed on smaller, pelagic prey, and LGR benthic forms to feed on larger, benthic prey (Amundsen *et al.* 2004; Howland *et al.* 2013; Leclaire 2016). Our results provide strong dietary evidence of a special ecological context occupied by cisco forms in White Partridge Lake, and moderate evidence for Trout Lake ciscoes.

In White Partridge Lake, the range of gill raker counts across both pelagic forms is broader than expected for inland lake Cisco populations. While gill raker counts are useful for classifying ciscoes, differences between benthic and pelagic LGR form diets may better correspond to variation in gill raker spacing and jaw morphology. Densely packed gill-rakers are hypothesized to increase retention capability after capture of zooplankton by increasing the filtering efficacy of the gill apparatus (Roesch *et al.* 2013). Compared to the benthic LGR form, the pelagic LGR form was much smaller and therefore expected to have a correspondingly shorter gill arch, resulting in narrower spaces between gill rakers and enhanced feeding of smaller, pelagic prey. Coregonid diets also reflect jaw orientation; a more ventrally place mouth is associated with benthic feeding and a more dorsally placed mouth is associated with pelagic feeding (Etheridge *et al.* 2012). The lower jaw was included within the upper jaw of 98% of benthic LGR individuals, while jaws of most (>90%) of the two pelagic forms were classified as either having a terminal profile or the lower jaw extended beyond the upper jaw (S.M.R. unpubl. data).

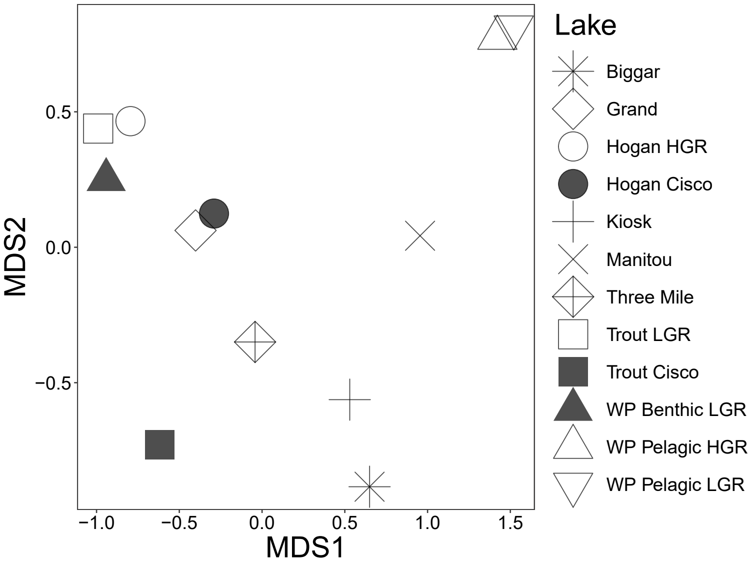

FIGURE 6. Bi-plot of mean non-metric multidimensional scaling (NMDS) scores for all cisco forms (LGR = low gill raker; HGR = high gill raker) and study lakes, representing the dissimilarity (Bray-Curtis) between stomach contents. For the lakes with multiple forms (White Partridge Lake [WP], Hogan Lake, Trout Lake) mean ordinations are presented for each.

Although strong dietary differences have been described among ciscoes collected from the Laurentian Great Lakes (Anderson and Smith 1971) and very large inland lakes (Turgeon *et al.* 1999; Leclaire 2016), such differences are not always apparent in smaller inland lakes. Wain (1993) reported spring and summertime diets of Cisco and Shortjaw Cisco collected from Sandybeach Lake (northwestern Ontario) to be both dominated (>98%) by zooplankton taxa. Alternatively, Steinhilber (2000) found Opossum Shrimp to be the dominant diet (96%) of Cisco and Shortjaw Cisco collected from Barrow Lake (northern Alberta). In both studies, there was also a high degree of spatial overlap in habitat use, which may explain the similarities in prey choice. In our study, stomach content differences between Hogan Lake forms were not substantial. Opossum Shrimp was the dominant prey item for both blackfin and Cisco, although zooplankton was a common prey item of Cisco. Compared to this result, Ridgway *et al.* (2020) present stronger evidence of diet differentiation using stable isotopes, with the trophic position of Hogan Lake blackfin being significantly greater than that of co-occurring Cisco. Interestingly, the contribution of Opossum Shrimp as a prey item was not identified by Carl and McGuiness (2006) who studied Hogan Lake Cisco in the early 1990s, before the recent discovery of co-occurring forms (Bell *et al.* 2019).

Stomach content data provide a "snapshot" of what individuals ate near the time of capture. However, previous diet studies have shown that the prey consumed by ciscoes and whitefishes varies with season and prey availability (Scharf *et al.* 2008; Isaac *et al.* 2012). A restricted sampling window limits the breadth of our description of variation in trophic position among ciscoes in study lakes. As well, in some lakes, a relatively high proportion of stomach items were too digested for visual identification. Stable isotope analysis of tissue samples can provide longer-term information on the dietary habitats of ciscoes (Schmidt *et al.* 2009; Ridgway *et al.* 2020) and is not affected by the condition of stomach contents. DNA barcoding (another more modern approach) of undigested and digested prey items can also improve the accuracy of diet studies (DeSousa *et al.* 2019). Stomach sample sizes from Hogan and Trout Lakes were small, as many individuals caught from these lakes had empty stomachs. Small sample sizes likely resulted in an under-representation of some prey types, and a less accurate and powerful multivariate analysis (Forcino *et al.* 2015). Overall, a more robust characterization of diet and trophic position differences among cisco forms in our study area could be achieved through the collection of a large number of seasonal diet samples (for visual and genetic-based identification), and tissue samples for stable isotope analysis.

Our understanding of cisco diversity in White Partridge Lake has evolved over the past 60 years. Based on gill raker counts from the first gill arch of six specimens provided to the Royal Ontario Museum (ROM) in 1961, Dr. Bev Scott (Department of Ichthyology and Herpetology, ROM) interpreted Shortjaw Cisco to be present. Later examination of 147 specimens provided to the ROM in 1991 revealed a bimodality in the number of gill rakers from small-bodied (dwarf) individuals that was consistent with descriptions of Cisco and Shortjaw Cisco (ROM 1992). Subsequent cisco collections from 2007 to 2009 have revealed at least two genetically distinct cisco forms are present in White Partridge Lake (Turgeon *et al.* 2016), which can be discriminated based on size, morphology, habitat, and diet (this study). Such differences among forms satisfy criteria for identifying conservation units of coregonid diversity (DFO 2013; Mee *et al.* 2015), and are interpreted to result from competition for food resources in lakes (Todd and Smith 1992) and divergent selection on morphological characters (Turgeon *et al.* 2016). Additionally, Opossum Shrimp was the dominant prey item diet of the White Partridge Lake benthic form, providing another example of the association (and potential role) of *Mysis*-based food webs with the post-glacial diversification of ciscoes in inland lakes (Ridgway *et al.* 2020).

Based on the occurrence of similar dwarf ciscoes in Lake Trout stomachs and the presence of other glacial relict species, Martin and Chapman (1965) identified Shortjaw Cisco to be present in six other Algonquin Provincial Park lakes. A secondary goal of our study was to evaluate these historical (1960s) but unconfirmed reports. Based on gill raker counts (all >40), jaw morphology (either extended lower jaws or terminal profiles), and a diet generally dominated by zooplankton, ciscoes captured from Biggar, Grand, Kioshkokwi, Manitou, North Tea, and Three Mile Lakes are classified as Cisco. The previous identification of additional Shortjaw Cisco populations was not supported by our sampling efforts.

In summary, we compared the stomach contents of cisco forms collected from Algonquin Provincial Park area lakes. Differences among forms and lakes largely reflected the varying importance of Opossum Shrimp and zooplankton as food items. In Trout Lake and White Partridge Lake, diet differences between forms support the inference that heritable phenotypic differences are adaptive, and that forms represent potential DUs. However, we are unable to assess whether these forms could be locally reconstituted if lost, a new criterion adopted by COSEWIC to assess whether potential DUs are evolutionary significant (COSEWIC 2020).

Author Contributions

Writing – Original Draft: A.D. and S.M.R.; Writing – Review and Editing: A.D. and S.M.R.; Conceptualization: S.M.R.; Investigation: S.M.R.; Methodology: S.M.R.; Formal Analysis: A.D. and S.M.R.; Visualization: A.D.; Funding Acquisition: S.M.R; Project Management: S.M.R.

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Appendix 1. Frequency of occurrence of prey items identified in stomachs of ciscoes (*Coregonus* spp.) collected from the eight Algonquin Park region lakes. Frequency was calculated as the percent of non-empty cisco stomachs with the prey item. For lakes with multiple forms (Hogan, Trout, and White Partridge [WP]) frequencies are presented for each with LGR = low gill raker and HGR = high gill raker.

Prey item	Biggar	Grand	Kiosk	Manitou	Three Mile	Trout (Cisco)	Trout (LGR)	WP (Benthic LGR)	WP (Pelagic LGR)	WP (Pelagic HGR)	Mean
Amphipod	0.0	5.3	4.7	10.5	12.3	0.0	0.0	16.9	2.0	0.0	4.3
Bivalve	0.0	0.0	0.0	5.3	0.0	0.0	33.3	23.4	0.0	0.0	5.2
Bosminid	0.0	0.0	7.8	5.3	0.0	11.8	1.2	1.6	41.2	54.9	10.3
Chaoborid	4.6	7.9	25.0	10.5	7.0	11.8	0.0	2.4	0.0	0.0	5.9
Chirnomidae larvae	0.8	9.2	20.3	21.1	7.0	5.9	7.1	18.6	2.0	2.0	8.1
Chirnomidae pupae	0.8	0.0	0.0	0.0	0.0	29.4	2.4	9.7	7.8	3.9	4.5
Chirnomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	0.0	0.0	0.7
Cladocerae	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Coleoptera	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.1
Copepods	8.5	1.3	42.2	57.9	0.0	11.8	0.0	0.8	29.4	35.3	16.9
Culicidae	0.0	1.3	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Daphnia sp.	92.3	34.2	84.4	36.8	61.4	35.3	0.0	8.1	11.8	9.8	34.1
Diptera	0.0	0.0	0.0	0.0	0.0	5.9	1.2	0.0	0.0	0.0	0.6
Eggs (*Daphnia* sp.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.1
Ephemeroptera	0.0	1.3	1.6	0.0	0.0	0.0	0.0	4.0	0.0	3.9	1.0
Fish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Formicidae	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Gastropoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.1
Hydrachnidia	0.0	1.3	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Opossum Shrimp	0.8	65.8	15.6	5.3	38.6	23.5	91.7	75.0	13.7	13.7	40.7
Ostracoda	0.0	0.0	1.6	21.1	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Plant material	0.0	0.0	0.0	0.0	0.0	0.0	1.2	9.7	0.0	0.0	0.9
Unknown	70.8	52.6	48.4	63.2	52.6	41.2	9.5	8.1	9.8	3.9	33.0
Zooplankton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	58.8	62.8	10.2

The Canadian Field-Naturalist

A review of beaked whale (Ziphiidae) stranding incidents from the inshore waters of eastern Canada

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Abstract

Cetaceans of the family Ziphiidae (beaked whales) include some of the least known whale species. We review 78 ziphiid stranding incidents from the inshore waters of eastern Canada (defined as the Atlantic provinces north to central Labrador, including the Gulf coast of Quebec, from ~latitude 43.5°N to 55.0°W), with outcomes that involve 84 individual whales. This includes all eastern Canadian ziphiid stranding incidents known to us from the first report of 24 February 1934 to 31 December 2021 for the five species documented from eastern Canada: Northern Bottlenose Whale (*Hyperoodon ampullatus*), Sowerby's Beaked Whale (*Mesoplodon bidens*), Blainville's Beaked Whale (*Mesoplodon densirostris*), True's Beaked Whale (*Mesoplodon mirus*), and Cuvier's Beaked Whale (*Ziphius cavirostris*). Northern Bottlenose Whale (41.0% of incidents, 40.4% of individuals) and Sowerby's Beaked Whale (46.1% of incidents, 46.4% of individuals) have stranded most frequently, with the remaining three species stranding very rarely in the region. An average of 0.55 individual ziphiids/year were reported stranded from 1934 to 1999 in eastern Canada, but since 2000 this has increased to an average of 2.2 stranded individuals/year. Much of this increase is undoubtedly due to improved reporting, but other factors may also be involved. We emphasize the importance of the ongoing documentation of cetacean stranding incidents, but especially the need to better understand causes of ziphiid mortality, particularly for those species that reach the edge of their range in the western North Atlantic or are of conservation concern.

Key words: Cetacean strandings; eastern Canada; *Hyperoodon ampullatus*; *Mesoplodon bidens*; *Mesoplodon densirostris*; *Mesoplodon mirus*; *Ziphius cavirostris*

Introduction

Cetaceans of the family Ziphiidae (beaked whales, the second largest cetacean family) characteristically live in deep water, usually offshore, and include some of the rarest and least known species of whales (MacLeod 2018). The International Union for the Conservation of Nature considers seven of the 24 ziphiid species currently recognized as Data Deficient, three as Near Threatened, and one Endangered. The remaining 12 are considered of Least Concern (https://www.iucnredlist.org/search?taxonomies=101272&searchType=species) while a recently described species remains unassessed (Carroll *et al.* 2021).

For many of these ziphiid species, virtually everything that is known about their biology has been gleaned from dead and live-stranded animals (Ellis and Mead 2017; Li and Rosso 2021). Although encountered far from their natural habitat when stranded, beached ziphiids remain an important source of information for both natural history and conservation. For example, Einfeldt *et al.* (2019a) sequenced the complete mitochondrial genome for True's Beaked Whale (*Mesoplodon mirus*) from tissue taken from an animal stranded on Iles de la Madeleine, Quebec (QC), while Desforges *et al.* (2021) was able to undertake full-depth blubber analysis for contaminants from a Northern Bottlenose Whale (*Hyperoodon ampullatus*) stranded in Newfoundland (NF). With the exception of the Northern Bottlenose Whale population that occupies the Scotian Shelf (Whitehead and Hooker 2012), the distributions of ziphiids that occur off Canada's east coast are not well understood. While dead or live-stranded ziphiids undoubtedly provide a very biased, and possibly even distorted, reflection of true distribution, stranding location and frequency may nevertheless reflect a shift in range. Furthermore, understanding cause of mortality in these animals may well be critical for conservation management.

Nemiroff *et al.* (2010) reported cetacean strandings in the Maritimes (provinces of New Brunswick [NB], Nova Scotia [NS], and Prince Edward Island [PEI]) from 1990 to 2008. During that 18-year period there were nearly 100 cetacean strandings documented from the coastline of the southern Gulf of St. Lawrence, with only a single ziphiid whale recorded (McAlpine and Rae 1999). Likewise, Truchon *et al.* (2013) analyzed 549 cetacean strandings from the St. Lawrence Estuary and northern Gulf from 1994 to 2008, with the only ziphiids included being Northern Bottlenose Whale and Sowerby's Beaked Whale (*Mesolodon bidens*). Truchon *et al.* (2013) classified both as rare in the Gulf. We are aware of only two reports of ziphiid whale strandings (of Northern Bottlenose Whale) in the Gulf of St. Lawrence prior to 1990 (cited in Hooker 1999), and prior to 2008 there appear to be only two Sowerby's Beaked Whale strandings for the Gulf. Lucas and Hooker (2000) summarized whale strandings for Sable Island, NS, from 1970 to 1998, a site well offshore on the Atlantic coast. Among 267 cetacean strandings, a mere four were ziphiids.

Here we review 78 stranding incidents comprising 84 ziphiid whales from the inshore waters of eastern Canada (defined as the Atlantic provinces north to central Labrador (NL), including the Gulf coast of QC, from ~latitude 43.5°W to 55.0°W; Figure 1) from the first report on 24 February 1934 to 31 December 2021 for the five species of ziphiids known from the region: Northern Bottlenose Whale, Sowerby's Beaked Whale, Blainville's Beaked Whale (*Mesoplodon densirostris*), True's Beaked Whale (*Mesoplodon mirus*), and Cuvier's Beaked Whale (*Ziphius cavirostris*). Stanistreet *et al.* (2017) detected Gervais' Beaked Whale (*Mesoplodon europaeus*) acoustically on the United States portion of the continental slope of Georges Bank; however, to date this species has not been reported in Canadian waters or recorded stranded on Canadian shores (Naughton 2012). The most northerly stranding of this species in the northwest Atlantic appears to be Cape Cod Bay, Massachusetts, in September 1997 (Moore *et al.* 2004).

Methods

Through the early 1990s, multiple agencies (Canadian Coast Guard, Department of Fisheries and Oceans Canada [DFO], Grand Manan Whale and Seabird Research Station [GMWSRS], New Brunswick Museum [NBM], Nova Scotia Stranding Network [NSSN], Nova Scotia Museum, and the Whale Release and Strandings Program of Memorial University of NF's Whale Research Group) monitored cetacean stranding incidents across the Canadian Maritime provinces and the Gulf of St. Lawrence and NF and NL. With the founding of the Marine Animal Response Society in 1999 (MARS, formerly the NSSN-1990–1996) based in Halifax, NS, Whale Release and Strandings (WR&S) in St. Johns, NF, in 2001, and the Réseau québécois d'urgences pour les mammifères marins (RQUMM) in 2004, the latter coordinated by the Group for Research and Education on Marine Mammals (GREMM; founded 1985) in Tadoussac, QC, documentation of marine mammal standings in the region has become much more systematic. Each of these groups maintains a public reporting hotline (Wimmer and Maclean 2021). Opportunity to report marine mammal stranding incidents to these 24 h hotlines has substantially enhanced reporting and documentation. Databases documenting stranding incidents for the region are now maintained by the Canadian Wildlife Health Cooperative (CWHC), DFO (NF & NL), GREMM, MARS, and the NBM. Ziphiid stranding incidents documented here were mainly reported through these agencies and WR&S. It should be noted that individually none of these databases are complete, even for the regions they encompass (e.g., CWHC is restricted to whales that have undergone veterinary necropsies by affiliated staff). Earlier stranding reports (<1980) are taken from the published literature. Where information on strandings from multiple sources and data are in disagreement (usually stranding dates, but sometimes location and total length of animals), we have chosen to follow veterinary necropsy reports and peer reviewed

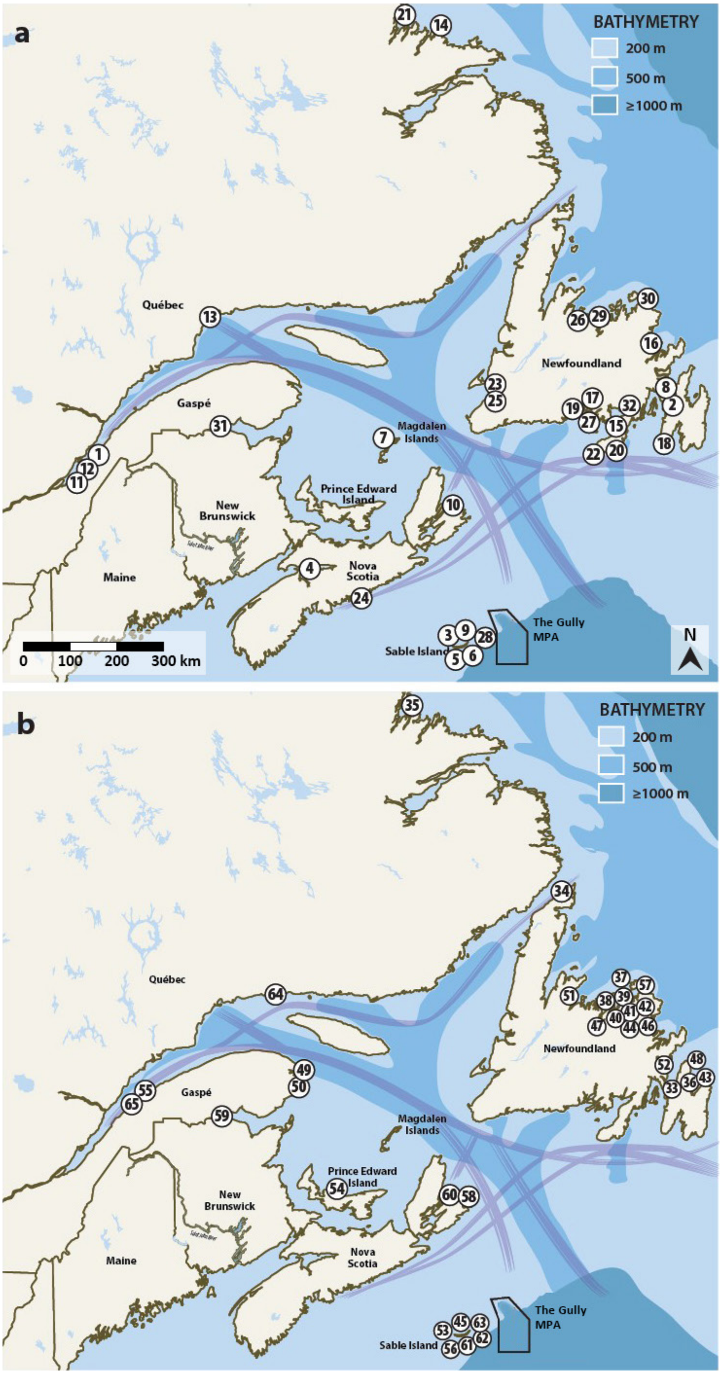

Figure 1. Distribution of ziphiid whale stranding incidents from the inshore waters of eastern Canada to December 2021. Each incident number represents one or more whales. Numbers correspond to incidents (not individuals) in Table 1. Major commercial shipping routes through the Gulf of St. Lawrence that might pose increased risk of cetacean–vessel strikes are also shown in purple and based on Réseau d'observation de mammifères marins (2014). The Gully Marine Protected Areas (MPA) is the marked polygon. a. Northern Bottlenose Whale (*Hyperoodon ampullatus*). b. Sowerby's Beaked Whale (*Mesoplodon bidens*). c. Blainville's Beaked Whale (*Mesoplodon densirostris*). d. True's Beaked Whale (*Mesoplodon mirus*). e. Cuvier's Beaked Whale (*Ziphius cavirostris*). Figure continued on the next page.

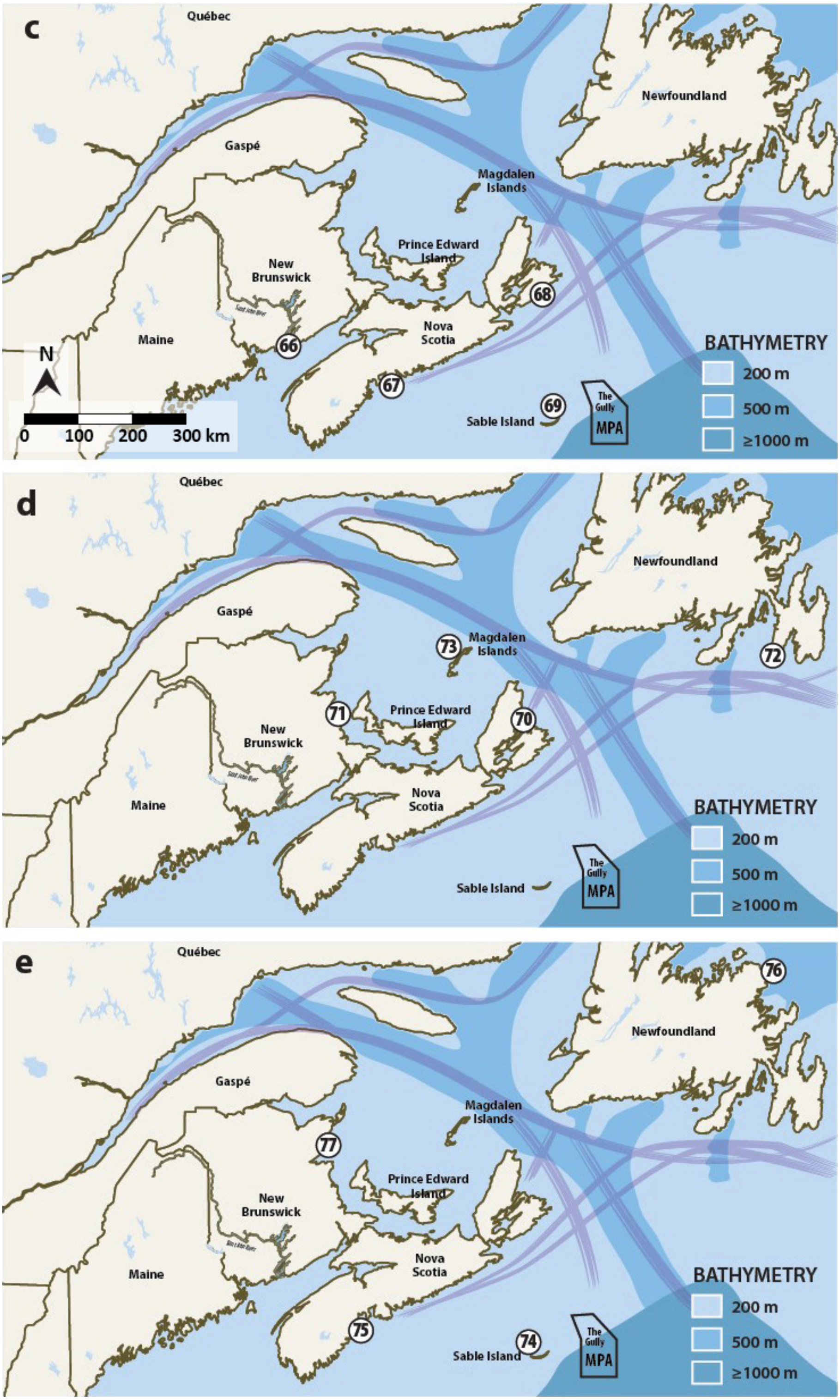

FIGURE 1. *Continued.*

sources as the most authoritative.

Ziphiid species, particularly those of the genus *Mesoplodon*, are not always easily identified. At minimum, we therefore provide confirmatory photos for stranding events, but also note the availability of museum specimens (and the nature of the material retained), necropsy reports, and published literature as confirming sources or supporting evidence for species identity. We sought to locate all ziphiid specimen material from eastern Canada deposited in public museum collections. In a few cases skeletal material has been collected from stranded ziphiids in eastern Canada but now resides in private hands or with groups or agencies that do not maintain permanent scientific collections. As this material is less accessible to the scientific community, and is likely to be even less so in the long-term, we have not included it here.

For purposes of this review we define a "stranding incident" as one or more cetaceans positioned dead or alive on the shoreline at or below high water or in water <20 m deep (atypical habitat for any ziphiid) at the same place and on the same date. Each stranding has been assigned a number consisting of 2–3 digits. Numbers have been assigned sequentially by date for each species, from the earliest to the most recent. The first 1–2 digits in the number sequence refer to the stranding incident. Because strandings may include more than a single whale, we have also assigned a fractional number to each stranded individual within an incident. The highest fractional number, paired with each whole number, records the total number of individuals comprising each stranding incident. This is usually a 1, because most strandings are single animals (e.g., 3.1 = the third stranding of a Northern Bottlenose Whale, a single male stranded 12 January 1968 on South Beach, Sable Island, NS), but some incidents include two animals. A "mass stranding incident" is defined as the (live) stranding of two or more whales (excluding female with calf pairs) at the same place and on the same date (Geraci and Lounsbury 2005). "Atypical mass stranding events", most often associated with detrimental underwater noise, include two or more whales (exclusive of female with calf pairs) found within a six-day period and spread apart along up to 74 km of coastline (D'Amico *et al.* 2009). By definition, atypical mass stranding events included multiple standing incidents. "Dead-stranded" refers to ziphiids discovered dead on the shoreline at or below high water. "Live-stranded" refers to animals that were beached alive when discovered or were observed inshore in waters <20 m deep. In several cases animals observed to live-strand were able to swim away, with their fate unknown. In other cases, these animals were discovered dead-stranded later at another location.

We also coded all stranding incidents using an incident narrative to briefly summarize the circumstances and final outcome of each stranding incident. We report some of these incidents in greater detail in the text where it contributes to a better understanding of these mortality events. We have included four incidents where ziphiids were purposely killed in inshore waters. We justify their inclusion here on the assumption there is some probability that these animals would have live or dead-stranded had they not been purposely killed. A single incident narrative may therefore include both live and dead-stranded (multiple) components, but a stranding incident includes only a single outcome (i.e., harpooned, live-stranded, shot, died on shore, dead at discovery, outcome unknown). In cases where animals are reported stranding in two provinces, this indicates either dead or live-stranding in the first province and usually a dead-stranding reported at a later date in an adjacent province. Dead-stranded animals were sometimes moved by tidal events and currents from an initial site of discovery in one province to another. Coordinates given are for the first stranding site, although information sources cited also record the final stranding site. We also emphasize that our list of eastern Canadian ziphid mortalities is not complete. Animals recorded entangled or floating dead offshore, of which there are reports (see Feyrer *et al.* [2021] and network records) are not included here.

Unfortunately, there are very limited published data available on minimum or mean total lengths at sexual maturity for ziphiids. For Northern Bottlenose Whale, males have been reported to reach maturity at 7.30 m, females at 6.00 m (Mead 1989). Age at sexual maturity is unconfirmed in Sowerby's Beaked Whale, but it appears animals may reach sexual maturity at about 4.7 m total length (MacLeod and Herman 2004). There appear to be no data on minimum or mean size at sexual maturity for True's or Blainville's Beaked Whales. Although some ziphiids display sexual size dimorphism (Pitman 2018), with females being the larger sex, sexual size dimorphism in Blainville's Beaked Whale has not been reported (MacLeod 2006). Omura *et al.* (1955) reported mean length at sexual maturity in male Cuvier's Beaked Whale as 5.5 m. For purposes of this review, a sexually mature whale (versus a sexually immature juvenile/calf) is defined based on the limited data cited above. Small whales accompanying females are considered to be calves.

When stranding incidents are attended by stranding network biologists, volunteers, or fisheries agencies, data are collected and recorded that generally include, at minimum, species identity, geographic location, date, sex, and total length, and often observations that document entanglement, other sources of injury, or aspects of natural history (i.e., reproductive state, stomach contents; Wimmer and Reid 2008). Over the past decade, stranding networks in the Atlantic region have become increasingly professionalized, with specially trained staff collecting an increasingly wide range of data and samples in support of research and facilitating the transport of carcasses to situations where they can be examined by specialists. Nonetheless, while observations recorded by stranding network staff are important, they are not a substitute for examination and necropsy by a qualified veterinary pathologist. For this review, we therefore only consider dissection by a veterinary pathologist with marine mammal experience, followed by any subsequent laboratory analysis and the filing of a formal report, to qualify as a "veterinary necropsy". This said, we also draw on information from "non-veterinary" necropsies where available (mostly reported in the annual reports of the WR&S, NL). We accessed all ziphiid veterinary necropsy reports for eastern Canada on file with the CWHC (n = 12) by searching the CWHC database under *Hyperoodon*, *Mesoplodon*, and *Ziphius*. We also received one report that was conducted prior to establishment of the CWHC partnership in 1992 (S. Hooker pers. comm. to D.F.M. 13 January 2022) and a second report undertaken by DFO scientists and biologists in the company of a veterinarian but not on file with CWHC. As we show below, relatively few veterinary necropsies have been completed on ziphiids in eastern Canada. Finally, we had eight, dermestid-cleaned, full skeletons of Northern Bottlenose Whale (n = 2), Sowerby's Beaked Whale (n = 4), and Cuvier's Beaked Whale (n = 2) from eastern Canada available to us in the collections of the NBM and these were carefully examined for signs of healed fractures indicative of past blunt force trauma, perhaps from vessel strikes.

Results

Stranding incident numbers throughout the text follow Table 1 and are keyed to Figure 1. Figures 1a–e map the geographic location of stranding incidents by species. Among those strandings documented here are the first confirmed records for Sowerby's Beaked Whale for PEI and NB, the first records of True's Beaked Whale from QC, the Gulf of St. Lawrence, and NF, and the first records of Cuvier's Beaked Whale from NB and the Gulf of St. Lawrence. Ziphiid strandings from Sable Island, NS, include the first east coast stranding for Canada of Cuvier's Beaked Whale.

All cases known to us of live and dead-stranded ziphiids in eastern Canada up to 31 December 2021 are reported in Table 1. The number of strandings reported as live-at-discovery (i.e., on shore) as a component in a stranding narrative (n = 24; 28.6%) undoubtedly underrepresents live-strandings as some animals may have stranded live, only to be first discovered and reported after death. The outcome of a live-stranding may be either a successful effort by stranding network staff to return the animal to the water, with the fate of the animal usually unknown, although an animal may live-strand again or be discovered dead-stranded at a later time. An animal in shallow water may also move into deeper water under its own power.

The first eastern Canadian ziphiid stranding incident, for a Blainville's Beaked Whale, occurred 24 February 1934 at Duck Cove, Saint John, NB (Table 1, 66.1, Figure 1c). Since then, ziphiid stranding incidents have been reported sporadically in eastern Canada, but with increasing frequency, through to our cut-off date (Figure 2). These incidents involved 37 males, 28 females, one intersex, and 18 of sex undetermined. In total, 78 incidents involving 84 individuals of five beaked whale species are documented from inshore eastern Canada. Four intentional killings occurred, one each in 1938 (70.1) and 1940 (67.1), and two in 1953 (2.1, 34.1). The first of these animals (True's Beaked Whale) was shot, the second was "captured" (Blainville's Beaked Whale), while the third (Northern Bottlenose Whale) and fourth (Sowerby's Beaked Whale) were animals harpooned by small whale hunters at Dildo Arm in Trinity Bay and Notre Dame Bay, NF, respectively. A Northern Bottlenose Whale that live-stranded at Cap Martin, QC, in 1940 was also shot on shore (1.1). Only four (4.8%) of the ziphiid strandings included here were reported to show signs of interactions with fishing gear. Likewise, only eight (9.5%) animals were reported to show signs of vessel strikes.

Figure 3 provides photo-confirmation for 36 of the 84 individual ziphiids stranded. Other incidents are represented by images or descriptions elsewhere in the literature, or by specimens deposited in museum collections. For three of the 84 strandings we were unable to find independent confirmation (e.g., news reports, published papers, photos, specimens, necropsy reports) of species identity. However, we feel confident in the species assigned based on verbal descriptions provided either by, or to, experienced marine mammalogists for two of these strandings (14.1, 23.1). The identity of the ziphiid species involved in the remaining stranding (78.1) is unknown.

There has been a noticeable increase in stranding reports of ziphiid species in eastern Canada since 2000 (Figure 2). Since 2000 inclusive, 48 individual ziphiids, involving four ziphiid species, have stranded in eastern Canada (average 2.2 stranded individuals/

Table 1. Records of ziphiid whale stranding incidents in eastern Canadian inshore waters, 1934–2021. The first one to two digits of No. are the stranding incident number. Incident numbers are arranged sequentially by date from the earliest to the most recent for each species. A final, fractional digit has been assigned to each individual whale within each stranding incident. Most stranding incidents involve only a single animal. NB = New Brunswick, NF = Newfoundland, NL =Labrador, NS = Nova Scotia, PEI = Prince Edward Island, QC = Quebec.

No.*	Location	Co-ordinates	Date	Sex	Length (m)	Incident narrative†	Source‡
Northern Bottlenose Whale (*Hyperoodon ampullatus*)							
1.1	Cap Martin, QC	47.355°N, 70.083°W	4 September 1940	Female	6.73	5, 6	Beauge (1941)
2. 1	Dildo Arm in Trinity Bay, NF	47.537°N, 53.561°W	27 July 1953	Male	6.70	3, 4	Sergeant and Fisher (1957)
3. 1	South Beach, Sable Island, NS	43.928°N, 59.978°W	12 January 1968	Male	8.70	10	Sergeant *et al.* (1970)
4. 1	Cobequid Bay, NS	45.316°N, 63.776°W	5 October 1969	Male	6.15	10	CMN^{A} 42836^{1,2}, Case and Densmore (1970), Mitchell and Kozicki (1975)
5. 1	South Beach, Sable Island, NS	43.928°N, 59.978°W	2 February 1974	Male	8.23	10	Mitchell and Kozocki (1975)
6.1	South Beach, Sable Island, NS	43.928°N, 59.978°W	1 July 1985	Male	5.25	10	Lucas and Hooker (2000)
7. 1*	Iles de la Madeleine, QC	47.532°N, 61.709°W	8 October 1987	Female	5.48	3, 5, 8, 9	Béland (1987), Hooker (1999)
8.1	Dildo, Trinity Bay, NF	47.565°N, 53.559°W	5 September 1990	?	?	1, 2	Lien *et al.* (1990b)
9. 1	Sable Island, NS	43.928°N, 59.978°W	18 May 1992	Female	7.50	10	Lucas and Hooker (2000)
10.1*	North Sydney, NS	46.211°N, 60.199°W	8 October 1992	Male	5.94	3, 8, 10	NBM 5671, Daoust (1992)
11.1*	Montmagny, QC	46.990°N, 70.560°W	6 November 1994	Female	7.40	5, 9	Anonymous (1994/1995), Lair et Martineau (1994a), Fontaine (1995)
12.1*	St-Roch des Aulnaies, QC	46.990°N, 70.560°W	9 November 1994	Male	3.88	10	Anonymous (1994/1995), Lair et Martineau (1994b), Fontaine (1995)
13.1	Sept Iles, QC	50.206°N, 66.300°W	8 September 1997	Male	6.60	5, 9	USNM 594511, Sylvestre (1997), Figure 3.1
14.1	Makovik, NL	55.080°N, 59.169°W	? September 2002	?	?	10	Verbal only
15.1	Fortune Bay, NF	47.229°N, 55.379°W	22 July 2004	?	?	10	Figure 3.2
16.1	Culls Harbour Point, NF	48.667°N, 53.957°W	6 August 2004	Male	6.50	5, 9	NBM MA-11490
16.2	Culls Harbour Point, NF	48.667°N, 53.957°W	6 August 2004	Female	6.45	5, 9	Figure 3.3
17.1	Milltown-Head Bay d'Espoir, NF	47.928°N, 55.754°W	4 August 2005	?	?	5, 9	Ledwell and Huntington (2006)
18.1	Golden Bay, Cape St. Mary's, NF	46.827°N, 54.148°W	19 March 2007	Male	?	10	Ledwell and Huntington (2007a), Figure 3.4
19.1	Milltown-Head Bay d'Espoir, NF	47.928°N, 55.754°W	6 May 2007	Female	4.90	10	Figure 3.5
20.1	Lawn, Burin Peninsula, NF	46.939°N, 55.545°W	26 June 2007	?	6.53	10	Ledwell and Huntington (2007b), Figure 3.6
21.1	Ellen Island, Hopedale, NL	55.607°N, 60.275°W	6 September 2008	?	?	10	Figure 3.7
22.1	W of Lamaline, NF	46.784°N, 56.089°W	7 June 2011	Male	4.00–5.00	10	Figure 3.8
23.1	Mattis Point, NF	48.486°N, 58.428°W	26 June 2011	?	7.60	10	Verbal only
24.1	Prospect/ Spry Bay, NS	44.830°N, 62.580°W	6-8 October 2013	?	?	3, 12	Figure 3.9
25.1	Stephenville Crossing, NF	48.498°N, 58.439°W	~12 June 2014	?	~7.60	10	Ledwell *et al.* (2014), Figure 3.10

Table 1. *Continued.*

No.*	Location	Co-ordinates	Date	Sex	Length (m)	Incident narrative†	Source‡
26.1	Leamington, NF	49.344°N, 55.396°W	2 September 2016	?	?	3, 12	Figure 3.11
27.1	Harbour Mille, Fortune Bay, NF	47.579°N, 54.886°W	11 August 2019	Female	7.20	5, 9,12	Ledwell *et al.* (2020), Desforges *et al.* (2021), Figure 3.12
28.1	Sable Island, NS	43.936°N, 59.976°W	~15 March 2021	?	?	10	Figure 3.13
29.1	Boyd's Cove, NF	49.444°N, 54.660°W	16 February 2021	Female	7.30	10	Ledwell *et al.* (2021), Figure 3.14
30.1	Musgrave Harbour, NF	49.447°N, 53.941°W	7 March 2021	Male	8.35	10, 11	Ledwell *et al.* (2021), Figure 3.15
31.1*	Point-à-la-Croix, QC	48.010°N, 66.738°W	30 September 2021	Male	6.00	5, 9	Bourque (2021), Figure 3.16
31.2	Point-à-la-Croix, QC/NB	48.010°N, 66.738°W	30 September 2021	Female	~ 5.98	5, 7, 10	Figure 3.17
32.1	Mortier Bay, Marystown, NF	47.166°N, 55.148°W	1 October 2021	Male	5.90	10	Ledwell *et al.* (2021), Figure 3.18
Sowerby's Beaked Whale (*Mesoplodon bidens*)							
33.1	Chapel Arm, Trinity Bay, NF	47.527°N, 53.670°W	26 August 1952	Male	4.72	10	CMN 26484[1,2], Sergeant and Fisher (1957)
34.1	Wild Bight, Notre Dame Bay, NF	51.607°N, 55.895°W	23 September 1953	Female	4.30	3, 4	CMN 26483[1,2], Sergeant and Fisher (1957)
35. 1	Double Mer, NL	54.142°N, 58.854°W	September 1973	Female	?	10	USNM 504146[1,2], Lien and Barry (1990)
36.1	Port de Grave, Conception Bay, NF	47.510°N, 53.134°W	26 July 1984	Male	4.10	1, 2, 10	Lien, *et al.* (1984), Dix *et al.* (1986)
37.1	Carmanville, NF	49.417°N, 54.267°W	29 August 1986	?	?	3, 5, 7, 13	Lien *et al.* (1986, 1990a)
37.2	Carmanville, NF	49.417°N, 54.267°W	29 August 1986	?	?	3, 5, 7, 13	Lien *et al.* (1986, 1990a)
37.3	Carmanville, NF	49.417°N, 54.267°W	29 August 1986	?	?	3, 5, 7, 13	Lien *et al.* (1986, 1990a)
37.4	Carmanville , NF	49.417°N, 54.267°W	29 August 1986	Male	4.62	3, 5, 9	CMN 1987-143.1[1], Lien *et al.* (1986, 1990a)
38.1	Carmanville , NF	49.417°N, 54.267°W	31 August 1986	Male	4.85	3, 5, 7, 10	CMN 1987-143.3[1], Lien *et al.*(1986, 1990a)
39.1	Davidsville, NF	49.333°N, 54.433°W	31 August 1986	Male	4.95	3, 5, 7, 10	CMN 1987-143.2[2], Lien *et al.* (1986, 1990a)
40.1	Norris Arm, Bay of Exploits, NF	49.090°N, 55.271°W	15 September 1987	?	?	5, 7, 13	Lien *et al.* (1990a)
41.1	Norris Arm, Bay of Exploits, NF	49.090°N, 55.271°W	17–18 September 1987	?	4.80	3, 5, 7, 13	Lien *et al.* (1987, 1990a)
42.1	Rattling Brook, Bay of Exploits, NF	49.074°N, 55.308°W	18 September 1987	Female	4.62	3, 10	Lien *et al.*(1990a)
43.1	Seal Cove, Conception Bay, NF	47.473°N, 53.077°W	9 June 1990	Male	4.9	9	NFM MA-70[1, 4], Lien *et al.* (1990b)
44.1	Roberts Arm, NF	49.489°N, 55.807°W	23 August 1995	Male	4.50	10	NFM MA-340[1], Figure 3.19
45.1	South Beach, Sable Island, NS	43.9281°N, 59.978°W	20 June 1997	Female	4.88	10	NBM MA-18027[3], Lucas and Hooker (2000)
46.1	Port Albert, Notre Dame Bay, NF	49.543°N, 54.527°W	5–6 July 2001	Female	4.70	3, 5, 9	Ledwell *et al.* (2001), Lein *et al.* (2002)
47.1	Boyd's Cove, Notre Dame Bay, NF	49.444°N, 54.659°W	7–8 October 2001	Male	4.42	3, 5, 10	Ledwell *et al.* (2001), Lein *et al.* (2002), Figure 3.20
48.1	Western Bay, Conception Bay, NF	47.908°N, 52.980°W	15 June 2004	Female	4.79	10, 12	NBM MA-11488[1,2], Ledwell *et al.* (2005)
49.1	Forillion National Park, QC	48.970°N, 64.342°W	22 June 2006	Male	?	10	Figure 3.21

Table 1. *Continued.*

No.*	Location	Co-ordinates	Date	Sex	Length (m)	Incident narrative†	Source‡
50.1	Penouille, QC	48.849°N, 64.432°W	29 June 2006	Male	4.30	10	Figure 3.22
51.1	Kings Point, NF	49.577°N, 56.185°W	17 September 2006	Female	3.35	10, 11	NBM MA-11494[1,2], Ledwell and Huntington (2007a)
52.1	Harcourt, Trinity Bay, NF	48.198°N, 53.868°W	22 May 2008	Male	4.40	3, 10	Ledwell and Huntington (2009), Figure 3.23
53.1	South Beach, Sable Island, NS	43.927°N, 59.949°W	3 June 2011	Male	4.55	10	Figure 3.24
54.1*	NNW of North Rustico, PEI	46.497°N, 63.349°W	5 June 2013	Male	4.76	10, 12	NBM-MA-12438[1,2], Daoust (2013)
55.1*	Îles aux Pommes, QC	48.106°N, 69.322°W	3 July 2013	Male	4.69	10	Lair *et al.* (2013), Figure 3.25
56.1	South Beach, Sable Island, NS	43.927°N, 59.949°W	17 June 2014	Female	2.12	10	Figure 3.26
57.1	Fogo, Fogo Island, NF	49.715°N, 54.269°W	21 July 2015	Female	4.67	3, 5, 10	Ledwell *et al.* (2015), Figure 3.27
58.1	Mira Gut, NS	46.054°N, 59.902°W	21 April 2016	Male	3.96	10	NSM[E] 78307[1,2]
59.1*	Gaspesie/Escuminac, QC/NB	48.113°N, 66.485°W	13 June 2016	Male	4.75	10	NBM MA-16530[1,3,4], Daoust (2016a)
60.1*	North Sydney, NS	46.210°N, 60.199°W	23 October 2016	Female	4.82	5, 7, 10	NBM MA- 16536[1,2,,3], Daoust (2016b)
61.1*	Sable Island, NS	43.935°N, 60.019°W	6 April 2017	Male	4.18	10	NBM MA-18143[1,3,4], Bourque (2017a), Figure 3.28
62.1*	Sable Island, NS	43.934°N, 59.915°W	13 May 2017	Female	4.72	10	NBM MA-19234[1,2,3], Bourque (2017b), Figure 3.29
63.1	Sable Island, NS	43.934°N, 59.915°W	12 January 2018	Male	3.90	5, 8, 9	Figure 3.30
64.1	Rivière-au-Tonnerre, QC	50.273°N, 64.770°W	17 September 2018	Female	4.60	10	Figure 3.31
65.1	Notre-Dame-des-Sept-Douleurs, QC	48.001°N, 69.464°W	26 August 2019	?	?	3, 5, 7, 13	Figure 3.32
Blainville's Beaked Whale (*Mesoplodon densirostris*)							
66.1	Duck Cove, NB	45.243°N, 66.091°W	24 February 1934	Male	4.60	10	McAlpine and Rae (1999)
67.1	Peggy's Cove, NS	44.493°N, 63.918°W	4 February 1940	Male	4.39	3, 6	AMNH[F] M-139931[1,2], Raven (1942)
68.1	Fourchu Bay, Cape Breton, NS	45.7227°N, 60.239°W	December 1968	Male	?	10	Sergeant *et al.* (1970)
69.1	Sable Island, NS	43.934°N, 59.915°W	26 November 1999	Female	4.40	10	NBM MA-18882[1]
True's Beaked Whale (*Mesoplodon mirus*)							
70.1	South Gut, St. Anne's Bay, NS	46.296°N, 60.542°W	5 August 1938	Female	5.03	3, 6	MCZ[G] 37274[1], Allen (1939)
71.1	Saint-Thomas-de-Kent, NB	46.435°N, 64.628°W	28 September 1993	Female	4.80	10	McAlpine and Rae (1999), Figure 3.33
72.1*	Point Lance, NF	46.809°N, 54.086°W	7 February 2015	Female	4.60	10, 12	Ledwell *et al.* (2015), Figure 3.34
73.1	Pointe-aux-Loups, Iles de la Madeleine, QC	47.532°N, 61.709°W	13 October 2017	Female	5.20	10	NBM MA-18276[2], Figure 3.35
73.2	Pointe-aux-Loups, Iles de la Madeleine, QC	47.532°N, 61.709°W	13 October 2017	Intersex	2.7	10	NBM MA-18280[1], Einfeldt *et al.* (2019a,b)

TABLE 1. *Continued.*

No.*	Location	Co-ordinates	Date	Sex	Length (m)	Incident narrative†	Source‡
Cuvier's Beaked Whale (*Ziphius cavirostris*)							
74.1	South Beach, Sable Island, NS	43.927°N, 59.949°W	3 May 2000	Female	5.60	10	NBM-MA-18883^{1}, Naughton (2012)
75.1*	Blanford, NS	44.493°N, 64.109°W	7 February 2016	Male	4.85	5, 9, 12	NBM MA-16513^{1,2,3,4}, Daoust (2016c)
76.1	Lumsden, NF	49.301°N, 53.600°W	24 July 2018	Female	5.67	10	Figure 3.36
77.1*	Val Comeau, NB	47.456°N, 64.877°W	9 December 2019	Male	5.50	10, 12	NBM MA-18233^{1,2,3,4,6}, Bourque (2019)
Unidentified ziphiid							
78.1	Bona vista, NF	48.651°N, 53.119°W	5 August 1989	?	?	10	Lien *et al.* (1990c)

*Veterinary necropsy performed.

†Incident narrative: 1. Live entanglement in fishing gear. 2. Successfully released from gear. 3. Observed live inshore. 4. Harpooned. 5. Live on shore at discovery. 6. Shot. 7. Rescued and released. 8. Attempted rescue. 9. Died on shore. 10. Dead at discovery. 11. Evidence of possible gear entanglement. 12. Evidence of possible ship strike. 13. Outcome unknown.

‡Source: ^{A}Canadian Museum of Nature; ^{B}New Brunswick Museum; ^{C}United States National Museum; ^{D}Newfoundland Museum; ^{E}Nova Scotia Museum; ^{F}American Museum of Natural History; ^{G}Museum of Comparative Zoology; ^{1}skull, ^{2}post-cranial, ^{3}frozen/dried tissue, ^{4}anatomical, ^{5}stomach contents, ^{6}parasites.

year). In comparison, there were only 36 individual strandings documented from 1934 to 1999 inclusive (average 0.55 individual stranded ziphiids/year).

Simultaneous ziphiid strandings of multiple individuals in eastern Canada are rare. Among the 78 incidents involving 84 individuals we report, there are only two cases of female with calf strandings: two incidents three days apart for Northern Bottlenose Whale where a calf stranded after the female (11.1, 12.1) and one incident for True's Bottlenose Whale (73.1, 73.2). A calf that is not known to have stranded, was also reported in the company of a female True's Bottlenose Whale that ultimately stranded at Point Lance, NF (72.1). A further two incidents encompass mass strandings of ziphiid pairs, both involving adult female–juvenile male Northern Bottlenose Whale (16.1, 16.2 and 31.1, 31.2), the latter occurring in the Gulf of St. Lawrence. Six incidents appear to qualify as two atypical mass strandings. The first atypical mass stranding is a remarkable event involving six Sowerby's Beaked Whales (37.1, 37.2, 37.3, 37.4, 38.1, 39.1) that stranded at two sites across about 35 km of coast over three days. Three of the animals were sexed as mature males. Unfortunately, the sex and length of the remaining animals is unknown. The second atypical mass stranding involves three Sowerby's Beaked Whales (40.1, 41.1, 42.1) that stranded at two sites about 2 km apart over a three- to four-day period.

A summary of the results of stranding incidents by species follows, with comments on seasonality, sex and age, and cause of death. We note where cause of death data are drawn from a non-veterinary necropsy report. All of these non-veterinary reports included valuable information. Otherwise, details provided and conclusions drawn are based on veterinary reports as defined above. Unfortunately, few veterinary necropsies have been performed on those ziphiids stranded in eastern Canada ($n = 14$), so detailed investigations on cause of death are often limited.

Annotated Species Accounts

Northern Bottlenose Whale

There have been 32 Northern Bottlenose Whale stranding incidents involving 34 individuals in eastern Canadian waters (Figure 1a, Table 1: 1.1 to 32.1), including six incidents (seven animals) in the Gulf of St. Lawrence. Nineteen Northern Bottlenose Whale stranding incidents (involving 21 animals) have occurred since 2002 inclusive, with two incidents in NL (14.1, 21.1) and one (involving two animals) reported from the Gulf of St. Lawrence (31.1, 31.2).

Seasonality—Eastern Canadian strandings of Northern Bottlenose Whale have occurred in all months of the year except April and December. However, there

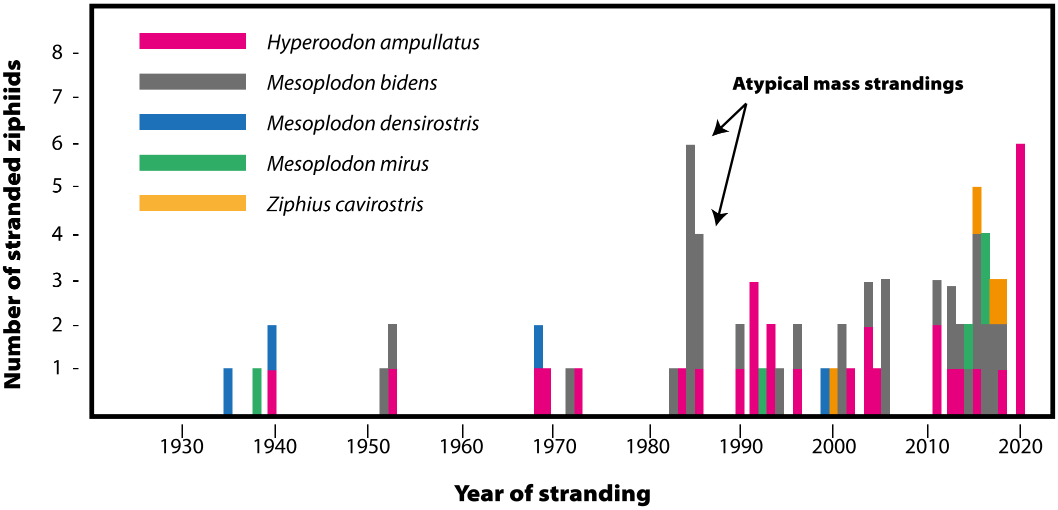

FIGURE 2. Yearly frequency of ziphiid whale stranding incidents from the inshore waters of eastern Canada by species (Northern Bottlenose Whale [*Hyperoodon ampullatus*], Sowerby's Beaked Whale [*Mesoplodon bidens*], Blainville's Beaked Whale [*Mesoplodon densirostris*], True's Beaked Whale [*Mesoplodon mirus*], and Cuvier's Beaked Whale [*Ziphius cavirostris*]), 1934–2021.

is a decided trend, with stranding incidents concentrated (62.5%) in the summer–early autumn period from July to October.

Sex and age—Fourteen males, nine females, and 11 of sex undetermined have stranded. Among strandings of known sex ($n = 23$) there are three adult males (13.0%), 11 juvenile males (47.8%), seven adult females (30.4%), and two juvenile females (8.7%). Most strandings incidents were single animals (87.5%) but there were two strandings of an adult female with a juvenile male (16.1, 16.2 and 31.1, 31.2), plus a single mother-male calf pair (11.1 and 12.2).

Cause of death—Five eastern Canadian strandings of this species have undergone veterinary necropsies (7.1, 10.1, 11.1, 12.1, and 31.1). Three animals were judged to be in good nutritional condition (7.1, 11.1, 12.1) and one was reported to be in "adequate" nutritional condition (10.1). In four of the animals cause of death was reported to be undetermined (7.1, 11.1, 12.1, and 31.1) and in one attributed to "mishap" associated with shallow water (10.1). Animal 10.1 was free-swimming in inshore waters for nine days before an attempt was made to harness the whale and tow it to deeper water. The animal escaped but was found dead-stranded two days later, with the veterinary report speculating that direct cause of death may have been related to capture myopathy. The first stomach compartment of one animal (7.1) contained an abundance of plastic and the veterinary report implied this might have been related to the death of this whale.

Details on four non-veterinary necropsies for Northern Bottlenose Whale were available to us (27.1, 29.1, 30.1, and 32.1). For 29.1, 30.1, and 32.1 cause of death is "unknown", but signs of a possible ship strike were reported for 27.1 (bruising, scarring, broken left nasal bone). The animal was emaciated and the stomach contained plastic debris, along with cod (gadoid) and squid remains (Ledwell *et al.* 2020). Necropsy revealed a ball of rope in the stomach of 30.1 (Ledwell *et al.* 2021). This animal showed signs of scarring believed to be the result of past entanglement in fishing gear.

Examination of the skeletons of NBM-MA-5671 (10.1) and 11490 (16.1) for healed fractures revealed a smooth bony callus surrounding a chronic malunion fracture and a fracture to a dorsal vertebral process of a thoracic vertebra in NBM-MA-11490, but no evidence of fractures in NBM-MA-5671.

Sowerby's Beaked Whale

Many of the 33 eastern Canadian stranding incidents involving 36 Sowerby's Beaked Whales are reported from eastern NF (33.1 to 65.1; 17 incidents involving 21 animals); others have been reported from QC and the Maritime provinces, including Sable Island (Figure 1b). Incidents from near North Rustico, Queens County, PEI (54.1) and near Campbellton (Richardsville), Restigouche County, NB (59.1) are the first confirmations for Sowerby's Beaked Whale for these provinces. A Sowerby's Beaked Whale found dead at Seal Cove Conception Bay, NF, 9 June 1990 (43.1) is reported in the literature (see

FIGURE 3. Images confirming the identity of ziphiid whale stranding incidents from the inshore waters of eastern Canada, 1934–2021. Dates given are stranding dates, not necessarily dates images were taken, and stranding incidents are as identified in Table 1. **Northern Bottlenose Whale (*Hyperoodon ampullatus*). 1.** Sept Illes, Quebec [QC], 8 September 1997 (Table 1: 13.1). Photo: J.-P. Sylvestre. **2.** Fortune Bay, Newfoundland [NF], 22 July 2004 (Table 1: 15.10). Photo: unknown/WR&S [Whale Release & Strandings Group]. **3.** Culls Harbour, Samson Point, NF, 6 August 2004 (Table 1: 16.2). Photo: W. Ledwell/WR&S. **4.** Golden Bay, Cape St. Mary's, NF, 19 March 2007 (Table 1: 18.2). Photo: T. Power. **5.** Milltown-Head, Bay d'Espoir, NF, 6 May 2007 (Table 1: 19.1). Photo: W. Ledwell/WR&S. **6.** Lawn, Burin Peninsula, NF, 26 June 2007 (Table 1: 20.1). Photo: W. Ledwell/WR&S. Figure continued on the next page.

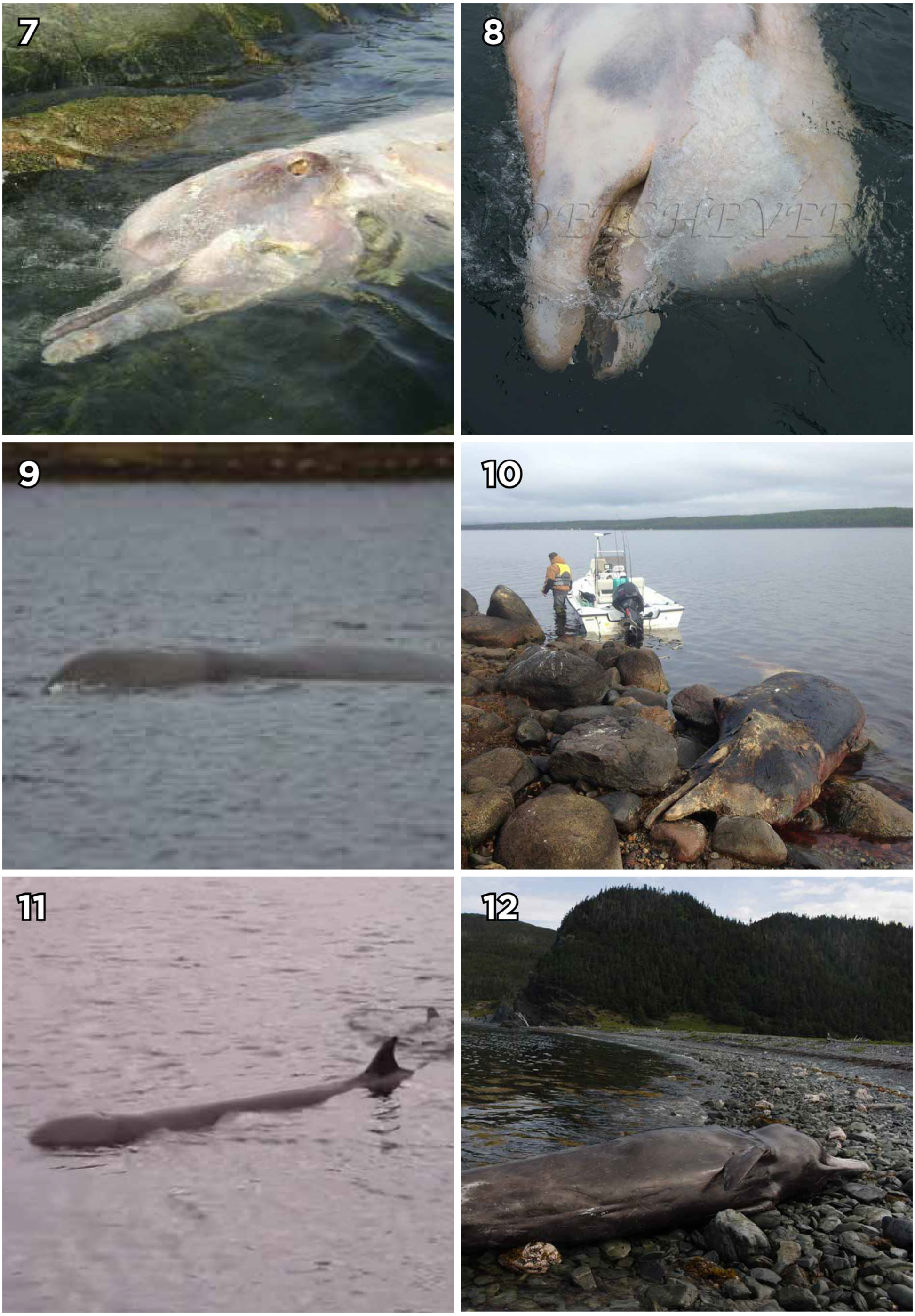

Figure 3. *Continued*. **Northern Bottlenose Whale (*Hyperoodon ampullatus*). 7.** Ellen Island, Hopedale, Labrador [NL], 6 September 2008 (Table 1: 21.1). Photo: F.P. Boase. **8.** W of Lamaline, NF, 7 June 2011 (Table 1: 22.1). Photo: G. Detcheverry. **9.** Prospect-Spry Bay, Nova Scotia [NS], 6–8 October 2013 (Table 1: 24.1). Photo: MARS [Marine Animal Response Society]. **10.** Stephenville Crossing, NF, ~12 June 2014 (Table 1: 25.1). Photo: Perry Bennett/Department of Fisheries and Oceans Canada [DFO]. **11.** Leamington, NF, 2 September 2016 (Table 1: 26.1). Photo: unknown/WR&S. **12.** Harbour Mille, Fortune Bay, NF, 24 July 2019 (Table 1: 27.1). Photo: W. Ledwell/WR&S.

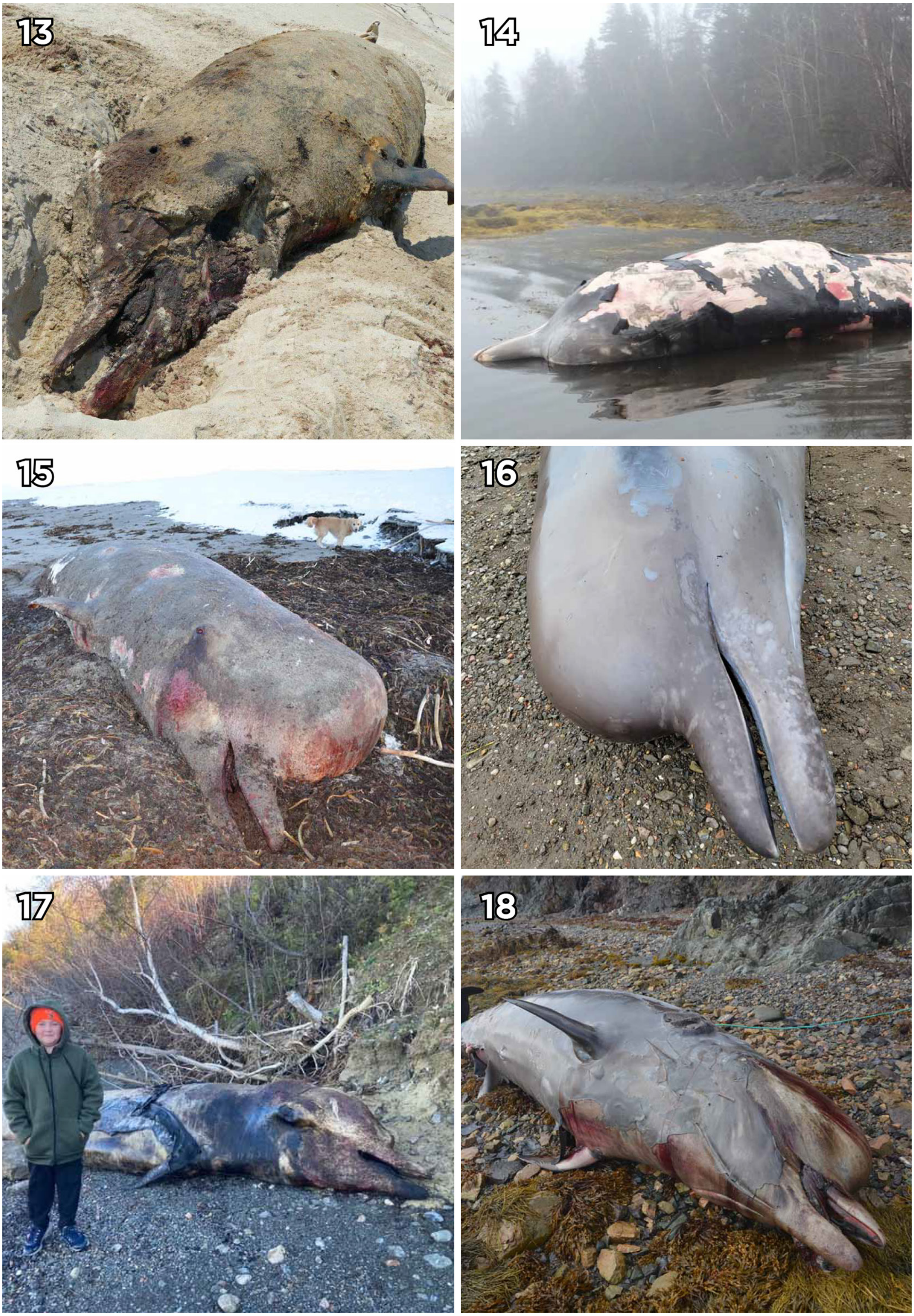

FIGURE 3. *Continued*. **Northern Bottlenose Whale (*Hyperoodon ampullatus*). 13.** Sable Island, NS, ~15 March 2021 (Table 1: 28.1). Photo: Z.N. Lucas. **14.** Boyd's Cove, NF, 16 February 2021 (Table 1: 29.1). Photo: W. Ledwell/WR&S. **15.** Musgrave Harbour, NF, 9 March 2021 (Table 1: 30.1). Photo: W. Ledwell/WR&S. **16.** Point-à-la-Croix, QC, 30 September 2021 (Table 1: 31.1). Photo: A. François. **17.** Point-à-la-Croix, QC/New Brunswick [NB], 30 September 2021 (Table 1: 31.2). Photo: M. Guitard. **18.** Mortier Bay, Marystown, NFL, 1 October 2021 (Table 1: 32.1). Photo: W. Ledwell/ WR&S.

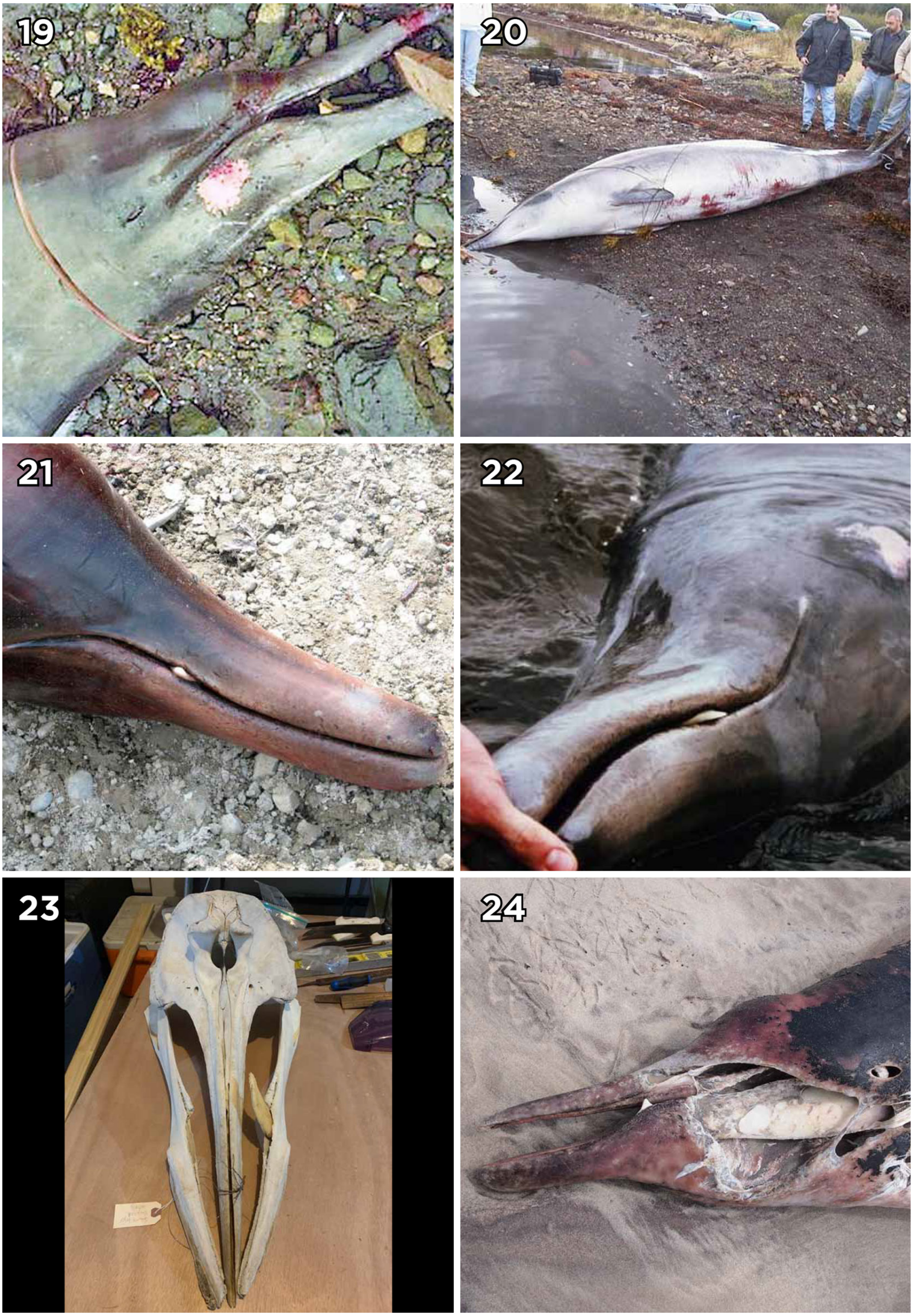

FIGURE 3. *Continued*. **Sowerby's Beaked Whale (*Mesoplodon bidens*). 19.** Robert's Arm, NL, 23 August 1995 (Table 1: 44.1). Photo: unknown/J. Maunder. **20.** Boyd's Cove, Notre Dame Bay, NF, 7–8 October 2001 (Table 1: 47.1). Photo: unknown. **21.** Forillion National Park, QC, 22 June 2006 (Table 1: 49.1). Photo: D. Boily. **22.** Penouille, QC, 29 June 2006 (Table 1: 50.1). Photo: Maurice Lamontagne Institute. **23.** Harcourt, Trinity Bay, NF, 22 May 2008 (Table 1: 52.1). Photo: unknown/WR&S. **24.** South Beach, Sable Island, NS, 3 June 2011 (Table 1: 53.1). Photo: Z.N. Lucas.

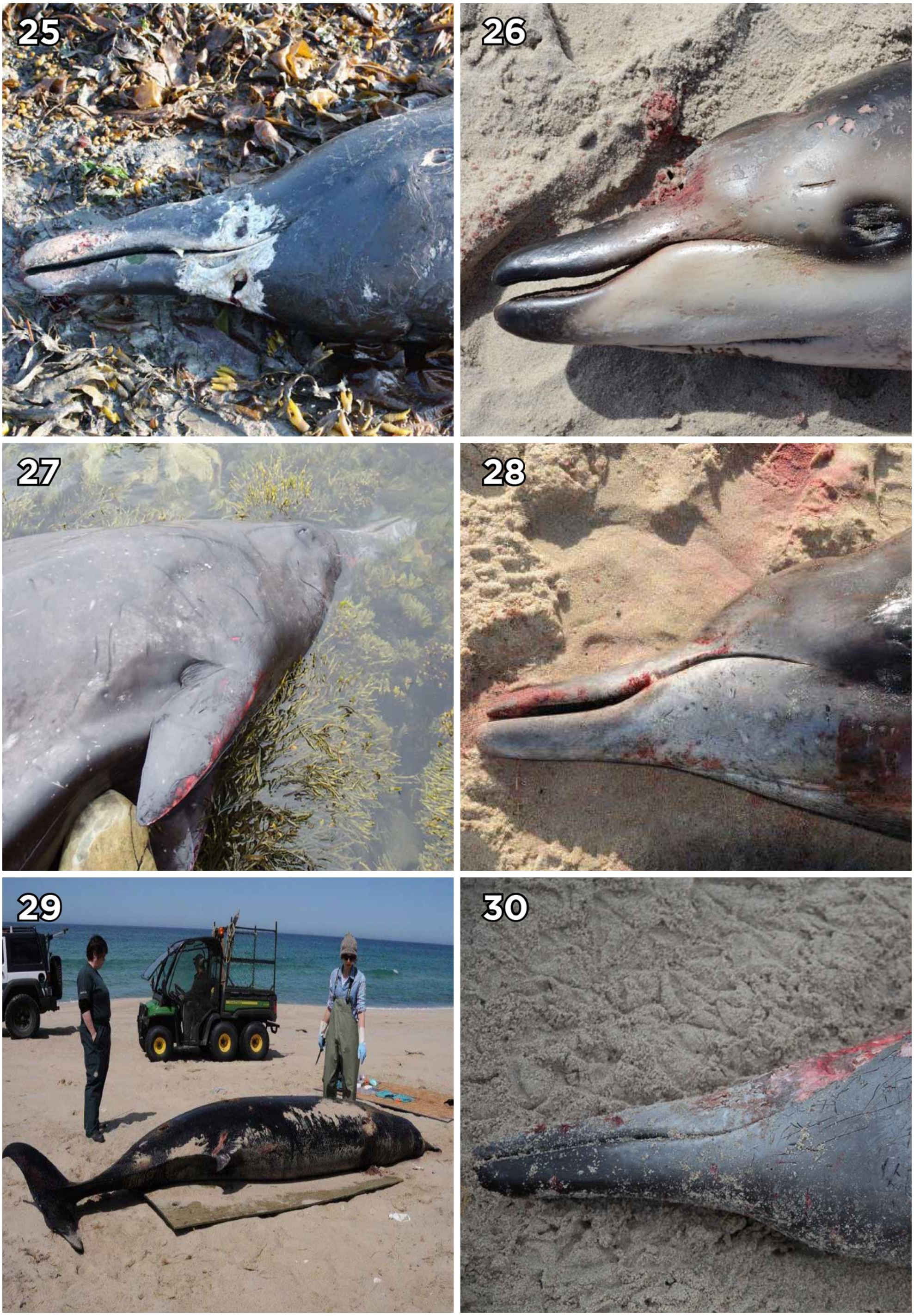

FIGURE 3. *Continued*. **Sowerby's Beaked Whale (*Mesoplodon bidens*). 25.** Îles aux Pommes, QC, 3 July 2013 (Table 1: 55.1). Photo: S. Lair. **26.** South Beach, Sable Island, NS, 17 June 2014 (Table 1: 56.1). Photo: Z.N. Lucas. **27.** Fogo, Fogo Island, NF, 21 July 2015 (Table 1: 57.1). Photo: unknown/WR&S. **28.** Sable Island, NS, 6 April 2017 (Table 1: 61.1). Photo: G. Stroud. **29.** Sable Island, NS, 13 May 2017 (Table 1: 62.1). Photo: G. Stroud. **30.** Sable Island, NS, 12 January 2018 (Table 1: 63.1). Photo: D. Lidgard.

Figure 3. *Continued*. **Sowerby's Beaked Whale (*Mesoplodon bidens*). 31.** Rivière-au-Tonnerre, Côte Nord, QC, 17 September 2018 (Table 1: 64.1). Photo: S. Pagès. **32.** Notre-Dame-des-Sept-Douleurs (Bout-d'en-Haut), QC, 26 August 2019 (Table 1: 65.1). Photo: L. Newbury. **True's Beaked Whale (*Mesoplodo mirus*). 33.** Saint-Thomas-de-Kent, NB, 28 September 1993 (Table 1: 71.1). Photo: B. Boulianne. **34.** Point Lance, NF, 7 February 2015 (Table 1: 72.1). Photo: DFO. **35.** Pointe-aux-Loups, Iles de la Madeleine, QC, 13 October 2017 (Table 1: 73.1). Photo: C. Bourque. **Cuvier's Beaked Whale (*Ziphius cavirostris*). 36.** Lumsden, NF, 24 July 2018 (Table 1: 76.1). Photo: unknown/WR&S.

Sources in Table 1) as female. However, the stated sex of this animal is in error. The skull, now housed in The Rooms Corporation of Newfoundland and Labrador, is male, and correspondence from the Lien Lab to then Newfoundland Museum curator John Maunder (N. Dejan-Chekar/J. Maunder pers. comm. to D.F.M. 22 February 2022) identifies the stranding as that of a male. We have recorded the sex as male (Table 1: 43.1).

Seasonality—Strandings of Sowerby's Beaked Whale have occurred almost exclusively April through October (97.2% of individuals) with only a single stranding outside this period, in January. There is a preponderance of strandings from June through September (77.8% of individuals).

Age and sex—Among 28 animals of known sex *and* total length, there are 17 males (60.7%) and 11 females (39.2%), of which 58.8% and 54.5%, respectively, are judged to be sexually immature.

Cause of death—Six of 35 Sowerby's Beaked Whale stranded in eastern Canada have been subjected to veterinary necropsies. Five of these animals were judged to be in good nutritional condition (54.1, 55.1, 59.1, 61.1, and 62.1), while one, a mature female (60.1), was reported to be in moderate nutritional condition. The final diagnosis for this latter animal included pneumonia and acute trauma (fracture of the caudal region of both jaws). The degree of inflammation of the right lung suggested that the pneumonia may have pre-dated stranding. Cause of death for the remaining veterinary necropsies of Sowerby's Beaked Whale have been reported as undetermined. Incidents 37.1 to 37.4; 38.1 and 39.1; and 40.1, 41.1, and 42.1 are here reported as three atypical mass strandings events (originally reported as mass strandings by Lien *et al.* 1990a) that occurred in eastern NF in August 1986 and September 1987. While it is not known why these whales were in nearshore waters, the steeply sloped and highly indented NF shoreline may have confused these normally deep water animals and been the primary cause of their stranding. However, it is noteworthy that the animals of incidents 37.1 to 37.4, 38.1, and 39.1 were reported to move erratically, one of them colliding repeatedly with a wharf and the hull of a moored ship in the days prior to stranding. Unfortunately, the animals did not undergo veterinary necropsies and no cause of death could be determined.

For two Sowerby's Beaked Whale that underwent veterinary necropsies, computed tomographic (54.1, from the Gulf) and magnetic resonance imagery (62.1, from Sable Island) of the auditory bullae showed no evidence of fractures or intracranial haemorrhage that might be associated with exposure to high amplitude underwater noise.

Entrapment in fishing gear has been reported for one Sowerby's Beaked Whale (36.1) and a second animal showed signs of entanglement (51.1, not a veterinary necropsy). Although a Sowerby's Beaked Whale that stranded in Conception Bay, NF (48.1) showed no external evidence of trauma, a non-veterinary necropsy suggested that fractures to the right jaw, five ribs, and the rostrum, as well as internal haemorrhaging prior to death, indicated a ship strike. A non-veterinary necropsy of a fresh carcass stranded at Trinity Bay, NF (52.1), found no evidence of entanglement in fishing gear or trauma and cause of death was undetermined. A non-veterinary necropsy reported a plastic bottle cap in the gut of a Sowerby's Beaked Whale that live-stranded at Fogo Island, NF (57.1). A veterinary necropsy of a Sowerby's Beaked Whale (54.1) detected previous fractures of two right ribs and possibly the dorsal processes of three thoracic vertebrae. This was confirmed during examination of the skeleton of NBM MA-12438 (54.1; Figure 4a). Skeletons NBM MA-16530 (59.1), 16536 (60.1), and 18143 (61.1) showed no evidence of fractures.

Blainville's Beaked Whale

Four incidents, one animal per incident, have been reported since 1934 (Table 1: 66.1 to 69.1), none of which have occurred in the Gulf of St. Lawrence

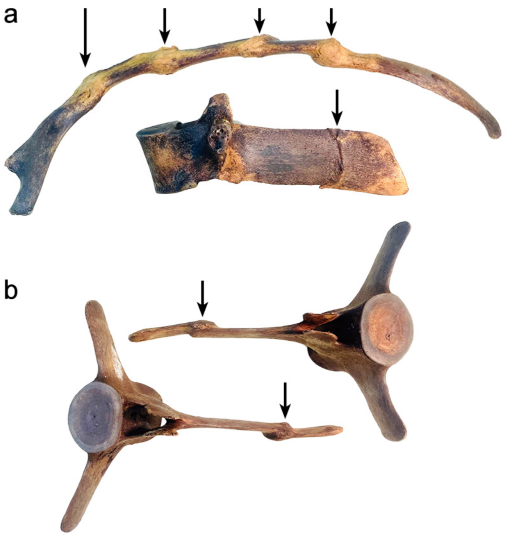

FIGURE 4. Healed skeletal fractures in ziphiid whales stranded in eastern Canada, possibly the result of past vessel collisions. Arrows mark fracture sites. a. Sowerby's Beaked Whale (*Mesoplodon bidens*) NBM- MA-12438 (see Table 1: 54.1), showing a fractured and healed rib and a healed fracture of the dorsal process of a thoracic vertebra. b. Cuvier's Beaked Whale (*Ziphius cavirostris*), NBM-MA-16513 (see Table 1: 75.1), showing healed fractures of the dorsal processes of two thoracic vertebrae. Photos: D.F. McAlpine.

(Figure 1c). The tooth and part of the left mandible were collected from the Forchu Bay, NS, animal (68.1); the tooth is illustrated in Sergeant *et al.* (1970). Efforts to locate these samples have been unsuccessful. The reported length for the animal is estimated at 18–20 feet (5–5.6 m), but this is certainly an overestimate because this exceeds the published maximum length of 4.7 m (Pitman 2018). Although we have reported length for this whale as unknown (Table 1), it is clear that this was an adult.

Seasonality—There are four eastern Canadian stranding incidents, including a "capture" and one animal shot, all during the winter months from November to February.

Age and sex—The three males and one female are believed to be adults. The reported total length for three of the animals ranged from 4.39 to 4.6 m.

Cause of death—The 1940 record from Peggy's Cove, NS (67.1), is one of four beaked whales reported here that were intentionally killed in inshore waters, rather than found stranded. This animal was shipped frozen and whole to the American Museum of Natural History where it was dismembered. The animal was reported as "old" and extremely thin. None of the remaining three Blainville's Beaked Whale involved in the eastern Canadian stranding incidents (66.1, 68.1, and 69.1) was necropsied, so cause of death is unknown.

True's Beaked Whale

Only four incidents involving five True's Beaked Whale (four females, one intersex) have occurred in eastern Canada up to December 2021 (Figure 1d, Table 1: 70.1 to 73.2). One incident (73.1, 73.2), involving an adult female and an intersex juvenile, occurred on Iles de la Madeleine in the Gulf of St. Lawrence in 2017. A ziphiid stranded at Saint-Thomas-de-Kent, NB, in the Gulf of St. Lawrence, 28 September 1993 (71.1) was originally reported as a Sowerby's Beaked Whale. Unfortunately, this animal was buried before it could be conclusively identified and is documented only on the basis of photographs now on file with the NBM (Figure 3.33). On the basis of head shape, jaw line, and distinctive light colouration, we now believe this animal to be True's Beaked Whale and provisionally report this specimen here as such, the only record for this species from the NB coast. Subsequently, a 1023 kg female True's Beaked Whale dead stranded at Point Lance, NF, on 7 February 2015 (72.1; Figure 3.34). A veterinary necropsy determined the animal had a postpartum uterus and was lactating. A *Mesoplodon* sp., assumed to be the same individual, was reportedly seen in the area, with what is presumed to be a calf, several weeks earlier.

Seasonality—Strandings have occurred from late summer (August) through the autumn (September–October) to winter (February), but there are too few records to determine if the lack of spring or summer strandings is meaningful.

Age and sex—Five individuals, include four adults/juveniles of 4.6–5.2 m total length and an intersex calf of 2.7 m.

Cause of death—The previous most northerly record for the western North Atlantic for True's Beaked Whale was an animal purposely killed in Saint Anne's Bay, Cape Breton, NS, in 1938 (70.1). The only eastern Canadian veterinary necropsy undertaken on this species, the animal discovered on the shore at Point Lance, NF (72.1), found evidence of a possible ship strike (ribs broken prior to death).

Cuvier's Beaked Whale

The four eastern Canadian records for this species have all occurred since 2000 (Figure 1e, Table 1: 74.1 to 77.1). A 5.6 m female that stranded 3 May 2000 on Sable Island, NS, is the first eastern Canadian stranding for the species (74.1). A 4.85 m live-stranded male near Blandford, NS, on 7 February 2016 (75.1) is the first mainland eastern Canadian stranding.

Seasonality—Two of the four eastern Canadian strandings occurred in winter (February, December), one in spring (May), and one in summer (July), too few to indicate any seasonality.

Sex and age—Strandings comprise two males and two females, ranging in length from 4.85 to 6.67 m. The shortest eastern Canadian animal (75.1), a male, was identified at veterinary necropsy as immature based on total length. This is supported by a testis length in this animal of 12.5 cm, which is much shorter than the few testes lengths reported for mature animals (Heyning 1989). The other three eastern Canadian strandings are considered adult based on total length. Unfortunately, no eastern Canadian females have been necropsied.

Cause of death—There have been two veterinary necropsies of eastern Canadian strandings of this species (75.1 and 77.1). Both animals were determined to be in good nutritional condition. Both also showed evidence of severe arterial sclerosis, a condition in Cuvier's Beaked Whale associated with infection with the renal parasite *Crassicauda* sp.; however, in neither of the eastern Canadian animals was the parasite judged to be the cause of death. Cause of death in both animals was undetermined, although one (77.1) showed significant trauma to the head, suggesting a possible ship strike. Examination of the skeletons of NBM MA-16513 (75.1) and 18233 (77.1) showed healed fractures of the dorsal processes of two thoracic vertebrae in NBM MA-16513 (Figure 4b), but no evidence of fractures in NBM MA-18233.

Discussion

As one of the least known cetacean families, understanding the biology and ecology of ziphiid species is fundamental to ensuring their protection, particularly from human-caused disturbance, harm, and mortality (Hooker *et al.* 2019). In eastern Canada, much of what is known about ziphiid whales comes from investigations of stranding incidents involving dead or distressed animals. The only exceptions are the well-studied Northern Bottlenose Whale population occupying the Scotian Shelf (Wimmer and Whitehead 2004; Dalebout *et al.* 2006; Whitehead and Hooker 2012; O'Brien and Whitehead 2013; Feyrer 2021) and those ziphiids monitored via acoustic means (e.g., Stanistreet *et al.* 2017; Delarue *et al.* 2018) in the region.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has assessed the Scotian Shelf population of Northern Bottlenose Whale as Endangered (COSEWIC 2011) and the species is listed as such under the Canadian *Species at Risk Act* (SARA; SARA Registry 2023a). The population, estimated at 174 individuals (Feyrer 2021), is considered to have a limited geographic range (Wimmer and Whitehead 2004; Dalebout *et al.* 2006) and is genetically distinct from the more northern Davis Strait-Baffin Bay-Labrador Shelf population (Feyrer *et al.* 2019). However, the boundary between these two populations is not well understood, especially as sightings are nearly continuous along the continental shelf from the Scotian Shelf to NL (COSEWIC 2011). The Davis Strait-Baffin Bay-Labrador Shelf population was assessed as Special Concern by COSEWIC (2011) but is not listed under SARA (SARA Registry 2023b). Recently, a concentration of bottlenose whales was discovered off eastern NF (Feyrer *et al.* 2019). Efforts should be made to sample future eastern Canadian strandings of this species for genetic analysis to confirm the source of stranded animals.

Northern Bottlenose Whale and Sowerby's Beaked Whale have been documented visually and acoustically in the deeper waters along the continental shelf and shelf break off NS, around the Grand Banks to northern NF and, in the case of Northern Bottlenose Whale, also into Davis Strait and Baffin Bay (MacLeod 2000, 2006; Whitehead and Hooker 2012; O'Brien and Whitehead 2013; Whitehead 2013; Stanistreet *et al.* 2017; Delarue *et al.* 2018; COSEWIC 2019). Not surprisingly, these two species comprise more than 80% of all individual ziphiids reported stranded from eastern Canada to date.

Sowerby's Beaked Whale was first designated Special Concern by COSEWIC in 1989 (COSEWIC 2019) and in 2011 was listed as Special Concern under SARA (SARA Registry 2023c). Since about 2000, there has been a dramatic increase in the number of sightings of Sowerby's Beaked Whale in The Gully Marine Protected Area and associated canyons at the edge of the Scotian Shelf (Whitehead 2013). Although the occurrence of these species in the region should not be considered unusual, their occurrence in nearshore waters, particularly in the Gulf of St. Lawrence, is certainly atypical behaviour, considering their dependence on deep water habitat.

Blainville's Beaked Whale and True's Beaked Whale appear to reach their northern range limit in the western North Atlantic (MacLeod 2000, 2006), which would account for apparent rarity in our study area. Both species have been assessed as Not at Risk in Canada by COSEWIC (SARA Registry 2023d,e) but these assessments (Houston 1990a,b) are now more than three decades old. Virtually nothing is known about the natural history of True's Beaked Whale. The species was believed to also be present in the southern hemisphere until Carroll *et al.* (2021) identified that population as a distinct species. All eastern Canadian strandings of True's Beaked Whale have occurred north and northeast of the few identified acoustic detections for this species that were recorded with a ship-towed hydrophone array off George's Bank (DeAngelis *et al.* 2018). Due to overlap in acoustic properties with Gervais Beaked Whale, published studies have yet to evaluate the presence of True's Beaked Whale in Canadian waters (e.g., Martin *et al.* 2017; Stanistreet *et al.* 2017).

Although stranding incidents involving Cuvier's Beaked Whale in the region are rare, acoustic monitors have detected the low, but consistent, presence of Cuvier's Beaked Whale in the deeper waters of the Gully Marine Protected Area, off NS, during 2012–2016 (Martin *et al.* 2017; Stanistreet *et al.* 2017), along the Scotian Shelf, the Grand Banks, and off eastern NF (Delarue *et al.* 2018). As few Cuvier's Beaked Whale have been observed along the Scotian Shelf (Whitehead 2013), Stanistreet *et al.* (2017) suggested the species may not have been historically present in the Gully and that recent acoustic data may reflect a trend towards increasing presence of this elusive and vessel-shy species in this habitat. Cuvier's Beaked Whale was assessed as Not at Risk in Canada by COSEWIC in 1990 (SARA Registry 2023f) but this was prior to the presence of any Atlantic Canadian reports for the species, all of which have occurred since 2000. Currently Cuvier's Beaked Whale is a mid-priority candidate for reassessment (COSEWIC 2024). In Canada, strandings for Cuvier`s Beaked Whale are far more frequent on the Pacific coast than the Atlantic (MacLeod *et al.* 2006; Naughton 2012).

Records suggest that prior to about 2005 ziphiid stranding incidents in eastern Canada occurred primarily in eastern NF and most frequently involved Sowerby's Beaked Whale. However, consistent response networks and reporting hotlines for QC and the Maritime provinces were not in place until the early 2000s, unlike NF & NL, where the late Jon Lien began attending cetacean entrapments in fixed fishing gear and strandings in the late 1970s (Lien 1994). Thus, early patterns are likely biased by uneven reporting effort. Wimmer and Maclean (2021) also show an upward trend between 2004 and 2019 for all cetacean stranding events in eastern Canada, including more frequent ziphiid reports, coincident with the establishment of regional marine mammal reporting hotlines and increased monitoring associated with North Atlantic Right Whale (*Eubalaena glacialis*) protection efforts by the Canadian government since 2017. Coombs *et al.* (2019) have likewise reported a dramatic increase in cetacean strandings along the United Kingdom coastline that correlates with the establishment of stranding networks since the 1980s.

Truchon *et al.* (2013) concluded that marine mammal stranding incidents in QC waters of the northern Gulf of St. Lawrence have increased since 1994, with higher frequencies of strandings of rare cetacean species correlated with positive North Atlantic Oscillation indices. Low ice volume in the Gulf was also correlated with an increased frequency of stranding incidents. Coombs *et al.* (2019) analyzed the large (n = 17 491), long-term (1913–2015) record of cetacean strandings for the United Kingdom but were unable to find any correlation between the numbers of cetacean strandings and potential environmental factors (including the North Atlantic Oscillation) and anthropogenic predictors. Coombs *et al.* (2019) did identify hotspots for strandings and attributed these to ocean currents transporting carcasses and regional areas of high cetacean diversity. The adjacency of deep waters and populations of Northern Bottlenose Whale and Sowerby's Beaked Whale to the eastern NF shoreline is probably a factor in the prevalence of strandings in this region for these species.

Dix *et al.* (1986) and Lien and Barry (1990) considered the contention of Sergeant and Fisher (1957) that the inshore occurrence of Sowerby's Beaked Whale was associated with an abundance of squid, but discounted this, noting that NF strandings for Sowerby's Beaked Whale were sometimes associated with years of low squid abundance. Whitehead and Hooker (2012) reviewed suggestions that Northern Bottlenose Whale may migrate, which could influence the timing of stranding incidents in eastern Canada. They concluded that the Scotian Shelf population of Northern Bottlenose Whale, and likely the Baffin-Labrador population, were both resident. Although there is evidence of migration within several species of ziphiids (Pitman 2018; Savage *et al.* 2021), knowledge about migration within ziphiid species is limited (MacLeod 2014).

While there has been an apparent increase in ziphiid stranding incidents in the Gulf of St. Lawrence since 2000 (62.5% of Gulf stranding incidents reported here), it is unclear how much of this increase may be the result of improved reporting, rather than the environmental changes referred to by Truchon *et al.* (2013), changes in distribution (e.g., Cuvier's Beaked Whale; Stanistreet *et al.* 2017), population growth (Sowerby's Beaked Whale; Whitehead 2013), or increased direct or indirect interactions with human activities. In summary, what prompts ziphiids to enter the inshore waters of eastern Canada remains unclear.

Potential causes of ziphiid mortality in eastern Canada

Underwater noise—One of the most widely recognized threats to beaked whales may be impacts from anthropogenic underwater noise, particularly seismic surveys and naval sonar (Miller *et al.* 2015; Bernaldo de Quirós *et al.* 2019; Hooker *et al.* 2019; Wensveen *et al.* 2019). Bernaldo de Quirós *et al.* (2019) note the rarity of global mass stranding events of beaked whales prior to the 1960s and the apparent association of such events with the introduction of naval mid-frequency active sonar since then. Most of these events have involved Cuvier's Beaked Whale (Bernaldo de Quiros *et al.* 2019), although this threat is considered to be potentially significant for Northern Bottlenose Whale and Sowerby's Beaked Whale in Canadian waters (DFO 2016, 2017a,b). Anthropogenic noise is also believed to have a greater detrimental impact on immature ziphiids (Cox *et al.* 2006). Arbelo *et al.* (2013) identified atypical mass strandings linked to naval exercises in 48.1% of ziphiid mortality incidents in the Canary Islands from 1999 to 2005.

Strandings (both live and dead) associated with noise exposure are believed to result more frequently from behavioural disturbance responses than from direct acoustic trauma. As a result, at necropsy there may be no physical evidence of noise exposure (Cox *et al.* 2006; Tyack *et al.* 2006). It should be noted that the ability to determine impacts of anthropogenic noise requires that any carcasses examined be fresh (Bernaldo de Quirós *et al.* 2019). It is therefore important not to underestimate the various sub-lethal impacts to cetaceans that may arise from exposure to noise pollution (Wright *et al.* 2011; Miller *et al.* 2015; Wensveen *et al.* 2019). Soto *et al.* (2006) provided circumstantial evidence that the noise of motorized commercial ship traffic may mask echolocation and communication in Cuvier's Beaked Whale and also disrupt foraging in this species. Stanistreet *et al.* (2022) monitored sonar signals from beaked whales before and after a 2016 naval exercise off Canada's east coast and found a significant reduction in echolocation clicks for Cuvier's Beaked Whale and the total absence of clicks for an unidentified mesoplodont. They concluded that beaked whales avoided and ceased foraging in the area. Behavioural changes may result in animals moving to unfamiliar or unsuitable habitat (e.g., the Gulf of St. Lawrence), where they may be exposed to additional threats (e.g., Wright *et al.* 2013; Davies and Brillant 2019) that can include vessel strikes and entanglement in fishing gear. Non-lethal, behavioural impacts may also result in prolonged stress (measured via the examination of stress-related hormones; Rolland *et al.* 2012), as well as long-term impacts on health, reproductive success, and longevity. Unfortunately, the sub-lethal impacts of noise pollution, including those from pervasive, chronic sources, such as marine traffic, have not been well documented or studied in ziphiids, either in eastern Canada or elsewhere. This highlights the importance of conducting professional necropsies, including examination for the pathologies associated with behaviourally induced decompression sickness and gas and fat embolic syndrome (Bernaldo de Quirós *et al.* 2011, 2019). Simonis *et al.* (2020) recommend improved coastline monitoring for stranded cetaceans before, during, and following naval exercises which suggests a possible role for stranding networks. Given the location for the atypical mass stranding incidents of Sowerby's Beaked Whale included here (facing the open Atlantic), and the associated puzzling behavioural observations, mid-frequency sonar as a possible catalyst for these (or any other) ziphiid strandings should not be discounted.

Interactions with commercial fishing gear—This remains one of the most pressing conservation issues facing cetaceans globally (Read *et al.* 2006; Lewison *et al.* 2014). Evidence includes live and dead animals entangled with fishing gear, those incidentally captured in stationary fishing structures, and animals possessing injuries and scars indicative of interactions with fishing gear. Unfortunately, ziphiids have not escaped the impacts of fishing activity. Ziphiids in eastern Canada having been reported entangled in fishing gear (DFO 2016, 2017b; COSEWIC 2019), and Waring *et al.* (2002) note that Sowerby's Beaked Whale is the most frequently recorded mesoplodont taken as bycatch in the east coast North American fishery. Feyrer *et al.* (2021) provide a summary of 66 ziphiid entanglements (mainly Northern Bottlenose Whale) in fishing gear reported from offshore in the Atlantic region since 1989. Evidence from research on live, free-swimming, cetaceans demonstrates that a substantially greater number of animals are interacting with fishing gear than those observed entangled or reported to incident hotlines as live or dead-stranded (Knowlton *et al.* 2012; Ramp *et al.* 2021). Although few studies exist on the impacts of fishing activities on free-swimming ziphiids, Hooker *et al.* (2019) and Feyrer *et al.* (2021) have suggested that scarring observed on Scotian Shelf Northern Bottlenose Whale from 1988 to 2019 is indicative of probable entanglement or propeller-vessel strikes. At minimum, scarring occurred on 6.6% of the Scotian Shelf Northern Bottlenose Whale population. Although we found few ziphiids stranded in eastern Canada were reported to show signs of interactions with fishing gear, most animals were not necropsied or even examined closely. Others were so badly decomposed that signs of interactions with fishing gear were likely difficult or impossible to detect.

As with ocean noise, there are also sub-lethal impacts arising from cetacean interactions with fishing activities. These include long-term effects on health, foraging ability, and reproductive capacity (Moore and van der Hoop 2012; van der Hoop *et al.* 2016; Rolland *et al.* 2017). Without further documentation and investigation, the full impact of fishing activity on eastern Canadian ziphiids will remain unknown.

Vessel strikes—Schoeman *et al.* (2020) reviewed the incidence and consequences of marine animal collisions with vessels, with a particular interest in mitigating vessel strikes of smaller cetacean species. While the extent of vessel collisions with small cetaceans is poorly known, there is clearly a reporting bias against small whales, in part perhaps because vessel operators may not even be aware such collisions have occurred. Although Schoeman *et al.* (2020: 5–6) report that the frequency of collisions with Cuvier's Beaked Whale can be "noticeable locally", for the eight other ziphiid species listed as struck by vessels (including Sowerby's Beaked Whale and True's Beaked Whale), such occurrences are reported as "rare". Schoeman *et al.* (2020) suggest that the criteria for identifying blunt force trauma (versus sharp force trauma) in small cetaceans may be lacking and cite a need for species-specific necropsy protocols that will allow the identification of collision-related blunt-force trauma. How practical this might be is unclear and the suggestion that veterinary pathologists are overlooking blunt force trauma as a cause of death in small cetaceans is arguable. Certainly, the Gulf of St. Lawrence, gateway to the Great Lakes, is one of the busiest coastal regions for vessel traffic in northeastern North America. Tracks for vessel density suggest that the lower St. Lawrence River estuary is likely to be a zone of relatively high risk for marine mammal vessel strikes, but there are clearly risks for any cetacean traversing any part of the Gulf

(Réseau d'observation de mammifères marins 2014), as well as at pinch points such as the Cabot Strait and Strait of Belle Isle. With more than 7000 commercial shipping voyages up the St. Lawrence River in 2018 (Laurentian Pilotage Authority 2019) and ~5000 fishing vessels active throughout the Gulf in that year (see https://dfo-mpo.gc.ca/stats/commercial/licences-permis/vess-embarc/ve18-eng.htm), the relative risk of small whale strikes would seem to be high.

Díaz-Delgado *et al.* (2018) identified anthropogenic, rather than natural, causes of death (foreign body associated pathology, vessel collision) for 44.4% of cases among 18 veterinary necropsies of ziphiids stranded in the Canary Islands 2006–2012. The authors were apparently able to distinguish both sharp and blunt force trauma. While vessel strikes are less likely to be a significant source of mortality for ziphiids in offshore waters, the importance of vessel strikes to beaked whales that may move to inshore areas off eastern Canada remains uncertain, largely due to the very limited number of veterinary necropsies of dead-stranded ziphiids undertaken to date. Although we found few ziphiids stranded in eastern Canada were *reported* to show signs of vessel strikes, very few animals underwent necropsy. Others were so badly decomposed as to obscure any obvious signs of interactions with vessels. Nonetheless, although our sample size of ziphiid skeletons is small ($n = 8$), it is noteworthy that at least 25% of the specimens available to us showed signs of healed fractures from previous blunt force trauma.

Marine debris and contaminants—Ingestion of marine debris and impacts from ocean contaminants are also of concern with respect to beaked whale mortality (Lusher *et al.* 2015; Baini *et al.* 2020). MacLeod (2018) noted that the ingestion of plastic debris may be a particular problem for beaked whales in specific regions where such debris is particularly common. With a diet predominantly of cephalopods (Hooker *et al.* 2001; Whitehead *et al.* 2003) and an intake mechanism referred to as "suction feeding", beaked whales may be prone to ingest micro- and macro-plastics (Lusher *et al.* 2015; Nelms *et al.* 2019; Zantis *et al.* 2020).

Information on contaminants in beaked whale species is limited, although Hooker *et al.* (2008) determined that levels measured in Scotian Shelf Northern Bottlenose Whale were not believed to be high enough to cause health problems. Nonetheless, contaminants have been identified as a serious issue for other cetaceans in the region (see Simond *et al.* 2020 and references cited therein) and at least one of the stranding mortalities we report here (7.1) may be associated with plastic ingestion (Béland 1987). Desforges *et al.* (2021) reported concentrations and patterns of persistent organic pollutants in Northern Bottlenose Whale from eastern Canada, including one animal stranded in NF (27.1). None of the whales sampled showed contaminant levels that exceed the established toxicity threshold for general immune or reproductive effects, and levels were generally lower than those reported for beaked whales in other parts of the world. However, most did show levels above a molecular toxicity threshold, suggesting effects at the molecular and cellular level. While individual ziphiids may face risks associated with marine debris and contaminants, more investigation is required as to the extent and impact of these potential sources of mortality. To date, few samples have been collected for contaminant analysis from ziphiids stranded in eastern Canada.

Emerging infectious diseases—Van Bressem *et al.* (2009) have reviewed the role of emerging infectious diseases in cetacean mortality, especially those coupled with anthropogenic environmental stressors. Although the authors note that those cetaceans resident inshore and in estuarine habitats are at greater risk than offshore species, the latter are not immune. Environmental pollution transported offshore from heavily polluted waterways (such as the St. Lawrence), heavy ship traffic, and offshore industrial activity may lead to stress and lowered immune response (Romano *et al.* 2004; Rolland *et al.* 2012). Cases of toxoplasmosis in cetaceans offshore have been linked to ship runoff or cases where rodents, cats, or contaminated soils are present on board (Van Bressem *et al.* 2009). Together Arbelo *et al.* (2013) and Diáz-Delgado *et al.* (2018) found 69.3% of 362 cetacean strandings in the Canary Islands 1999–2012 were attributed to natural pathologies. Although Díaz-Delgado *et al.* (2016) report that crassicaudiasis appears to be a leading natural cause of mortality in Cuvier's Beaked Whale in the Canary Islands Archipelago, this was not judged to be the cause of death for animals so infected in eastern Canada. Unfortunately, conclusively linking mortality from what may appear to be entirely natural pathologies to anthropogenic environmental stressors is hampered by a lack of base-line data on the incidence of disease in cetaceans.

Ziphiid strandings in eastern Canada and conservation research

Although the biology of the Scotian Shelf population of Northern Bottlenose Whale may be better known than that of any other ziphiid (e.g., Whitehead and Hooker 2012; Feyrer *et al.* 2020), there remains a scarcity of data regarding ziphiid species in general (Li and Rosso 2021). This includes four of the five species that have been recorded stranded in eastern Canada. Also, virtually nothing is known about the Davis Strait–Baffin Bay–Labrador Shelf population of Northern Bottlenose Whale (Feyrer *et al.* 2019). Although sources of potential mortality in eastern Canada noted above have been identified as of particular concern for ziphiid whales, much remains to be learned about the impact of ecosystem changes now underway and impending on these animals, particularly those associated with climate change. Meyer-Gutbrod *et al.* (2018) have commented on climate-mediated range shifts in marine mammals (with emphasis on North Atlantic Right Whale) and the need for expanded monitoring of cetaceans in the Gulf of St. Lawrence and elsewhere. MacLeod (2014) has noted that water temperature, for reasons that remain unclear, seems to play a significant role in determining distribution among beaked whales, suggesting that warming seas could have a significant impact on ziphiids. Deep water temperatures have been increasing overall, including in the Gulf of St. Lawrence (Galbraith *et al.* 2017), which may be responsible for changes in species observed and their perceived distributions.

Although passive acoustic monitoring and tagging technologies have started to help researchers better understand ziphiid biology and ecology (Schorr *et al.* 2014; Martin *et al.* 2017; Stanistreet *et al.* 2017), response to stranding incidents remains an important source of unique information for this group of marine mammals (e.g., Cook *et al.* 2006; Lusher *et al.* 2015; Einfeldt *et al.* 2019a,b) and is likely to remain so. MacLeod *et al.* (2006) identified the value of stranded carcasses and museum collections of ziphiid specimens as an important source of data for research. Smith *et al.* (2021) collated information from museum skeletal collections of Sowerby's Beaked Whales worldwide (including specimens reported here) to reveal new findings about the species. Unfortunately, only a minority (34.5%) of dead eastern Canadian ziphiids have had skeletons, tissue, parasites, stomach contents, or anatomical parts deposited in publicly accessible museum collections. Many institutions now maintain frozen tissue collections in support of genetic studies, which have demonstrated the potential to provide unique insights into ziphiid biology (e.g., Dalebout *et al.* 2008; Thompson *et al.* 2016). There is also a need to support expert examination, especially veterinary necropsies, of dead-stranded ziphiids (for that matter, all cetaceans) at every opportunity. Prior to the establishment of the CWHC partnership in 1992 and the establishment of formal stranding response networks in eastern Canada, the opportunities for such necropsies in the Maritimes were few. Most eastern Canadian ziphiid strandings have occurred on the island of Newfoundland. With a coastline of over 10 000 km, much of it dominated by cliffs and often without easy access to the shoreline, there are often considerable challenges in reaching cetacean strandings and conducting necropsies, whether veterinary or non-veterinary. Furthermore, a number of ziphiid strandings have occurred on Sable Island, which is 175 km offshore and not easily accessible. Support to enhance the monitoring, reporting, and necropsy of fresh beaked whale carcasses before, during, and after acoustic events involving military sonar or seismic testing should be made available so that such threats can be adequately assessed at every opportunity. As Wimmer and Maclean (2021) note, critical data are being lost because a consistent and coordinated approach to marine mammal incident response and health surveillance in Canada is lacking.

Data from non-veterinary necropsies was sometimes difficult to locate and access for our review, suggesting opportunity for better data handling. Stranding networks, which do the "heavy-lifting" in documenting marine mammal strandings in eastern Canada (e.g., operating hotlines, training and equipping responders, facilitating necropsies, collecting data and samples) are generally under-staffed, over-prescribed, and under-funded. Support for systematic and collaborative reporting, response, and handling of stranding data and samples are needed. This would enable networks to have the support to produce and publicly post annual reports and provide information on strandings and the results of investigations, including veterinary, and especially non-veterinary, necropsies. This would enhance transparency and help capture data that might otherwise be lost, particularly as several species are considered of conservation concern under Canadian law. There are several good models for annual reports which exist that could be adopted (e.g., Newfoundland Whale Release and Strandings Program annual reports: Ledwell *et al.* 2020; Scottish Marine Animal Stranding Scheme: Davison and ten Doeschate 2021).

Data derived from stranding incidents will be an important source of support for several of the research priorities for ziphiids outlined by Hooker *et al.* (2019), and can also inform federally mandated SARA recovery strategies, as well as action and management plans for those ziphiid species-at-risk (DFO 2016, 2017a,b). Collection of such data from eastern Canadian stranding incidents will help the Government of Canada meet its priorities related to understanding whale health, national, and international commitments for ensuring industry sustainability, the goal of reducing the incidence of human-caused harm and mortalities to cetaceans, and protecting biodiversity more generally. The ongoing documentation of eastern Canadian cetacean stranding incidents, but especially for species of conservation concern and those that reach their edge of range in the western North Atlantic, should remain a priority for those concerned with the management and conservation of cetaceans in the region.

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Writing – Original Draft: D.F.M. and T.W.; Writing – Review & Editing: All; Conceptualization: D.F.M., T.W., P.-Y.D., W.B., L.B., and W.L.; Visualization: D.F.M. and T.W.; Data Curation: W.L., G.A.R., T.W., J.W.L., S.L., Z.N.L., D.F.M., R.M., and W.B.; Investigation: D.F.M., P.-Y.D, L.B., W.L., T.W., G.A.R., J.W.L., Z.N.L., S.L., and A.F.; Funding Acquisition: D.F.M. and T.W.

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Note

An observation of incest avoidance in Gray Wolf (*Canis lupus*)

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Abstract

Free-ranging Gray Wolf (*Canis lupus*) tends to avoid inbreeding, but there is no information about how they manage this avoidance. Our observation of a female wolf in Yellowstone National Park actively rebuffing her father's sexual advances but then copulating with a distantly related male is the first and only report of one means by which wolf pack members avoid inbreeding.

Key words: Behaviour; *Canis lupus*; Gray Wolf; inbreeding avoidance; incest; reproduction; Yellowstone National Park

Free-ranging Gray Wolf (*Canis lupus*) tends to avoid inbreeding (Smith *et al.* 1997), although when the chances of such avoidance are low, such as in captivity (Packard *et al.* 1985) or on Isle Royale (Wayne *et al.* 1991), they will inbreed. Some work shows that avoidance occurs primarily within packs, but not necessarily outside the pack (Geffen *et al.* 2011). Generally, wolves avoid inbreeding by (1) not copulating with related pack members, (2) male-biased dispersal and copulating with non-relatives, and (3) female-biased subordinate breeding (vonHoldt *et al.* 2008). However, no information has been available about the specific mechanism or mechanisms that might facilitate the avoidance of inbreeding. Here we describe an instance of copulation avoidance between closely related members of the same pack even though both animals successfully copulated with unrelated pack members.

Several members of the Junction Butte Pack in Yellowstone National Park (YNP), Wyoming, USA, were radio-collared (Smith *et al.* 2015). R.M. located and observed these wolves and their packmates daily as often as possible for four years from the ground using binoculars and a 60× spotting scope during daylight (McIntyre 2019, 2020, 2021). A combination of radio frequency and/or natural body markings made each wolf individually identifiable. At the time of this observation, the pack consisted of 11 members, including five radio-collared adults (dominant female 970F, dominant male 911M, subordinate male 890M, and subordinate females 907F and 969F), as well as two other adults and four offspring from the previous year (Table 1). The genetic relatedness (vonHoldt *et al.* 2020) of the five collared wolves was as follows: (1) unrelated: 890M/907F, 970F/911M, and 890M/969F, (2) offspring/parent: 907F/911M and 969F/911M, (3) full sibling: 907F/969F, and (4) cousins or more distant: 890M/911M, 890M/970F, 907F/970F, and 969F/970F; Table 2).

Wolf 911M helped raise his daughter 907F to the end of the year, then dispersed but returned to the pack about a year later. Wolf 907F's mother, who was not collared, was observed copulating only with 911M the year 907F was born but could have copulated with others when not observed. Although we did not observe 890M provisioning 907F as a pup, he regularly attended the den and provisioned the pack, so there is every reason to believe that he did.

On 16 February 2016 between 0743 and 1646, R.M. made the following observations. Wolves 907F and 890M were seen in a copulatory tie at 0801 for several minutes but for an unknown total period. When canids copulate, they remain hooked together for varying periods in a "copulatory tie". Throughout the day, 907F and 969F repeatedly averted their tails to wolf 890M (unrelated or very distantly related to

Table 1. Status of adult radio-collared members of the Yellowstone National Park Junction Butte Pack of Gray Wolf (*Canis lupus*) in February 2016.*

Wolf no.†	Age, years	Rank	Relationships
890M	4 or 5	Subordinate	Immigrant
907F	3	Subordinate	Daughter of 911M and a non-collared female
911M	at least 5	Dominant	Immigrant father of 907F and 969F
969F	3	Subordinate	Daughter of 911M and a non-collared female
970F	at least 4	Dominant	Immigrant

*The pack also included two non-collared adults and four offspring from 2015.
†F = female, M = male.

Table 2. Pairwise relatedness matrix estimated from 598 single nucleotide polymorphism genotypes for five focal Gray Wolf (*Canis lupus*) in Yellowstone National Park.

	907F	911M	969F	970F
890M	0.001	0.114	0.033	0.025
907F		0.493	0.445	0.099
911M			0.482	0.000
969F				0.173

Source: vonHoldt *et al.* (2020).
Note: F = female, M = male.

those females), but never averted them to their father, 911M. Female tail aversion signals estrus and allows copulation (Concannon *et al.* 1977). Wolf 911M repeatedly tried to copulate with 907F, but 907F blocked each of his attempts, often by rolling over on her back. Male wolves cannot force copulation with female wolves; i.e., both wolves must be willing for a copulatory tie to be successful.

Once 911M bedded and appeared to give up trying to copulate with 907F, 907F went to 890M and, at 1605, they copulated and tied for 15 min. While they were tied, 911M still tried to mount 907F and even did some thrusting.

During these observations, dominant wolf 970F, considered the mate of 911M, several times averted her tail to 911M, but he ignored her. He was previously seen copulating with her on 8 and 10 February.

All three of these females denned in April, with 907F and 969F denning together and producing a total of at least nine pups. Both male wolves 911M and 890M attended the den and helped provision the pups. Wolf 970F denned away from the pack at a remote location and died of unknown cause(s) soon after the time when she should have borne pups; it was unknown whether she had produced any pups.

Most wolf packs include a pair of unrelated parents and their immature offspring; thus, within such groups, incest is not even possible. However, Yellowstone's Junction Butte pack included both related and unrelated mature individuals. This observation of both females 907F and 969F averting their tails and copulating with less-related wolf 890M but not their father, 911M, and 907F's rebuffing sexual advances by her father, is the first and only report of one of the possible ways in which wolf pack members avoid inbreeding. It also suggests the hypothesis that incest avoidance tends to be furthered by female wolves rather than males, as in non-human primates (Pusey 1990).

Author Contributions

Writing – Original Draft: L.D.M. and R.M.; Writing – Review & Editing: L.D.M. and R.M.; Conceptualization: L.D.M.; Investigation: R.M.; Methodology: R.M.; Formal Analysis: L.D.M. and R.M.

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Note

Himalayan Blackberry (*Rubus bifrons*) in eastern Canada: a timely discovery

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Abstract

Currently, the invasive Himalayan Blackberry (*Rubus bifrons* Vest) is sparsely distributed in eastern Canada and the northeastern United States, documented in Ontario, Quebec, and New England. In summer 2022, patches of this plant were found in Yarmouth, Nova Scotia, at the shrubby edges of gravel parking lots and in the town maintenance area. Of most concern is its occurrence along a former railway line that is now a trail system connecting many communities. In the fall and winter of 2022 established populations were noticed at three locations in Digby County, Nova Scotia, between 80 km and 100 km northeast of Yarmouth, where the evergreen thickets were noticeable from a distance. Climate warming and a variety of dispersal agents have likely contributed to the recent spread. Control is recommended to protect native biodiversity from this highly competitive invasive shrub.

Key words: Himalayan Blackberry; *Rubus bifrons*; invasive; dispersal; climate warming; control

Himalayan Blackberry (*Rubus bifrons* Vest; see discussion of taxonomy in Alice *et al.* 2014) is one of the world's most invasive species (Gaire *et al.* 2015). It is a naturalized scourge in southern Australia and in the Pacific Northwest because it forms 3-m tall impenetrable thickets composed of arching and tip-rooting stems that bear stout, lacerating thorns. It has been repeatedly introduced into new areas by humans because of its large crop of delicious fruit. Introduced plants have interbred to form new genetic combinations that include both sexual and mainly asexual entities (Clark *et al.* 2013). Currently, it is sparsely distributed in eastern Canada and the northeastern United States, documented in Ontario, Quebec (Brouillet *et al.* 2010; NatureServe 2023), Connecticut (Alice *et al.* 2014), Massachusetts, and Rhode Island (GoBotany 2023). Image-vouchered reports from iNaturalist (2022) reflect this distribution (Figure 1). Here we report several new occurrences of Himalayan Blackberry in southwest Nova Scotia.

In North America, Himalayan Blackberry is a cultivar derived in the 1890s in Oregon from European specimens of the microspecies *Rubus armeniacus* Focke (Clark *et al.* 2013; Griesman 2020). In Yarmouth, the most southerly location of the species in Nova Scotia (Figure 1), rooted canes from British Columbia were directly introduced to a private garden 30 years ago for fruit production (garden owner pers. comm. to N.H. 2022). In summer 2022, patches of the plant were found in Yarmouth at the shrubby edges of gravel parking lots, in the town maintenance area, and, of most concern, along a former railway line that is currently a trail system connecting many communities. At all of these sites, the blackberries grow in association with, or in close proximity to, one or more other exotic endozoochorous (dispersed by animals through ingestion) shrubs including Multiflora Rose (*Rosa multiflora* Thunberg), which has substantially increased in both rural and urban Nova Scotia over the past two decades (N.H. and S.B. pers. obs.); English Hawthorn (*Crataegus monogyna* Jacquin); and Rugosa Rose (*Rosa rugosa* Thunberg). The latter two species were noted as potential invasive problems in an assessment of eastern Canadian exotic vascular plants (Hill and Blaney 2009). The close association of the invasive blackberry with the exotic fleshy-fruited shrubs suggests that fruit-eating birds and mammals may be distributing a complex of exotic

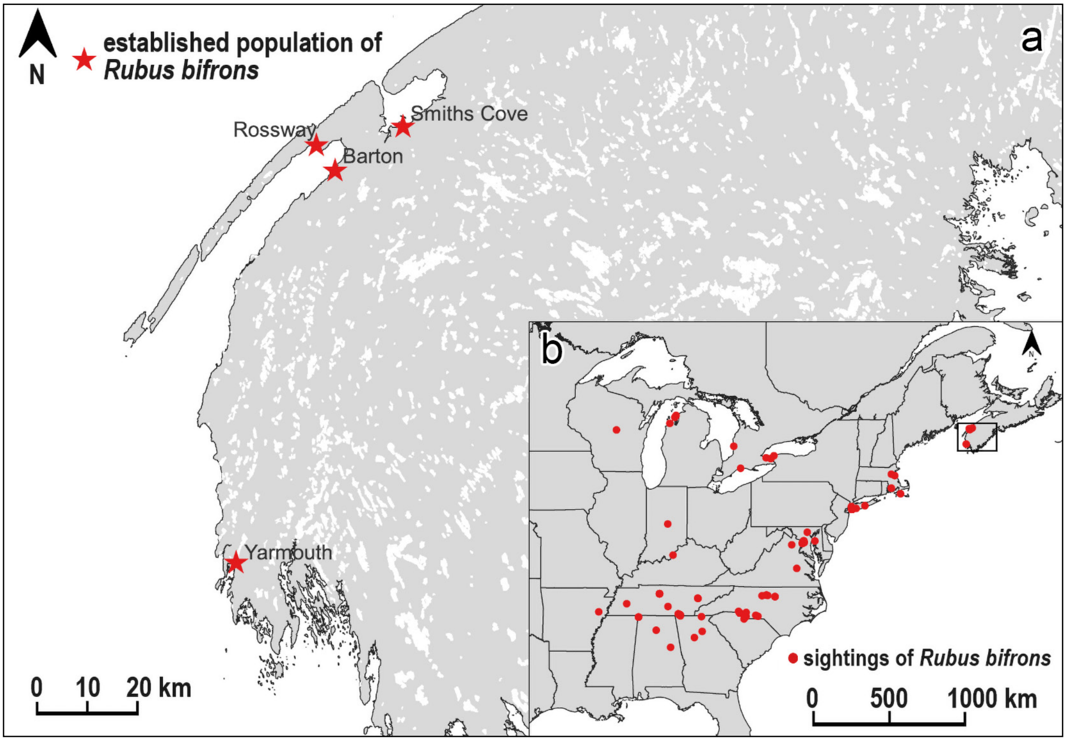

FIGURE 1. a. New Nova Scotian records for Himalayan Blackberry (*Rubus bifrons*) found over distances of 5.2 km along Highway 1 at Barton, 1.7 km along a rail trail at Smith's Cove, and 2.7 km along streets and rail trail at Yarmouth, Nova Scotia, Canada. The Rossway population consists of two patches separated by 100 m. b. Observations of Himalayan Blackberry from iNaturalist (2022) and N. Hill. Because the species is frequently misidentified on iNaturalist, mapped iNaturalist records include only author-verified "Research Grade" observations, reviewed in October 2022.

invasive shrubs. The pattern of spread of Himalayan Blackberry along the rail trail suggests that it is following the pattern of spread of Multiflora Rose; however, this hypothesis must be tested through field observation, e.g., by examining seed communities in scats.

The discovery of Himalayan Blackberry in Yarmouth was noted in the summer newsletter of the Southwest Nova Biosphere Reserve (Hill 2022). This alerted botanist Naomi Cappuccino, who found a 1.7-km long, linear population of the species along a former railway (now a rail trail) 96 km northeast of Yarmouth at Smith's Cove, Digby County, Nova Scotia in October 2022. It was then realized that evergreen thickets of Himalayan Blackberry were recognizable from the road and two other occurrences were identified in Digby County within 20 km of the first: an extensive population over 5.2 km of roadside at Barton, including some up to 86 m from the road in clearings and gardens; and a singular occurrence of two main patches 100 m apart at Rossway (Figure 1). The property owner at Rossway said that the blackberries had occupied a discrete area in the garden for ~30 years before they had started to spread in the last five years.

Himalayan Blackberry and Multiflora Rose smother lower, slower-growing vegetation and stems of both species can root at their tips when they arch over and contact the ground. Himalayan Blackberry differs from other tall, palmate-leaved *Rubus* species in Nova Scotia (e.g., Allegheny Blackberry [*Rubus alleghieniensis* Porter], Canada Blackberry [*Rubus canadensis* L.], and Pennsylvania Blackberry [*Rubus pensilvanicus* Poiret]) in maximum height (>2.5 m), canes rooting at their tips, and evergreen leaves. Himalayan Blackberry retained green leaves into early February in 2023 despite a severe cold snap (–22°C on 4 February, pers. obs. D.S.). In summer, the taxon is unique among Nova Scotian species of *Rubus* in having a dense white tomentum on the abaxial leaf surfaces and, usually, pink petals.

Where Himalayan Blackberry outcompetes native shrubs along river valleys, bank stability can be reduced as native, deeper-rooted plants are replaced (Gaire *et al.* 2015). Other corridors for exotic shrub migration include roadsides and reservoir shores (Hill and Blaney 2009).

Without effective control, this new invasive species will likely spread widely in Nova Scotia, aided by a warming winter climate (Garbary and Hill 2021). Southern Nova Scotia has the warmest winters in Atlantic Canada, and the nearby coastal region has warmed as much as 1.7°C since 1991, relative to the 1961–1990 average (Garbary and Hill 2021). Various dispersal agents, such as birds, wild mammals, and people (intentionally or otherwise by vehicles) as well as the availability of open habitat throughout the province, will contribute to rapid spread.

Mechanical removal of the thickets is possible, and their regrowth may be prevented by spot applications of herbicide (Soll 2004). We observed that landowners were in favour of eradicating the aggressive plant from their property, whereas community members valued the thickets for the abundant fruit production.

This is a timely discovery, because there is a very limited time window for effective control. Apart from its presence in urban waste areas, the plant is mostly found along roads (at Barton) and along rail trails (Yarmouth and Smith's Cove). Its evident ability to disperse along these linear corridors makes it a priority to control this spread and identify the mechanisms of dispersal (snowplows, birds, mammals, people, etc.). Failure to eradicate the invasion will result in expanded distribution and dominance of Himalayan Blackberry that could make removal virtually impossible and so limit the use of and access to recreation areas and reduce native biodiversity.

Voucher specimens

CANADA, NOVA SCOTIA: Yarmouth, on south side of Killam Shipping Building, 3-m tall canes, overgrowing a garden planting of *Rosa rugosa* and spreading throughout edges of parking lot, 43.8360°N, 66.1216°W, 25 August 2022, D. Sollows, C.W. O'Driscoll, K. Noel, P. Mills, S. Nickerson, and N. Hill, s.n. (ACAD ECS051004).

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Note

Red Squirrel (*Tamiasciurus hudsonicus*) feeding on Balsam Poplar (*Populus balsamifera*) galls induced by aphids

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Abstract

Red Squirrel (*Tamiasciurus hudsonicus*) specializes in feeding on conifer cone seeds but will feed opportunistically on a wide variety of other food items, including fungi, eggs, small vertebrates, and invertebrates. In much of their range, Red Squirrels experience fluctuations in the availability of their primary diet (conifer seeds) seasonally and annually because of variation in seed production. We document a seemingly uncommon or unreported feeding behaviour by a Red Squirrel in a year of an exceedingly low conifer cone production in Yukon, Canada: a squirrel foraging for and feeding on aphids hidden within galls formed on Balsam Poplar (*Populus balsamifera*). We searched for community-reported observations of Red Squirrels through iNaturalist and found additional evidence of apparently similar gall feeding behaviour elsewhere in Canada. We estimate that aphids can be a substantial source of caloric energy for Red Squirrels. Our observation represents another example of the diet breadth of Red Squirrels during periods of low conifer seed availability.

Key words: Diet; foraging; insectivory; Poplar Leaf-base Gall Aphid; *Pemphigus populiglobuli*; Red Squirrel; *Tamiasciurus hudsonicus*

Red Squirrel (*Tamiasciurus hudsonicus*) is a common forest-dwelling rodent that is broadly distributed across much of North America (Steele 1998). Red Squirrels are conifer specialists, deriving much of their caloric intake from seeds in mature female cones, which they cache in centralized larders called middens. In regions where conifers produce non-serotinous cones (e.g., White Spruce [*Picea glauca* (Moench) Voss]), squirrels cache cones in late summer into autumn before the cones open naturally and release seeds (Archibald *et al.* 2012). Red Squirrels are opportunistic omnivores (Layne 1954) and will feed on fungi (Smith 1968a; Fletcher *et al.* 2010), non-seed plant material such as conifer pollen cones (Smith 1968a), and rust-induced pine galls (Salt and Roth 1980), as well as vertebrates, including leporids, birds, and salamanders (Sullivan 1991). Their diets can shift with the seasons and fluctuations in the availability of the food source (e.g., Salt and Roth 1980; Fletcher *et al.* 2010).

Even with stored resources available, Red Squirrels will change their diets considerably during cone crop failures (Smith 1968b) and will feed on insects, even peeling the bark from standing White Spruce to feed on Spruce Beetle (*Dendroctonus rufipenni* (Kirby)) larvae in the cambium (Pretzlaw *et al.* 2006). During three years of low cone abundance and a simultaneous outbreak of Spruce Beetle in Yukon, 20% of Red Squirrels' energetic intake was from Spruce Beetle larvae (Pretzlaw *et al.* 2006). Here, we document another example of Red Squirrel feeding behaviour during an exceedingly low conifer cone crop.

In the early evening of 7 July 2019, at Twin Lakes Campground in central Yukon (130 km north of Whitehorse; 61.702424°N, 135.935528°W), M.D.J. observed a Red Squirrel that appeared to be feeding on the leaves of Balsam Poplar (*Populus balsamifera* L.) and recorded a 1.33-min video of its behaviour (Jackson 2019) using a smart phone (Apple iPhone SE 2016 model, Apple Inc., Cupertino, California, USA). Closer observation revealed that the squirrel was not eating the leaves but rather chewing open

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surface galls located near the leaf petiole (Figures 1a,d), feeding on the contents, and then dropping the leaf with the emptied gall to the ground before moving on to another leaf (Figure 1b; Jackson 2019). The squirrel fed in this fashion for ~1 h, leaving the discarded leaves below its perch (Figure 1c). Uneaten galls, collected from the tree in which the squirrel was observed, were later found to have been induced by aphids (Hemiptera: Aphididae; Figure 1e); galls and the aphids within, preserved in 95% ethanol, were deposited in the Lyman Entomological Museum at McGill University (LEMQ; accession numbers not yet assigned). Although the density of aphid galls in the area was not quantified, the occupied tree and surrounding poplars appeared heavily infested with galls; most leaves visible from the ground showed evidence of galls. The Red Squirrel was not observed feeding on larvae of Aspen Serpentine Leaf Miner (*Phyllocnistis populiella* Chambers, Lepidoptera: Gracillariidae), which could be found in most of the leaves on the tree, including leaves with predated aphid galls (Figure 1d).

We calculated the maximum caloric intake of the squirrel during the 1-h observation period by estimating mean (± SD) time spent searching for and feeding on aphid galls by evaluating the video recording (Jackson 2019). We used the energy intake equation in Pretzlaw *et al.* (2006), established for bark beetle larvae predation by Red Squirrels, to estimate energy consumption assuming 56 reproductive adult aphids per gall as established by previous studies (Harper 1959a) and an energy content of three calories per adult aphid based on previous studies involving microbomb calorimetry (Dixon 1971; Randolph *et al.* 1975).

We also estimated cone abundance in the area to understand better the resource context of this behaviour. Twin Lakes campground lies among small lakes in the boreal forest of the Central Yukon Plateau region. The dominant conifer is Black Spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenburg), which produces small semi-serotinous cones. Also present was White Spruce, which produces

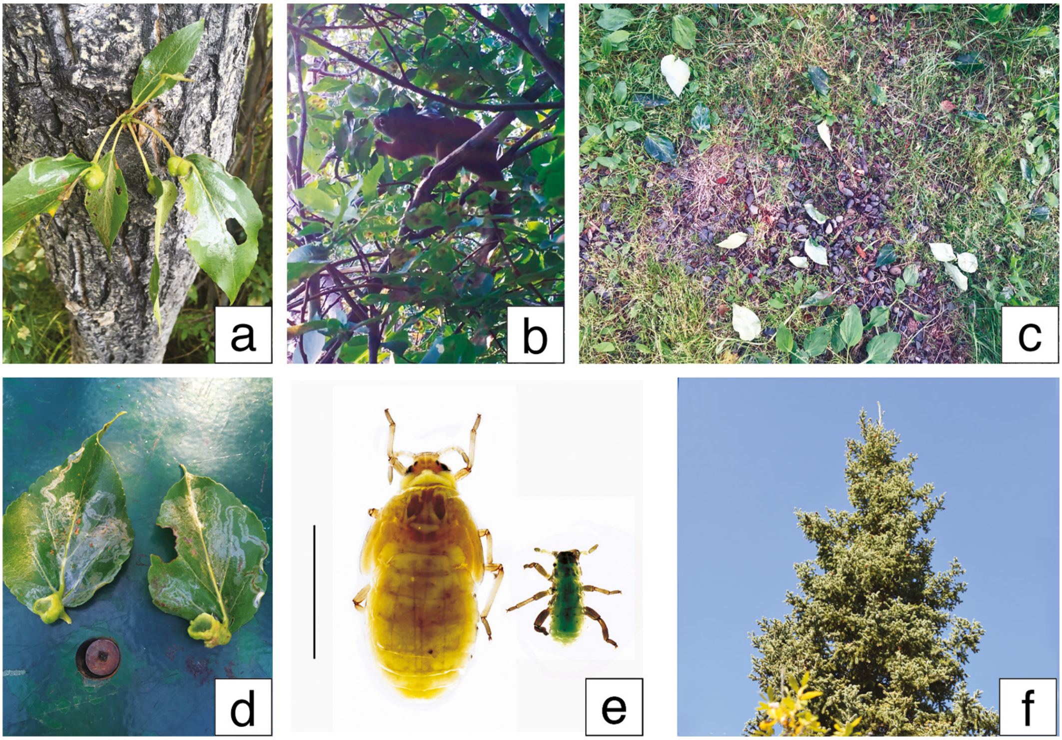

FIGURE 1. a. Galls of the Poplar Leaf-base Gall Aphid (*Pemphigus populiglobuli*) on Balsam Poplar (*Populus balsamifera*) leaves *in situ*. b. Still from video (Jackson 2019) showing a Red Squirrel (*Tamiasciurus hudsonicus*) feeding on Poplar Leaf-base Gall Aphid galls. c. Example of undergrowth below the Red Squirrel's perch; 22 discarded Balsam Poplar leaves can be seen, at least nine of which show evidence of damaged petiole galls. d. Recovered Balsam Poplar leaves displaying results of Red Squirrel aphid gall feeding and serpentine leaf mines of Aspen Serpentine Leaf Miner (*Phyllocnistis populiella*). e. Poplar Leaf-base Gall Aphid specimens recovered from a collected uneaten gall. Scale bar = 1 mm. f. Spruce cone survey photo from Twin Lakes Campground, Yukon. Photos a–e: Morgan Jackson. Photo f: Ashley Mills.

non-serotinous cones that release wind-dispersed seeds in late autumn. Cone production by both species varies in abundance from year to year and the year we made our observations was one of the lowest cone-crop years on record (A.E.W. and M.D.J. pers. obs.). In early fall (1 September), we returned to the same cluster of trees where the Red Squirrel was observed and photographed the crowns of 20 spruce trees in the vicinity with diameter at breast height >5 cm. From these photos of Black Spruce and White Spruce (e.g., Figure 1f), we counted all cones in the top 3 m of the crown of each tree and applied the transformation by LaMontagne *et al.* (2005) to estimate the total number of cones per tree (Wishart and Jackson 2020).

Finally, we searched for additional observations of potential aphid gall feeding by Red Squirrels by downloading all iNaturalist (inaturalist.org) research-grade observations (those with a date, a geolocation, a photo, and a confirmed species-level identification by at least one other user) of Red Squirrels in Canada, with observation dates from May to September. We archived this iNaturalist dataset using the Global Biodiversity Information Facility (GBIF 2021) and looked at all the photos for gall-aphid feeding behaviour.

Using Harper (1959b), we identified the aphids as Poplar Leaf-base Gall Aphid (*Pemphigus populiglobuli* Fitch) based on the position and morphology of the galls. Of the four instances of aphid gall-feeding captured in the 1.33-min video (Jackson 2019), the Red Squirrel spent an average of 3.0 ± 0.8 s searching for galls and an average of 14.5 ± 6.9 s/gall feeding. If the squirrel fed at this rate continuously during the hour-long observation period, we estimate it could consume up to 206 galls representing a maximum of 117 kJ of metabolizable energy derived from aphids.

The 20 photographed spruce trees had an average of 1.6 ± 0.8 SE cones per tree. When we photographed the tree tops, one squirrel was observed caching cones but not in a visibly discernable larder (the conspicuous area of discarded cone refuse in which squirrels cache newly harvested cones and which squirrels defend from conspecifics; Smith 1968a).

Only two of the 4447 iNaturalist records showed squirrels apparently feeding in a similar fashion on poplar leaf galls, both from Gwillim Lake Provincial Park, northeastern British Columbia (Headley 2019; Kushneryk 2019). These two records were submitted by different users but were ~100 m from each other on concurrent days (30 July and 31 July 2019) and may be of the same squirrel foraging for galls.

Red Squirrel feeding ecology has been studied intensively in Yukon for decades (Dantzer *et al.* 2020), yet their handling and feeding from galls formed by aphids has yet to be reported in the literature. Published records of Red Squirrels feeding on aphids directly was first noted by Smith (1968a), who observed squirrels eating aphids (likely *Tamalia* spp.) exposed by chewing leaves of Common Bearberry (*Arctostaphylos uva-ursi* (L.) Sprengel) in southern British Columbia. He hypothesized that the relatively greater use of "animal materials" (including aphids) by juvenile or reproductive females (pregnant or lactating) compared with adult males may indicate that these materials could provide dietary salts. A Pallas's Squirrel (*Callosciurus erythraeus*) was observed feeding on four galls of *Astegopteryx bambucifoliae* (Takahashi) in Taiwan (Chou *et al.* 1985). Pallas's Squirrels have also been observed feeding on gall-forming *Pseudoregma carolinensis* (Takahashi) in Thailand (Aoki *et al.* 2007). In North America (Arizona), a Mount Graham Red Squirrel (*Tamiasciurus hudsonicus grahamensis*) was seen eating spruce aphids (*Elatobium abietinum* (Walker); Lynch 2009). More distantly related chipmunks also feed on aphids, but it is not known whether they are retrieved from galls (Baysinger 1940; Tevis 1953).

Globally, accounts of aphid gall predation by vertebrates are limited (Sunose 1980; Burstein and Wool 1992), with some Old World aphid species actively deterring vertebrate grazing via galls that produce volatile organic compounds and are aposematically coloured (Rostás *et al.* 2013). The galls of Poplar Leaf-base Gall Aphid reported here were similar in colour to the remaining leaf, and the squirrel appeared to have little hesitation in opening the galls, suggesting that any sequestered noxious chemicals were insufficient to deter squirrel predation.

Previous estimates of Red Squirrel daily energy expenditure in autumn (when not actively hoarding food) in southwestern Yukon were ~300–400 kJ/day (Fletcher *et al.* 2010). Our estimated maximum hourly caloric intake of 117 kJ from consuming gall aphids implies that aphid gall feeding may provide a substantial source of energy when the abundance of a primary food source is low. Even in a highly infested tree, such as we observed, a Red Squirrel is unlikely to sustain that estimated maximum hourly caloric intake for long periods, but the ready availability of gall aphids as a high-calorie food source for squirrels warrants consideration in future research. In addition, aphid galls contain much higher concentrations of amino acids than the surrounding leaf tissue (Suzuki *et al.* 2009), possibly providing a valuable nitrogen source.

We observed a three-way mammal–insect–plant interaction that could be important to consider from a behavioural ecology and community ecology framework. Feeding innovation rate is associated with invasion success in birds (Sol *et al.* 2002); whether this holds true for mammals may be important to monitor as ranges are likely to shift with a changing climate. Insect galls are likely to be reliably accessible as a food source in southern Yukon, with at least three other species of gall-inducing aphids known from the territory (Foottit and Maw 1997), as well as an unknown number of species of gall-inducing sawflies (Hymenoptera: Tenthredinoidea) on willow (*Salix* spp.) and leaf-rolling sawflies on aspen (*Populus* spp.; S. Monckton pers. comm. 2020). However, given that the squirrel we observed dismissed leaf-mining insects in favour of more densely populated gall aphids on the same leaf, discrimination among species by Red Squirrels presents opportunities for further study.

Our observation of a Red Squirrel feeding on poplar-gall aphids, accompanied by community science documentation of apparently similar behaviour elsewhere, expands our collective knowledge of Red Squirrel diet breadth and behaviour. This observation is also significant for entomology and forestry applications in that this is the first documentation of Poplar Leaf-base Gall Aphid in Yukon (Foottit and Maw 1997). Finally, our observation serves as a timely reminder that much remains to be discovered about the biology and associations of even the most common species. Moreover, this observation further points to the increasing role that new technologies and platforms (i.e., iNaturalist) may have in new scientific findings.

Author Contributions

Writing – Original Draft: A.E.W. and M.D.J.; Writing – Review & Editing: A.E.W. and M.D.J.; Conceptualization: M.D.J.; Investigation: A.E.W. and M.D.J.; Methodology: A.E.W. and M.D.J.

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Note

Canada Jay (*Perisoreus canadensis*) harvesting and caching fruits of Thin-leaved Snowberry (*Symphoricarpos albus*)

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Hendricks, P., and S.S. Pagano. 2023. Canada Jay (*Perisoreus canadensis*) harvesting and caching fruits of Thin-leaved Snowberry (*Symphoricarpos albus*). Canadian Field-Naturalist 137(3): 243–248. https://doi.org/10.22621/cfn.v137i3.3079

Abstract

On 17 September 2021, we observed three Canada Jay (*Perisoreus canadensis*) harvesting and caching Thin-leaved Snowberry (*Symphoricarpos albus*) fruits in a mixed conifer forest in western Montana, USA. Thin-leaved Snowberry has not been reported previously in their diet. During 3 min of direct observation, each jay harvested snowberries similarly and cached them on the trunks of nearby pines. In each case (11 caches), the jay flew by the snowberry shrubs twice, plucking a fruit while airborne, landing on the ground between passes, the first fruit carried in the throat, the second in the bill. The jays then landed, most often out of view on tree trunks, but, nevertheless, appeared to cache the fruits each time. One cache observed in the making contained two harvested fruits wedged in a crevice on the trunk and covered with a flake of bark. Thin-leaved Snowberry is considered a low-quality fall-ripening fruit because of the small energy gain for each fruit consumed. Nevertheless, the energy density of snowberries (16.65 kJ/g dry mass) collected at the same location in October exceeded that required by non-migratory Canada Jays for daily maintenance during winter. It is unlikely jays could cache enough fruits each day to sustain them for several winter months. Instead, snowberries could be an important and readily available autumn and winter food for Canada Jays resident in this region when used to supplement other stored foods with greater energy, fat, and protein content.

Key words: Caching behaviour; Canada Jay; diet; energy density; foraging behaviour; fruits; Montana; *Perisoreus canadensis*; *Symphoricarpos albus*; Thin-leaved Snowberry

Canada Jay (*Perisoreus canadensis*) is a permanent year-round resident inhabiting boreal and montane coniferous forests in North America, although some local autumn movements have been reported (Bent 1946; Goodwin 1976; Strickland and Ouellet 2020). The strategies that Canada Jays employ for survival during winter differ substantially from those of birds that breed in the same coniferous forest habitats but migrate long distances to avoid harsh and food-limited conditions during the non-breeding season. Similar to many corvids, Canada Jays are omnivorous and opportunistic (Bent 1946; Goodwin 1976; Strickland and Ouellet 2020). They feed on arthropods, carrion, nestling birds, small mammals, fungi, a variety of human foods and waste, and berries. Classified as a scatter-hoarding species (Vander Wall 1990), jays cache large quantities of food in autumn and retrieve and consume it throughout winter when food is otherwise scarce. Caches are spread widely, typically above ground to avoid burial in snow, and contain only one or two items (at most, the contents of a single throat and bill load) in a sticky saliva-coated bolus (Strickland and Ouellet 2020; Swift *et al.* 2022). Although Canada Jays are frequently encountered in the mountains of western Montana, their biology and food habits in the state remain unstudied (Marks *et al.* 2016).

Thin-leaved Snowberry (*Symphoricarpos albus* (L.) S.F. Blake) is an open-canopy and understorey shrub widely distributed across Canada and the western United States (Lesica 2012) within the range of Canada Jays. It reaches ~1.5 m in height and produces numerous fleshy white fruits, which ripen in late summer and autumn; fruits may remain available on shrubs for several months (Martin *et. al.* 1951). The

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fruits of snowberry may at times be important autumn and winter food for some resident birds (Gabrielson 1924; Martin *et al.* 1951; Crawford *et al.* 1986), such as Dusky Grouse (*Dendragapus obscurus*) and Pine Grosbeak (*Pinicola enucleator*). Although considered low-quality food among bird-dispersed species (Stiles 1980), largely because the energy gain per fruit consumed is low, they have sometimes appeared in relatively large numbers in the stomachs of the mentioned species. Here we report opportunistic observations of a trio of Canada Jays harvesting and caching Thin-leaved Snowberry fruits during autumn in western Montana. We describe the behaviour of the jays while they collected and stored fruits, provide an assessment of the nutritional quality of the fruits harvested, and speculate on why Canada Jays would spend time and energy harvesting seemingly low-quality fruit.

On 17 September 2021, while P.H. hiked a road at the University of Montana's Lubrecht Experimental Forest, Missoula County, Montana, three Canada Jays suddenly appeared at 1020 Mountain Daylight Time about 10–15 m from him. Forest cover at the site (46.88898°N, 113.44490°W; 1276 m elevation) included Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), Ponderosa Pine (*Pinus ponderosa* Douglas ex P. Lawson and C. Lawson), and Western Larch (*Larix occidentalis* Nuttall), in order of abundance, with numerous snowberry shrubs lining the road and in the adjacent understorey. At this season and location, snowberries were relatively abundant and the most-available fleshy fruit in the forest, and the three jays busied themselves with harvesting and caching snowberries. During the next 3 min, P.H. watched the jays with 10× binoculars, attention focussed on whichever bird was in view, as all appeared to be behaving similarly. The jays were spread over a linear distance of ~10 m.

Each jay harvested snowberries in a similar manner using a method apparently unreported previously (Bent 1946; Strickland Ouellet 2020). The first bird to appear flew through a low (0.5–0.6 m tall) patch of snowberries and plucked a fruit from one shrub while airborne, landed on the ground near the shrub, then flew with the first fruit carried in its throat and plucked a second fruit from a different shrub, again while airborne, and then flew with the second fruit grasped in its bill to the trunk of a pine about 4–5 m distant, where it was out of view ~1–2 m above ground. It appeared to cache the two fruits in the bark on the tree trunk because it departed from the pine without a fruit in the bill and the throat not enlarged. This behavioural sequence was observed multiple times for each bird before the three jays flew together into the forest and out of view. In every case observed (*n* = 11) the birds harvested only two fruits at a time (one carried in the throat, one in the bill) and cached the fruits on the trunks of pines within 2–8 m of where fruits were harvested. In some cases, it appeared that multiple caches were created on the same tree trunk by the same bird. Snowberries that the jays harvested appeared to be the largest ones (~8 mm × 10 mm in length and diameter); the wet weight of 20 fruits of this approximate size collected just after the jays departed was 4.3 g (~0.2 g each).

After the jays departed, P.H. attempted to locate some of the presumed caches, but was unsuccessful. Fortunately, he directly observed one jay creating a cache. What appeared to be both fruits were wedged into a vertical crack in the bark of the tree trunk (Figure 1) and covered with a flake of pine bark taken from the trunk while the jay remained clinging to the trunk at the cache site (Figure 2a); the cached fruits were coated with sticky saliva (Bock 1961; Dow 1965) on the lower part of the cache bolus (Figure 2b) to which the flake of bark was attached. This cache was 140 cm above ground in a pine with diameter at breast height (DBH) of 15.4 cm. Diameter at breast height for three of the apparent cache trees was 11.7 cm, 14.2 cm, and 16.3 cm. The cache was still present at 1220 the following day (18 September), 26 h after creation, but had been removed by the next check on 30 September.

Cache location on tree trunks, cache concealment with bark, and cache duration (<14 days) were consistent with findings for other fruits from elsewhere (Strickland and Ouellet 2020; Swift *et al.* 2022). Caching behaviour of Canada Jays is influenced by the potential for their caches to be pilfered by other resident species during periods of food scarcity (Dally *et al.* 2006), thus their need to spread caches widely, place them above ground in obscure sites and sometimes conceal them, which helps reduce the total amount of cached food lost if a few caches are pirated. Our observations of three Canada Jays openly caching in close proximity to each other are consistent with those of Burnell and Tomback (1985), who suggest cache pilferage is more likely by individuals of other species rather than conspecifics. Steller's Jay (*Cyanocitta stelleri*) routinely attempt to steal Canada Jay caches (Burnell and Tomback 1985) and are present throughout much of the range of Canada Jays, including western Montana (Marks *et al.* 2016); Canada Jays suppress or hide caching activity in the perceived presence of Steller's Jay or Blue Jay (*Cyanocitta cristata*; Burnell and Tomback 1985; Martin and Sherry 2021). Three Canada Jays harvesting and caching together in autumn suggests they were related (Strickland and Ouellet 2020) and not likely to steal each other's caches.

We wanted to determine energy content of the

FIGURE 1. Cache location (white circle) on the trunk of a Ponderosa Pine (*Pinus ponderosa*) made by a Canada Jay (*Perisoreus canadensis*) on 17 September 2021 at Lubrecht Experimental Forest, Missoula County, Montana USA. Cache is partly concealed by a flake of pine bark. Photo: P. Hendricks.

snowberries, because we have rarely observed birds feeding on snowberries. On 19 October 2021, P.H. collected fruits up to 0.5 km from the harvest and cache site of 17 September 2021, and S.S.P. analyzed them for energy density, crude fat, crude protein, and water content. Fruits were stored frozen at -20°C until analyses. They were dissected in aluminium trays to remove seeds (nine trays of 20 fruits), and the remaining pulp, juice, and skin were freeze-dried for 48 h (FreeZone Triad benchtop freeze dryer, Labconco, Kansas City, Missouri, USA). Water content (%) was determined by mass loss from dissected fruit trays after freeze-drying, averaged over all trays. Freeze-dried samples were homogenized and combined for further nutritional analysis. Percent dry mass of fat was determined by extracting ~1 g of dried sample in a fat extractor (Ankom XT-10, ANKOM Technology, Macedon, New York, USA) using petroleum ether ($n = 3$ trials; see Smith *et al.* 2015). Energy density (as kJ/g) was determined using ~1 g of dried pelleted sample combusted in a Parr 6100 bomb calorimeter and a Parr 1108 oxygen bomb vessel (Parr Instrument Company, Moline, Illinois, USA), and energy density was determined using a benzoic acid standard ($n = 3$ trials). Crude protein was determined using a modification of the micro-Kjeldahl analysis as described in Smith *et al.* (2015). Briefly, ~0.5 g of dried sample was digested and then distilled in a micro-Kjeldahl still (Labconco), then titrated against 0.01N HCl to calculate percentage nitrogen content, which was multiplied by a conversion factor of 4.4 (Witmer 1998) to obtain percentage protein content of the samples ($n = 3$ trials).

Thin-leaved Snowberry fruits from Montana were relatively low (mean ± SE) in energy density (16.65 ± 0.02 kJ/g dry mass), crude fat (0.99 ± 0.02% dry mass), crude protein (1.74 ± 0.01% dry mass), and high in water content (84.07 ± 0.17% wet mass) compared with many other native fall-ripening fruits consumed and disseminated by migratory birds (Stiles 1980; Smith *et al.* 2007, 2013, 2015; Cullen *et al.* 2020), some of which have energy densities exceeding 28.0 kJ/g dry mass, crude fat ranging from 6.0% to 49.0%, and crude protein usually exceeding 3.0%. Even low-quality fruits of some native fall-ripening boreal/low Arctic shrubs, such as bearberry (*Arctostaphylos*), crowberry (*Empetrum*), and blueberry (*Vaccinium*), which overwinter under snow and are important foods for migrant passerines when they first arrive on the breeding grounds in early summer (Norment and Fuller 1997), are generally of higher quality than Thin-leaved Snowberry fruit (Table 1). The

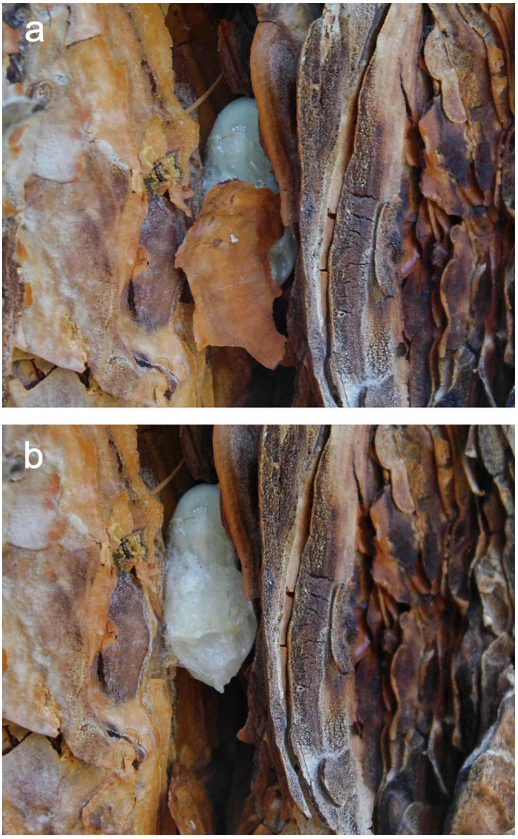

FIGURE 2. Closeup of the Canada Jay (*Perisoreus canadensis*) cache photographed in Figure 1, showing a. a flake of pine bark partly concealing the cache, and b. the flake removed to show the cached fruit of a Thin-leaved Snowberry (*Symphoricarpos albus*). The sticky saliva of the jay, to which the bark flake was attached, is visible coating the lower part of the cache bolus. Photos: P. Hendricks.

fruit quality of Thin-leaved Snowberry in Montana and New Jersey (Table 1; White 1989) was quite similar, indicating that the nutritional quality of snowberries is probably on the low end across its range. Further, fruit quality of Thin-leaved Snowberry is more similar to that of invasive non-native shrubs in eastern North America (Smith *et al.* 2013), with energy densities of ~16.3–17.2 kJ/g dry mass and crude fat content of ~0.5–1.0%.

A review of the published literature on fruits consumed by Canada Jays resulted in a list of at least 16 plant species in eight families (Table 1), typically harvested during late summer and autumn. At least some of these (e.g., *Arctostaphylos*, *Empetrum*, *Vaccinium,* native *Viburnum*; Norment and Fuller 1997; Smith *et al.* 2007, 2013) offer jays greater energy, fat, and protein rewards than Thin-leaved Snowberry. Neither Thin-leaved Snowberry nor any member of the genus *Symphoricarpos* appears to have been reported previously in the diet of Canada Jays. So, why would Canada Jays in Montana harvest and cache them?

Experimental evidence with artificial Canada Jay diets suggests that the energy density of Thin-leaved Snowberry fruits (16.65–17.43 kJ/g dry mass; Table 1) may be sufficient to meet maintenance energy targets of the jays (~15.97 kJ/g dry mass) during food-scarce periods (Martin *et al.* 2022) if the fruit is consumed in large quantities. Canada Jays require a daily energy intake of ~197 kJ (Shank 1986; Strickland and Ouellet 2020); thus, a jay would need to consume a minimum of 11.8 g dry mass of snowberries each day to meet daily energy needs, given an energy density of 16.6 kJ/g dry mass and without factoring in assimilation efficiency of snowberries by the jays. Average fresh weight of snowberries with seeds was ~0.2 g (20 fruits weighed 4.3 g), of which 84% was water and ~0.02 g was seed mass. Thus 1 g dry pulp mass of snowberries represents ~34 fruits, and ~404 fruits would be required to produce 197 kJ of energy. Even when snowberries are readily available and abundant for harvest and caching, as they were at the Montana site in September and October 2021 before being covered by winter snow, it is very unlikely that a Canada Jay could sustain itself through winter on a diet consisting largely of snowberries. It seems more probable that snowberries were harvested and cached by the jays because they were the most available fleshy fruits at the time and used to supplement other stored foods (e.g., meat, carrion, arthropods, fungi, other fruits) with higher energy, fat, and protein content, a conclusion analogous to that reached by Smith *et al.* (2007) on the needs of autumn migrant songbirds to consume insects as well as fruits to meet energy and protein requirements.

Author Contributions

Writing – Original Draft: P.H. and S.S.P.; Writing – Review & Editing: P.H. and S.S.P.; Investigation: P.H. and S.S.P.; Methodology: P.H. and S.S.P.; Formal Analysis: P.H. and S.S.P.

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Table 1. Fruits harvested by Canada Jay (*Perisoreus canadensis*). Mean nutritional values for native fruits are from localities other than where they were harvested by the jays.

Family	Species*	Energy, kJ/g dry mass†	% fat, dry mass (wet pulp)†	% protein, dry mass†
Anacardiaceae	Sumac (*Rhus*)[1]	26.18[d]	16.4[d]	2.4[d]
Caprifoliaceae	Elderberry (*Sambucus*)[1]	19.12[d]	4.9[d]	9.1[d]
	Thin-leaved Snowberry (*Symphoricarpos albus* (L.) S.F. Blake)[13]	17.43[d]	1.0[d]	2.6[d]
	Viburnum (*Viburnum*)[1]	27.40[c]	41.3[c]	2.6[c]
Elaeagnaceae	Soapberry (*Shepherdia canadensis* (L.) Nuttall)[9]		(1.7[b])	
Ericaceae	Bearberry (*Arctostaphylos*)[1, 10]	17.91[a]	3.1[a]	3.1[a]
	Black Crowberry (*Empetrum nigrum* L.)[6, 9]	18.90[a]	4.9[a]	2.5[a]
	Crowberry (*Empetrum*)[10]			
	Bog Bilberry (*Vaccinium uliginosum* L.)[9]		(6.0[b])	
	Mountain Cranberry (*Vaccinium vitis-idaea* L.)[9, 10]	16.38[a]	3.7[a]	2.5[a]
	Blueberry (*Vaccinium*)[3, 5, 8, 11]	17.51[d]	1.4[d]	3.3[d]
Liliaceae	Wild Lily-of-the-Valley (*Maianthemum canadense* Desfontaines)[8]		(1.4[b])	
	Solomon's Seal (*Maianthemum* (= *Smilacina*))[8]	20.12[d]	0.0[d]	3.0[d]
Rosaceae	Saskatoon (*Amelanchier alnifolia* (Nuttall) Nuttall ex Roemer)[12]			
	Serviceberry (*Amelanchier*)[2]	15.64[d]	1.2[d]	5.6[d]
	Chokecherry (*Prunus virginiana* L.)[7]	17.94[d]	0.7[d]	3.4[d]
	Arctic Raspberry (*Rubus arcticus* L.)[4]			
	American Mountain-ash (*Sorbus americana* Marshall)[5]	19.28[d]	1.7[d]	3.9[d]
Santalaceae	Northern Comandra (*Geocaulon lividum* (Richardson) Fernald)[9]		(1.1[b])	
Vitaceae	Virginia Creeper (*Parthenocissus quinquefolia* (L.) Planchon)[2]	22.30[c]	23.6[c]	6.0[c]

*Sources for fruits harvested by Canada Jays: 1. Bailey (1928), 2. Bent (1946), 3. Harper (1958), 4. Nelson (1983), 5. Ouellet (1970), 6. Preble (1908), 7. Rutter (1969), 8. Strickland and Ouellet (1993), 9. Swift *et al.* (2022), 10. Todd (1963), 11. Waite (1988), 12. P.H. pers. obs., and 13. this paper.
†Sources for fruit nutritional values: a. Norment and Fuller (1997), b. Traveset *et al.* (2004), c. Smith *et al.* (2007), and d. White (1989).

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Assessing terrestrial movements of Eastern Musk Turtle (*Sternotherus odoratus*) using iNaturalist Canada

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Abstract

Eastern Musk Turtle (*Sternotherus odoratus*) is known to be a highly aquatic species, yet it is occasionally found away from waterbodies. If such movements are common, then road mortality may pose a substantial risk to the species. We examined iNaturalist Canada observations of Eastern Musk Turtle on roads and found 15 in which individuals were >25 m from water. The median distance to the nearest permanent waterbody was 100 m (range 30–330 m). All observations that were ≥100 m from the nearest waterbody occurred from mid-July onward, suggesting that the movements were not related to nesting activity. At least under some circumstances, Eastern Musk Turtle can move >100 m away from waterbodies increasing the risk of road mortality.

Key words: Community science; Eastern Musk Turtle; *Sternotherus odoratus*; iNaturalist; movement; road mortality

Introduction

Eastern Musk Turtle (*Sternotherus odoratus*) is the widest ranging member of the turtle family Kinosternidae and is native to eastern North America (Ernst and Lovich 2009). It is rarely found far from water, and home ranges are often confined to a single waterbody (Ernst and Lovich 2009; Wilhelm and Plummer 2012). The use of multiple waterbodies has been reported, but they are often wet meadows or streams adjacent to a main waterbody (Ernst 1986; Rowe *et al.* 2009). Aquatic movements can exceed 1.5 km along waterways (Laverty *et al.* 2016) but terrestrial movements away from water appear to be uncommon. During one study, none of the radio-tracked musk turtles were found on land (Wilhelm and Plummer 2012). The sporadic drying of relatively permanent wetlands can cause turtles to move to other wetlands; however, Eastern Musk Turtle is more likely to remain in drying wetlands than many other turtle species (Gibbons *et al.* 1983), and the maximum observed terrestrial movement from a seasonal wetland is only 48.7 m (Buhlman and Gibbons 2001). Nesting is usually within 20 m of water (Cagle 1937; Ernst 1986; Edmonds 1998) with a maximum reported distance of 45 m inland (Ernst and Lovich 2009).

Eastern Musk Turtle experiences a higher evaporative water loss rate compared with many other turtle species (Ernst 1968; Murphy *et al.* 2016), and this likely explains at least part of the lack of terrestrial movements. Despite its highly aquatic nature, Eastern Musk Turtle is occasionally found away from water. For example, we found a dead adult Eastern Musk Turtle on a road in eastern Ontario that was 280 m away from aquatic habitat (Seburn and Burns 2021). Another adult Eastern Musk Turtle "was found abroad in a hardwood forest about 396 m from the nearest known body of water" in North Carolina (Palmer and Braswell 1995: 88). Clearly, Eastern Musk Turtle can make substantial movements away from water, at least under some circumstances. It remains unclear how often and how far individuals move away from aquatic habitat.

If Eastern Musk Turtle movements away from aquatic habitat are not rare, then this species may be more at risk from road mortality than is generally believed. Given that Eastern Musk Turtle is a species-at-risk in Canada (SARA Registry 2021), it is important to assess potential threats to it. Although road mortality has been identified as a threat, it was not quantified (COSEWIC 2012). A number of researchers have reported road mortality of Eastern Musk Turtle in Canada (Garrah *et al.* 2015; Choquette and Valliant 2016; Carstairs *et al.* 2018) and in the United States (Smith and Dodd 2003; Aresco 2005; Palis 2021), but typically in low numbers. If terrestrial

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movements are uncommon or of short duration, then they may be difficult to detect through radio-tracking studies, but may be more apparent through opportunistic observations of them found on roads.

To help quantify terrestrial movements in Eastern Musk Turtle, we examined observations from iNaturalist Canada, a community science, or citizen science, platform to record native and exotic species in Canada that includes over nine million observations of more than 34 000 species observed by more than 170 000 people (iNaturalist Canada 2022a). It contains more than 400 observations of Eastern Musk Turtle in Canada with an accompanying photo that has been identified by at least two people (termed "research grade"). Data from iNaturalist have been used to address a variety of spatial questions in ecology, including patterns in urban biodiversity (Callaghan *et al.* 2020) and the distribution of exotic species (Werenkraut *et al.* 2020; Mo and Mo 2022). Using data from iNaturalist Canada is an easy way to assess terrestrial movement over a large area by looking at observations of Eastern Musk Turtle on roads.

Methods

We downloaded observations of Eastern Musk Turtle to the end of September 2022 from the iNaturalist project "Canadian Amphibians and Reptiles on Roads", which was created by the Canadian Herpetological Society. We used the roads project as an unambiguous way to obtain observations of the turtles on land. We recognized that not all Eastern Musk Turtle observations of individuals on roads would have been added to this project, so we also reviewed all other Canadian observations of this species and added relevant ones to the project. Such additions were limited to photos showing an Eastern Musk Turtle that had been hit by a vehicle or observations with notes indicating that the turtle was found on a road.

Given the perceived risk to Eastern Musk Turtle of poaching (iNaturalist Canada 2022b), the locations of observations are obscured on iNaturalist, with a random location mapped within a cell of 0.2° × 0.2° or roughly 20 km × 20 km at mid-latitudes (iNaturalist 2022). Thus, we obtained the private location of all the observations from iNaturalist Canada. Observations lacking any spatial accuracy or with a spatial accuracy >35 m were excluded from analyses, as these points were often distant from roads making it more difficult to estimate the actual location on the road and hence an accurate distance to water. Observations with a spatial accuracy ≤35 m were all within 10 m of a road. We mapped all observations in QGIS 3.4 (QGIS Development Team 2022) and selected those that were at least 25 m from water and determined the straight-line distance to the nearest lake, river, or permanent wetland. Observations <25 m from water were excluded as minor movements away from waterbodies. Lakes, rivers, and streams were visible on aerial imagery, while wetlands were mapped using Ontario GeoHub's wetland layer (Ontario GeoHub 2022). To ensure that our measurement was a conservative estimate of terrestrial movements, we measured the straight-line distance from the edge of the nearest waterbody to the edge of the road nearest the observation and rounded down to the nearest 10 m. To consider the possibility that turtles were moving from one waterbody to another, we also calculated the distance to the next waterbody from the turtle in any direction away from the nearest waterbody. We used Google Street View (Google 2023) to assess habitat adjacent to roads when there was the possibility of a flooded, roadside ditch that could facilitate Eastern Musk Turtle movement. We determined the amount of precipitation over the previous five days at the nearest weather station to each of the Eastern Musk Turtle observations (Government of Canada 2023) that were at least 100 m from the nearest waterbody. We selected a window of five days as freshwater turtles typically do not persist on the road for longer than that (Santos *et al.* 2011).

Results

We found 82 observations of Eastern Musk Turtle on roads. Most of these observations were within 25 m of water, had low spatial accuracy, or the private coordinates were not available. This reduced the dataset to 15 observations of Eastern Musk Turtle on roads that were more than 25 m from any waterbody (i.e., lake, permanent wetland, river) and had a high degree of spatial accuracy (mean ± SD, 13.7 ± 9.7 m). Nine of the 15 (60%) observations were of dead turtles. The 15 observations were widely distributed across eastern and central Ontario, with one in southwestern Ontario (Figure 1). The observations were on 10 different roads, with up to four observations on one road. The road with four observations was parallel to a lake ~2 km in length with several bays that came within 150 m of the road.

The sex and size of most turtles were not available, although all photos showed individuals that were either large juveniles or adults. The turtles were observed from 5 June to 9 August. The median distance from the nearest waterbody was 100 m (range 30–330 m). Eight of the 15 (53.3%) observations were 100 m or more from the nearest waterbody and occurred between 14 July and 9 August. The median distance to the next waterbody for those eight observations was 315 m (range 100–1100 m).

For five of the eight observations ≥100 m from the nearest waterbody, the line from the waterbody to the

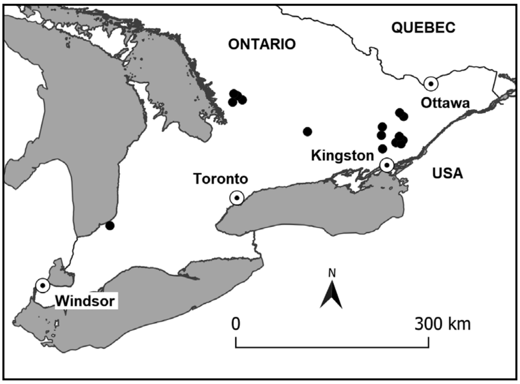

Figure 1. Locations of Eastern Musk Turtle (*Sternotherus odoratus*) observed on roads from the iNaturalist Canada project "Canadian Amphibian and Reptiles on Roads". Only observations that were >25 m from any water body and had a high degree of spatial accuracy are mapped. A few overlapping points were shifted slightly to make them visible.

turtle was perpendicular to the road; thus, any movement to the road would have been overland, not in any roadside ditch (Table 1). Of the remaining three observations, the turtle could have moved along a roadside ditch for at least part of the distance from the wetland for two of the observations. In the third observation there was no roadside ditch present and so the turtle likely moved along the road or the road shoulder. The nearest waterbody to five of the observations was permanent (a lake or stream) and, hence, these turtles likely did not move because the waterbody dried up.

Precipitation data were missing for one of the eight observations, but all but one of the other seven observations had precipitation during the five days preceding the observations, suggesting that rain could have triggered the terrestrial movement of the turtles. The average amount of precipitation was 1.5 cm (range 0.4–2.9 cm). For the three turtles found alive on roads, there was precipitation on two of those three days. For the third turtle found alive there was no precipitation the day it was found on the road or on the preceding five days.

Discussion

Data from iNaturalist yielded 15 observations of Eastern Musk Turtle at distances >25 m from waterbodies, with one turtle observed more than 300 m from water. Our measurements of terrestrial movement may underestimate actual movements as we assumed the turtles came from the nearest waterbody to the road. This was likely true, but in a few instances, the nearest waterbody, as determined by Google imagery and the wetland layer, was a small wetland with no open water habitat but a larger waterbody was farther away.

Movements away from water can occur among adult females looking for places to lay their eggs. Although documented Eastern Musk Turtle nests are typically <45 m from water (Ernst and Lovich 2009), it is possible that some females may move longer distances to nest. The fact that all of the longest terrestrial movements were found from mid-July to August suggests that they were not related to nesting, as nesting by this species in northern areas is generally in June or early July (Ernst 1986; Laverty 2010). For five of the eight observations with the longest overland movements, the turtles were found dead, so it is possible that they were killed by vehicles some time before they were observed, although turtle carcasses typically do not persist on roads for more than five days (Santos *et al.* 2011), so it is unlikely these turtles were seeking nesting sites. If these turtles were not moving for nesting purposes, then their movement between waterbodies may have been related to

Table 1. Habitat characteristics associated with Eastern Musk Turtle (*Sternotherus odoratus*) observations at least 100 m from a waterbody.

Turtle no.	Distance to water, m	Type of waterbody	Orientation*	Roadside ditch†
1	100	Lake	Perpendicular	Present
2	100	Marsh	Parallel	Shallow and rocky
3	250	Swamp and creek	Parallel	Present
4	330	Marsh	Perpendicular	Present
5	100	Stream	Parallel	None
6	150	Lake	Perpendicular	Present
7	230	Lake	Perpendicular	Present
8	110	Lake	Perpendicular	Present

*Orientation of the water body relative to the location of the turtle on the road. Perpendicular: the shortest straight line from the water body to the turtle is perpendicular to the road. Parallel: the turtle was found down the road from the water body.
†Assessed using Google Street View.

dispersal or seasonal movements. The median distance to the next waterbody was over 300 m indicating that, if these movements were from one waterbody to another, then the turtles are moving hundreds of metres overland.

Eastern Musk Turtle is known to make use of flooded roadside ditches (Berry 1975), although it is unclear how often this occurs. The eight turtles observed ≥100 m from a waterbody were all found in July or August, and it is unlikely that roadside ditches were flooded at that time of year. The nearest waterbody to five of these eight turtles was permanent (Table 1) suggesting that the turtles were not forced to move because the water dried up. The turtles may have moved overland in association with rainfall events, as it rained before most of the observations in which turtles had moved at least 100 m. Eastern Musk Turtle is known to have a high rate of evaporative water loss (Murphy *et al.* 2016), so it is not surprising that terrestrial movements would be related to rainfall.

It remains unclear how often Eastern Musk Turtle moves >25 m away from waterbodies and the purpose of these terrestrial movements. The fact that individuals were found on roads >25 m from water in various parts of Ontario (Figure 1) suggests that such movements are widespread, although not likely common. Although the observations were widespread, some of them were also clustered, which may suggest longer terrestrial movements are correlated with certain habitat configurations. It is also possible that clustered points are an artifact of sampling biases in the iNaturalist data. Additional research on terrestrial movements of Eastern Musk Turtle is warranted to better understand the spatial ecology of this species and the risks that road mortality and terrestrial habitat development may pose.

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Note

Torpor may facilitate opportunistic predation of live-trapped small mammals: a cautionary note

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Abstract

Small mammals are often key components in ecological monitoring programs, and live trapping is often used to obtain small mammal density estimates or other metrics. However, an aspect of such trapping that has received little attention is opportunistic predation of captured animals. Here, we report a Common Raven (*Corvus corax*) preying on a deermouse (*Peromyscus* spp.) after it was released from a live trap. The mouse was torpid when removed from the trap. The raven preyed on the deermouse right after it was released, likely because the mouse had not yet fully aroused from torpor and was not able to find adequate shelter or evade the raven. Best practices to avoid similar occurrences include passively warming the animal before releasing it or returning it to the trap to arouse from torpor in safety. Our observation further highlights the need for researchers to be vigilant about opportunistic predation of small mammals captured and released from live traps and to take actions to mitigate the risk, especially if the mammals are exhibiting signs of torpor.

Key words: *Corvus*; *Peromyscus*; small mammal monitoring; small mammal trapping

Small mammals are important in most terrestrial food webs as key consumers, seed dispersers, and prey. Hence, they are often key ecological indicators and important components in ecosystem monitoring programs worldwide (e.g., Solari *et al.* 2002; Avenant 2011; Meserve *et al.* 2011; Boonstra *et al.* 2018; Torre *et al.* 2018). Monitoring small mammal populations often relies on live-trapping campaigns, which permit analyses based on capture–mark–recapture designs (Krebs *et al.* 2011, 2019; Jung *et al.* 2020); however, less-invasive means to monitor small mammal populations are also being explored (e.g., camera trapping; Villette *et al.* 2016; Littlewood *et al.* 2021; Parsons *et al.* 2021). Live trapping small mammals carries with it inherent risks to captured mammals. For instance, captured individuals may die in live traps because of exposure to the elements or stress (Sealander and James 1958; Corke 1967; Ferns 1978; Montgomery 1980; Gurnell 1982; Slade *et al.* 1993; Fletcher and Boonstra 2006; Lemckert *et al.* 2006; Stephens and Anderson 2014; Jung 2016; Torre *et al.* 2016; Read *et al.* 2018). In addition, some small mammals may sustain fatal injuries while trying to escape from wire mesh live traps (Jung and O'Donovan 2005). As such, trapping protocols, best practices, and standards are often available—and continually refined—to ensure the welfare of captured individuals and increase the probability of them surviving capture and handling (Petit and Waudby 2012; Hampton *et al.* 2016; Waudby *et al.* 2019; Machtinger and Williams 2020).

One aspect of live trapping that has received scant attention in the literature is opportunistic predation of captured animals (Ferguson and Forstner 2006; Ferguson *et al.* 2008). One exception is the opportunistic predation of bats captured in mist nets, which has recently been documented and mitigations to reduce the problem have been proposed (e.g., Rocha-Mendes and Bianconi 2009; Jung *et al.* 2011; Serra-Goncalves *et al.* 2017; Gallego *et al.* 2021). Small rodents captured in pitfall traps have been reported to be predated while in traps. For example, Delicate Mouse (*Pseudomys delicatulus*) and Northern Hopping Mouse (*Notomys aquilo*) were observed being predated from pitfall traps by Ghost Bat (*Macroderma gigas*) in

Australia (Diete *et al.* 2016). In Texas, several mammalian and avian predators were observed investigating pitfall traps and preying on captured animals, with Northern Raccoon (*Procyon lotor*) and American Crow (*Corvus brachyrhynchos*) the most detected species (Ferguson *et al.* 2008). Accordingly, modifications to pitfall traps have been suggested to mitigate the risk of predation to captured animals (e.g., Aubry and Stringer 2000; Ferguson and Forstner 2006; Edwards and Jones 2014). Larger animals are also sometimes subject to opportunistic predation when live trapped. For instance, Honey Badger or Ratel (*Mellivora capensis*) have preyed on foxes (Rüppell's Fox [*Vulpes rüppelli*] and Red Fox [*Vulpes Vulpes*]) live trapped by researchers in Saudi Arabia (Lenain and Ostrowski 1998).

Similar observations of opportunistic predation of small mammals during live-trapping campaigns using box-style traps (e.g., Sherman, Longworth, Elliot, or Ugglan traps) are less reported. This may be because predation events have not been well studied or observed, not because they do not occasionally occur. Predators disturbing small mammal traps is a long-standing problem and several mitigations to reduce their access to traps have been developed (e.g., Getz and Batzli 1974; Watson and Watson 1985; Layne 1987; Matlack *et al.* 2006; Roden-Reynolds *et al.* 2018). For instance, small mammal live traps in Yukon must often be protected with a wire cage to prevent disturbance by Red Squirrel (*Tamiasciurus hudsonicus*) and Arctic Ground Squirrel (*Urocitellus parryii*; Boonstra and Krebs 2006). Access to trap contents by predators may be primarily to obtain the bait, but opportunistic predation of captured small mammals is likely. In an exceptional observation, up to 41% of Sherman traps in Kansas were opened by crows (Matlack *et al.* 2006). Direct predation of captured small mammals was not observed, but, based on fresh pellets in the traps, some predation was suspected. Also in Kansas, carnivores, including raccoons, Virginia Opossum (*Didelphis virginiana*), Long-tailed Weasel (*Mustela frenata*), Striped Skunk (*Mephitis mephitis*), and Domestic Cat (*Felis catus*), preyed on small mammals captured in Sherman traps (Slade *et al.* 1993). In the Pacific Northwest, Spotted Skunk (*Spilogale gracilis*) also disturb small mammal traps (Hooven *et al.* 1979). Wild Boar (*Sus scrofa*) disturbed or destroyed small mammal traps in Spain (Torre *et al.* 2022). Fire Ant (*Solenopsis invicta*) introduced to the southern United States, preyed on 12.7% of captured small mammals, with Northern Pygmy Mouse (*Baiomys taylori*) the most affected (Masser and Grant 1986). In agricultural fields in Australia, birds opportunistically preyed on House Mouse (*Mus musculus*) after they were released from live traps, when the mice were at high densities and little cover was available (C.J.K. and A.J.K. pers. obs.). Here, we report a Common Raven (*Corvus corax*) preying on a deermouse (*Peromyscus* spp.) after it was released from a live trap and we provide best practices to avoid similar occurrences.

On 27 May 2021, we live trapped small mammals (mice and voles; <60 g) near the border of Kluane National Park, in southwestern Yukon, Canada, as part of a long-term monitoring program of food webs in the boreal forest (e.g., Krebs *et al.* 2011, 2019; Boonstra *et al.* 2018). Briefly, we used a 10 × 10 array of Longworth live traps (Longworth Scientific Instruments Co., Oxford, United Kingdom), baited with whole oats and apple and supplied with a wooden cover and cotton bedding, to capture small rodents (see Krebs *et al.* 2011, 2019 for details). At ~0730 local time, T.S.J. caught an adult male deermouse (21 g) that was lethargic and appeared to be arousing from torpor. After processing the animal (i.e., determining its weight and sex and reading the ear tag), we held it for 3–4 min to warm it passively. On release, it was moving slowly, so we recaptured it by hand and held it for another 2–3 min before releasing it beside a log within 2 m of the trap and moving to the next trapping station. After leaving, we heard the call of a raven from near the trap. Working on the adjacent grid line about 15–20 m away, A.J.K. saw a raven rise from the vicinity of where the deermouse was trapped, and she noticed it had a small mammal with a long tail in its beak. She communicated this information to T.S.J. and C.J.K., and T.S.J. immediately saw two ravens fly toward him. The lead raven landed in the top of a tall, dead White Spruce (*Picea glauca* (Moench) Voss) tree, where we could clearly see a small mammal with a long tail in its beak, as it was silhouetted against the sky. Unfortunately, it perched too briefly to photograph, as it quickly flew off to avoid the approach of the other raven. The ravens were not seen again. Temperature at the time of capture was about 5°C and it was slightly overcast.

We believe that the raven successfully preyed on the deermouse because the mouse had not yet fully aroused from torpor and was not able to find adequate shelter or evade the raven. Deermice may use daily torpor as an energy conservation measure in response to inclement weather or food shortages (Lynch *et al.* 1978; Vogt and Lynch 1982; Tannenbaum and Pivorun 1988, 1989; Nestler 1990). Use of torpor may occur any time of the year but is most likely when the ambient temperature is <5°C (Lynch *et al.* 1978; Tannenbaum and Pivorun 1988). Arousal from torpor occurs via nonshivering thermogenesis (Tannenbaum and Pivorun 1989) and takes about 12 min (Nestler 1990), during which time the animal is likely to be listless and slow or unable to respond to stimulus or potential threats. Had the deermouse not been in torpor, it would likely have had a better chance of escaping predation by the raven.

Several best practices to prevent similar incidents of opportunistic predation of live-trapped small mammals that are torpid are apparent. Perhaps most important is that those live capturing small mammals be cognizant of the possibility of animals in traps being in torpor, especially when trapping at cooler temperatures. Detecting animals in torpor is straightforward if trapping crews are aware that it is possible. Researchers should consider trapped animals that are noticeably listless or lethargic as torpid. Passively warming the animal in the researchers' hands can be effective if done long enough. In our case, the time we held the animal to warm it was likely insufficient. Nestler (1990) indicated that it takes deermice about 12 min to arouse from daily torpor. More important than the elapsed time, for passive warming to be effective to mitigate predation risks, it should continue until the animal is notably active, which can be subjectively measured by how vigorously it struggles and tries to escape. Another solution is to return the torpid animal to a locked-open live trap so that it can arouse from torpor in relative safety. This approach may be enhanced by placing a warming device in the trap for at least 12 min before releasing the animal. This would not protect it from terrestrial predators, such as weasels (*Mustela* spp.) or snakes, but it would provide protection from aerial predators. Alternatively, the trap could be closed to protect the animal; however, a researcher would have to return to release the animal once it aroused from torpor.

Researchers must be constantly aware and mindful of potential predators when processing small mammals, regardless of whether they are torpid. Prior identification of species of predators where trapping occurs is essential. Some species of corvids and mustelids may be attracted to small mammal traps and researchers processing captured animals. In our case, we were unaware of the ravens watching the deermouse being processed. Captured animals must always be released only when they appear fully able to respond to threats and where they can immediately seek cover, such as under a log or shrub, down a hole, or in a thicket of grass. Our observation further highlights the need for researchers to be vigilant for potential opportunistic predation of small mammals captured in live traps and to take actions to mitigate the risk.

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An overview of known species killed during Alberta's Gray Wolf (*Canis lupus*) strychnine program, 2005–2020

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Abstract

To determine the minimum effect of strychnine baits placed for wolves in winter during a program targetting Gray Wolf (*Canis lupus*) in west-central Alberta from 2005 to 2020, I present a summary of all recorded species killed (*n* = 522). Fewer wolves (*n* = 245) were killed compared with non-target animals (*n* = 277), which included 10 mammal and four bird species. These data provide context on the environmental and ethical impacts of using poison as a component of wildlife management.

Key words: Gray Wolf; *Canis lupus*; wolf; predator; predacide; scavenge; strychnine; non-target kill; non-target species; non-target animal; predator control; secondary poisoning; Alberta

Introduction

Strychnine, a highly toxic compound, was first registered for use as a vertebrate pesticide in Canada in 1928 (PMRA 2005). Its use as a wildlife management tool has since been abandoned in all provinces and territories except Alberta (Health Canada 2022). Alberta maintains two separate use permits for strychnine: registration no. 20410 (155 mg/tablet, minimum 38.6% strychnine), which is authorized for use on Gray Wolf (*Canis lupus*), Coyote (*Canis latrans*), and American Black Bear (*Ursus americanus*); and registration no. 24510 (liquid 35 mg/mL), which is authorized for use on Striped Skunk (*Mephitis mephitis*). Both applications involve the use of bait, which is ingested, to deliver the toxin (Health Canada 2021a, 2022, 2023). Strychnine is considered to be a "predacide" by Health Canada, and I use that term in this paper to describe a toxicant registered in Canada as a product to kill predators. Strychnine remains highly persistent in baits and poisoned carcasses (Eason and Wickstrom 2001).

Strychnine affects the central nervous system; clinical symptoms include frequent periods of severe tetanic seizures, hyperthermia, and extreme agitation and restlessness before death by asphyxiation (Eason and Wickstrom 2001; Khan 2010). Death typically occurs within 1–2 h of the onset of symptoms (Khan 2010), but can take 24 h or more with a low dose (Eason and Wickstrom 2001; Proulx *et al.* 2016a). Strychnine also causes death from secondary poisoning (i.e., relay toxicity) when scavengers ingest a poisoned carcass (Cain *et al.* 1972; USEPA 1980; Allan 1989).

Recently, Harris and Armstrong (2021) provided an overview of experimental Gray Wolf poisoning programs carried out in northern Ontario (1956–1965), which included the use of strychnine, cyanide, and compound 1080. In that synopsis, 10 mammal and nine bird species—which the authors emphasize represents minima—were recorded among the non-target organisms killed, with target mammals (wolves, *n* = 119) accounting for ~31% of total toxicant kills (*n* = 384; Harris and Armstrong 2021). In Ontario, the use of poison as a wolf-management tool was disallowed by the early 1980s (Kolenosky 1983) and remains prohibited under Ontario's 1997 *Fish and Wildlife Conservation Act* (Harris and Armstrong 2021).

In March 2020, Health Canada's Pest Management Regulatory Agency (PMRA) announced its decision to cancel and discontinue the use of 2% liquid strychnine for purposes of poisoning Richardson's Ground Squirrel (*Urocitellus richardsonii*; Health Canada 2020). In that application, baits coated with liquid strychnine were placed below ground in squirrel tunnels. Nonetheless, the decision to discontinue use was made because of environmental risks to non-target organisms, including species-at-risk.

I consolidated known kills of non-target species during a wolf-strychnine program in west-central Alberta. I focussed on a wolf population reduction program carried out in Alberta as part of provincial recovery efforts for select herds of federally Endangered

Woodland Caribou (*Rangifer tarandus caribou*; Hervieux *et al.* 2014, but also see Bekoff 2014; Brook *et al.* 2015; and Field *et al.* 2019). In the winter of 2005/2006, Alberta's Ministry of Environment and Sustainable Resource Development (AESRD) initiated an annual winter wolf population reduction program that entailed using strychnine in two Woodland Caribou herd ranges in west-central Alberta, in addition to shooting wolves from aircraft (Hervieux *et al.* 2014). The government-delivered toxicant portion of the program was conducted annually in winter until 2019/2020, inclusive, except for 2009/2010 and 2018/2019.

Data on deaths during the program had not been tabulated to compare recorded deaths among target and non-target species, annually or cumulatively. Also, the number of species impacted had not been tallied. To make the data more comprehensive, meaningful, and publicly available, I compiled the existing records and organized known deaths by species. Little peer-reviewed data exist for non-target kills from strychnine programs that target predators. Thus, it is important to shed light on what is known.

The operation and delivery of the wolf-strychnine program I examined are outlined in Hervieux *et al.* (2014), but see Field *et al.* (2019). Ungulate populations in the area included Woodland Caribou, Moose (*Alces americanus*), Elk (*Cervus elaphus*), White-tailed Deer (*Odocoileus virginianus*), and Mule Deer (*Odocoileus hemionus*; Hervieux *et al.* 2014). Large mammalian carnivores in the area included Gray Wolf, Grizzly Bear (*Ursus arctos*), American Black Bear, Cougar (*Puma concolor*), Canada Lynx (*Lynx canadensis*), Wolverine (*Gulo gulo*), and Coyote (Hervieux *et al.* 2014). Scientists and policymakers consider this area "the most highly disturbed woodland caribou range in Canada" (Government of Alberta 2019b: 30/78; also see Denhoff 2016; Hebblewhite 2017).

My objectives were to determine the number and species of non-target birds and mammals recorded as killed incidentally in the aforementioned strychnine program targetting wolves in west-central Alberta from 2005 to 2020. Although this particular strychnine program was not carried out during 2021 or 2022, the federal authorizing permit (no. 20410), under the authority of Health Canada's PMRA, remains active until 31 December 2024. On expiration of the use permit, Alberta may apply for renewal.

Methods

I reviewed and compiled data on all carcass retrievals associated with the wolf-strychnine program from 2005 to 2020. Data came from a variety of sources, including an annual report by the government of Alberta (AESRD 2012), supplementary material from a scientific publication (Hervieux *et al.* 2014), AESRD records obtained through Alberta's freedom of information and protection of privacy process (Government of Alberta 2018, 2019a,b, 2020), Health Canada pesticide incident reports (Health Canada 2013, 2018), and direct communication with the program lead (D. Hervieux).

Records were grouped into mammal and bird categories, and the number of kills was tallied by species. I compared the number of intended kills (wolves) with the number of unintended, non-target kills by strychnine. Where multiple records for the same year showed discrepancies in the data, I used the higher number of toxicant deaths reported and noted the inconsistency. Hervieux *et al.* (2014) describe an average of 15 to 20 strychnine bait stations active during mid to late winters from 2005/2006 to 2011/2012, excluding 2009/2010, for a total of 5709 bait-site days. Although this information was not available beyond 2012, records indicate that from 2012 to 2020 the Woodland Caribou Recovery Program used a total of 8433 strychnine tablets (155 mg/tablet), ranging from 40 tablets in 2016 to 1842 tablets in 2013 (PMRA 2020a).

Results

Overall, strychnine killed fewer wolves ($n = 245$) than non-target animals ($n = 277$; Table 1). Recorded deaths of non-target animals exceeded those of the target species (wolves) during nine of the 13 winters in which strychnine was used (Figure 1).

Mortalities were documented for 10 mammal and four bird species (Table 1) including: Bald Eagle (*Haliaeetus leucocephalus*), Canada Jay (*Perisoreus canadensis*), Canada Lynx, Coyote, Domestic Dog (*Canis familiaris*), Fisher (*Pekania pennanti*), Red Fox (*Vulpes vulpes*), Golden Eagle (*Aquila chrysaetos*), Grizzly Bear, Mink (*Mustela vison*), Pine Marten (*Martes martes*), Raven (*Corvus corax*), Striped Skunk, and weasel (*Mustela* sp.).

Discussion

The data presented here should be regarded as the minimum number of kills. Additional kills were likely undocumented and, thus, underreported. For instance, animals wandering away from a bait site with bait in their mouth or a poisoned animal that moves into forest cover before dying (Figure 2b), can preclude carcass detection and retrieval. Scavengers may also consume (Figure 2b) or carry off/translocate a poisoned carcass or part(s) of it. In addition to contributing to undocumented kills, such circumstances can also further distribute strychnine to unknown areas, thereby increasing the likelihood of secondary poisoning and

TABLE 1. Mammals and birds killed by strychnine during west-central Alberta's winter wolf reduction program, by year.

	Year of strychnine program (2005/2006 to 2019/2020)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total (%)
Mammals																
Gray Wolf (*Canis lupus*)	28	19	28	16	0	34	29	27	23	16	0	10	8	0	7	245 (46.9)
Coyote (*Canis latrans*)	6	3	7	9	0	6	5	4	1	1	1	3	8	0	2	56 (10.7)
Red Fox (*Vulpes vulpes*)	0	8	9	6	0	7	1	1	8	3	0	1	0	0	0	44 (8.4)
Domestic Dog (*Canis familiaris*)	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4 (0.8)
Canada Lynx (*Lynx canadensis*)	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	4 (0.8)
Marten (*Martes martes*)	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4 (0.8)
Fisher (*Pekania pennanti*)	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	3 (0.6)
Striped Skunk (*Mephitis mephitis*)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2 (0.4)
Weasel (*Mustela* sp.)	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2 (0.4)
Grizzly Bear (*Ursus arctos*)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1 (0.2)
Mink (*Mustela vison*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1 (0.2)
Birds																
Common Raven (*Corvus corax*)	8	7	17*	8	0	29	24†	12	14	12	2	6	4	0	9	152 (29.1)
Golden Eagle (*Aquila chrysaetos*)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2 (0.4)
Bald Eagle (*Haliaeetus leucocephalus*)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1 (0.2)
Canada Jay (*Perisoreus canadensis*)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1 (0.2)

Sources, by year: 1–7: AESRD (2012), Hervieux *et al.* (2014: Tables S2, S3), Government of Alberta (2018); 8: AESRD (2012), Health Canada (2013), Government of Alberta (2018); 9, 10: Government of Alberta (2018); 11: D. Hervieux pers. comm. (2022); 12, 13: Government of Alberta (2018); 14: Government of Alberta (2019a); 15: Government of Alberta (2020).
Note: Shaded columns indicate years in which the strychnine program was not conducted.
*Discrepancy in data, where AESRD (2012) and Hervieux *et al.* (2014: Table S3) indicate 16 toxicant kills.
†Discrepancy in data, where AESRD (2012) and Hervieux *et al.* (2014: Table S3) indicate 23 toxicant kills.

further underreporting of strychnine kills. Although the search effort for both target and non-target species killed during the program discussed here was unknown, strychnine-poisoned wolves have been found at distances >1 km from poisoned baits (Rettie 1958; Harris and Armstrong 2021). Furthermore, evidence of mortality may be obscured by snow burial or other weather conditions which cannot be mitigated. For example, in winter 2008/2009, records indicate that although 16 wolves were documented as killed by strychnine, "additional wolves [were] not recovered due to poor snow conditions" (AESRD 2012: 5).

The use of poison as a wildlife management tool is highly controversial because of its reputation for causing prolonged suffering and broad damage (i.e., non-selectivity; Cluff and Murray 1995; Brook *et al.* 2015; Proulx *et al.* 2016a; Field *et al.* 2019; Parr and Barron 2021). Given the limited datasets used in my study, it was not possible to infer population-level effects or impacts on community ecology. However, it is worth noting that the data include species that have been designated by the provincial government as "sensitive" (Canada Lynx, Fisher, Golden Eagle) and "at-risk" (Grizzly Bear; AEP 2022). Grizzly Bear is also listed as a species of Special Concern under the Canadian *Species at Risk Act*, schedule one (SARA Registry 2023). At least one Grizzly Bear was killed by strychnine during winter 2012/2013 (Government of Alberta 2018). Public accounts with photo evidence have also been reported to the PMRA by local citizens with registered traplines in the area, suggesting that Grizzly Bear poisoning has occurred more frequently (D. Handy and S. Ramstead unpubl. data) and that additional animals killed by strychnine have gone unrecorded (see Health Canada 2018).

Proulx *et al.* (2016a) point out that the use of strychnine to kill wolves is in contravention of guidelines for the Canadian Council on Animal Care (CCAC 2003, 2023), the American Veterinary Medical Association (AVMA 2013, 2020), the Canadian

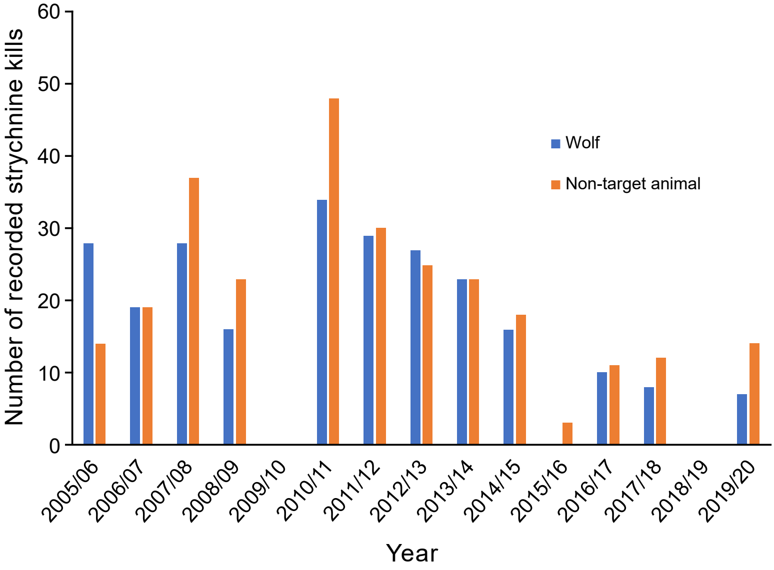

FIGURE 1. Numbers of wolves and non-target animals killed in each year of Alberta's annual winter wolf-strychnine program, 2005–2020. Of 522 recorded kills by strychnine, 46.9% were target animals (wolves, *n* = 245), while 53.1% were incidental kills of non-target organisms (*n* = 277), comprising ten mammal and four bird species.

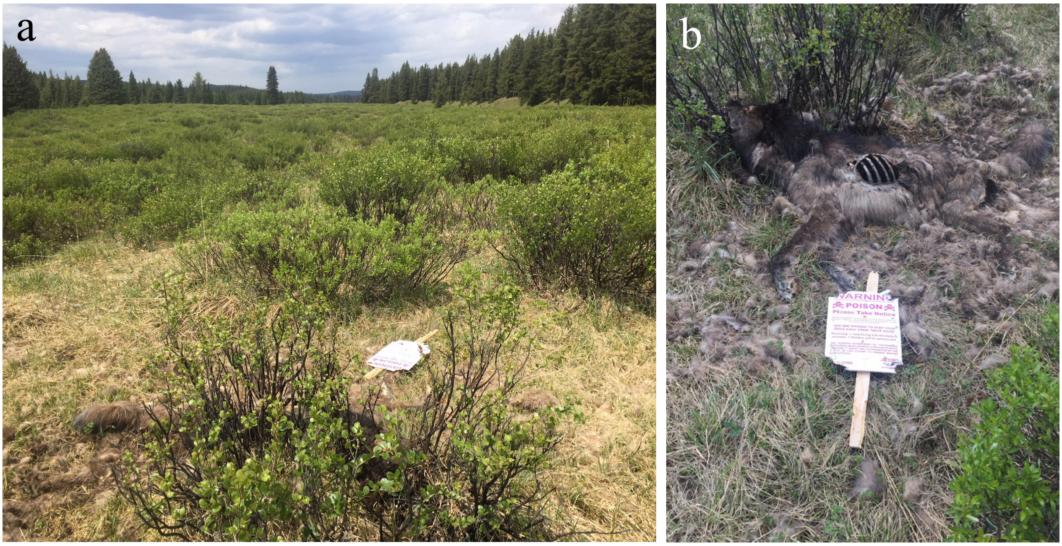

FIGURE 2. Strychnine bait station from Alberta's wolf-strychnine program, 8 June 2018. a. This station was located near forest cover where poisoned animals may move before dying, making kills more difficult to find. b. Close-up image of the scene showing poison-use sign and strychnine-killed wolf carcass. Photos: Darcy Handy.

Veterinary Medical Association (CVMA 2014, 2022), and the American Society of Mammalogists (Sikes *et al.* 2011). The International Union for Conservation of Nature does not condone poisoning wolves (IUCN Wolf Specialist Group of the Species Survival Commission 2000).

Many people, including scientists, argue that animal welfare should be sufficient grounds for ending the use of strychnine (Paquet and Darimont 2010; Dubois *et al.* 2017; Parr and Barron 2021). Contrary to this sentiment, following a consultation period on "humane vertebrate pest control", Health Canada announced in 2021 that the PMRA would "not be taking steps towards incorporating humaneness considerations into the pesticide risk assessment framework" (PMRA 2021). Although the PMRA may have determined that the level of suffering to individual animals and the environmental risk of non-target deaths to terrestrial organisms is acceptable, many disagree with this assessment (Cluff and Murray 1995; Bekoff 2014; Brook *et al.* 2015; Proulx *et al.* 2016a,b, 2017; Dubois *et al.* 2017; Wolf Awareness 2018; Mitchell 2020; Health Canada 2021b; Weber 2020, 2021; Animal Alliance of Canada 2023). According to a national poll, commissioned by non-governmental organizations and carried out by Environics in 2020, 69% of Canadians say that the risks posed by predacides used in Canadian wildlife management programs are unacceptable (Animal Justice 2022; S.P. unpubl. data). Local Indigenous Peoples, specifically those of the Aseniwuche Winewak Nation, have also expressed their disdain for the Alberta government's use of strychnine as part of caribou recovery efforts, despite having a deep connection with caribou and a strong desire for their recovery (Denhoff 2016). Currently, Alberta is the sole province in Canada with authorized permits, which are registered through Health Canada's PMRA, for predacide use (strychnine and sodium monofluoroacetate). Outside of Alberta, provinces and territories with caribou recovery efforts underway, including British Columbia, Saskatchewan, Manitoba, Ontario, Quebec, Northwest Territories, and Nunavut, do not use these toxicants. Of note, in the caribou ranges of Alberta where strychnine is used, the level of industrial disturbance has increased since the lethal wolf reduction program began in 2005 (Hervieux *et al.* 2014; Hebblewhite 2017; Nagy-Reis *et al.* 2021), indicating a lack of willingness by Alberta's government to address the ultimate causes of decline and favouring instead other stop-gap measures.

Health Canada's PMRA is undergoing a re-evaluation of the uses of predacidal strychnine and sodium monofluoroacetate and their associated end-use products (Health Canada 2022). Following an initial process of re-evaluation which included a review of the data presented here, on 31 August 2022, the PMRA announced a proposal to continue registration of predacidal strychnine and sodium monofluoroacetate (Health Canada 2022).

In summary, I have shown that from 2005 to 2020, west-central Alberta's wolf-strychnine program killed more non-target animals than wolves, including various bird and mammal species. A variety of non-target animal species were killed in the program, including federally listed species-at-risk and domestic animals. Management agencies considering the use of poison as part of wildlife management programs should carefully consider the ethical and environmental costs associated with such programs, which here have included the suffering and death of both the target species and a significant number (>50%) of non-target animals.

Note

As of 7 March 2024 Health Canada's Pest Management Regulator Agency announced that all predacide uses of strychnine products in Canada have been cancelled. Alberta was the only province that allowed the use of this predacide. After the six-month phasing out period ends in early September 2024, strychnine will no longer be permitted/legal to use. See https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/reevaluation-decision/2024/predacide-uses-strychnine-sodium-monofluoroacetate.html. Information contained in the current paper contributed to this ruling.

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Note

Chilostigma itascae (Trichoptera: Limnephilidae), a globally rare caddisfly new for Canada

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Abstract

Headwater Chilostigman Caddisfly (*Chilostigma itascae*) is an enigmatic winter-active caddisfly previously reported solely from Minnesota. This note reports the first Canadian records from southern Manitoba and northwestern Ontario.

Key words: *Chilostigma itascae*; caddisfly; Trichoptera; peatland; Manitoba; Ontario

Headwater Chilostigman Caddisfly (*Chilostigma itascae* Wiggins; Trichoptera: Limnephilidae) is an enigmatic winter-active caddisfly first discovered between 20 February and 10 March 1974 in Itasca State Park, Minnesota (Wiggins 1975). Adults were encountered on the snow surface on relatively warm, sunny winter days. Additional locations were not found until 21 March 2005, during a snowshoeing trek through the Sand Lake Peatland in northeastern Minnesota (K.E.J. pers. obs.). Between 2011 and 2017, four additional locations were added in northwestern Minnesota (K.E.J. pers. obs.; C. Novak pers. comm. 23 March 2011; Figure 1). Records were from 13 February to 29 March, and all individuals were active from 1100 to 1530 on the snow surface during relatively warm (2–8°C) days with full to partial sun. Most were within, or immediately adjacent to, rich fens and conifer swamps with seepage areas; one individual was found on uplands within 350 m of a sedge meadow/carr.

Larvae have not been positively identified; they probably inhabit streams and seeps (Wiggins 1996). The only other species in the genus, *Chilostigma sieboldi* McLachlan, 1876, occurs in Poland, Sweden, Lapland, Finland (Morse 2023), and Japan (Tanida *et al.* 1999).

On 17 February 2017, K.E.J. collected a single *C. itascae* specimen from the Manitoba side of the Pine Creek Peatland (49.00093°N, 95.89704°W; Figures 2 and 3a), a large patterned peatland complex spanning the Manitoba–Minnesota border, which is recognized as a "scientific and natural area" on the Minnesota side (MDNR 2023a). The site was a spring fen channel complex—a mosaic of graminoid rich fen channels within a rich conifer swamp. Snow depth was 30–50 cm, but standing water punctuated the snow surface in some spring fen channels. The rich conifer swamp was dominated by Black Spruce (*Picea mariana* (Miller)), with fewer Tamarack (*Larix laricina* (DuRoi) K. Koch) and Eastern White Cedar (*Thuja occidentalis* L.). Sphagnum and feathermosses formed a continuous carpet dominated by ericaceous shrubs (Ericaceae), sedges (Cyperaceae), and various forbs. The channels were composed of a quaking (in the growing season) sedge mat dominated by Woolly-fruited Sedge (*Carex lasiocarpa* Ehrhart) with plentiful Bogbean (*Menyanthes trifoliata* L.) and Pitcher Plant (*Sarracenia purpurea* L.). Low shrubs, including Bog Birch (*Betula pumila* L.) and Shrubby Cinquefoil (*Dasiphora fruticosa* (L.) Rydberg), were common along channel edges.

A.G.H. and L.V.H.S. searched for *C. itascae* in northwestern Ontario by snowshoeing in fen and conifer swamp habitat and searching the surface of

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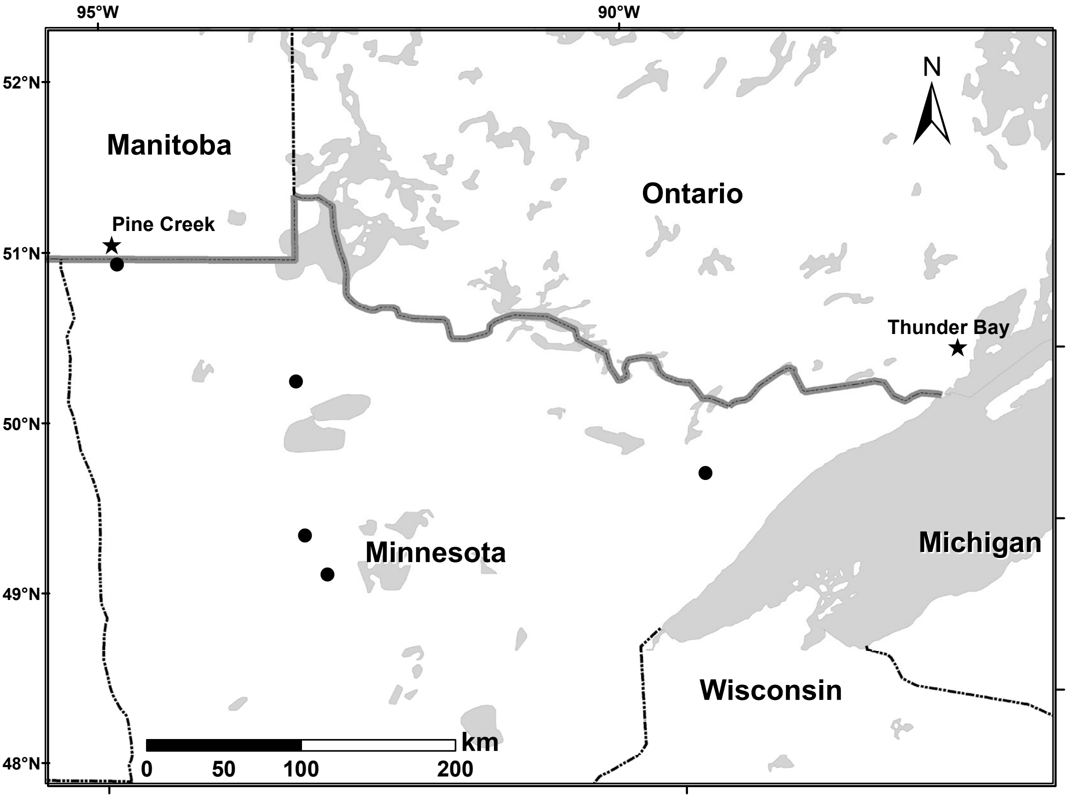

FIGURE 1. Global range of Headwater Chilostigman Caddisfly (*Chilostigma itascae*). The stars represent the only Canadian records and the black circles represent all other known records of the species.

FIGURE 2. Headwater Chilostigman Caddisfly (*Chilostigma itascae*) at Pine Creek, Manitoba, 17 February 2017. Photo: K.E. Johnson.

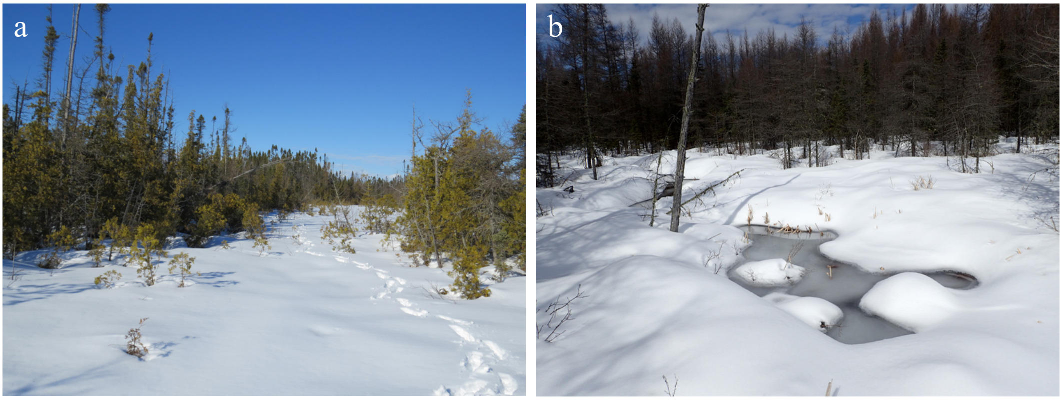

FIGURE 3. Habitat of Headwater Chilostigman Caddisfly (*Chilostigma itascae*) at a. Pine Creek, Manitoba, 17 February 2017 and b. at William Bog, Thunder Bay, Ontario, 22 March 2018. Photo a: K.E. Johnson. Photo b: A.G. Harris.

the snow for invertebrates. Surveys were conducted on 16 days between February 2018 and April 2021 (Table 1). Between April 2018 and May 2019, water temperatures (HOBO UA-001-64 Pendant Temperature Data Logger, Onset Computer Corporation, Bourne, Massachusetts, USA) were recorded in a small stream at the William Bog. The logger recorded water temperature every 2 h, and the mean daily temperature was calculated. Surface water pH and conductivity were measured on 26 February 2021 (Hanna Combo Meter, Hanna Instruments, Woonsocket, Rhode Island, USA).

Most of the survey effort was at William Bog, a peatland covering over 600 ha of predominantly fen and conifer swamp habitat within the city limits of Thunder Bay (Noble *et al.* 1993). Other survey sites with similar habitat included the Trewartha Township, Scotch Lake, and Black Bay fens (Table 1).

Chilostigma itascae was observed on the surface of the snow at William Bog on seven of 12 search dates between 17 February and 19 March (Table 1). None was observed at other sites. A maximum of 10 individuals was seen on 19 March 2019. None was observed on the two search dates in early April.

TABLE 1. Survey effort for Headwater Chilostigman Caddisfly (*Chilostigma itascae*), 2017–2021.

Location	Latitude, °N	Longitude, °W	Date	Time	Air temperature, °C	No. *C. itascae*
Pine Creek Peatland	49.0009	95.8970	17 February 2017	1430–1500	5–8	1*
William Bog	48.3985	89.3012	28 February 2018	1220–1350	0	4
William Bog	48.3985	89.3012	9 March 2018	1300–1430	−2	7
William Bog	48.3985	89.3012	14 March 2018	1315–1434	4	7
William Bog	48.3985	89.3012	22 March 2018	1700–1840	3	2
William Bog	48.3985	89.3012	25 March 2018	1430–1550	5	2
William Bog	48.3985	89.3012	5 April 2018	1230–1345	2	0
William Bog	48.3985	89.3012	10 April 2018	1730–1825	6	0
William Bog	48.3985	89.3012	13 February 2019	1700–1830	−3	0
William Bog	48.3985	89.3012	19 March 2019	1315–1500	7	10
Scotch Lake	49.2264	91.1359	25 March 2019	0930–1120	−1	0
Trewartha Peatland	49.1657	90.8067	25 March 2019	1220–1340	0	0
Black Bay Peatland	48.8578	88.2851	14 March 2020	1030–1230	−2	0
William Bog	48.3985	89.3012	26 February 2021	1200–1330	5	2
William Bog	48.3985	89.3012	7 March 2021	1200–1320	4	0
William Bog	48.3985	89.3012	17 March 2021	1200–1345	11	0
Sawmill Bay	48.9061	90.3531	4 April 2021	0830–1030	0	0

*Another 12 were observed on the Minnesota side of the peatland.

Weather for all surveys was relatively calm (<3 on the Beaufort Wind Scale) with temperatures between −2° and 7°C. Snow cover was estimated at 30–100 cm on search dates.

On 14 March 2018, four *C. itascae* specimens were collected and deposited at the Royal Ontario Museum (ROM) and Clemson University. Identification was confirmed by Doug Currie (ROM) and John Morse (Clemson University Arthropod Collection). All collected individuals were males. Vouchers are listed below.

All observations were <250 m from a small stream originating in the conifer swamp to the northwest and flowing southeast through the open fen (Figure 3b). The stream's flow is perennial and depth is mainly <50 cm. Between April 2018 and May 2019, mean daily water temperatures were <12°C (Figure 4). On 26 February 2021, stream water pH was 6.52 and conductivity was 837 μS/cm.

Observations of *C. itascae* were on a cleared pipeline right-of-way through a fen and rich conifer swamp with seepy organic soil. Vegetation consisted of sedges (especially Creeping Sedge [*Carex chordorrhiza* L. f.] and Woolly-fruited Sedge) and scattered low shrubs (honeysuckle [*Lonicera* spp.], Sweet Gale [*Myrica gale* L.]). The conifer swamp on either side of the right-of-way consists of small (<10 m tall) Tamarack, Black Spruce, and Eastern White Cedar.

Individual *C. itascae* walked rapidly on the snow surface at a rate measured at 230 cm/min in one case. No interactions between conspecifics were observed.

Globally, *C. itascae* is ranked as Imperilled (G2) because of its restricted range, narrow environmental requirements, and unusual phenology (NatureServe 2023). In Minnesota, it is listed as Threatened, based on its restricted range and small number of occurrences (MDNR 2023b). The species is not ranked in Manitoba or Ontario (NatureServe 2023). Despite its imperilled status, the range of *C. itascae* is undoubtedly underrepresented. Entomologists tend to avoid both peatlands and snow-covered habitats (A.G.H. pers. obs.), which readily explains the paucity of records. Fen and conifer swamp cover over 700 000 ha in northwestern Ontario (Riley and Michaud 1989), including some extensive, unsurveyed peatlands within the currently known extent of occurrence of the species. A much broader distribution across the boreal zone cannot be discounted, given the lack of focussed surveys and vast areas of potential habitat.

Habitat loss and degradation, especially pollution, changes to riparian habitat, and warming water temperatures are potential threats to this caddisfly (MDNR 2023b). William Bog formerly covered over 1000 ha but development of housing, commercial land, and highways has reduced the wetland area to less than 600 ha since the 1940s (Noble *et al.* 1993). Although the peatland receives protection as a provincially significant wetland (Land Information Ontario 2023) and portions are held as nature reserves by the Thunder Bay Field Naturalists, changes to hydrology and water quality from highway and residential runoff are ongoing threats to putative larval habitat.

Voucher specimens

CANADA, MANITOBA: Pine Creek Peatland, 49.00093°N, 95.89704°W, rich fen, 17 February 2017,

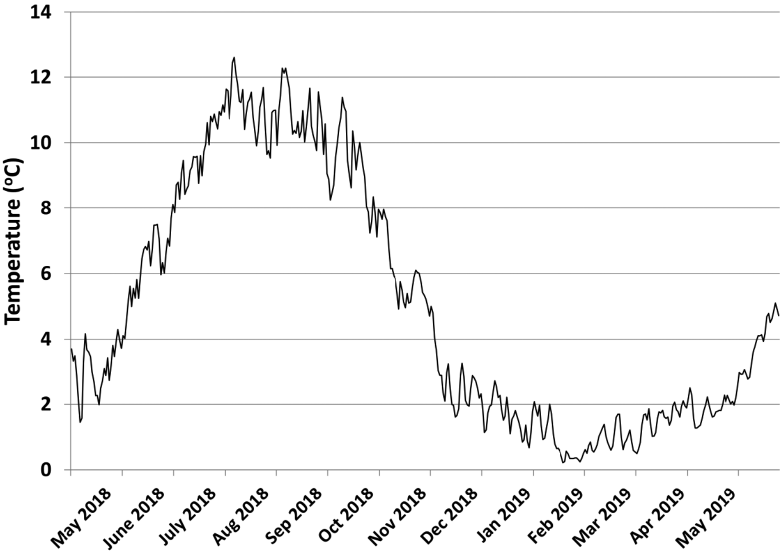

FIGURE 4. Mean daily stream water temperature at William Bog, Thunder Bay, Ontario, Canada, April 2018 to May 2019.

K.E. Johnson N-2017-26. Wisconsin Insect Research Collection (no accession number).

CANADA, ONTARIO: City of Thunder Bay, 48.3985°N, 89.3012°W, rich fen, 14 March 2018, *L.V.H. Spenceley and A.G. Harris 18-011, 18-012* (Royal Ontario Museum accession numbers ROM E206214 to ROME206221).

CANADA, ONTARIO: City of Thunder Bay, 48.3985°N, 89.3012°W, rich fen, 14 March 2018, *L.V.H. Spenceley and A.G. Harris 18-009, 18-010* (Clemson University Arthropod Collection database numbers CUAC000068109 and CUAC000068110).

Author Contributions

Fieldwork: A.G.H., L.V.H.S., and K.E.J.; Writing: A.G.H., L.V.H.S., and K.E.J.

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Note

First records of the ant genus *Dolichoderus* (Hymenoptera: Formicidae) from Saskatchewan, Canada

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Glasier, J.R.N., and M. Rudy. 2023. First records of the ant genus *Dolichoderus* (Hymenoptera: Formicidae) from Saskatchewan, Canada. Canadian Field-Naturalist 137(3): 272–275. https://doi.org/10.22621/cfn.v137i3.2957

Abstract

We report the first provincial records of the genus *Dolichoderus* in Saskatchewan, represented by two species: Taschenberg's Long-necked Ant (*Dolichoderus taschenbergi*) and Mary's Long-necked Ant (*Dolichoderus mariae*). These species are previously known from eastern Canada and the eastern United States. The new discoveries fill in the range for *D. taschenbergi*, which has previously been found in Alberta and Manitoba, but has not been reported from Saskatchewan, and they represent a significant westerly range expansion of *D. mariae*, which has previously been reported in southeastern Manitoba and Ontario.

Key words: *Dolichoderus*; Saskatchewan; Canadian Formicidae: Taschenberg's Long-necked Ant; *Dolichoderus taschenbergi*; Mary's Long-necked Ant; *Dolichoderus mariae*

Dolichoderus is the most speciose ant genus in the subfamily Dolichoderinae, with over 200 species worldwide (Ellison *et al.* 2012). However, only four species are found in temperate North America (Johnson 1989): Mary's Long-necked Ant (*Dolichoderus mariae* Forel, 1885), Mottled Long-necked Ant (*Dolichoderus plagiatus* Mayr, 1870), Bog Long-necked Ant (*Dolichoderus pustulatus* Mayr, 1866), and Taschenberg's Long-necked Ant (*Dolichoderus taschenbergi* Mayr, 1866). (Note: We continue with scientific names, which are shorter and more widely used than common names.) All four temperate North American *Dolichoderus* species are from the Hypoclinea group and exhibit a distinct cleft in the back of the thorax (Mackay 1993; Ellison *et al.* 2012). Although they occupy different habitats, they have similar feeding behaviours, feeding on insects and plant nectar, and farming aphids for their honey dew (Johnson 1989; Ellison *et al.* 2012). Moreover, they share similar physical and behavioural characteristics, although Johnson (1989) describes their differences and how to identify them.

In Canada, all four species have been reported from Manitoba, Ontario, Quebec, and the Maritimes (Ellison 2012). West of Manitoba, *D. plagiatus* and *D. taschenbergi* have been reported from Alberta (Glasier *et al.* 2016), but there are no records of *Dolichoderus* in Saskatchewan (Glasier *et al.* 2016). In Alberta, *D. taschenbergi* is an uncommon ant, found in Jack Pine (*Pinus banksiana* Lambert) sand hills along the transition zone between the parkland and boreal forest natural regions of central Alberta (Glasier *et al.* 2013, 2019). *Dolichoderus plagiatus* is common in eastern Canada, and in Alberta a single female alate was reported near Mildred Lake (Specimen label: "57°03″N, 111°35″W malaise trap, 19–25 VIII.1979", J. Ryan & G. Hiltchie, Canadian National Collection 2020; no unique identifier number). More recently, *D. plagiatus* was collected from the Edmonton River Valley (53.503°N, 113.588°W, 5 July 2021, Hand Collection, JRNG.0140 in Glasier Collection 2023), but it is relatively rare in Alberta. For both species, these are the most northern and most western records in North America.

The first record of a *D. mariae* colony in Saskatchewan was found on 26 June 2020, by M.R. in an unusual cluster of wetlands that was being surveyed for rare plants, ~70 km ENE of Hudson Bay, Saskatchewan (52.927559°N, 101.786666°W; Figure 1). The wetlands occur as a complex of long graminoid fen bands alternating with elevated and sandy aspen-dominated ridges. The colony was constructed

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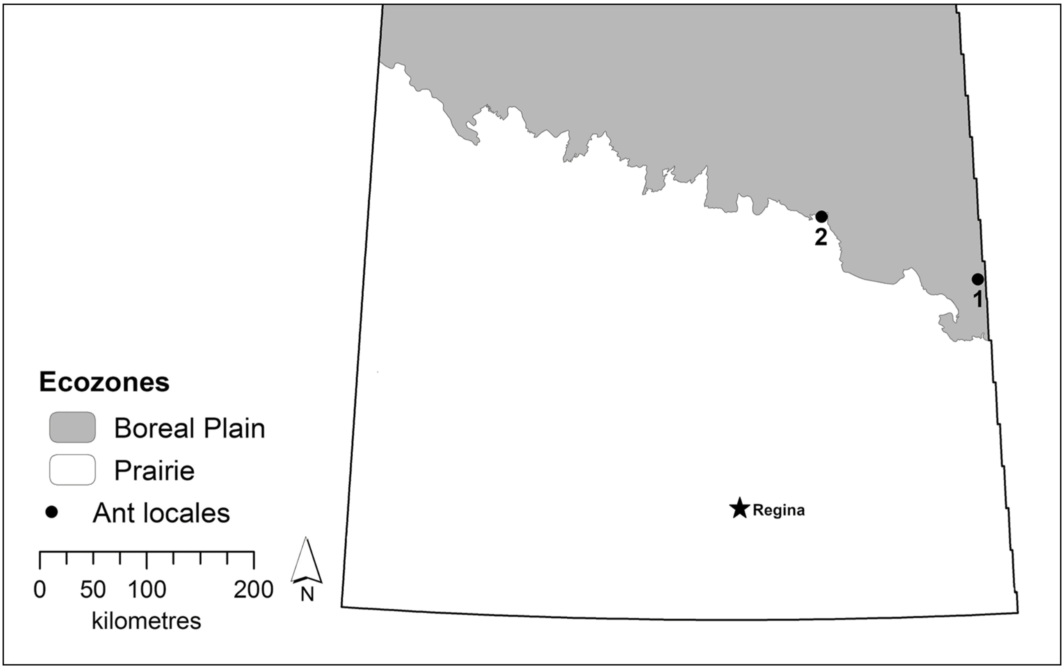

Figure 1. Map of southern Saskatchewan showing the two new *Dolichoderus* records. 1. First record of Mary's Long-necked Ant (*Dolichoderus mariae*) near Hudson Bay. 2. Record of Taschenberg's Long-necked Ant (*Dolichoderus taschenbergi*) near Carrot River. Ecozones are according to Ecological Stratification Working Group (1996).

atop a small mound of moss surrounded by pools of water and wetland vegetation, including Bog Cranberry (*Vaccinium oxycoccos* L.), dwarf birches (*Betula* spp.), Bog Rosemary (*Andromeda polifolia* L.), and sedges (*Carex* spp.). The mound seemed to be constructed of material from the surrounding vegetation, mainly sedge leaves/stems and Bog Cranberry leaves (Figure 2). On 11 July 2020, the colony was revisited to collect a sample, which was confirmed by J.R.N.G. and accessioned at the Royal Alberta Museum and J.R.N.G.'s personal research collection (see Voucher specimens, below, for accession numbers). This record is a northern and western extension of the range of *D. mariae* of over 600 km.

The first record of *D. taschenbergi* for Saskatchewan was identified in the Northern Forestry Centre entomology collection by J.R.N.G. (no accession numbers assigned in this ant collection). Two specimens from Carrot River, Saskatchewan (Figure 1) were collected in Jack Pine forest, on 6 June 1958. The collector was not recorded, and no other records for this species have been reported from Saskatchewan.

The pattern of "eastern" insect species ranges expanding westward is seen in Lepidoptera (Pohl and Acorn pers. comm. 2022) and Corixidae (Lapierre *et al.* 2021) and has also been reported for other ant species, including Canadian Robber Ant (*Harpagoxenus canadensis* Smith, 1939; Glasier *et al.* 2016), the obligate dulotic ant (*Polyergus bicolor* Wasmann, 1901; Sosiak *et al.* 2019), and beetles, such as the ant-associated Ulke's Sap Beetle (*Amphotis ulkei* LeConte, 1866; Glasier and Acorn 2013). However, it is still uncertain whether these reports represent actual range expansions or a lack of survey effort. In the case of *D. taschenbergi*, the species has obviously been in Saskatchewan for more than 60 years (and further west in Alberta); however, only through more surveys will we understand its range. In contrast, *D. mariae* is often cited as being a more southerly species (Ellison *et al.* 2012), and its two recent records in Manitoba from iNaturalist (Matties 2021; Pratt 2021), and now our record in Saskatchewan, may indicate an actual expansion of its range, as these reports are rather new.

Studies of ant species in the prairie provinces, especially in Saskatchewan, are lacking (Glasier *et al.* 2016). As *Dolichoderus* is relatively uncommon in Alberta (J.R.N.G. pers. obs.) and is rarely posted on community science sites, such as iNaturalist for Canada (only 80 research-grade observations in Canada as of March 2023), these records are important contributions to our understanding of ant species distributions. With these two new records, the total number of known ant species in Saskatchewan increases

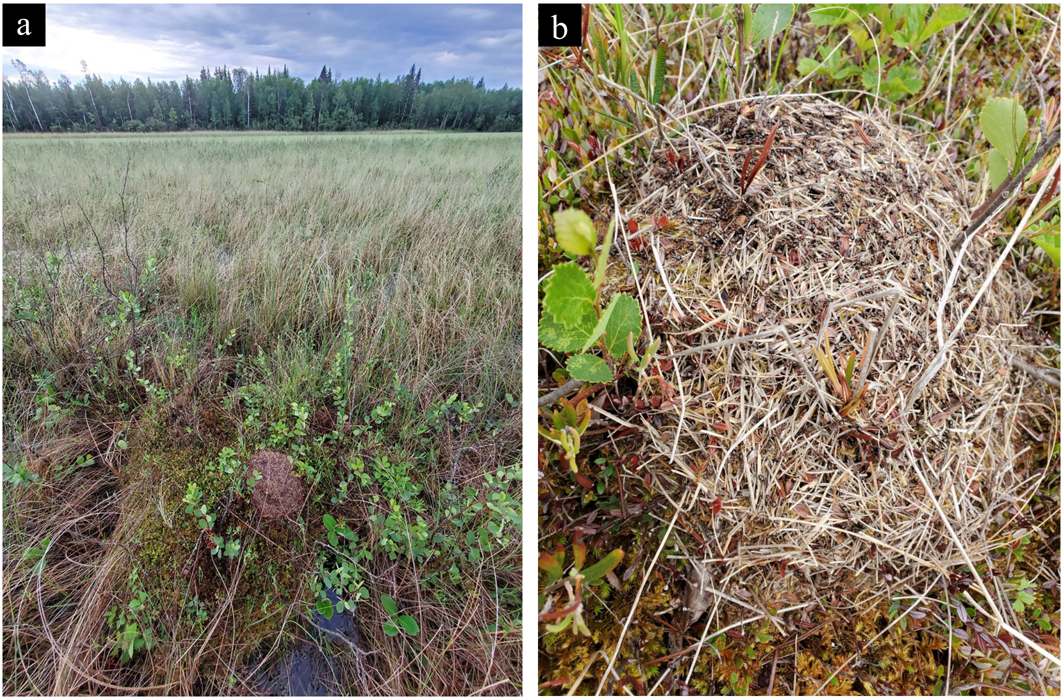

FIGURE 2. A Mary's Long-necked Ant (*Dolichoderus mariae*) mound near Hudson Bay, Saskatchewan, showing a. its setting atop a mossy hummock in a graminoid fen, and b. a closeup of the mound. Photos: Michael Rudy.

to at least 78 (Glasier *et al.* 2016; Janicki *et al.* 2016; Guénard *et al.* 2017; AntMaps 2022). Future surveys of ants should focus on ant ranges in Saskatchewan, in western Manitoba, and even near the eastern border of Alberta, which may reveal additional records for *Dolichoderus*.

Voucher specimens

Dolichoderus mariae (Figure 3a)

CANADA, SASKATCHEWAN: Hudson Bay, Hummock Boreal Fen, 52.927°N, 101.786°W, 25 June 2020, Hand Collection, collector Michael Rudy, determiner J.R.N. Glasier. Unique identifiers: JRNG. 0128–132. J.R.N. Glasier Collection. Pinned specimens. Specimens available on request.

Specimens JRNG.0133, JRNG.0134, and JRNG. 0135 were deposited in the Royal Alberta Museum under the codes: pmae.iz00167125, pmae.iz00167 124, and pmae.iz00167123.

Dolichoderus taschenbergi (Figure 3b)

CANADA, SASKATCHEWAN: Carrot River, Jack Pine*,* WS8-860, 6 June 1958, 53.292°N, 103.557°W, determiner J.R.N. Glasier. Northern Forestry Entomology Collection. Unique identifier: JRNG.0139

Author Contributions

Writing – Original Draft: J.R.N.G. and M.R..; Writing – Review & Editing: J.R.N.G. and M.R; Investigation: M.R.

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FIGURE 3. a. Mary's Long-necked Ant (*Dolichoderus mariae*) specimen JRNG.0129 from Hudson Bay, Saskatchewan. b. Taschenberg's Long-necked Ant (*Dolichoderus taschenbergi*) specimen, JRNG.0139, from Carrot River, Saskatchewan. Photos: John Acorn.

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A tribute to Laurie D. Murison, 1959–2021

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McAlpine, D.F., and M.J. Edwards. 2023. A tribute to Laurie D. Murison, 1959–2021. Canadian Field-Naturalist 137(3): 276–287. https://doi.org/10.22621/cfn.v137i3.3355

Laurie Dianne Murison (Figure 1), daughter of James Murison and Marion Murison (*nee* Shewell), whale researcher, Grand Manan (New Brunswick) heritage activist, and a mainstay of the North Atlantic Right Whale (*Eubalaena glacialis*) conservation community, passed away 3 January 2021 at the Saint John Regional Hospital after a lengthy battle with cancer. She was 61.

Surprisingly perhaps for a marine scientist, Laurie was a prairie girl, born 23 February 1959 in Edmonton, Alberta, nearly 3500 km from the Bay of Fundy, which would become the focus of her life's work and her home. Laurie's early years were unsettled. Drought had ravaged the family farm a decade before Laurie's birth. Her parents moved to Edmonton and her father cycled through a series of hardscrabble jobs—oil rigger, chauffeur, travelling salesman, prospector—that left him absent from his family much of the time. By 1962 the family was broke and living in a motel. Shortly after, Laurie's father abandoned the family, leaving mother Marion with toddler Laurie and brother, Tom, five years older. Grandparents and friends interceded and Marion moved with the children to Saskatoon to start over. With Dad back on the scene a year later, the family headed back to Edmonton briefly, and then to Calgary, before the marriage disintegrated and Marion took the children and headed home to the village of Harris, Saskatchewan, where her husband's parents farmed and her mother operated a grocery and dry goods store. Laurie's grandparents would figure prominently in her adolescence.

Always a top student, Laurie completed grade 8 with the highest marks for a female graduate, and then sailed through Evan Hardy High School as a Top Ten Honours student before entering the University of Saskatchewan on an Undergraduate Honours scholarship. A stint in a University of Saskatchewan soil physics lab led to efforts to entice Laurie into a graduate program in soil science, but she knew her interests lay elsewhere. For a while she toyed with medicine or veterinary science. It was during a marine mammal course at the Bamfield Marine Station (now the Bamfield Marine Sciences Centre) on Vancouver Island, British Columbia, following her final undergraduate year, that Laurie was introduced to the marine

Figure 1. Laurie Murison, 1959–2021. Photo taken in 2016 at Association Heritage New Brunswick Awards ceremony. Photo: M.J. Edwards.

environment, and to whales, Grey Whale (*Eschrichtius robustus*) in particular. Under the direction of famed marine mammalogist Kenneth Norris, Laurie spent three weeks in a small boat adjacent to Bamfield studying the diving patterns and feeding behaviour of Grey Whales (see Bibliography: Murison *et al.* 1984; Figure 2). James Darling, who would go on to an illustrious career studying Humpback Whale (*Megaptera novaengliae*), was the teaching assistant and provided much of the field support. The experience left Laurie determined to pursue a career of her own devoted to marine mammals. Her classmate and Grey Whale co-investigator, Debra Murie, was about to start a graduate program at the University of Guelph studying Harp Seal (*Phoca groenlandica*) feeding ecology under the supervision of David Lavigne. Debra mentioned David Gaskin, by then well-known for his studies on Harbour Porpoise (*Phocoena phocoena*) in the Bay of Fundy, New Brunswick.

David Gaskin arrived at the University of Guelph in 1968. Assigned responsibility for the marine biology option, he was probably introduced to the lower Bay of Fundy through field programs delivered at the Huntsman Marine Station (now the Huntsman Marine Science Centre), of which the University was a consortium member. With its abundant populations of seabirds, whales, and other marine life, David immediately realized the research potential of the area. By 1969 he had initiated long-term studies on the seabirds and marine mammals of the Bay of Fundy, particularly Harbour Porpoise, and soon established a small research station at Lord's Cove on Deer Island in Passamaquoddy Bay (Gaskin *et al.* 1979a). Together with a group of students, the Fundy Cetacean and Seabird Research Group was formed (of which Laurie was to become a member). The "research station" actually consisted of little more than the upper floor (with research and sleeping space combined) of a building belonging to Marine Research Associates, a biological supply and consulting company. Marine Research Associates most important role though was to fulfill boat requirements for field studies by the Research Group. Even with these modest facilities, by 1981 when Laurie was looking for a graduate supervisor to

Figure 2. The August 1981 marine mammal class at the Bamfield Marine Station (now the Bamfield Marine Science Centre), Vancouver Island, British Columbia. It was this class, taught by famed marine mammologist Ken Norris (first left back row) and James Darling (back row, fifth left in red plaid) that convinced Laurie (second row, second left) that a life studying whales was for her. Deb Murie, who directed Laurie to David Gaskin as a potential supervisor, and went on to her own research career in fish biology, is seated directly in front of Laurie. Together they would publish Laurie's first academic paper based on data on Gray Whale (*Eschrichtius robustus*) feeding ecology collected during the course. Photo: Bamfield Marine Science Centre.

help her launch a career with whales, David, students, and collaborators had already produced a significant body of research on the small cetaceans and seabirds of the Bay (see Gaskin 1998).

Although Neave and Wright (1968) reported a small summering population of North Atlantic Right Whale in the Bay of Fundy, the information was immediately discounted (Schevill 1968). However, Arnold and Gaskin (1972) documented observations of at least five North Atlantic Right Whale in the lower Bay of Fundy during work on Harbour Porpoise in 1969–1971. By the early 1980s there was little doubt that the Bay of Fundy was important to a significant portion of the North Atlantic Right Whale population, then estimated at 100–150 animals (Kraus *et al.* 1982). Even then, it was not known whether the Bay of Fundy animals represented evidence of an expanding population or had been simply overlooked in the past. Regardless, David had already stated that the population "exist[ed] on a knife-edge" and that "even the most basic data [are] lacking about this population" (Gaskin 1979b: 17). Laurie's arrival at the University of Guelph for the 1982–1983 semester coincided with the recognition that there were indeed Endangered North Atlantic Right Whale summering in the Bay of Fundy, and that essentially nothing was known about the natural history of the species on its Canadian summering grounds. Serendipity and motivation combined, and Laurie became the first graduate student in Canada to study North Atlantic Right Whale. Ultimately, her studies on the feeding ecology of the North Atlantic Right Whale in the Bay of Fundy, carried out over the summers of 1983 to 1985 (see Bibliography: Murison 1986) helped lay the groundwork for what has become one of the most intensively studied cetacean populations in the western North Atlantic.

Hoyt (1984: 163) reported that the rediscovery of a summer concentration of North Atlantic Right Whale in the lower Bay of Fundy sent "whale-sized ripples" through a growing whale-watch community. By 1994 the industry in North America was worth over $293 million US and involved 4 074 195 whale watchers. In New Brunswick alone, whale watching involved 462 000 watchers who generated $64 million in the province (Hoyt 1995). On Grand Manan, anticipating a windfall for both the local economy and a means of generating research funds, David, local lobster fisherman Ivan Green, and Jim Leslie, then owner of Grand Manan's Marathon Inn, established Ocean Search, a whale watch company. In 1981 the partners purchased a weather-beaten house at North Head on Grand Manan, adjacent to the ferry terminal, and established the Grand Manan Whale and Seabird Research Station (GMWSRS). By 1983 the GMWSRS had charitable status, allowing David and his students to supplement research grants with donations.

But by 1987 David was ready to leave guided whale watching behind, and with Laurie by then resident on the Island year-round, it must have seemed natural that she should became Managing Director, and then at David's death in 1998, Executive Director, of the GMWSRS. Along with whales, the GMWSRS was to become the centre of Laurie's life (Figure 3). It would be Laurie's organizational skills that would keep the GMWSRS humming along for 34 years and result in it becoming the base of operations for a wide variety of Bay of Fundy research projects, including those on seabirds, marine mammals, and Basking Shark (*Cetorhinus maximus*; see Bibliography). Although the University of Guelph Marine Mammal Research Program was shuttered in September 1996, following faculty retirements and several years of cuts to David's Natural Science and Engineering Research Council funding (Gaskin 1997), the GMWSRS continued to prosper. In part, this was achieved through Laurie's fund-raising skills and an expansion in mandate. This expanded mandate included collaborating with the newly established, but short-lived, Grand Manan/Fundy Bird Observatory (Text box 1).

When not on the water, Laurie devoted her considerable interpretive skills to lecturing about whales and whale conservation, essentially to anyone who would listen. Mainly this included Elderhostel and children's whale camp participants on Grand Manan, but for periods she also taught in the tourism and entrepreneurship programs at the New Brunswick Community College in St. Andrews, on the adjacent mainland. Even New England Aquarium (NEA) staff felt Laurie had probably delivered more public lectures on North Atlantic Right Whale than any other North Atlantic Right Whale researcher (Anderson Cabot Center for Ocean Life 2019). She joined the executive of the Grand Manan Chamber of Commerce, and was a long-term member of the Grand Manan Tourism Association, producing multiple editions of the tourism guide to the Island over a two-decade period (see Bibliography: Murison and Dalzell 1997; Murison 1999, 2000, 2001, 2002, 2003, 2004, 2006, 2007, 2010, 2011, 2013, 2017). With funding provided through the federal Habitat Stewardship Program for Species-at-Risk and other sources, Laurie devoted her winter months to producing a steady stream of leaflets and educational resources concerned especially with marine mammals and directed at mariners, fishermen, teachers, and the general public (GMWSRS n.d.). As a member of the Canadian Right Whale Recovery Team, Laurie helped craft the first Canadian North Atlantic Right Whale Recovery Plan (WWF/DFO 2000), published before the *Species at Risk Act*

Figure 3. a. The Grand Manan Whale and Seabird Research Station, July 2022. b. In 1998 a specimen-rich public exhibit that Laurie had prepared on the ground floor of the Station was renamed the Gaskin Museum of Marine Life. Photos: M.J. Edwards.

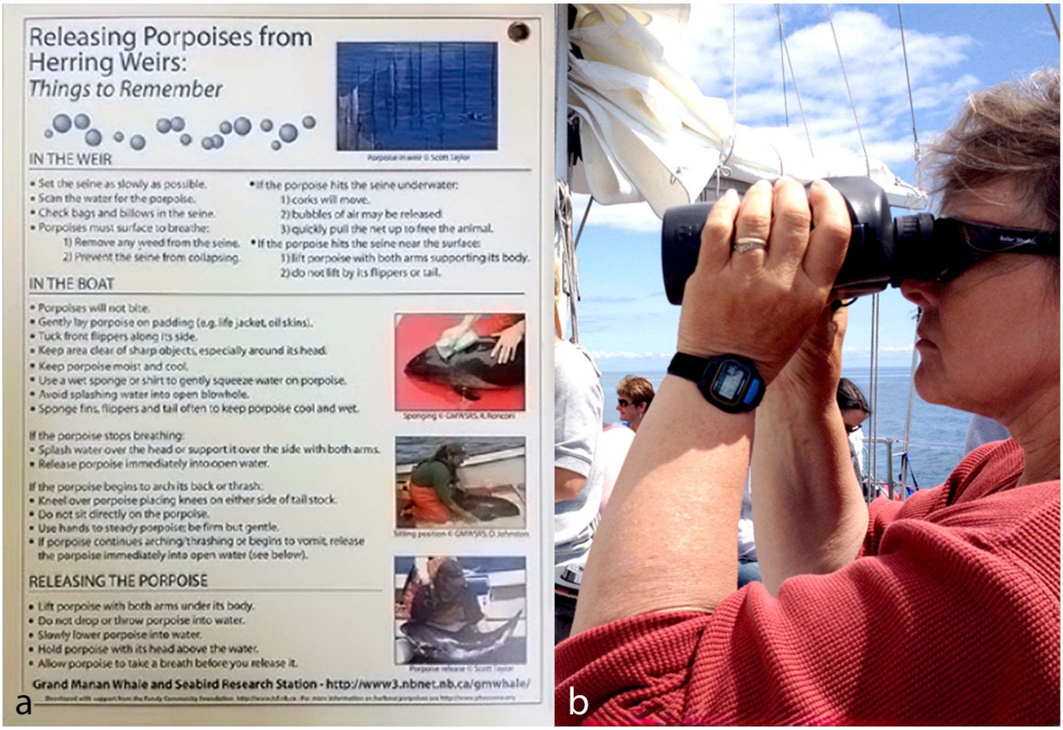
(SARA) was implemented, and the SARA-compliant Recovery Strategy for the North Atlantic Right Whale in Atlantic Canadian Waters (Brown *et al.* 2009). From 1999 until her death, Laurie was a member of the North Atlantic Right Whale Consortium, a body overseeing access to multiple North Atlantic Right Whale research databases and recognized as a model for other endangered species-related consortia. Some 125 peer-reviewed papers and 20 graduate theses flowed from the GMWSRS during Laurie's tenure as Managing/Executive Director (1987–2019; Gaskin 1998; H. Koopman pers. comm. to D.F.M. October 2023). The Station became a magnet for whale-obsessed students seeking mentoring opportunities. It was therefore no surprise when the GMWSRS received the 2000–2001 Gulf of Maine Visionary Award for public education, as well as contributions to the understanding and protection of marine mammals and seabirds in the Gulf of Maine.

Text Box 1. Grand Manan/Fundy Bird Observatory.

Established by Grand Manan birdman Brian Dalzell in 1996, the Observatory focussed on a variety of land and seabird projects. Unfortunately, the Observatory project ended with the premature death of Dalzell in 2011. Laurie help to produce the last two numbers (volume 6.1, 6.2), of the Observatory newsletter, *The Razorbill* (http://www.gmwsrs.org/publications.htm) and the GMWSRS sponsored the 2004 *Checklist of Grand Manan Birds* (Dalzell 2004).

Ken Ingersoll's Grand Manan roots run deep. The 1821 Grand Manan census reports Joel and Jane Ingersoll, with their six children, nine oxen, four cows, 25 sheep, and four hogs resident on Grand Manan. Barto (1975) gives the Ingersoll arrival in Charlotte County as the 1760s. Ken was an experienced boatman and marine field technician with the Fundy Cetacean and Seabird Research Group when he and Laurie met. They married in 1990. It was Ken who drew Laurie back to Grand Manan to live permanently after she had defended her thesis. And although Laurie would always be "from away", her marriage to an Islander provided a level of trust and acceptance in the Fundy fishing community that might otherwise not have been possible. This connection proved to be singularly important to the marine conservation work in which Laurie was to become involved. Most notable was the Harbour Porpoise Release Program, established in 1991 and active until 2010. Working with the local fishing community, the staff of the GMWSR developed techniques to safely remove Harbour Porpoise trapped in herring weirs without loss of fish catch (Wong *et al.* 2001; Figure 4a). From 1993 to 2003, nearly 850 Harbour Porpoises were successfully released from weirs (Koopman *et al.* 2003). The program also provided the platform for a number of studies, most notably by GMWSRS Senior Scientists Heather Koopman and Andrew Westgate, on porpoise health, physiology, and movements (Koopman *et al.* 1995, 1999; Westgate *et al.* 1995; see also Bibliography). Undoubtedly, Laurie's year-round residency on Grand Manan, and the trust she was able to build in the fishing community, contributed greatly to the success of this program. In the years that followed, it was Laurie, quiet but determined, who repeatedly brought members of the fishing industry on Grand Manan to the table to engage in discussions about both small and large whale conservation. She even secured funding to train Bay of Fundy fishermen in whale disentanglement techniques. The Grand Manan Fisherman's Association (1999) referred to Laurie's bridge building between the fishing and scientific communities as "unprecedented" and noted the deep respect in which she was held by the industry. In the last years of her life Laurie worked with the Association to test new acoustic release ropeless fishing technology designed for the high-current, offshore, marine habitats that the local industry fished (see Bibliography: Murison 2019). The hope is that this new technology will reduce large whale entanglements, now recognized as one of the principal threats to the survival of the North Atlantic Right Whale population (Moore 2019). Finally, it was Laurie and Ken who convinced Ivan, by 2006 the only surviving member of Ocean Search, to donate the North Head building to the GMWSRS shortly before his death.

In the summer of 1986, with her thesis on North



Releasing Porpoises from Herring Weirs:
Things to Remember

Porpoise in weir © Scott Taylor

IN THE WEIR

- Set the seine as slowly as possible.
- Scan the water for the porpoise.
- Check bags and billows in the seine.
- Porpoises must surface to breathe:
  1) Remove any weed from the seine.
  2) Prevent the seine from collapsing.
- If the porpoise hits the seine underwater:
  1) corks will move.
  2) bubbles of air may be released.
  3) quickly pull the net up to free the animal.
- If the porpoise hits the seine near the surface:
  1) lift porpoise with both arms supporting its body.
  2) do not lift by its flippers or tail.

IN THE BOAT

- Porpoises will not bite.
- Gently lay porpoise on padding (e.g. life jacket, oil skins).
- Tuck front flippers along its side.
- Keep area clear of sharp objects, especially around its head.
- Keep porpoise moist and cool.
- Use a wet sponge or shirt to gently squeeze water on porpoise.
- Avoid splashing water into open blowhole.
- Sponge fins, flippers and tail often to keep porpoise cool and wet.

Sponging © GMWSRS, R. Ronconi

If the porpoise stops breathing:
- Splash water over the head or support it over the side with both arms.
- Release porpoise immediately into open water.

If the porpoise begins to arch its back or thrash:
- Kneel over porpoise placing knees on either side of tail stock.
- Do not sit directly on the porpoise.
- Use hands to steady porpoise; be firm but gentle.
- If porpoise continues arching/thrashing or begins to vomit, release the porpoise immediately into open water (see below).

Sitting position © GMWSRS, O. Johnston

RELEASING THE PORPOISE

- Lift porpoise with both arms under its body.
- Do not drop or throw porpoise into water.
- Slowly lower porpoise into water.
- Hold porpoise with its head above the water.
- Allow porpoise to take a breath before you release it.

Porpoise release © Scott Taylor

Grand Manan Whale and Seabird Research Station - http://www3.nbnet.nb.ca/gmwhale/

FIGURE 4. a. Flashcard produced and distributed in 2001–2002 by the Grand Manan Whale and Seabird Research Station to weir operators and coastal communities in the lower Bay of Fundy describing a method for the safe release of Harbour Porpoise (*Phocoena phocoena*) from herring weirs. b. Surveying for North Atlantic Right Whale (*Eubalaena glacialis*) aboard the ship *Elsie Menota*, off Whitehead Island, 10 August 2014. Laurie spent decades leading whale watching excursions and participating in surveys for North Atlantic Right Whale on the Bay of Fundy. Whale watching provided her with an opportunity to collect data and thousands of photos of North Atlantic Right Whale and other cetacean species, all of which have contributed to knowledge and conservation efforts.Photo a: D.F. McAlpine. Photo b: Ann Ross.

Atlantic Right Whale feeding successfully defended, Laurie headed north to Isabella Bay, Baffin Island (Figure 5). Laurie joined veteran Arctic marine mammal biologist K.J. (Kerry) Finley, Bob Evans, and Inuit research assistant, "Isumataq" Apak Qaqqasiq, for the third year of what would become a 14-year study of a remnant population of the Endangered Bowhead Whale (*Balaena mysticetus*) in the eastern Arctic (Finley 1990, 2001). Overseen by LGL Ltd. (Environmental Research Associates) and sponsored by the World Wildlife Fund, this project provided Laurie with a unique opportunity to learn open-ocean and land-based observational techniques for marine mammals. These would prove important for her later work in the Bay of Fundy. Also, much of Laurie's future success on Grand Manan rested on her "unprecedented" ability to tap into local knowledge holders in the fishing community, paralleled in her exposure to data obtained via traditional Inuit knowledge in Isabella Bay.

The 1986 field season in Isabella Bay was a difficult one. It started in early September, and that year saw the team attempt to extend observations long enough to document the arrival of whales migrating from summering areas farther north. With limited logistical support, high seas, and deteriorating weather prior to freeze up, Laurie, Kerry, Bob, and Apak were forced from the field five weeks later (typically the field season was only three weeks), but not before Laurie had calmly weathered several Polar Bear (*Ursus maritimus*) encounters, and been christened Eetsiak ("Good eyes") by Apak, so impressed was he with her ability to spot a whale blow at 35–40 km from the hilltop observation post (Text box 2).

Spotting whales would become Laurie's bread and butter in the years ahead. That same summer Laurie began what would become a 31-year stretch as a whale watch naturalist for various Grand Manan-based operations, initially of course with Ocean Search (Figure 4b). But Laurie was no run-of-the-mill tour guide. While "Eetsiak" could certainly spot a whale for a visitor, she also maintained careful notes and observations of her cetacean sightings, particularly North Atlantic Right Whale, contributing over 3000 images, with associated data, to the North Atlantic Right Whale Catalog maintained at NEA. Laurie, and her notes (the latter now archived in the New Brunswick Museum [NBM]) would also figure prominently in one of the most notable North Atlantic Right Whale conservation efforts that lay ahead.

In September 1992 the North Atlantic Right Whale known as Delilah died by ship-strike off Grand Manan. Laurie was by then an active member of an informal Maritime marine mammal stranding network organized by Dalhousie University marine mammal technician John Parsons (Text box 3). Laurie

Figure 5. Bob Evans (left) and Laurie Murison at the Balaena Lookout observation post, overlooking Isabella Bay, Baffin Island in 1986. That year the observation period lasted 5 September to 9 October. Close-up photos of individual whales were also obtained from shore and from kayaks. When weather permitted, as many as 34 Bowhead Whale (*Balaena mysticetus*) were seen daily that year. Photo: K.J. Finley.

TEXT BOX 2. Observing whales.

Due to curvature of the earth, maximum straight-line viewing distance is about 5 km. However, Kerry Finley, who initiated Arctic marine mammal ecology studies for LGL Ltd. in 1974, reports (pers. comm. to D.F.M. 19 July 2022) that:

> from our observation post we were able to spot blows back-lit to the east and southeast in one of two offshore troughs, with Cape Kater and stranded icebergs for reference. This and ranges from kayaks allowed fairly precise positions of feeding whales to about 15 km, as I recall. Cross reference from Aultiving Island, where the whalers had lookout sites, indicates that we were seeing whales at 35–40 km. This was probably due to bending of the light, and the fact that Bowhead Whale blows are powerful and high.

TEXT BOX 3. Marine mammal stranding network origins.

Following Parsons' early death, the Marine Animal Response Society (MARS), a more formal, Halifax-based, Maritime network evolved. Initially organized by Tonya Wimmer, then a graduate student in the Hal Whitehead Cetacean Lab at Dalhousie University, Laurie supported network activities into the last months of her life (Figure 6a). MARS continues to thrive (see Wimmer and MacLean 2021).

provided a base of operations at the GMWSRS for stranding network volunteers, whale researchers, and wildlife pathologists who congregated on Grand Manan to necropsy Delilah and salvage her skeleton for deposit in the NBM. Delilah's articulated skeleton, accompanied by a life-size fiberglass model produced by Halifax-based whale biologist Paul Brodie, was unveiled in the NBM marine mammal gallery in 1996; the display would become an iconic exhibit for the NBM and also a symbol for the plight of the species (Hamilton-Barry 2019). A first time mother with a dependent calf, Delilah's tragic death was also to play an essential role in the direction of Laurie's professional activities in marine mammal conservation over the decade that followed.

Later that autumn, North Atlantic Right Whale researchers Amy Knowlton and Moira Brown of NEA met with Clarence Miller, Officer in Charge of Fundy Traffic, in Saint John, New Brunswick, to discuss approaches to minimizing North Atlantic Right Whale ship-strikes in the Bay. Miller suggested his operators send a seasonal North Atlantic Right Whale alert to vessels transiting the Bay of Fundy, but also proposed a much more radical solution—altering the Traffic Separation Scheme (i.e., shipping lanes) established in 1983, to avoid areas where feeding whales were known to concentrate. That autumn the Canadian Department of Fisheries and Oceans (DFO) Marine Mammal Manager, Jerry Conway, met with Brown and Scott Kraus at NEA in Boston, and using observations collected by Laurie and others, placed boundaries around 95% of North Atlantic Right Whale observations in the Bay of Fundy and Roseway Basin, off southwestern Nova Scotia. These two areas of concentration were designated as North Atlantic Right Whale Conservation Areas in 1993, and from 1995 alerts were issued to ships of 20 m length or greater transiting the Bay (Knowlton 1997). Fisheries and Oceans Canada published a pamphlet for mariners about North Atlantic Right Whale and the conservation areas, but to no avail. North Atlantic Right Whale continued to die by ship-strike. Mariner education alone was clearly not working.

On 13 February 2001, a meeting was organized in Saint John to bring interested parties together to try and solve the east coast North Atlantic Right Whale vessel strike problem. Laurie attended that meeting and was part of the working group formed from the stakeholders in attendance. Over the following year, researchers assembled sightings data to assess the risks and probability of various amendments to the Fundy Traffic Separation Scheme in the Bay (Vanderlaan *et al.* 2008). Laurie contributed North Atlantic Right Whale locations and photographic data from her sightings on whale watch boats, as well as reports from her network of contacts in the fishing industry. Those data were particularly important in rounding out the June–December season describing North Atlantic Right Whale habitat use in the Bay, especially for those years when funding shortfalls limited NEA surveys to an early August–middle October window. The resulting final proposal was submitted by Transport Canada to the International Maritime Organization Sub-committee on the Safety of Navigation in 2002, where it was approved, subsequently adopted by the Maritime Safety Committee, and then implemented by Transport Canada in 2003. The decade following the unprecedented 6 km move of the Fundy shipping lanes witnessed something of a boom in the production of North Atlantic Right Whale calves (Meyer-Gutbrod *et al.* 2021; Pettis *et al.* 2021). Whether this was the direct or indirect result of the change in the shipping lanes remains unclear (excellent feeding conditions in the Bay of Fundy and elsewhere during that period also supported female reproduction). Nonetheless, moving the shipping lanes was a major conservation achievement—wildlife conservation had, for once, bested big business. In 2004 the Canadian Whale Institute recognized three Canadians—Moira Brown, Jerry Conway, and Laurie—for their contributions to North Atlantic Right Whale conservation in Canadian waters. Laurie also continued to play an active role in marine mammal stranding incidents in the region (Figure 6b).

Although Laurie joined the Grand Manan Heritage Trust in 1991 shortly after it was formed (GMWSRS 1991), during the last decade of her life she expanded the scope of her built-heritage conservation activities. This was most notable in connection with the iconic Swallowtail Lighthouse (Figure 7). First operational in 1860, the lighthouse was accorded the status of a Recognized Federal Heritage Building in 1991. However, in 2010 the Swallowtail Light was included on a list of lighthouses declared surplus by the Canadian Coast Guard and the future of what is considered Grand Manan's "signature vista" (Miller *et al.* 2017), and billed by Tourism New Brunswick as the most photographed lighthouse in the province, seemed uncertain. Together, Laurie and Ken founded the Swallowtail Keepers Society. With Laurie at the helm, the Society went on to raise more than a quarter of a million dollars to restore, maintain, and repurpose the light station and associated outbuildings, using them as a focus for both historical and environmental education (see *Swallowtail Keepers Society Newsletter*, produced by Laurie 2010–2015). In 2012 she deepened her ties with the Grand Manan Museum, one of the best regional museums in the province and home to the bird collection of notable early 20th Century ornithologist Allan Moses (see Ingersoll 1991). Initially working as a volunteer consultant, by the time of her death, Laurie was President of the Board of Directors of the Grand Manan Museum. In this latter capacity, she worked with the Director to, again, source funds that promoted the conservation of the cultural and natural heritage of the lower Bay of Fundy and improved the Museum. Her contributions were recognized with an Award of Distinction from the Association Heritage New Brunswick to the Swallowtail Keepers Society in 2016 and a posthumous honorary doctorate of science degree from the University of New Brunswick at its virtual graduation in the spring of 2021.

Figure 6. Laurie recognized that marine mammal strandings provide an important source of biological information (see McAlpine *et al.* this issue) and supported, through the Grand Manan Whale and Seabird Research Station and her own participation, the salvage of data and specimens from dead-stranded marine mammals. a. Laurie collecting the skull of a dead Grey Seal (*Halichoerus grypus*) in October 2020 at the Anchorage Provincial Park, Grand Manan, about three months before her death (now NBM-MA-18566). b. A crew assembled, on Grand Manan in October 2003 to salvage the skeleton of a 15-m Fin Whale (*Balenoptera physalus*), for deposit in the New Brunswick Museum (NBM-MA-5977). The back of the truck is loaded with baleen. Left to right: Laurie Murison, Graham Forbes, Donald McAlpine, Liam Hughes, Dan Keppie, and Jeff Higdon. Photo a: M.J. Edwards. Photo b: M. Sollows/New Brunswick Museum.

FIGURE 7. Laurie, with the iconic Swallowtail light and Keepers residence in the background in June of 2019. The site now boasts a lighthouse museum, welcome centre, gift shop, artist-in-residence program, weather station with on-line access, a MOTUS wildlife tracking antennae, and a regular schedule of public events. Photo: Peter Cunningham.

Acknowledgements

Laurie was a very private person, always reluctant to talk about her own activities and accomplishments, and her resume provided very little information about her life prior to moving to Grand Manan to live permanently. We are particularly grateful to her brother, Tom, for filling in details on her early years and to both Tom and Ken Ingersoll, Laurie's husband, for helping navigate the narrative. We also thank the following colleagues, friends, and family for assistance in piecing together information and images and providing helpful comments on early versions of the manuscript: Peter Cunningham, Peter Devine, Kerry Finley, Heather Koopman, Art MacKay, Elizabeth Mancke, Allan McDonald, Sarah McDonald, Bonnie Morse, Deb Murie, Ann Ross, and Andrew Westgate. A special thanks to Moira Brown and Kerry Finley for checking and correcting text reporting details surrounding the movement of the shipping lanes in the Bay of Fundy and Laurie's time in the Arctic, respectively. Heather Alexander of The Bamfield Marine Science Centre kindly provided Figure 2.

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The Canadian Field-Naturalist

Book Reviews

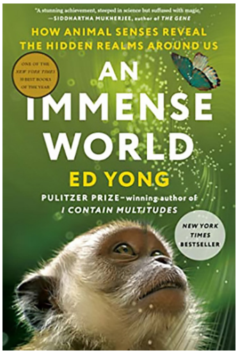
Book Review Editor's Note: *The Canadian Field-Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those 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 United States Dollars, EUR Euros, AUD Australian Dollars, GBP British Pounds.

Biology

An Immense World: How Animal Senses Reveal the Hidden Realms Around Us

By Ed Yong. 2022. Random House. 464 pages, 38.00 CAD, Hardcover, 25.95 CAD, Paper, 14.99 CAD, E-book.



Ed Yong, an award-winning science journalist, begins *An Immense World* with an imaginary story about a collection of animals in a school gym. Unlike fictional classics, where animals share a common language and sensory experience, these animals—an elephant, mouse, robin, owl, bat, rattlesnake, spider, mosquito, bumble bee, and human—are only able to experience a small sliver of the immense worlds the others inhabit. Yong refers to each small sliver as an animal's Umwelt, a term that appears frequently throughout the book. Umwelt—coined by zoologist Jakob von Uexküll—is a species' unique perceptual world. In the book, Yong describes a fascinating scope of animal sensory diversity, but he does not stop there. He uses these descriptions to illustrate the importance of overcoming human sensory bias; in understanding an animal's Umwelt, we can improve conservation and recovery efforts. Yong's use of accessible language to explain his ecological insights will appeal to general readers and professional researchers.

The book explores 11 senses in as many chapters. The first of these covers senses familiar to the human Umwelt: smell, taste, and vision. Later chapters describe the less familiar sensory worlds of animals that can detect electric and magnetic fields. The penultimate chapter discusses "uniting the senses", which Yong describes as understanding "how animals use their senses together" (p. 322). The final chapter discusses how human activities interfere with animals' sensory perceptions. Each chapter starts with an example of how a sense is used by a particular animal and a few words from a researcher investigating it. Gradually, Yong considers the more unusual and surprising uses of that sense. He uses footnotes effectively to provide details and historical asides for those interested. Puns, wordplay, and suspenseful transitions from one chapter to the next keep the reader engaged. Yong cleverly uses the text to grab the reader's attention and emphasize his points. For example, the time required for Big Brown Bat to catch a moth is identical to the time needed to read the last seven words in Yong's paragraph describing this predatory event (p. 255). Colour photographs spotlighting the senses add to the joy of reading this book.

Overcoming human sensory bias to prevent inaccurate interpretations of an animal's Umwelt is a major theme that weaves its way throughout *An Immense World*. Yong argues for abandoning preconceived notions of the links between animal behaviours and their senses that have historically been a part of scientific speculation. Modern research by scientists who stepped outside of standard dogma and, at least partially, into an animal's Umwelt has revealed much in the animal world. We now know that bats hunt by echolocation rather than using air currents along their wings, and Blue and Fin Whales communicate over long distances with repetitive vocalizations or songs.

Magnetoreception (which allows an animal to sense the Earth's magnetic field) is the least understood and last of the senses presented in *An Immense World*. Many animals use magnetic fields for migrating and locating themselves on the Earth, but no one knows how they do it. Unlike the rapid vision and hearing processing that humans share with many animals, the completely different, relatively slower, and likely more variable inputs that occur in animals navigating by magnetoreception inhibit researchers from stepping into these Umwelten (p. 319). Yong outlines the three major hypotheses that explain the ability to sense magnetic fields: magnetite crystals that animals might form within sensory cells as north-south aligning chains could provide directional information; electromagnetic induction, which could explain the ability in animals capable of sensing electric fields, such as sharks and rays; and radical pair spin dynamics in retinal cryptochrome proteins (pp. 311–312). However, the inability to replicate experiments has been a stumbling block to resolving these hypotheses. Yong concludes the chapter by wondering just how big a role the sensory gap between researchers and subjects plays in preventing the design of definitive experiments.

The importance of overcoming sensory bias culminates in the final chapter where Yong proposes that conservation efforts could be improved by explicitly considering the Umwelten of animals under threat. Field naturalists and others interested in assessing threat impacts on population changes or developing mitigation efforts to recover endangered species will find this chapter thought provoking. Threat assessments typically focus on the effects of human activities on non-human animal populations; but if the effects are evaluated solely using human sensory perceptions, the total threat will be poorly estimated. There are examples of this throughout the book: vultures colliding with wind turbines because their sightlines are impacted while hunting (pp. 69–70); elephant calls having greater range after sunset when the atmosphere is cold, clear, and calm, compared to the heat of midday (pp. 236–237); and electric fish sensitivity changing with salinity concentrations (p. 281). Our ability to detect other Umwelten is an asset we can use to increase the likelihood that our recovery activities enhance, rather than distort, other animals' sensory environments.

Yong's book emphasizes that animals rely on uniting multiple senses to support their life history needs. It provides a framework for integrating the knowledge its readers may have gained from more academic books or their own research on sensory perceptions. If *An Immense World* makes you curious about how humans unite their senses, you may want to read M.R. O'Connor's book *Wayfinding: the Science and Mystery of How Humans Navigate the World* (St. Martin's Press, 2019).

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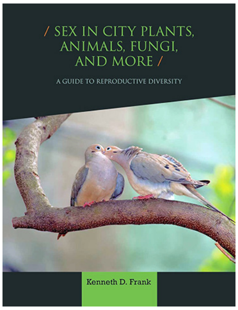
Sex in City Plants, Animals, Fungi, and More: a Guide to Reproductive Diversity

By Kenneth D. Frank. Foreword by Jonathan Silvertown. 2022. Columbia University Press. 208 pages, 120.00 USD, Hardcover, 39.00 CAD, Paper. Also available as an E-book.



Sex in City Plants, Animals, Fungi, and More is a collection of examples of reproductive diversity. The author describes these as "illustrated essays on mating systems and sexual behavior" (p. xi), and each essay is a single page in length. All examples were selected based on their locale in the city of Philadelphia, USA (where the author resides) and the existence of published literature on the reproductive biologies of the organisms featured. The book is composed of 13 chapters, each with a different focus (e.g., Nonflowering Plants, Mammals, and Birds), with chapters further divided into a variety of topic sections that include one accompanying example (e.g., Urban Self-Fertilization: Creeping Wood Sorrel). It is well-illustrated; most of the photos included are large, clear, high-quality, and well-selected to compliment the text.

Sex in City Plants, Animals, Fungi, and More has the look and dimensions of a thin paperback textbook (22 cm × 28 cm). However, it is not exactly a textbook, nor is it a guide so much as a tasting menu of reproductive strategies in an urban environment, showcasing the diversity of practices but never digging deeper into the topics raised. Sometimes this brevity comes at the expense of clarity; to fit each topic onto a single page, some ideas feel clipped or over-edited to the point of being disjointed. These short examples collectively touch on a variety of topics, including light and noise pollution, introduced parasites, and the benefits of urban environments such as low competition (e.g., Purple Cliffbrake Fern establishing colonies on dry stone walls [p. 6]) or uniquely suitable environments (e.g., Pavement Ants that specialize in cities, including buildings [p. 56]). I would have liked more depth or a unifying narrative around these topics; but this is not that book, and the one-page conclusion doesn't effectively pull the topics together.

The examples included are interesting and varied, and the book is well-researched. Common and Latin names are provided for all organisms, and the end of the book boasts an excellent Glossary and Index. It also includes a whopping 33 pages of Notes, which is organized by page number and topic (e.g., "Page 12. Nectar Robbery: Jewelweed [*Impatiens capensis*]" [p.132]), providing detailed references. In the text, references are cited as superscript numbers, which makes for easy cross-referencing but does not distract from the writing.

I certainly learned new facts from this book. A humorous highlight is the "male stuffing" behaviour of European Paper Wasps (*Polistes dominula*). To prevent males from poaching food brought into the nest to feed larvae, female wasps stuff males headfirst into empty nest cells by using aggression and coercion—biting, grappling, and threatening to sting the males (p. 53). Under threat of restuffing, males stay put for a short time, and the larvae can be fed without interruption. As the author explains, "when not stuffed into a cell, a male can forage on his own outside of the nest; but he may prefer to eat in" (p. 53).

Although it left something to be desired for me as a guide, overall this is a well-executed collection that showcases the diversity and peculiarities of reproductive strategies in urban environments using Philadelphia as a case study. As a quasi coffee-table book, it would be a good jumping-off point for additional research on the examples provided and suitable for those with an interest in learning interesting facts about the common North American organisms that surround us.

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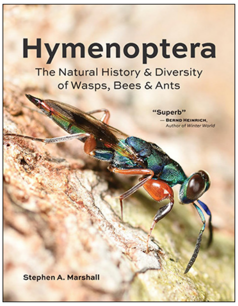
ENTOMOLOGY

Hymenoptera: the Natural History and Diversity of Wasps, Bees & Ants

By Stephen A. Marshall. 2023. Firefly Books. 640 pages and 1000+ colour photos, 95.00 CAD, Hardcover.



Wasps seem to be enjoying a moment. Recent publications include Heather Holm's *Wasps: Their Biology, Diversity, and Role as Beneficial Insects and Pollinators of Native Plants* (Pollination Press, 2021), Eric R. Eaton's *Wasps: the Astonishing Diversity of a Misunderstood Insect* (Princeton University Press, 2021), and Seirian Sumner's *Endless Forms: the Secret World of Wasps* (HarperCollins, 2022), to name three from my own bookshelf. Chris Alice Kratzer's *The Social Wasps of North America* was promoted on iNaturalist and published in 2022 by her company, Owlfly LLC. Each of these books sticks to the 'wasp' side of the bees, wasps, ants, and sawflies that make up the hymenopteran order. Being 'popular science' books, they follow the common, limited idea of wasps in order to redeem them from the misleading view that everything wasp is dangerous and worthy of destruction. Books on Hymenoptera as a whole are rare—the first I know of came out in Russian in 1966 by S.I. Malyshev and was translated into English under the title *Genesis of the Hymenoptera and the Phases of Their Evolution* (Methuen, 1968); Springer reissued it in 2012. Eric Grissell's *Bees, Wasps, and Ants: the Indispensable Role of Hymenoptera in Gardens* (Timber Press, 2010) provides a highly readable and informative overview of the order and the roles the various groups play in our gardens. Ian Gauld and Barry Bolton—both prominent hymenopterists—edited *The Hymenoptera* (Oxford University Press, 1988), describing families of Britain, which has utility for North American crossover groups.

I think it's fair to say, given this quick overview, that Marshall's *Hymenoptera* is the first book to tackle the entire world of this large and highly diverse order for the interested public. It's his fourth magnum opus in a series beginning with *Insects* (Firefly Books, First Edition 2006, Second Edition 2017), followed by big books on two other major groups: *Flies* (Firefly Books, 2012) and *Beetles* (Firefly Books, 2018). The subtitles of each of these volumes include the phrase "Natural History and Diversity", and the books deliver the goods on both. These previous titles have all been well received, and *Hymenoptera* should be no exception. As with its predecessors, it is written with the lay person (like me) in mind: technical terms are described, and eschewed, as jargon, being used only when necessary—"this book is for naturalists, not taxonomists" (p. 9)—and Marshall's light and casual humour frequently spices the text. Hymenoptera are one of the four big orders of insects (the others being Coleoptera [beetles], Lepidoptera [butterflies and moths], and Diptera [true flies]); one wonders if a book on Lepidoptera is also in the works. Some people count five major orders, the fifth being Hemiptera (true bugs), so there is scope to keep this man busy for a long time yet!

The subtitle to *Hymenoptera* could have included Sawflies, of the suborder Symphyta, from whose only carnivorous family, the Orussidae, evolved the wasp-waisted Hymenoptera (Apocrita) about 250 million years ago (pp. 11, 55–56). However, as Marshall notes in his Preface, although "the order is often awkwardly referred to as the 'ants, wasps, bees, and sawflies,' they are all wasps" (p. 8). If you think you hate 'wasps', you had better update that file! Things are much more complicated, as this book reveals.

Each of the suborders and superfamilies making up Hymenoptera is richly complex and diverse. Marshall sets an ambitious goal: "to explore the entire Hymenoptera tree" (p. 8) via its 100 or so families and

> to seek a colorful [*sic*], accessible and reasonably comprehensive overview. This [task] is analogous to touching on all of the states, major cities and significant regional attractions of a continent in a single travel book. (p. 8)

The analogy is apt, given the amount of travel Marshall has accomplished in his career; these travels are reflected in his brilliant photographs, taken all over the world, that illustrate the text throughout.

The reader's journey begins with Part 1, Life Histories, Habits and Habitats of Hymenoptera, comprised of six chapters. The first, Form and Function, describes the origins and anatomy of the characteristic 'wasp waist' and the many variations on behaviours of mating, egg laying, and nest making and provisioning. These topics lead into the next chapter, Hymenopteran Parasitoids and Predators, that opens with the line "Most wasps are killers" (p. 37), reflecting their ancestral parasitoid lineage. Those that are not "have changed their ways to become vegetarians, predators, omnivores or kleptoparasites (thieves)" (p. 37). Chapter 3 discusses hymenopteran interactions with plants and fungi. These include phytophagy, gall formation, pollination—wasps' elaborate role in fig production being especially interesting—and the symbiotic protective relations shared by several ant and plant species. The extensive interactions of hymenopterans with vertebrates—we humans, primarily—are covered in Chapter 4, which opens with the obvious: wasps' capacities to sting. While many species are stingless, the most dangerous have extremely painful stings. The news isn't all bad—honey bee venom is an ingredient in some face creams. More importantly, wasps are useful as sources of food and medicine, and as agents of biocontrol; on the downside, human movements have turned some wasps into invasive species, others into endangered species. Wasps, in the form of beehives, were used as weapons of warfare in medieval and more ancient times. And given the ambiguities we humans experience toward them, it is no surprise that they have been sources of inspiration in art, culture, fiction, and film.

The fifth chapter discusses Conflict and Cooperation within the order. Wasps are not only killers and thieves; many have varying degrees of sociality and social organization. Research and popular interest generally tend to focus on social hymenopterans, such as ants and honey bees, but less than 2% of all hymenopteran species are eusocial (p. 121). One result is a huge imbalance in our knowledge of the other 98%.

Part 2 covers Diversity in 14 chapters, starting (as in Marshall's previous volumes) with Classification and Phylogeny. This short section on the shifting sands of taxonomy is summarized in a two-page chart that broadly outlines the current thinking. It also provides, as Marshall suggests, a table of contents to the chapters on the various suborders and superfamilies. These chapters each open with a brief but more detailed look at the taxonomy of the subject groups. Throughout, this information is presented with the lay reader in mind. Organization of these chapters also follows previous volumes: several pages of text outline the major groups, followed by pages of photos illustrating and providing further details on their respective families. Each group has their own frequently unique natural history, and Marshall provides many stories recounting their life ways, from the familiar to the almost unbelievably exotic. But, despite the great mass of information currently available, much remains unknown, a fact he readily acknowledges.

As in Marshall's other books, Part 3, Studying Wasps, contains sections on collecting, photographing, and identifying wasps. The first two sections are short and to the point; the third provides simplified keys focussed on the most common families. Part 3 also includes the back matter: Acknowledgments, References, and an Index. Here and throughout the book, Marshall is generous in his attributions of assistance from other experts and specialists in making and confirming identifications, an indication in itself of how large the field is.

As implied above, the use of photography and the format (both physical and thematic) of *Hymenoptera* will be familiar to readers of Marshall's earlier volumes. The book is illustrated by thousands of excellent photographs. The heavily, and beautifully, illustrated text in each of the 13 chapters on the hymenopteran suborders and superfamilies is followed by three-column pages that include a column of text keyed to two columns of photos organized by Superfamily, Family, and Subfamily. This format change from previous volumes results in photos almost 30% larger, allowing more information per photo. The use of photographs in identifying insects has long been controversial, and Marshall addresses this at various times in the book, cautioning that photos alone can seldom be relied upon for accurate identification to the species level. His work shows, however, that photos can also be extremely useful in getting to the higher levels, helping us develop gestalts for particular groups. Few of us are able to place a specimen under a microscope and use the arcane language of specialists to locate and determine the nature of identifying characters. Furthermore, taxonomists are increasingly in short supply while citizen scientist numbers grow apace, allowing the specialists to collect data otherwise unavailable. Appreciation of this reality is increasing, and books such as this are terrific aids to that end. Marshall is to be congratulated on yet another signal achievement in both entomological literature and the ongoing building of bridges between the worlds of professional and citizen scientists. Anyone interested in Hymenoptera will benefit from reading this marvellous—and marvel-filled—book and using it in further study of an amazing part of life on this planet.

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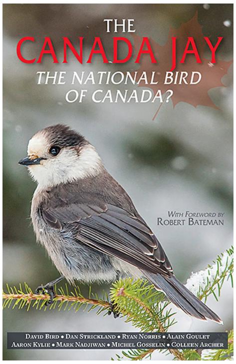
EDITOR'S COMMENT: Look for a review of Holm's *Wasps* in an upcoming issue of *The Canadian Field-Naturalist*; Sumner's *Endless Forms* was reviewed in 137(1–2): 156–157. https://doi.org/10.22621/cfn.v137i1.3321

ORNITHOLOGY

The Canada Jay: the National Bird of Canada?

By David Bird, Dan Strickland, Ryan Norris, Alain Goulet, Aaron Kylie, Mark Nadjiwan, Michel Gosselin, and Colleen Archer. Foreword by Robert Bateman. 2022. Hancock House. 88 pages and 42 photos and illustrations, 14.95 CAD, Paper.



This slim, well-illustrated book makes the argument that it is high time Canada choose a national bird to go with its other national symbols, and thus join about half the other countries in the world that have official birds (as listed in Chapter 2: National Birds of the World).

In early 2015, *Canadian Geographic* launched the National Bird Project in an attempt to choose a species by the country's sesquicentennial in 2017. (One of the authors of *The Canada Jay*, Aaron Kylie, was Editor-in-Chief at the magazine when the project began [CBC 2017].) The project had three basic criteria: 1) the species had to be found in every province and territory, 2) it could not already be an official species anywhere, and 3) it had to be important to Indigenous peoples. The public could vote online from a list of 50 species, or they could nominate a species not on the list. It is important to note that the nominating committee did not commit to choosing the bird with the highest number of votes. The final round of voting and subsequent expert debate was limited to five species: Common Loon (*Gavia immer*), Snowy Owl (*Bubo scandiacus*), Canada Goose (*Branta canadensis*), Black-capped Chickadee (*Poecile atricapillus*), and Canada Jay (*Perisoreus canadensis*).

In November 2016, after 50 000 votes and consultations with conservation, ornithological, and Indigenous groups, *Canadian Geographic* announced that its recommendation for a national bird was Canada (or Gray) Jay (Canadian Geographic 2016). The next step was to have the bird officially recognized by the federal government; spoiler alert: it didn't happen, thus the impetus for this book. (Due to its status as a not-for-profit organization, *Canadian Geographic* was unable to directly lobby the government on Canada Jay's behalf [CBC 2017].)

In *The Canada Jay*, author Bird actually lists 18 reasons in favour of Canada Jay in Chapter 4 (Why the Canada Jay Should be Canada's National Bird). The species is considered a safe choice because it is not hunted or killed for being a nuisance anywhere, it is not endangered, and thus it will not disappear any time soon. In Chapter 6 (Why the Very Neat Gray [Canada] Jay Beat Out the Very Common Loon), Bird explains why Canada Goose would not have been a good candidate: "its exploding numbers and unfortunate habit of coating lawns and golf courses with layers of poop makes it a non-starter for any political entity" (p. 39).

(Anyone interested in an alternative method for choosing official birds should check out "A Modest Proposal: Can eBird Help Choose Better State Birds?" [Smith and Devokaitis 2023] where the authors nominate species based on eBird data. Part 5 of the series is on Canada's official provincial species.)

In Chapter 7 (The Canada Jay—Our Country's Really Cool Ecological Wonder of Wonders), Strickland and Norris discuss jay ecology, focussing especially on how these birds survive Canada's sub-zero winters. The two authors are part of a study in Algonquin Provincial Park that has been underway for over 65 years. Co-author Archer (Chapter 3, A Whimsical Look at the Official Birds of Canada's Provinces and Territories) includes a few of Canada Jay's behavioural adaptations in a six-line ode of rhyming couplets:

> These smart birds found throughout the land
> Will come and eat right from your hand.
> Sometimes called a campground robber,
> They cover food with preserving slobber,
> Then store as much as they can stash
> And dine in winter on their cache. (p. 25)

In Chapter 8 (The Names of the Canada Jay), Strickland discusses the etymology of Canada Jay's common English name, colloquial English name (whiskyjack, a version of the Algonquian [Cree] word wîskicâhk), scientific name, official French name (Mésangeai du Canada), and colloquial French name (pie). While the authors lament that they were not able to publish the entire book in both of Canada's official languages, in Chapter 10 (Le mésangeai du Canada, une présence ancienne dans la culture Francophone) Goulet writes in French about the importance of the species to French-Canadian culture. Illustration captions throughout the book are also in English and French.

Besides contributing his drawing *For Seven Generations*, which features Canada Jay, Nadjiwan provides his Anishinabek view in Chapter 9 (An Indigenous View: the Canada Jay as Reconciliatory Agent and Environmental Emissary—a Most Worthy National Bird). He describes the book as "ultimately intended to be more aspirational than informational" (p. 62), which leads to the concluding chapter (Ten Things We Canadians Can Do). Suggested actions fall roughly into two categories: natural history oriented and advocacy. In the first category, the authors tell readers to seek out and get to know Canada Jay. This might include introducing children to the species, maintaining bird feeders properly, and donating to environmental organizations. Suggested advocacy actions revolve around lobbying for the official designation: contact your Member of Parliament (MP), sign a petition on the website www.canadajay.org, convince any organization you belong to to write a letter of endorsement, and use local print and electronic media to promote Canada Jay as the national bird.

There is some wonderful detail in this book, but it would have benefited from a Notes or Bibliography section for readers who would like more information on this species. There is some repetition between chapters, as can happen when each is written by a different author. I noted one error, where the cartoon on p. 38 is attributed to Gilles LaMontagne rather than Patrick LaMontagne, although the creator is credited properly in the Acknowledgements. I only spotted this because I am a big fan of LaMontagne, who is the editorial cartoonist for our local paper, the *Rocky Mountain Outlook*, and is syndicated in major newspapers across the country.

All of which raises the question … why hasn't Canada Jay been designated Canada's national bird?

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CBC. 2017. Canada isn't getting a national bird after all. Accessed 23 November 2023. https://www.cbc.ca/news/canada/nova-scotia/national-bird-grey-jay-canada-150-1.4187987.

Smith, M., and M. Devokaitis. 2023. Living bird spring 2023 table of contents—a modest proposal: can eBird help choose better state birds? [Parts 1–5]. Living Bird Spring 2023. Accessed 27 November 2023. https://www.allaboutbirds.org/news/living-bird-spring-2023-table-of-contents/.

CYNDI M. SMITH
Canmore, AB, Canada

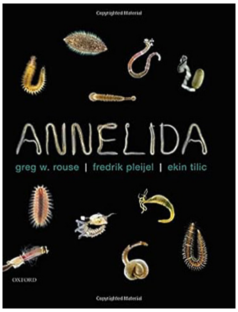
EDITOR'S COMMENT: If you'd like to learn more about Canada Jay's unique caching behaviour and see a photo of its "preserving slobber", see the article in this issue:

Hendricks, P., and S.S. Pagano. 2023. Canada Jay (*Perisoreus canadensis*) harvesting and caching fruits of Thin-leaved Snowberry (*Symphoricarpos albus*). Canadian Field-Naturalist 137(3): 243–248. https://doi.org/10.22621/cfn.v137i3.3079.

ZOOLOGY

Annelida

By Greg W. Rouse, Fredrik Pleijel, and Ekin Tilic. 2022. Oxford University Press. 432 pages, 155 colour line figures and illustrations, and 16 pages of colour gallery illustrations, 211.30 CAD, Hardcover. Also available as an E-book.



I'm going to bet that you have never heard the words "coffee-table book" and "worms" in the same sentence before, but here it goes: this new book on annelid worms has just as much of a place on the coffee table as it does on a zoologist's bookshelf. Now, maybe that coffee table is in the living room of a naturalist or macrophotographer, but nonetheless the hundreds of images in *Annelida* draws the attention of readers and encourages them to read about the biology of segmented worms.

Annelida is a classic taxon book. That is, it has a couple of introductory chapters (e.g., Systematics, Anatomy) followed by 77 taxon summaries (mostly to the family level). Within the chapter on systematics is a large cladogram illustrating our current understanding of the relationships among these worms. A subsequent table repeats the information with the Linnaean hierarchies added, despite being told in the Preface that these were going to be avoided in this book. The table could have been omitted and nothing would have been lost. As a refresher, the annelids were historically broken down into three taxa: Oligochaeta (the earthworms being the poster children of this taxon), Hirudinea (everyone's favourite, the leeches), and Polychaeta (Clam Worms and allies). As is currently understood, among the 77 taxa covered in this book the earthworms and leeches reside together as the "*Clitellata*", which is simply one of many taxa all residing within (not sister to) the "*Polychaeta*".

There is something counter-intuitive, anti-conventional, and just plain confusing happening in my last sentence (for demonstration purposes) as well as the aforementioned table and cladogram, and the reader must go back to the Preface to find out the rationale.

Historically, the binomen (e.g.*,* *Lumbricus terrestris*, our common, introduced Dew Worm or Common Nightcrawler) is written in italics with only the genus capitalized; no other names are italicized. This is high school (or first-year university) level knowledge. Family names of animals always end in -idae (-aceae for plants). There is less convention with ordinal names (as well as more encompassing hierarchies), but what we do know is that if a name is italicized or ends in one of those two suffixes, the name is not an order (or higher). From the Preface,

> There are a few stylistic issues that readers may find a little disconcerting in that we attempt to treat all taxon names in the same way … we … present all formal taxon names in italics instead of just species binomens. (p. vii)

What this means is that when reading a new name (e.g., *Paralacydonia*) the reader now has no idea where in the hierarchy of taxonomy it belongs—is it a broad, very encompassing term akin to order in the Linnaean system, or is it a very restrictive one, such as a genus? Why throw out hundreds of years of organized and effective protocol only to replace it with confusion, all in the name of equality? These ranks are different, let's keep them that way.

Most of the book is a taxon-by-taxon look at the surprising diversity of annelid worms. Flip anywhere within it and you'll almost always be met with superb line drawings (often from the original papers) and beautiful photographs, some as highly detailed electron micrographs, others as amazing colour macrophotographs. In some cases, the reader will encounter full-page plates of stunning images, but I have a minor quibble here. If there are nine plates, they are labelled "a–i". So far so good. It's the captions that host the quibble: after the figure number would typically be the nine names of specimens "a–i". However, the authors of *Annelida* then offer another set of "a–i" with specimen information (e.g., whole specimen, ventral view, maxillae). If a reader is scanning for information on image "e" for example, there are two e's in the caption, and at least half the time one will anchor to the wrong image—a minor frustration.

The text of each taxon chapter is divided into three sections: Morphology and Physiology, Natural History, and Systematics. Occasionally, Natural History is omitted simply due to a lack of existing knowledge in the field. A cladogram would have been a nice addition to each Systematics section, but I suspect that for many taxa the relationships have yet to be satisfactorily worked out. The text flows well, but a background in anatomy and systematics will be helpful to the reader; the Natural History sections are more consumable, but technical terms still pop up there as well.

The book has a Glossary, suggesting that the targetted readership is not confined to professionals. The

References section is nothing short of impressive; I didn't count them all, but my estimate is that over the 71 pages of references there are no less than 1600 works listed. Sixteen-hundred!

Overall, this is a massive book that surely took years to amalgamate and deserves a place on the bookshelf, nay, the coffee table, of any naturalist.

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NEW TITLES

Prepared by Jessica Sims

If you are interested in reviewing a book on this list, please contact Jessica Sims (bookrevieweditor@canadianfieldnaturalist.ca). This list covers a range of upcoming and new releases in field biology, ecology, and natural history. We also welcome your suggestions for new titles and offers to review unlisted books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, or books covering topics of global relevance, including climate change, biodiversity, species extinction, habitat loss, evolution, and field research experiences.

Please note: Books marked with a * have already been assigned to a *Canadian Field-Naturalist* reviewer. All other books are available for review and review copies of books marked with a † have been explicitly offered by publishers.

Currency Codes: CAD Canadian Dollars, AUD Australian Dollars, USD United States Dollars, EUR Euros, GBP British Pounds.

BIOLOGY

Biological Motion: a History of Life. By Janina Wellmann. Translated by Kate Sturge. 2024. Zone Books. Distributed by Princeton University Press. 336 pages and 27 black and white illustrations, 42.00 CAD, Hardcover. Also available as an E-book.

How Life Works: a User's Guide to the New Biology. By Philip Ball. 2023. University of Chicago Press. 552 pages and 92 halftones, 37.95 CAD, Hardcover, 28.99 CAD, E-book.

Imperfection: a Natural History. By Telmo Pievani. Translated by Michael Gerard Kenyon. Foreword by Ian Tattersall. 2024. MIT Press. 176 pages, 29.95 CAD, Paper, 27.99 CAD, E-book. Hardcover edition published in 2022.

The Internet of Animals: Discovering the Collective Intelligence of Life on Earth. By Martin Wikelski. Foreword by Keith Gaddis. 2024. Greystone Books. 264 pages, 38.95 CAD, Hardcover.

Kingdom of Play: What Ball-Bouncing Octopuses, Belly-Flopping Monkeys, and Mud-Sliding Elephants Reveal about Life Itself. By David Toomey. 2024. Scribner. 304 pages, 39.00 CAD, Hardcover, 20.99 CAD, E-book.

†Organismic Animal Biology: an Evolutionary Approach. By Ariel Chipman. 2023. Oxford University Press. 240 pages, 37.99 GBP, Paper.

Pavlov's Legacy: How and What Animals Learn. By Robert A. Boakes. 2023. Cambridge University Press. 375 pages, 97.95 CAD, Hardcover. Also available as an E-book.

Performance All the Way Down: Genes, Development, and Sexual Difference. By Richard O. Prum. 2023. University of Chicago Press. 368 pages and 16 halftones, 128.95 CAD, Hardcover, 29.50 CAD, Paper, 21.99 CAD, E-book.

BOTANY

50 Keystone Flora Species of Coastal British Columbia and the Pacific Northwest: a Pocket Guide. By Collin Varner. 2024. Heritage House. 128 pages, 19.95 CAD, Paper, 9.99 CAD, E-book.

The Beauty of the Flower: the Art and Science of Botanical Illustration. By Stephen A. Harris. 2023. Reaktion Books. Distributed by University of Chicago Press. 336 pages, 80 colour plates, and 64 halftones, 58.50 CAD, Hardcover, 44.99 CAD, E-book.

The Cactus Hunters: Desire and Extinction in the Illicit Succulent Trade. By Jared D. Margulies. 2023. University of Minnesota Press. 400 pages and 50 black and white photos, 139.99 CAD, Hardcover, 34.99 CAD, Paper, 24.99 CAD, E-book.

Carnivorous Plants. By Dan Torre. 2024. Reaktion Books. Distributed by University of Chicago Press. 240 pages, 100 colour plates, and 10 halftones, 29.50 CAD, Paper, 22.99 CAD, E-book. Hardcover edition published in 2019.

A Cultural History of Plants in Antiquity. The Cultural Histories Series. Edited by Annette Giesecke and David Mabberley. 2023. Bloomsbury Academic. 288 pages and 63 black and white illustrations, 152.95 CAD, Hardcover, 72.99 CAD, E-book.

A Cultural History of Plants in the Early Modern Era. The Cultural Histories Series. Edited by Andrew Dalby, Annette Giesecke, and David Mabberley. 2023. Bloomsbury Academic. 264 pages and 60 black and white illustrations, 152.95 CAD, Hardcover, 72.99 CAD, E-book.

A Cultural History of Plants in the Modern Era. The Cultural Histories Series. Edited by Stephen Forbes, Annette Giesecke, and David Mabberley. 2023. Bloomsbury Academic. 264 pages and 50 black and white illustrations, 152.95 CAD, Hardcover, 72.99 CAD, E-book.

A Cultural History of Plants in the Nineteenth Century. The Cultural Histories Series. Edited by David Mabberley and Annette Giesecke. 2023. Bloomsbury Academic. 256 pages and 56 black and white illustrations, 152.95 CAD, Hardcover, 72.99 CAD, E-book.

A Cultural History of Plants in the Post-Classical Era. The Cultural Histories Series. Edited by Alain Touwaide, Annette Giesecke, and David Mabberley. 2023. Bloomsbury Academic. 248 pages and 52 black and white illustrations, 152.95 CAD, Hardcover, 72.99 CAD, E-book.

A Cultural History of Plants in the Seventeenth and Eighteenth Centuries. The Cultural Histories Series. Edited by Jennifer Milam, Annette Giesecke, and David Mabberley. 2023. Bloomsbury Academic. 256 pages and 62 black and white illustrations, 152.95 CAD, Hardcover, 72.99 CAD, E-book.

Dispersals: on Plants, Borders, and Belonging. By Jessica J. Lee. 2024. Penguin Canada. 288 pages, 26.95 CAD, Paper, 14.99 CAD, E-book.

†The Dynamics of Plant Growth: Integrating Morphology, Physiology, and Development. By E. David Ford. 2024. Oxford University Press. 224 pages, 125.00 USD, Hardcover, 50.00 USD, Paper. Also available as an E-book.

The Ethnobotanical: a World Tour of Indigenous Plant Knowledge. By Sarah Edwards. 2024. Hodder. 256 pages, 50.00 CAD, Hardcover.

Ferns, Spikemosses, Clubmosses, and Quillworts of Eastern North America. Princeton Field Guides. By Emily Sessa. 2024. Princeton University Press. 528 pages, 1100 colour and black and white illustrations, and 300 maps, 38.00 CAD, Paper. Also available as an E-book.

†Flora of North America: Volume 14, Magnoliophyta: Gentianaceae to Hydroleaceae. By Flora of North America Editorial Committee. 2023. Oxford University Press. 536 pages, 123.50 CAD, Hardcover.

The Herbarium Handbook. New Edition. Edited by Nina M.J. Davies, Clare Drinkell, and Timothy M.A. Utteridge. 2024. Royal Botanic Gardens, Kew. Distributed by University of Chicago Press. 256 pages and 700 colour photos, 75.99 CAD, Paper. Also available as an E-book.

The Hidden Histories of Flowers: Fascinating Stories of Flora. By Maddie Bailey and Alice Bailey. 2024. Hardie Grant/Chronicle Books. 160 pages, 31.50 CAD, Hardcover, 11.99 CAD, E-book.

The Little Book of Trees. Little Books of Nature. By Herman Shugart and Peter White. Illustrations by Tugce Okay. 2024. Princeton University Press. 160 pages and 140 colour illustrations, 18.99 CAD, Hardcover, 14.99 CAD, E-book.

The Lives of Seaweeds: a Natural History of Our Planet's Seaweeds and Other Algae. By Julie A. Phillips. 2023. Princeton University Press. 288 pages and 150 illustrations and photos, 44.00 CAD, Hardcover, 34.99 CAD, E-book.

Medicinal Plants of the Pacific Northwest: a Visual Guide to Harvesting and Healing with 35 Common Species. By Natalie Hammerquist. 2024. The Mountaineers Books. 288 pages, 37.95 CAD, Paper.

Pathless Forest: the Quest to Save the World's Largest Flowers. By Chris Thorogood. 2024. Allen Lane. 288 pages, 25.00 GBP, Hardcover. Also available as an E-book.

Plants in Place: a Phenomenology of the Vegetal. Critical Life Studies Series. By Edward S. Casey and Michael Marder. 2023. Columbia University Press. 208 pages, 130.00 CAD, Hardcover, 34.00 CAD, Paper. Also available as an E-book.

Pocket Nature: Flower Finding—Delight in the Splendor of Wild Blooms. Pocket Nature Series. By Andrea Debbink. 2024. Chronicle Books. 128 pages, 19.95 CAD, Hardcover.

Twelve Trees: the Deep Roots of Our Future. By Daniel Lewis. 2024. Avid Reader Press/Simon & Schuster. 304 pages, 39.99 CAD, Hardcover. Also available as an E-book.

CONSERVATION AND CLIMATE CHANGE

Challenge to Civilization: Indigenous Wisdom and the Future. By Blair A. Stonechild. 2024. University of Regina Press. 184 pages, 29.95 CAD, Paper.

Climate Capitalism: Winning the Race to Zero Emissions and Solving the Crisis of Our Age. By Akshat Rathi. 2024. Greystone Books. 272 pages, 37.95 CAD, Hardcover.

Climate Change Education. An Earth Institute Sustainability Primer. By Cassie Xu and Radhika Iyengar. 2023. Columbia University Press. 192 pages, 104.00 CAD, Hardcover, 26.00 CAD, Paper. Also available as an E-book.

Climate Change: Examining the Facts. Contemporary Debates Series. By Daniel Bedford and John Cook. 2023. Bloomsbury Academic. 232 pages, 97.50 CAD, Hardcover, 41.95, CAD, Paper. Also available as an E-book.

Conservation in the Context of a Changing World: Concepts, Strategies, and Evidence. By Bertie J. Weddell. 2023. Cambridge University Press. 490 pages, 74.95 CAD, Paper. Also available as an E-book.

Conservation Leadership: a Practical Guide. Routledge Studies in Conservation and the Environment. By Simon Black. 2024. Routledge. 296 pages and 49 black and white illustrations, 69.50 CAD, Paper.

The Empire of Climate: a History of an Idea. By David N. Livingstone. 2024. Princeton University Press. 552 pages and 16 black and white illustrations, 38.00 USD, Hardcover. Also available as an E-book.

The End of Eden: Wild Nature in the Age of Climate Breakdown. By Adam Welz. 2023. Bloomsbury USA. 288 pages, 38.99 CAD, Hardcover, 21.99 CAD, E-book.

Endangered Species: a Reference Handbook. Contemporary World Issues Series. By Jan A. Randall. 2023. Bloomsbury Academic. 424 pages, 90.50 CAD, Hardcover, 41.95 CAD, Paper. Also available as an E-book.

Gaia's Web: How Digital Environmentalism Can Combat Climate Change, Restore Biodiversity, Cultivate Empathy, and Regenerate the Earth. By Karen Bakker. 2024. MIT Press. 280 pages, 39.95 CAD, Hardcover, 31.99 CAD, E-book.

H is for Hope: Climate Change from A to Z. By Elizabeth Kolbert. Illustrations by Wesley Allsbrook. 2024. Clarkson Potter/Ten Speed. 160 pages, 33.99 CAD, Hardcover, 16.99 CAD, E-book.

The High Seas: Greed, Power and the Battle for the Unclaimed Ocean. By Olive Heffernan. 2024. Greystone Books. 368 pages, 42.95 CAD, Hardcover.

Intertwined: Women, Nature, and Climate Justice. By Rebecca Kormos. 2024. New Press. 304 pages, 36.99 CAD, Hardcover.

Life as We Know It (Can Be): My Search for a World Worth Passing Down. By Bill Weir. 2024. Chronicle Books. 272 pages, 41.95 CAD, Hardcover, 15.99 CAD, E-book.

Medicine Wheel for the Planet: a Journey toward Personal and Ecological Healing. By Jennifer Grenz. 2024. Knopf Canada. 280 pages, 34.00 CAD, Hardcover, 16.99 CAD, E-book.

The Nature-Study Idea: and Related Writings. The Liberty Hyde Bailey Library Series. By Liberty Hyde Bailey. Edited by John Linstrom. Foreword by David W. Orr. 2024. Cornell University Press. 378 pages and 31 black and white halftones, 168.95 CAD, Hardcover, 43.95 CAD, Paper. First published in 1903.

Not the End of the World: How We Can Be the First Generation to Build a Sustainable Planet. By Hannah Ritchie. 2024. Chatto & Windus. 352 pages, 22.00 GBP, Hardcover. Also available as an E-book.

Restoring the Balance: What Wolves Tell Us about Our Relationship with Nature. By John A. Vucetich. 2024. Johns Hopkins University Press. 416 pages, 38.95 CAD, Paper. Also available as an E-book.

Revenant Ecologies: Defying the Violence of Extinction and Conservation. By Audra Mitchell. 2024. University of Minnesota Press. 392 pages, 167.99 CAD, Hardcover, 41.99 CAD, Paper, 29.99 CAD, E-book.

Signs of Life: Field Notes from the Frontlines of Extinction. By Sarah Cox. 2024. Goose Lane Editions. 240 pages, 24.95 CAD, Paper.

The Sixth Extinction (10th Anniversary Edition): an Unnatural History. By Elizabeth Kolbert. 2024. Henry Holt and Co. 352 pages, 26.99 CAD, Paper.

Solved: How the World's Great Cities are Fixing the Climate Crisis. Edition, Revised and Updated. By David Miller. Foreword by Bill McKibben. Afterword by Anne Hidalgo. 2024. University of Toronto Press. 280 pages, 24.95 CAD, Paper. Also available as an E-book. Hardcover edition published in 2020.

Stuck Monkey: the Deadly Planetary Cost of the Things We Love. By James Hamilton-Paterson. 2024. Bloomsbury USA. 304 pages, 36.99 CAD, Hardcover.

***The Summer Canada Burned: the Wildfire Season that Shocked the World.** By Monica Zurowski and Postmedia. 2023. Greystone Books. 192 pages, 34.95 CAD, Hardcover.

This System is Killing Us: Land Grabbing, the Green Economy and Ecological Conflict. By Xander Dunlap. 2024. Pluto Press. 272 pages, 32.95 CAD, Paper.

Transformative Politics of Nature: Overcoming Barriers to Conservation in Canada. Edited by Andrea Olive, Chance Finegan, and Karen F. Beazley. 2023. University of Toronto Press. 320 pages, 95.00 CAD, Hardcover, 39.95 CAD, Paper. Also available as an E-book.

Wild Woman: Empowering Stories from Women who Work in Nature. By Philippa Forrester. 2024. Bloomsbury USA. 256 pages, 37.00 CAD, Hardcover.

A Wilder Kingdom: Rethinking Nature in Zoos, Wildlife Parks, and Beyond. Edited by Ben A. Minteer and Harry W. Greene. 2023. Columbia University Press. 280 pages, 169.00 CAD, Hardcover, 42.00 CAD, Paper. Also available as an E-book.

ECOLOGY

The Canadian Mountain Assessment: Walking Together to Enhance Understanding of Mountains in Canada. By Graham McDowell, Madison Stevens, Shawn Marshall, *et al*. 2023. University of Calgary Press. 370 pages, 124.99 CAD, Hardcover, 68.99 CAD, Paper. Also available as an E-book.

Common Ecology. Excellence in Ecology Series, Volume 32. By Kevin J. Gaston. 2023. International Ecology Institute. 210 pages, 36.99 GBP, Hardcover.

Eat, Poop, Die: How Animals Make Our World. By Joe Roman. 2023. Little, Brown and Company. 288 pages, 39.00 CAD, Hardcover, 19.99 CAD, E-book.

Settler Ecologies: the Enduring Nature of Settler Colonialism in Kenya. By Charis Enns and Brock Bersaglio. 2024. University of Toronto Press. 224 pages, 34.95 CAD, Paper. Also available as an E-book.

Wetland Ecology: Principles and Conservation. Third Edition. By Paul A. Keddy. 2023. Cambridge University Press. 566 pages, 172.95 CAD, Hardcover, 74.95 CAD, Paper. Also available as an E-book.

The World Atlas of Rivers, Estuaries, and Deltas. By Jim Best, Stephen Darby, Luciana Esteves, and Carol Wilson. 2024. Princeton University Press. 400 pages and 250 colour illustrations, 75.00 CAD, Hardcover. Also available as an E-book.

ENTOMOLOGY

The Ant Collective: Inside the World of an Ant Colony. By Armin Schieb. 2024. Princeton University Press. 128 pages and 120 colour illustrations, 32.00 CAD, Hardcover. Also available as an E-book.

†Cow Patty Critters: an Introduction to the Ecology, Biology and Identification of Insects in Cattle Dung on Canadian Pastures. By K.D. Floate. 2023. Agriculture and Agri-Food Canada. 224 pages, free PDF available at https://publications.gc.ca/collections/collection_2023/aac-aafc/A59-90-2022-eng.pdf.

A Cultural History of Insects, Volumes 1–6. The Cultural Histories Series. Edited by Gene Kritsky. 2024. Bloomsbury Academic. 279 black and white illustrations, 764.50, CAD, for 6-volume pack.

†Effects of Climate Change on Insects: Physiological, Evolutionary, and Ecological Responses. Edited by Daniel González-Tokman and Wesley Dáttilo. 2024. Oxford University Press. 400 pages, 125.00 USD, Hardcover. Also available as an E-book.

The Little Book of Beetles. Little Books of Nature Series. By Arthur V. Evans. Illustrations by Tugce Okay. 2024. Princeton University Press. 160 pages and 140 colour illustrations, 18.99 CAD, Hardcover, 14.99 CAD, E-book.

The Little Book of Butterflies. Little Books of Nature Series. By Andrei Sourakov and Alexandra A. Sourakov. Illustrations by Tugce Okay. 2024. Princeton University Press. 160 pages and 140 colour illustrations, 18.99 CAD, Hardcover, 14.99 CAD, E-book.

The Lives of Butterflies: a Natural History of Our Planet's Butterfly Life. The Lives of the Natural World Series. By David G. James and David J. Lohman. 2024. Princeton University Press. 288 pages and 150 colour illustrations, 44.00 CAD, Hardcover, 34.99 CAD, E-book.

Meetings with Moths: Discovering Their Mystery and Extraordinary Lives. By Katty Baird. 2024. Fourth Estate. 272 pages, 36.99 CAD, Hardcover. Also available as an E-book.

Metamorphosis: How Insects are Changing Our World. By Erica McAlister. With Adrian Washbourne. 2024. Smithsonian. 216 pages and 80+ colour illustrations, 39.95 CAD, Hardcover.

Papilionidae Part 4 (Guide to the Butterflies of the Palearctic Region): Subfamily Papilioninae, Tribe Papilionini, Genus Papilio (Partim). Guide to the Butterflies of the Palearctic Region Series, Volume 26. By V. Nazari, A.M. Cotton, J.G. Coutsis, N. Shapoval, V. Todisco, and G.C. Bozano. Edited by G.C. Bozano. 2023. Omnes Artes. 91 pages, 32.00 EUR, Paper.

Piping Hot Bees and Boisterous Buzz-Runners: 20 Mysteries of Honey Bee Behavior Solved. By Thomas D. Seeley. 2024. Princeton University Press. 312 pages and 106 colour and black and white illustrations, 38.00 CAD, Hardcover, 29.99 CAD, E-book.

Velvet Ants of North America. Princeton Field Guides. By Kevin Williams, Aaron D. Pan, and Joseph S. Wilson. 2024. Prince University Press. 440 pages, 1290 colour illustrations, and 30 tables, 44.00 CAD, Paper. Also available as an E-book.

Wasps of the World. A Guide to Every Family Series. By Simon van Noort and Gavin Broad. 2024. Princeton University Press. 240 pages and 300 colour illustrations, 38.00 CAD, Hardcover, 29.99 CAD, E-book.

What the Bees See: the Honeybee and its Importance to You and Me. By Craig P. Burrows. 2024. Chronicle Books. 192 pages and 70 ultraviolet photos, 60.00 CAD, Hardcover.

HERPETOLOGY

The Book of Snakes: a Life-Size Guide to Six Hundred Species from Around the World. Second Edition. By Mark O'Shea. 2024. University of Chicago Press. 656 pages and 2400 colour plates, 60.00 USD, Hardcover. Also available as an E-book.

Frogs of the World: a Guide to Every Family. A Guide to Every Family Series. By Mark O'Shea and Simon Maddock. 2024. Princeton University Press. 240 pages and 300 colour illustrations, 38.00 CAD, Hardcover. Also available as an E-book.

†Islands and Snakes: Diversity and Conservation. By Harvey B. Lillywhite and Marcio Martins. 2023. Oxford University Press. 352 pages, 130.00 USD, Hardcover. Also available as an E-book.

Lost Frogs and Hot Snakes: Herpetologists' Tales from the Field. Edited by Martha L. Crump. 2024. Cornell University Press. 320 pages and 42 black and white halftones, 36.95 CAD, Paper.

My Life with Sea Turtles: a Marine Biologist's Quest to Protect One of the Most Ancient Animals on Earth. By Christine Figgener. Translated by Jane Billinghurst. 2024. Greystone Books. 272 pages, 38.95 CAD, Hardcover.

Snakes: Biology, Diversity, and Behavior. By David Gower, Katie Garrett, and Simon Maddock. 2023. Cornell University Press. 176 pages and 165 colour photos, 29.95 CAD, Paper.

***Turtles of North America: an Illustrated Field Guide to the Turtles of the Continental United States and Canada.** By Kyle Horner. Introduction by Sue Carstairs. 2024. Firefly Books. 208 pages and 250+ photos, 29.95 CAD, Paper.

ORNITHOLOGY

Avian Architecture: How Birds Design, Engineer, and Build. Edition, Revised and Updated. By Peter Goodfellow. Edited by Tony D. Williams. 2024. Princeton University Press. 176 pages and 300+ colour illustrations, 38.00 CAD, Hardcover. Also available as an E-book.

The Backyard Bird Chronicles. By Amy Tan. Illustrations by Amy Tan. Foreword by David Allen Sibley. 2024. Knopf Doubleday. 320 pages, 48.00 CAD, Hardcover. Also available as an E-book.

Bird Pellets: a Complete Photographic Guide. By Ed Drewitt. 2024. Pelagic Publishing. 250 pages, 49.00 CAD, Paper.

Bird Photographer of the Year. By Bird Photographer of the Year Competition. Foreword by Gordon Buchanan. 2024. HarperCollins. 256 pages, 52.00 CAD, Hardcover.

Birding to Change the World: a Memoir. By Trish O'Kane. 2024. HarperCollins. 368 pages, 36.99 CAD, Hardcover, 18.99 CAD, E-book.

***Birds and Flowers: an Intimate 50 Million Year Relationship.** By Jeff Ollerton. 2024. Pelagic Publishing. 336 pages, 39.00 CAD, Hardcover.

Birds through Indigenous Eyes: Native Perspectives on Birds of the Eastern Woodlands. By Dennis Gaffin. With Michael Bastine and John Volpe. 2024. Princeton University Press. 176 pages, 32.00 CAD, Hardcover. Also available as an E-book.

†Blue-Footed Boobies: Sibling Conflict and Sexual Infidelity on a Tropical Island. By Hugh Drummond. 2023. Oxford University Press. 304 pages and 51 illustrations, 83.00 USD, Hardcover. Also available as an E-book.

Dare to Bird: Exploring the Joy and Healing Power of Birds. By Melissa Hafting. Photography by Melissa Hafting. 2024. Rocky Mountain Books (RMB). 224 pages, 45.00 CAD, Paper, 19.99 CAD, E-book.

Field Guide to North American Flycatchers: Kingbirds and Myiarchus. By Cin-Ty Lee. Illustrations by Andrew Birch. 2024. Princeton University Press. 200 pages, 56 colour illustrations, 18 black and white illustrations, and 17 maps, 24.99 CAD, Paper. Also available as an E-book.

Journeys with Emperors: Tracking the World's Most Extreme Penguin. By Gerald L. Kooyman and Jim Mastro. Foreword by Jessica Ulrika Meir. 2023. University of Chicago Press. 256 pages, 25 colour plates, and 46 halftones, 42.50 CAD, Hardcover, 31.99 CAD, E-book.

***The Last of its Kind: the Search for the Great Auk and the Discovery of Extinction.** By Gísli Pálsson. 2024. Princeton University Press. 328 pages, 16 colour illustrations, and 37 black and white illustrations, 35.00 CAD, Hardcover, 27.99 CAD, E-book.

The Life of Birds. Edition, Revised and Updated. By David Attenborough. 2024. HarperCollins. 320 pages, 45.00 CAD, Hardcover, 26.99 CAD, Paper. Also available as an E-book.

A Little Book of Hummingbirds. Little Book of Natural Wonders Series. By Tara Austen Weaver. Illustrations by Emily Poole. 2024. Sasquatch Books. 144 pages and 45 illustrations, 16.95 CAD, Hardcover.

The Little Owl: Population Dynamics, Behavior and Management of *Athene noctua*. Second Edition. By Dries Van Nieuwenhuyse, Ronald van Harxen, and David H. Johnson. 2024. Cambridge University Press. 539 pages, 114.95 CAD, Hardcover. Also available as an E-book.

The Migration Ecology of Birds. Second Edition. By Ian Newton. 2023. Academic Press. 724 pages, 259.50 CAD, Hardcover. Also available as an E-book.

The Osprey. Poyser Monographs Series. By Tim Mackrill. 2024. Bloomsbury USA. 304 pages and 150 colour photos, 60.00 CAD, Paper. Also available as an E-book.

The Owl: a Biography. The Bird Biography Series. By Stephen Moss. 2023. Square Peg. 208 pages, 14.99 GBP, Hardcover. Also available as an E-book.

The Painted Stork: Exploring Ecology and Conservation in India. By Abdul Jamil Urfi. 2024. Pelagic Publishing. 208 pages, 44.00 CAD, Paper.

Purposeful Birdwatching: Getting to Know Birds Better. By Rob Hume. 2024. Pelagic Publishing. 304 pages and 100 black and white illustrations, 35.00 CAD, Paper.

Quetzals: Icons of the Cloud Forest. By Alan F. Poole. 2023. Cornell University Press. 120 pages, 69 colour photos, and 5 colour line drawings, 36.95 CAD, Paper.

Thinking with Birds: Signs and Meaning in the Natural World. By Felice Sea Wyndham. 2024. W.W. Norton. 336 pages, 39.99 CAD, Hardcover.

The Vanishing Mew Gull: a Guide to the Bird Names of the Western Palaearctic. By Ray Reedman. 2024. Pelagic Publishing. 336 pages, 113.00 CAD, Hardcover.

ZOOLOGY

50 Keystone Fauna Species of Coastal British Columbia and the Pacific Northwest: a Pocket Guide. By Collin Varner. 2024. Heritage House. 128 pages, 19.95 CAD, Paper, 9.99 CAD, E-book.

Aesop's Animals: the Science Behind the Fables. By Jo Wimpenny. 2024. Bloomsbury Sigma. 368 pages, 38.00 CAD, Hardcover, 24.00 CAD, Paper, 19.20 CAD, E-book.

The Age of Deer: Trouble and Kinship with Our Wild Neighbors. By Erika Howsare. 2024. Catapult. 368 pages, 36.00 CAD, Hardcover, 27.99 CAD, E-book.

Big Meg: the Story of the Largest, Fiercest and Most Mysterious Predator that Ever Lived. By Tim Flannery and Emma Flannery. 2024. Grove Atlantic. 224 pages, 41.50 CAD, Hardcover. Also available as an E-book.

Carrier Shells—Garbage Collectors of the Oceans: a Portrait of the Gastropod Family Xenophoridae. Molluscan Science Series, Volume 4. By Kurt Kreipl and Felix Lorenz. 2023. ConchBooks. 96 pages, 49.00 EUR, Hardcover.

Field Guide to Sharks, Rays and Chimaeras of the East Coast of North America. Wild Nature Press Series. By David A. Ebert and Marc Dando. 2024. Princeton University Press. 432 pages, 50.00 CAD, Paper. Also available as an E-book.

Finding the Fox: Encounters with an Enigmatic Animal. By Andreas Tjernshaugen. Translated by Lucy Moffatt. 2024. Greystone Books. 240 pages, 32.95 CAD, Hardcover.

***Grizzly Bear Science and the Art of a Wilderness Life: Forty Years of Research in the Flathead Valley.** By Bruce McLellan. 2023. Rocky Mountain Books (RMB). 336 pages, 32.00 CAD, Paper, 15.99 CAD, E-book.

The Little Book of Spiders. Little Books of Nature Series. By Simon D. Pollard. Illustrations by Tugce Okay. 2024. Princeton University Press. 160 pages and 140 colour illustrations, 18.99 CAD, Hardcover, 14.99 CAD, E-book.

Otter Country: an Unexpected Adventure in the Natural World. By Miriam Darlington. 2024. W.W. Norton. 368 pages, 36.95 CAD, Hardcover, 29.99 CAD, E-book.

Plankton: a Worldwide Guide. By Tom Jackson and Jennifer Parker. Edited by Andrew Hirst. 2024. Princeton University Press. 224 pages and 250 colour illustrations, 38.00 CAD, Hardcover. Also available as an E-book.

RSPB Spotlight: Hares. By Nancy Jennings. 2024. Bloomsbury Wildlife. 128 pages and 200 colour photos, 24.00 CAD, Paper. Also available as an E-book.

Secrets of the Octopus. By Sy Montgomery. 2024. Disney Publishing Group. 192 pages, 41.00 CAD, Hardcover, 19.99 CAD, E-book.

Sharkpedia: a Brief Compendium of Shark Lore. Pedia Books Series. By Daniel C. Abel. Illustrations by Marc Dando. 2024. Princeton University Press. 176 pages and 50 black and white illustrations, 22.99 CAD, Hardcover. Also available as an E-book.

Shells of the World: a Natural History. A Guide to Every Family Series. By M.G. Harasewych. 2024. Princeton University Press. 240 pages and 300 colour illustrations, 38.00 CAD, Hardcover, 29.99 CAD, E-book.

Shrews and Moles of British Columbia. Royal BC Museum Handbook. By David W. Nagorsen and Nick Panter. 2024. Royal BC Museum. 336 pages, 34.95 CAD, Paper.

Stoat, Weasel, Marten and Polecats. Collins New Naturalist Library Series. By Jenny MacPherson. 2024. William Collins. 496 pages, 87.99 CAD, E-book.

Wild Florida: an Animal Odyssey. By Kirsten Hines. Foreword by Ron Magill. 2023. University Press of Florida. 328 pages, 51.95 CAD, Hardcover.

The Wild Horses of the Chilcotin: Their History and Future. By Wayne McCrory. 2023. Harbour Publishing. 368 pages, 39.95 CAD, Hardcover, 21.99 CAD, E-book.

Worm. By Kevin Butt. 2024. Reaktion Books. Distributed by University of Chicago Press. 176 pages, 80 colour plates, and 28 halftones, 28.95 CAD, Paper, 21.99 CAD, E-book.

OTHER

†40 Days and 40 Hikes: Loving the Bruce Trail One Loop at a Time. By Nicola Ross. 2024. ECW Press. 330 pages, 26.95 CAD, Paper. Also available as an E-book.

All through the Night: Why Our Lives Depend on Dark Skies. By Dani Robertson. 2024. HarperCollins. 320 pages, 34.99 CAD, Hardcover, 21.99 CAD, E-book.

André Michaux in Florida: an Eighteenth-Century Botanical Journey. By Walter Kingsley Taylor and Eliane M. Norman. 2023. University Press of Florida. 266 pages, 34.95 CAD, Paper, 29.99 CAD, E-book. Hardcover edition published in 2002.

Animal Dignity: Philosophical Reflections on Non-Human Existence. Edited by Melanie Challenger. 2023. Bloomsbury Academic. 296 pages, 125.50 CAD, Hardcover, 37.50 CAD, Paper. Also available as an E-book.

Beneath the Surface of Things: New and Selected Essays. By Wade Davis. 2024. Greystone Books. 264 pages, 36.95 CAD, Hardcover.

Beyond the Park: an Anthology of Ecological Experiences. Edited by Angel Mota. 2024. Laberinto Press. 120 pages, 25.00 CAD, Paper.

A Book of Noises: Notes on the Auraculous. By Caspar Henderson. 2023. University of Chicago Press. 272 pages, 31.50 CAD, Hardcover, 23.99 CAD, E-book.

The Calf with Two Heads: Transatlantic Natural History in the Canadas. By Louisa Blair. 2023. Baraka Books. 160 pages, 29.95 CAD, Paper.

Costa Rica: a Journey through Nature. Third Edition. By Adrian Hepworth. 2024. Cornell University Press. 216 pages and 181 colour halftones, 39.95 USD, Hardcover.

Countryside History: the Life and Legacy of Oliver Rackham. Edited by Ian D. Rotherham and Jennifer Moody. 2024. Pelagic Publishing. 416 pages, 87.00 CAD, Hardcover. Also available as an E-book.

Curious Species: How Animals Made Natural History. By Whitney Barlow Robles. 2023. Yale University Press. 328 pages, 14 colour illustrations, and 65 black and white illustrations, 52.00 CAD, Hardcover, 39.99 CAD, E-book.

Echo Loba, Loba Echo: of Wisdom, Wolves, and Women. By Sonja Swift. Foreword by Winona LaDuke. 2023. Rocky Mountain Books (RMB). 248 pages, 32.00 CAD, Hardcover, 12.99 CAD, E-book.

Econarrative: Ethics, Ecology, and the Search for New Narratives to Live By. By Arran Stibbe. 2024. Bloomsbury Academic. 288 pages and 10 black and white illustrations, 51.50 CAD, Paper, 35.99 CAD, E-book.

Entangled Life (the Illustrated Edition): How Fungi Make Our Worlds. By Merlin Sheldrake. 2023. Random House. 240 pages, 100 colour and black and white illustrations and photos, 54.00 CAD, Hardcover, 18.99 CAD, E-book.

Fungi: Discover the Science and Secrets Behind the World of Mushrooms. By Lynne Boddy and Ali Ashby. 2024. DK. 304 pages, 54.00 CAD, Hardcover.

Hearsay is Not Excluded: a History of Natural History. Yale Agrarian Studies Series. By Michael R. Dove. 2024. Yale University Press. 288 pages and 29 black and white illustrations, 143.00 CAD, Hardcover, 45.50 CAD, Paper, 34.99 CAD, E-book.

Islands in Deep Time: Ancient Landscapes Lost and Found. By Markes E. Johnson. 2023. Columbia University Press. 312 pages, 176.00 CAD, Hardcover, 42.00 CAD, Paper. Also available as an E-book.

Local: a Search for Nearby Nature and Wildness. By Alastair Humphreys. 2024. Eye Books Ltd. US. 368 pages, 16.99 CAD, Paper.

The Man Who Loved Pink Dolphins: a True Story of Life and Death in the Amazon. By Anthony Ham. 2024. Allen & Unwin. 296 pages, 24.99 CAD, Paper, 9.99 CAD, E-book.

Molds, Mushrooms, and Medicines: Our Lifelong Relationship with Fungi. By Nicholas Money. 2024. Princeton University Press. 240 pages, 29.95 USD, Hardcover. Also available as an E-book.

Monkey to Man: the Evolution of the March of Progress Image. By Gowan Dawson. 2024. Yale University Press. 392 pages, 7 colour illustrations, and 75 black and white illustrations, 52.00 CAD, Hardcover.

The New Beachcomber's Guide to the Pacific Northwest. Second Revised Edition. By J. Duane Sept. 2024. Harbour Publishing. 416 pages, 34.95 CAD, Paper.

Protest and Partnership: Case Studies of Indigenous Peoples, Consultation and Engagement, and Resource Development in Canada. Edited by Jennifer Winter and Brendan Boyd. 2024. University of Calgary Press. 258 pages and 11 illustrations, 68.99 CAD, Hardcover, 38.99 CAD, Paper. Also available as an E-book.

Purified: How Recycled Sewage is Transforming Our Water. By Peter Annin. 2023. Island Press. 248 pages and 20 illustrations and photos, 28.00 USD, Paper, 13.99 USD, E-book.

Scientific Collaboration: Strategies for Successful Research Teams. By Jeanne M. Fair. 2023. Johns Hopkins University Press. 200 pages, 77.95 CAD, Hardcover, 59.99 CAD, E-book.

Stones: a Material and Cultural History. By Cally Oldershaw. 2023. Reaktion Books. Distributed by University of Chicago Press. 296 pages, 98 colour plates, and 23 halftones, 45.50 CAD, Hardcover, 34.99 CAD, E-book.

Thermal Imaging for Wildlife Applications. By Kayleigh Fawcett Williams. 2023. Pelagic Publishing. 176 pages, 96.00 CAD, Hardcover, 62.79 CAD, Paper, 55.99 CAD, E-book.

The Travel Journals and Correspondence of Charles Fothergill 1816–1840. Edited by John W. Sabean. 2023. Amazon Publishing. 227 pages, 33.42 CAD, Paper.

What We Sow: on the Personal, Ecological, and Cultural Significance of Seeds. By Jennifer Jewell. 2023. Timber Press. 392 pages, 38.00 CAD, Hardcover. Also available as an E-book.

Where the Falcon Flies: a 3400 Kilometre Odyssey from My Doorstep to the Arctic. By Adam Shoalts. 2023. Penguin Canada. 368 pages, 27.00 CAD, Hardcover, 16.99 CAD, E-book.

Wild Chorus: Finding Harmony with Whales, Wolves, and Other Animals. By Brenda Peterson. 2024. The Mountaineers Books. 240 pages, 37.95 CAD, Hardcover.

The Wit and Wisdom of David Attenborough: a Celebration of Our Favourite Naturalist. By Chas Newkey-Burden. 2024. Mobius. 208 pages, 16.99 CAD, Hardcover, 4.99 CAD, E-book.

A Woman in the Polar Night. Pushkin Press Classics Series. By Christiane Ritter. Translated by Jane Degras. Foreword by Sara Wheeler. 2024. Pushkin Press. 224 pages, 25.95 CAD, Paper, 15.99 CAD, E-book. First published in 1938.

The Canadian Field-Naturalist

News and Comment

Compiled by Amanda E. Martin

Upcoming Meetings and Workshops

Canadian Society of Ecology & Evolution Annual Meeting

The annual meeting of the Canadian Society of Ecology & Evolution to be held 26–29 May 2024 at the University of British Columbia, Vancouver, British Columbia. Registration is currently open. More information is available at https://csee-scee2024.ca/en/.

Society for Freshwater Science

The annual meeting of the Society for Freshwater Science to be held 2–6 June 2024 at the Sheraton Philadelphia Downtown, Philadelphia, Pennsylvania. The theme of the conference is: 'Connecting to Enhance Freshwater Science'. Registration is currently open. More information is available at https://sfsannualmeeting.org/.

American Society of Mammalogists Annual Meeting

The 103rd annual meeting of the American Society of Mammalogists to be held 7–11 June 2024 at the University of Colorado Boulder, Boulder, Colorado. The annual meeting will be joined by the North American Pika Consortium. Registration is currently open. More information is available at https://mammalmeetings.org/.

Mycological Society of America Annual Meeting

The annual meeting of the Mycological Society of America to be held 9–12 June 2024 at the Hilton Toronto/Markham Suites Conference Centre & Spa, Markham, Ontario. The theme of the conference is: 'Expanding Networks'. Registration is currently open. More information is available at https://msafungi.org/2024-msa-annual-meeting-expanding-networks/.

North American Congress for Conservation Biology

The North American Congress for Conservation Biology to be held 23–28 June 2024 at the University of British Columbia Point Grey (Vancouver) campus, Vancouver, British Columbia. The theme of the conference is: 'Celebrating Diversity in Conservation from Summit to Sea'. Registration is currently open. More information is available at https://scbnorthamerica.org/index.php/naccb-2024/.

Plant Canada

The Plant Canada conference to be held 7–10 July 2024 at the RBC Convention Centre, Winnipeg, Manitoba. The theme of the conference is: 'Plants: Adapting to a Changing World'. Registration is currently open. More information is available at https://www.plantcanada.ca/eng/conference_plantcanada2024.html.

AFO–SCO–WOS 2024 Joint Meeting

The joint meeting of the Association of Field Ornithologists, the Society of Canadian Ornithologists, and the Wilson Ornithological Society to be held 29 July–1 August 2024 at the Peoria Civic Center, Peoria, Illinois. Registration is currently open. More information is available at https://afoscowos2024.org/.

In Memoriam: Ronald J. Brooks (16 April 1941—18 December 2023)

As the year 2023 ended, Canada and *The Canadian Field-Naturalist* (CFN) lost a great conservationist, a former member of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and a CFN Associate Editor (AE) and book reviewer, with the passing of Dr. Ron Brooks.

I first met Ron when I became an incoming member of COSEWIC in November 2008. His passionate status report presentations on amphibians and reptiles, especially on turtles, and huge presence at COSEWIC wildlife species assessment meetings was immediately noticed. I particularly remember his tendency to insert a sentence or two in status reports just to confirm COSEWIC members were indeed reading the status reports. But, he was more than just an expert on turtles; as his last book review suggested (Brooks, R. 2023 [Book Review].Voles, Not Moles: a Personal Journey Connecting with Nature: Canadian Field-Naturalist 137(1–2): 163–164. https://doi.org/10.22621/cfn.v137i1.3329), Ron was an expert on small mammals too. His unique way with words and straight-forwardness extended to his being an AE for CFN. I will miss his embedded comments in manuscripts, signed as “Darwin”, in admiration for Charles Darwin.

A full tribute is planned for CFN.

D.A.W. LEPITZKI
CFN Editor-in-Chief

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VOLUME 137, NUMBER 3 • 2023

(continued inside back cover)

ISSN 0008-3550

Table of Contents (*concluded*)

Tributes

Book Reviews

News and Comment

Upcoming Meetings and Workshops

Mailing date of the previous issue 137(1–2): 7 February 2024