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COVER: Collared Pika (*Ochotona collaris*) in the Ogilvie Mountains at km 158 of Dempster Highway (65.078786°N, 138.360606°W), north of Tombstone Territorial Park, northern Yukon. Aerial and ground surveys were conducted in July 2018 to document occurrence and general habitat suitability of this cold-adapted, at-risk Beringian species. See article in this issue by Syd Cannings *et al.*, pages 130–135. Photo: Jeffrey H. Skevington, 11 July 2018.

The Canadian Field-Naturalist

Roadkill of Eastern Newts (*Notophthalmus viridescens*) in a protected area in Quebec

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Abstract

Roadkill is a threat to populations of many amphibian species, including Eastern Newt (*Notophthalmus viridescens*), which is widespread in eastern Canada and the northeastern United States. Little is known about the level of road mortality experienced by dispersing Eastern Newts in Canada. During extensive road surveys from May to October 2016 and 2017, 279 dead Eastern Newt efts were found on roads in Gatineau Park, Quebec. We found 107 dead Eastern Newts along a 425 m section of road in 2016, but only 30 dead individuals at the same location in 2017. Thus, although the amount of roadkill can vary annually, it may pose a significant threat to the species in some areas.

Key words: Eastern Newt; *Notophthalmus viridescens*; road ecology; salamander; hotspot; Gatineau Park

Introduction

Roadkill is a threat for many species of amphibians (Ashley and Robinson 1996; Andrews *et al.* 2008), and they are often the vertebrate group most commonly killed on roads (Ashley and Robinson 1996; Smith and Dodd 2003; Glista *et al.* 2008). Traffic mortality can have a negative effect on amphibian populations (Fahrig *et al.* 1995; Rytwinski and Fahrig 2012). Although roadkill numbers are often greatest for frogs and toads, roadkill can also be a threat for salamanders (Clevenger *et al.* 2001; Gibbs and Shriver 2005; Pagnucco *et al.* 2012). Salamanders may remain immobile on roads when a vehicle approaches, increasing their risk of being run over (Mazerolle 2004). Mortality of >10% of the adult population of Spotted Salamanders (*Ambystoma maculata*) can lead to population decline and possibly extirpation (Gibbs and Shriver 2005).

Here we report on substantial roadkill of Eastern Newt (*Notophthalmus viridescens*), a species widespread in eastern Canada and the northeastern United States (Cook 1984). Eastern Newt is a pond breeding salamander with a complex and variable life cycle. The typical life cycle of Eastern Newt includes four distinct stages: egg, aquatic larva, terrestrial juvenile or eft, and adult (Gill 1978). After larvae transform, the juvenile eft stage disperses from the breeding ponds in late summer and early fall (Gill 1978). The eft stage can last for three or more years (Healy 1974), after which maturing efts return to breeding ponds (Hurlbert 1969). Adults may remain in aquatic habitats or hibernate on land (Hurlbert 1969; Gill 1978). The eft stage is the primary growth and dispersal stage in the life cycle, whereas emigrating adults are believed to return to the same breeding ponds repeatedly (Gill 1978). It is unclear how far efts can disperse, but they have been documented to move up to 80 m in a single night (Roe and Grayson 2008) and take up to a year to migrate 800 m (Healy 1974, 1975). The multi-year maturation and dispersal period allows Eastern Newts to colonize newly formed and distant wetlands (Semlitsch 2008) and represents a vulnerable life history stage (Gill 1978). When migration or dispersal routes cross roads, mortality can occur.

Methods

Road surveys were conducted by car in Gatineau Park, Quebec (45.5°N, 75.8°W) along Meech Lake Road, Gatineau Parkway, Dunlop Road, and Fortune Lake Parkway for a total of ~20 km. Gatineau Park covers an area of 36 131 ha and is managed by the National Capital Commission (NCC 2005). Most of the roads within the park date back to the 1950s or earlier (NCC 2005), but upgrades have occurred over the last several decades. All roads surveyed have

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existed for several decades and were paved, two-lane roads. Roadside habitats varied along the roads, but typically the shoulder was narrow with adjacent forests coming within a few metres of the road.

The car was driven at ~30–35 km/h and two surveyors participated in each survey, scanning both the road surface and road shoulder. All dead animals were removed from the road or road shoulder to prevent double counting in a subsequent survey. Surveys were conducted in the morning before scavengers could remove all the roadkill from the previous day or night. Surveys were typically conducted twice a week. Surveys were not conducted during heavy rainfall, but were conducted during light to moderate rain. In addition to driving surveys, walking surveys were conducted at eight locations in the park along the survey route. Walking survey locations were not randomly selected, but based on proximity to designated parking areas in the park to ensure safe parking as well as safety for walking along the roads. Each walking transect was ~90 m in each direction from the stopping point, but extended if high numbers of roadkill were observed. All vertebrate species were recorded, but only results for Eastern Newt are presented here.

Weather data from the closest weather station, Chelsea, Quebec, were obtained to compare rainfall patterns with observed roadkill. On dates where no weather data were available from the Chelsea station, data were obtained from the Ottawa International Airport station, ~25 km to the southeast.

Results and Discussion

We conducted 37 surveys from 12 May until 3 October 2016 and 32 surveys from 15 May to 16 October 2017, for a total of 69 surveys. We found 150 dead Eastern Newts in 2016, and 129 in 2017, for a total of 279. All of the dead Eastern Newts were juveniles (efts). Dead Eastern Newts were found on the road from 18 July to 3 October in 2016, and from 15 May to 8 October in 2017 (Figure 1). The peak mortality events were 36 Eastern Newts on 28 July 2016 and 30 Eastern Newts on 5 June 2017 (Figure 1).

High counts of dead Eastern Newts likely coincide with peak dispersal events, which usually occur in late summer following rains (Gill 1978; Paton *et al.* 2000; Leclair *et al.* 2005). The peak mortality event on 28 July 2016 does not appear to be connected to rainfall as there was no rain on 28 July or the two previous days, although there was 5.2 mm of rain on 25 July (Government of Canada 2019). Rainfall data are missing for the first five days of June 2017, but only 1.0 mm of rainfall was recorded on 4 June 2017, at the Ottawa International Airport. No rainfall was recorded on 3 June and only 0.2 mm on 2 June 2017.

Over 90% of Eastern Newts were found during the walking surveys. We found 107 of the 150 (71.3%) dead Eastern Newts in 2016 along a 425-m section of Meech Lake Road. Smaller numbers of dead Eastern Newts were found at other walking survey locations. The main mortality site was associated with a small creek and numerous wetlands. Habitat at the main mortality site was not obviously different from that at other locations in the park, as creeks, wetlands, and forest are widespread, and the park contains 50 lakes and "several hundred ponds" (NCC 2005). A peak of 30 dead Eastern Newts was found in this mortality "hotspot" on 28 July. Secondary peaks occurred on 12 August (15 Eastern Newts) and 18 August (18 Eastern Newts).

Fewer dead Eastern Newts were found in the main hotspot in 2017: only 30 (25.4%) of the 129 individuals found that year. A peak of 11 dead Eastern Newts was found in the hotspot on 29 June; no more than five mortalities were found on other survey days. There are many possible reasons why fewer dead Eastern

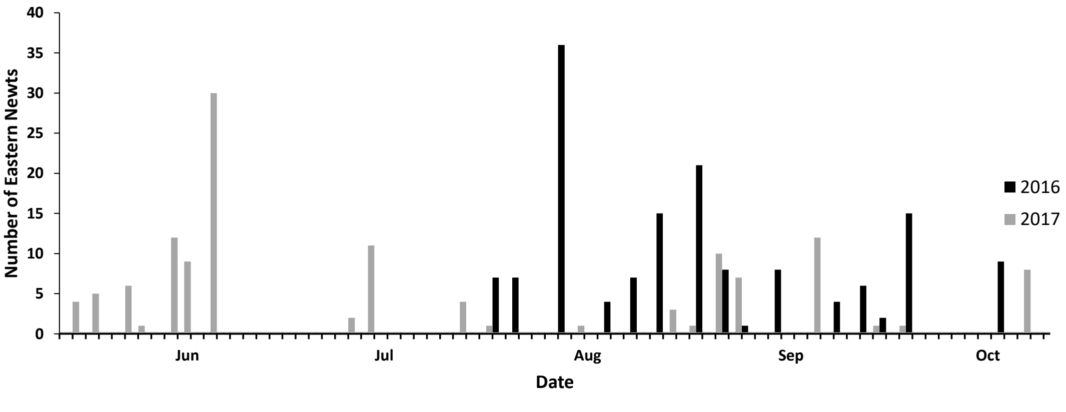

FIGURE 1. Number of Eastern Newt (*Notophthalmus viridescens*) efts found dead on roads in Gatineau Park, Quebec, during road surveys from 12 May to 3 October 2016 and from 15 May to 16 October 2017.

Newts were found in 2017: survey timing not matching peak dispersal events, fewer dispersing efts, or weather conditions limiting dispersal. It does not appear that rainfall is responsible for fewer Eastern Newts being found dead at the main hotspot in 2017, as 2017 was a rainier spring and summer, with 344.6 mm from May to August, compared with only 185.4 mm during the same period in 2016 (Government of Canada 2019).

Over the two years, 137 dead Eastern Newts were found at the main hotspot. Likely many other Eastern Newts were killed there, but not observed, given their small size, obliteration by vehicles, and removal by scavengers. Unlike many other salamanders, Eastern Newts are active during the day (Petranka 1998) when motorists are more likely to travel park roads.

Other researchers have reported significant numbers of dead Eastern Newts on roads. Mitchell (2000) found 182 dead Eastern Newts along a 250-m stretch of road on 4 October 1991 in Virginia. An additional 24 dead Eastern Newts were found at the same site over the course of three subsequent surveys in 1992 (Mitchell 2000). The large number of mortalities in 1991 may have been a chance event, or the result of a large production of efts that year (Mitchell 2000). The results from Virginia are similar to our results from Quebec, i.e., substantially different numbers of observed roadkill at the same site in different years. Such results emphasize the fact that one year of road surveys will not always provide a complete picture of the overall rate of roadkill. Individuals in our study were not measured, but were assumed to be recently metamorphosed juveniles dispersing from the natal wetland.

The population-level effect of roadkill on salamanders is not well known. Our results indicate that many Eastern Newts can be killed on roads in some areas. Although efts likely have a relatively high rate of natural mortality, it is unclear what effect the additive mortality of roadkill has on populations. Further research on this topic is warranted.

Acknowledgements

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Literature Cited

Andrews, K.M., J.W. Gibbons, and D.M. Jochimsen. 2008. Ecological effects of roads on amphibians and reptiles: a literature review. Urban Herpetology 3: 121–143.

Ashley, E.P., and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110: 403–412. Accessed 30 July 2019. https://biodiversitylibrary.org/page/34343309.

Clevenger, A.P., M. McIvor, D. McIvor, B. Chruszcz, and K. Gunson. 2001. Tiger Salamander, *Ambystoma tigrinum*, movements and mortality on the Trans-Canada Highway in southwestern Alberta. Canadian Field-Naturalist 115: 199–204. Accessed 30 July 2019. https://biodiversitylibrary.org/page/34995273.

Cook, F.R. 1984. An Introduction to Canadian Amphibians and Reptiles. National Museum of Natural Sciences, Ottawa, Ontario, Canada.

Fahrig, L., J.H. Pedlar, S.E. Pope, P.D. Taylor, and J.F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 73: 177–182. https://doi.org/10.1016/0006-3207(94)00102-V

Gibbs, J.P., and W.G. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? Wetlands Ecology and Management 13: 281–289. https://doi.org/10.1007/s11273-004-7522-9

Gill, D.E. 1978. The metapopulation ecology of the Red-spotted Newt, *Notophthalmus viridescens* (Rafinesque). Ecological Monographs 48: 145–166. https://doi.org/10.2307/2937297

Glista, D.J., T.L. DeVault, and J.A. DeWoody. 2008. Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 3: 77–87.

Government of Canada. 2019. Historical data: Chelsea and Ottawa MacDonald-Cartier Int'l A. Environment and Natural Resources, Weather, Climate and Hazard, Ottawa, Ontario, Canada. Accessed 25 March 2019. http://climate.weather.gc.ca/historical_data/search_historic_data_e.html.

Healy, W.R. 1974. Population consequences of alternative life histories in *Notophthalmus v. viridescens*. Copeia 1974: 221–229. https://doi.org/10.2307/1443027

Healy, W.R. 1975. Terrestrial activity and home range in efts of *Notophthalmus viridescens*. American Midland Naturalist 93: 131–138. https://doi.org/10.2307/2424111

Hurlbert, S.H. 1969. The breeding migrations and interhabitat wandering of the vermilion-spotted newt *Notophthalmus viridescens* (Rafinesque). Ecological Monographs 39: 465–488. https://doi.org/10.2307/1942356

Leclair, R., M.H. Leclair, and M. Levasseur. 2005. Size and age of migrating eastern red efts (*Notophthalmus viridescens*) from the Laurentian Shield, Quebec. Journal of Herpetology 39: 51–57. https:/doi.org/10.1670/0022-1511(2005)039[0051:saaome]2.0.co;2

Mazerolle, M.J. 2004. Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica 60: 45–53. https://doi.org/10.1655/02-109

Mitchell, J.C. 2000. Mass mortality of red-spotted newts (*Notophthalmus viridescens viridescens* Rafinesque) on a central Virginia road. Banisteria 15: 45–47.

NCC (National Capital Commission). 2005. Gatineau Park master plan. National Capital Commission, Ottawa. Accessed 16 March 2019. http://ncc-ccn.gc.ca/our-plans/gatineau-park-master-plan.

Pagnucco, K.S., C.A. Paszkowski, and G.J. Scrimgeour. 2012. Characterizing movement patterns and spatio-temporal use of under-road tunnels by Long-toed Salamanders in Waterton Lakes National Park, Canada. Copeia 2012: 331–340. https://doi.org/10.1643/CE-10-128

Paton, P., S. Stevens, and L. Longo. 2000. Seasonal phenology of amphibian breeding and recruitment at a pond in Rhode Island. Northeastern Naturalist 7: 255–269. https://doi.org/10.2307/3858358

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, DC, USA.

Roe, A.W., and K.L. Grayson. 2008. Terrestrial movements and habitat use of juvenile and emigrating adult Eastern Red-spotted newts, *Notophthalmus viridescens*. Journal of Herpetology 42: 22–30. https://doi.org/10.1670/07-040.1

Rytwinski, T., and L. Fahrig. 2012. Do species life history traits explain population responses to roads? A meta-analysis. Biological Conservation 147: 87–98. https://doi.org/10.1016/j.biocon.2011.11.023

Semlitsch, R.D. 2008. Differentiating migration and dispersal for pond-breeding amphibians. Journal of Wildlife Management 72: 260–267. https://doi.org/10.2193/2007-082

Smith, L.L., and C.K. Dodd, Jr. 2003. Wildlife mortality on US highway 441 across Paynes Prairie, Alachua County, Florida. Florida Scientist 66: 128–140.

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First records of Finescale Dace (*Chrosomus neogaeus*) in Newfoundland and Labrador, Canada

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Abstract
The island of Newfoundland has no official record of cyprinid fishes. Here, we report the discovery of a minnow, Finescale Dace (*Chromous neogaeus*) from four ponds located in a first order tributary of the Exploits River, in central Newfoundland. This finding represents the first record of the species in the province. The location where the species was found is in a localized, central portion of insular Newfoundland, therefore, the most parsimonious explanation for this new record is that it was an illegal, intentional introduction. Such introductions in other provinces have occurred by anglers who felt it would serve as a forage fish for other species. The consequences of this introduction to native species are unknown; however, the dace's local abundance, foraging behaviour, and reproductive capacity are discussed in terms of the interspecific competition with native species.

Key words: Finescale Dace; *Chrosomus*; Goldfish; intentional introduction; interspecific competition; exotic species

Introduction

The province of Newfoundland and Labrador has a very low rate of introduction for exotic fish (van Zyll de Jong *et al*. 2004). There are 28 native freshwater fish species in Newfoundland and Labrador; 15 species can be found in insular Newfoundland with an additional 13 species occurring in Labrador (van Zyll de Jong *et al*. 2004; Table 1). For the island portion of the province there have been five attempts at species introductions. These introductions were all salmonids including Brown Trout (*Salmo trutta*), Rainbow Trout (*Onchorhynchus mykiss*), Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*), and Pink Salmon (*Oncorhynchus gorbuscha*; Table 1). However, of these five introductions only the first two succeeded. These species were introduced by government agencies intending to use stocking programs to enhance freshwater fisheries (Scott and Crossman 1964; Hustins 2007).

The only other account of a species introduction documented for the province is Goldfish (*Carassius auratus*). This species has been reported in three locations, but as yet, has not been substantiated by a government agency. The three alleged locations include Mundy Pond (47.55152°N, 52.73891°W) centrally located in the city of St. John's, a small pond near the town of Heart's Delight (47.78691°N, 53.46752°W), and Janes Pond (47.16617°N, 55.16229°W) located in the town of Marystown. All of these locations are in proximity to urban areas, suggesting the likelihood of intentional release of household aquaria pets. In Labrador, there are no records of exotic freshwater fish.

On 4 June 2010 the provincial department of Environment and Conservation received a request to identify an unusual fish that had allegedly been angled by a sport fisher in central Newfoundland. The examination of a photograph suggested the unknown species was a minnow from Cyprinidae family. The fish was reportedly angled from a pond on a tributary of the Exploits River. A field trip was subsequently planned to verify the report or determine the extent of its presence. Herein we report on the occurrence of an exotic invasive minnow species existing in four ponds of a first order tributary of the Exploits River watershed, central Newfoundland.

Methods

Sample collection

To verify the species present and the extent of their distribution two site visits occurred. The first occurred 4–16 June 2012 and the second 9–17 June 2014. During the latter trip the number of sites

TABLE 1. A list of native and introduced freshwater fish species of Newfoundland and Labrador, Canada (van Zyll de Jong *et al.* 2004).

Common name	Scientific name	Newfoundland	Labrador
American Eel	*Anguilla rostrata*	+	+
Fourspine Stickleback	*Apeltes quadracus*	+	−
Threespine Stickleback	*Gasterosteus aculeatus*	+	+
Blackspotted Stickleback	*Gasterosteus wheatlandi*	+	−
Ninespine Stickleback	*Pungitius pungitius*	+	+
Atlantic Salmon	*Salmo salar*	+	+
Brook Trout	*Salvelinus fontinalis*	+	+
Arctic Char	*Salvelinus alpinus*	+	+
Lake Trout	*Salvelinus namaycush*	−	+
Lake Whitefish	*Coregonus clupeaformis*	−	+
Round Whitefish	*Prosopium cylindraceum*	−	+
Rainbow Smelt	*Osmerus mordax*	+	+
Sea Lamprey	*Petromyzon marinus*	+	+
Alewife	*Alosa pseudoharengus*	+	+
American Shad	*Alosa sapidissima*	+	+
Atlantic Tomcod	*Microgadus tomcod*	+	+
Banded Killifish	*Fundulus diaphanus*	+	−
Mummichog	*Fundulus heteroclitus*	+	−
Northern Pike	*Esox lucius*	−	+
Lake Chub	*Couesius plumbeus*	−	+
Longnose Dace	*Rhinichthys cataractae*	−	+
Northern Pearl Dace	*Margariscus nachtriebi*	−	+
Longnose Sucker	*Catostomus catostomus*	−	+
White Sucker	*Catostomus commersonii*	−	+
Burbot	*Lota lota*	−	+
Mottled Sculpin	*Cottus bairdii*	−	+
Slimy Sculpin	*Cottus cognatus*	−	+
Logperch	*Percina caprodes*	−	+
Rainbow Trout*	*Onchorhynchus mykiss*	+	−
Brown Trout*	*Salmo trutta*	+	−
Goldfish*	*Carassius auratus auratus*	+	−

*Introduced species.

searched was expanded. Initial samples were taken from four headwater lakes located on the south side of the Exploits River near the town of Bishop's Falls. The lakes are located on a first order tributary (Jumpers Brook 49.02667°N, 55.40216°W: Tributary 1; Figure 1). Jumpers Brook flows into the main stem of the Exploits River (49.02857°N, 55.40164°W), entering the Exploits ~8 km upstream from the Atlantic Ocean (in Exploits Bay). Three of the sampled ponds (Mina 1, Mina 2, and Mina 3) were in close proximity (<1 km) to each other and were both small (surface area <0.10 km^2) and shallow (<2 m depth). The fourth lake, Mina 4 was larger (surface area = 0.35 km^2) and deeper (>4 m depth). Mina 4 was ~2 km upstream from Mina 3. The substrate in each pond was mud with scattered rubble and cobble with emergent grasses surrounding the shorelines. The water was dark in colour, the product of humic conditions. During the 2012 sampling, surface temperatures ranged from 8°C to 10°C. In 2014 the temperatures were between 11°C and 20°C.

During the first sampling event, in 2012, both fyke (FYKE-001-06, 10 mm mesh, Shandong, China) and gill nets (Miller Nets, Memphis, Tennessee, USA) were used. Gill nets were composed of nylon monofilament and each set consisted of two stretch mesh sizes measuring 1.91 cm and 2.54 cm, with the smallest mesh being set closest to the shoreline. Three gill nets were set in Mina 1, two in Mina 2 and 3, and four sets were placed in Mina 4. All gill nets were set perpendicular to the shoreline and were set overnight, for an average of 12 h. Fyke (trap) net exterior netting consisted of 1.91 cm stretch mesh size with front hoop of 1 m through to four cylindrical interior hoops with a tied trap end. These nets were set with a 9.8 m mesh lead extending from the front hoop perpendicular to the shoreline. This lead net also consisted of 1.91 cm stretch mesh size. Three small fyke nets were set in the littoral area of Mina 2. All captured native species were retained for measurement and stomach examinations in the laboratory. A subset of unidentified minnow species were retained and preserved in 95% ethanol.

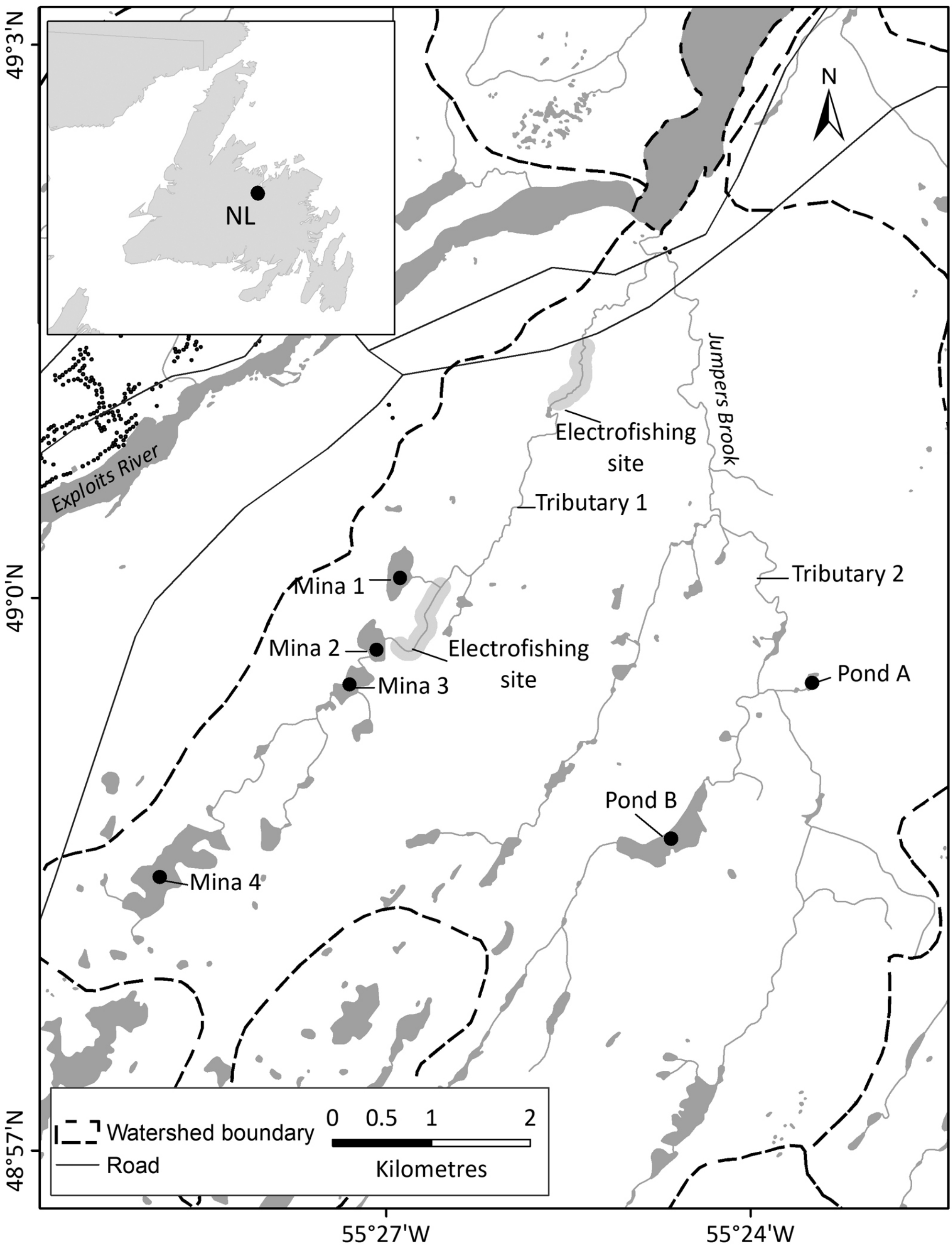

FIGURE 1. The four ponds (Mina 1, 2, 3, and 4) on Tributary 1 from which Finescale Dace (*Chrosomus neogaeus*) was sampled, central Newfoundland. Also shown are the locations of Tributary 2, Ponds A and B, and the locations of the electrofishing stations.

In 2014, sampling was repeated on each of the four ponds originally sampled in 2012. However, instead of gill and fyke nets, minnow pots were used as they have proven to be very effective when sampling dace (He and Lodge 1990). The minnow pots (Gees Feets G-40 Minnow trap, Tackle Factory, Fillmore New York, USA) were constructed of galvanized steel wire with length 42 cm, diameter 23 cm, and square mesh size of 6 mm. Thirty-nine overnight pot sets were placed in ponds Mina 1, 2, 3, and 4 (Table 2). A

TABLE 2. Year and location of sampling, gear type, and numbers set (*n*). Frequency of fish sampled per species for all ponds 4–16 June 2012 and 9–17 June 2014 in central Newfoundland. All sets were overnight.

Year	Location	Gear Type (*n*)	Brook Trout (*Salvelinus fontinalis*)	Atlantic Salmon (*Salmo salar*)	Threespine Stickleback (*Gasterosteus aculeatus*)	Finescale Dace (*Chrosomus neogaeus*)
2012	Mina 1	Gill (3)	29	1	2	10
	Mina 2	Gill (2)	10	9	1	1
	Mina 2	Fyke (3)	7	1	3	—
	Mina 3	Gill (2)	—	—	—	—
	Mina 4	Gill (4)	9	—	—	3
2014	Mina 1	Pot (16)	2	—	26	391
	Mina 2	Pot (9)	—	—	19	24
	Mina 3	Pot (6)	—	—	43	2
	Mina 4	Pot (8)	—	—	15	110
	Pond A	Pot (4)	—	—	—	—
	Pond B	Pot (3)	6	—	29	—

sub-sample of 20 unidentified minnow species were retained, preserved in 95% ethanol, and sent to the Department of Biology at Dalhousie University for genetic-based identification. The sub-sample was a random selection of 10 male and 10 female fish.

To determine if the dace were isolated to just the four ponds or were present in other areas of Jumpers Brook, the lower (1.5 km) and upper (1 km) reaches of Tributary 1 (Figure 1) were sampled by electrofishing. Two small ponds located in another first order tributary were also sampled (Tributary 2; Figure 1). In Tributary 2, four pots were set in Pond A and three pots were placed in Pond B.

Morphometric and subsequent genetic analysis

External morphological measures were recorded for 200 dace chosen from the 2014 collection (Table 3). With the exception of fork length, the morphological characters measured followed those described by Hubbs and Lagler (1958) and Doeringsfeld *et al.* (2004) which included the predorsal length, pectoral fin position, head length, maximum body width, maximum body depth, caudal peduncle depth, interorbital width, gape width, and the upper jaw length.

Species identification using the morphometric data was attempted but proved difficult for several reasons. Given the morphological variability among the sampled dace it was determined that it could be one, or a combination of, three possible species, each sharing very similar physical characteristics. The three species included Northern Redbelly Dace (*Chrosomus eos* (Cope, 1862)), Finescale Dace (*Chrosomus neogaeus* (Cope, 1867)), or their hybrid *Chrosomus eos-neogaeus*. Subsequently, genetic analysis was used for determining species. Nevertheless, this did not remove all the difficulty in identification.

Standard DNA barcoding/sequencing methods using the mitochondrial CO1 gene would not be suf-

TABLE 3. Variation in morphological characters measured from 200 *Chrosomus* sp. collected 9–17 June 2014 from ponds in the Jumpers Brook watershed, central Newfoundland. Measurements as described by Hubbs and Lagler (1958) and Doeringsfeld *et al.* (2004): fork length (FL), predorsal length (PDL), pectoral fin position (PFP), head length (HDL), maximum body width (BYW), maximum body depth (BYD), caudal peduncle depth (CPD), interorbital width (IOW), gape width (GPW), upper jaw length (UJL).

Character	Range	95% CI	Mean	SE
FL	39.00–93.00	64.7–68.7	66.69	0.998
TBM	0.71–10.23	3.64–4.26	3.95	0.157
PDL	18.00–48.10	32.80–34.86	33.83	0.520
PFP	6.30–20.70	13.67–14.50	14.08	0.210
HDL	7.90–21.23	13.81–14.65	14.23	0.214
BYW	4.40–15.10	8.28– 8.92	8.59	0.162
BYD	7.50–20.80	13.35–14.25	13.80	0.228
CPD	0.30–3.60	1.27–1.46	1.37	0.046
IOW	2.50–8.50	5.58–5.97	5.78	0.098
GPW	3.90–13.20	8.01–8.55	8.28	0.136
UJL	1.70–8.90	4.64–4.95	4.79	0.079

ficient for all necessary species identifications in this case. Hybrid individuals (*C. eos-neogaeus*) share mitochondrial DNA with their maternal parent, most commonly *C. neogaeus* (Binet and Angers 2005) and these standard identification techniques would not allow us to distinguish these two complexes. As a result, a method of species identification based on nuclear DNA, in addition to mitochondrial DNA, was required.

Caudal fin tissues were digested with proteinase K (Bio Basic Inc., Markham, Ontario, Canada) for ~8 h at 50°C. DNA was extracted from these tissue digests following a glassmilk approach modified from Elphinstone *et al.* (2003) for use with a Multiprobe II liquid handling system (PerkinElmer, Waltham, Massachusetts, USA). The resulting DNA was examined for quality and quantity by means of gel electrophoresis using a 1% agarose gel.

To perform the species identification, we followed the recommendations found in Binet and Angers (2005) in which the GH and the PEG1/MEST nuclear loci were amplified using polymerase chain reaction (PCR). The resulting PCR products were visualized on a 2% agarose gel and examined for band combination and size to detect the presence of *C. neogaeus*, *C. eos*, or their hybrid.

Five complete *Chrosomus* sp. from the 2012 collection were archived at the Royal Ontario Museum (accession number: ROM 104124). Additionally, 20 caudal fin tissues, used for genetics-based identification, were transferred to The Rooms Corporation of Newfoundland and Labrador, Provincial Museum Division (accession number: NFM T-2018-63). All specimens were preserved in 95% ethanol.

Results

Species account

In 2012, native fish species captured included Brook Trout (*Salvelinus fontinalis*), Atlantic Salmon (*Salmo salar*), and Threespine Stickleback (*Gasterosteus aculeatus*; Table 2). In addition, 14 dace were also sampled from three of the four ponds surveyed (Mina 1, 2, and 4; Table 2). Stomach examinations revealed that one Brook Trout, from Mina 1, contained approximately 20 partially digested young-of-the-year dace (Figure 2a).

In 2014, 527 dace were sampled from all four lakes, for an average capture of 13.5 fish per pot. Figure 2b shows three representative specimens from the collection. In Tributary 2 we did not capture any dace in either Ponds A or B, nor did we sample any dace when electrofishing the lower and upper reaches of Tributary 1. Only native species Brook Trout, American Eel (*Anguilla rostrata*), Atlantic Salmon, and Threespine Stickleback were sampled.

Genetic results

Of the 20 selected samples, 16 yielded sufficient DNA quantity and quality for species identification. The remaining four were excluded due to DNA quality concerns. Our examination of the amplifications of the GH locus showed band size uniformity among all individuals, with a band size of approximately 250 bp. This particular fragment/band size is indicative of *C. neogaeus* (Binet and Angers 2005). A similar result was observed for the PEG1/MEST amplifications: band size uniformity of approximately 177 bp. Again, this particular band size is indicative of *C. neogaeus* (Binet and Angers 2005). There was no

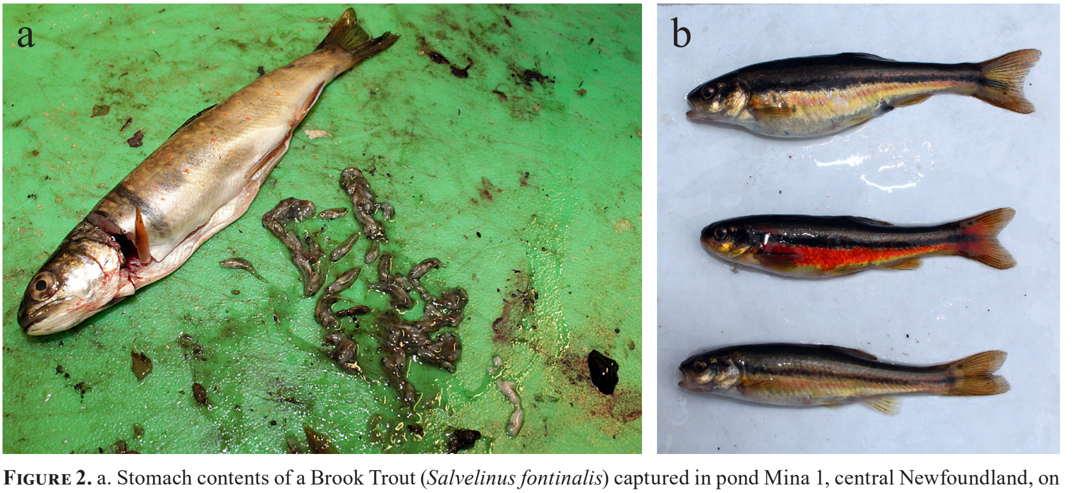

FIGURE 2. a. Stomach contents of a Brook Trout (*Salvelinus fontinalis*) captured in pond Mina 1, central Newfoundland, on 7 June 2012, showing approximately 20 partially decomposed immature cyprinid species. b. Finescale Dace (*Chrosomus neogaeus*) sampled from pond Mina 2, central Newfoundland, on 14 June 2014 Photo: a. Robert Perry. Photo: b. Donald Keefe.

evidence of any other band size or combination in any of the 16 individuals tested at either of these two nuclear DNA loci, indicating the absence of both hybrid *C. eos-neogaeus* and *C. eos* individuals.

Discussion

The record of Finescale Dace in four headwater ponds in the Exploits River watershed represents the first report of an introduced Leuciscinae species for insular Newfoundland. The species complement for the island portion of the province contains only euryhaline (saltwater tolerant) species (Scott and Crossman 1964; van Zyll de Jong *et al*. 2004) and Finescale Dace is not considered euryhaline. Therefore, it is unlikely that the species colonized the area naturally and indicates that an exotic introduction has occurred. The known distribution of Finescale Dace extends across the southern and northwest parts of Canada (Scott and Crossman 1998). In the east, its distribution reaches New Brunswick and Nova Scotia while in the United States it can be found in the Mississippi and Missouri river drainages (Stasiak 1980; Page and Burr 1991). The origin for the Jumpers Brook population is uncertain.

Because young-of-the-year minnows were found during stomach examination of Brook Trout it is evidence that the nonindigenous species is established. The habitat preferences for Finescale Dace include acidic beaver ponds, boggy waters, and small lakes with bottom detritus and silt (Stasiak and Cunnigham 2006). The locations in which we discovered Finescale Dace fit the habitat requirements for the species (Mee and Rowe 2010).

In accordance with our 2014 field sampling, we did not find evidence for the presence of Finescale Dace in either Tributary 1 or in the headwater ponds of Tributary 2. It would appear that the presence of the dace is currently limited to the four headwater ponds of Tributary 1. We believe the containment is owing to the presence of beaver dams in ponds Mina 1 and Mina 2 which limit the outflow of water and impedes fish movement. The outflow from Mina 2 is downstream from Mina 3 and 4 and therefore controls the flow of water from these two ponds.

If the intent of the introduction was to provide a food source for both Brook Trout and juvenile Atlantic Salmon, it may have been short-sighted. Although we did find juvenile dace in the stomach of an adult Brook Trout, it is unclear how additional competition for food sources will affect native fish populations into the future. Finescale Dace are sight feeding, carnivorous predators and have been documented as eating a wide variety of food items including aquatic insects, vegetation, and molluscs (Stasiak and Cunnigham 2006; Mee *et al*. 2013). For example, adult fish have been documented eating midges (Diptera), beetles (Coleoptera), caddisflies (Trichoptera), mayflies (Ephemeroptera), and bugs (Hemiptera; Stasiak 1972). Native species such as Brook Trout, Atlantic Salmon, and Threespine Stickleback depend upon micro and macro invertebrates, particularly at juvenile stages (Scott and Crossman 1998). Further, these types of minnows have a large reproductive capacity. It has been reported that Northern Redbelly Dace can produce 316 000 fish per ha of surface area in a single season (Cooper 1935). Finescale Dace also has a substantial reproductive capability. For example; a 70 mm female may produce 2600 eggs (Stasiak 2011). Given the potential for these types of cyprinids to have a large reproductive capacity, it is probable that the presence of Finescale Dace will lead to interspecific resource competition with native species.

Competition among piscivores and planktivores can have a large influence on rates of primary production in an aquatic ecosystem (Carpenter *et al*. 1985; Carpenter and Kitchell 1988). Following the introduction of Eurasian Minnow (*Phoxinus phoxinus*) into a Norwegian subalpine lake, Øvre Heimdalsvatn, researchers witnessed major changes to both the structure and composition of macroinvertebrate benthos (Naestad and Brittain 2010). These changes led to negative effects on the native Brown Trout population, including reduced annual recruitment and growth rates. Researchers attributed the changes to competition for food (Borgstrom *et al*. 2010).

There may also be a direct effect on native species abundance, as these types of predatory minnows have been documented eating the eggs and young of other species. A dissected large male Finescale Dace was reported having its intestinal tract full of fish eggs (presumed to be the eggs of the Northern Redbelly Dace; Stasiak 1972). Becker (1983) reported that dace will eat guppies in an aquarium setting. Furthermore, it has been reported that Northern Redbelly Dace, a species whose dietary preferences overlap with the Finescale Dace (Cochran *et al.* 1988), would eat Smallmouth Bass (*Micropterus dolomieu*) fry (Scott and Crossman 1999). Thus, it is possible that fry of Brook Trout and stickleback could also provide a food source for Finescale Dace. Further work is required to determine the short and long-term impacts of this introduction on native fauna.

The discovery of Finescale Dace in this particular watershed is disconcerting. The Exploits River represents one of the largest Atlantic Salmon producing rivers in North America (Pinfold 2011). The spread of this stenohaline species throughout the Exploits watershed may be limited by the presence of the Grand Falls Hydro-electric facility. The facility serves as a major barrier to fish passage and is located just upstream from where the tributary containing dace enters the main branch of the Exploits River.

The origin of Finescale Dace found in the four headwater ponds is uncertain. However, there are two possible explanations. The species current documented range limit in eastern Canada are the provinces of New Brunswick and Nova Scotia (Stasiak 1980; Page and Burr 1991). Therefore, it is possible that anglers imported the species as an illegal form of bait from the Maritime region. However, this explanation seems improbable given that these ponds are small in size and not known as a favoured area for recreational fishing. Another possible explanation may be that minnows kept in aquaria by area residents were released. Local residents interviewed regarding this possibility suggested that an unknown species of minnow had been housed in close proximity to the headwater ponds. Speculation by those interviewed was that minnows were imported from Labrador. Although interesting, this idea is unsubstantiated.

The presence of Finescale Dace in Labrador (even if remote) is an intriguing possibility. The present range distribution for Finescale Dace does not extend into Labrador and the only known species of dace existing in the province is Northern Pearl Dace (*Margariscus nachtriebi*). Thus, one may speculate that an undiscovered species is present or, alternatively, the current identification for the species in Labrador maybe an error. Further genetic work is required to investigate these possibilities.

Our findings suggest these minnow species are readily trapped and therefore could easily be moved as bait to other regions of the province. However, it is illegal in Newfoundland and Labrador to transport live fish or to use live fish as bait in inland waters. It is hoped that these regulatory restrictions will serve as a deterrent to the spread of the species. Additionally, to limit the spread of Finescale Dace, we recommend the launch of a public education and awareness program pertaining to the existence of these species in the province. Such an initiative would be beneficial and low cost for regulatory authorities. Through this effort, it is hoped that further illegal introductions or transfers could be curtailed. Additionally, the four ponds where these dace were found were small and therefore we recommend some consideration should be given to an eradication program to halt their spread.

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Literature Cited

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison, Wisconsin, USA.

Binet, M.C., and B. Angers. 2005. Genetic identification of members of the *Phoxinus eos-neogaeus* hybrid complex. Journal of Fish Biology 67: 1169–1177. https://doi.org/10.1111/j.0022-1112.2005.00802.x

Borgstrom, R., J. Museth, and J.E. Brittain. 2010. The brown trout (*Salmo trutta*) in the lake, Øvre Heimdalsvatn: long term changes in population dynamics due to exploitation and the invasive species, European minnow (*Phoxinus phoxinus*). Hydrobiologia 642: 82–91. https://doi.org/10.1007/s10750-010-0161-7

Carpenter, S.R., and J.F. Kitchell. 1988. Consumer control of lake productivity. BioScience 38: 764–769. https://doi.org/10.2307/1310785

Carpenter, S.R., J.F. Kitchell, and J.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. BioScience 35: 634–639. https://doi.org/10.2307/1309989

Cochran, P.A., D.M. Lodge, J.R. Hodgson, and P.G. Knapik. 1988. Diets of syntopic finescale dace, *Phoxinus neogaeus*, and northern redbelly dace, *Phoxinus eos*: a reflection of trophic morphology. Environmental Biology of Fishes 22: 235–240. https://doi.org/10.1007/bf00005384

Cooper, G.P. 1935. Some results of forage fish investigations in Michigan. Transactions of the American Fisheries Society 65: 132–142. https://doi.org/10.1577/1548-8659(1935)65[132:SROFFI]2.0.CO;2

Doeringsfeld, M.R., I.J. Schlosser, J.F. Elder, and D.P. Evenson. 2004. Phenotypic consequences of genetic variation in a gynogenetic complex of *Phoxinus eos-neogaeus* clonal fish (Pisces: Cyprinidae) inhabiting a heterogeneous environment. Evolution 58: 1261–1273. https://doi.org/10.1111/j.0014-3820.2004.tb01705.x

Elphinstone, M.S., G.N. Hinten, M.J. Anderson, and C.J. Nock. 2003. An inexpensive and high-throughput procedure to extract and purify total genomic DNA for population studies. Molecular Ecology Notes 3: 317–320. https://doi.org/10.1046/j.1471-8286.2003.00397.x

He, X., and D.M. Lodge. 1990. Using minnow traps to estimate fish population size: the importance of spatial distribution and relative species abundance. Hydrobiologia 190: 9–14. https://doi.org/10.1007/BF00020683

Hubbs, C.L., and K.F. Lagler. 1958. Fishes of the Great Lakes Region. University of Michigan Press, Ann Arbor, Michigan, USA.

Hustins, D. 2007. Brown Trout and Rainbow Trout: a Journey into Newfoundland Waters. Tight Line Publishers, St. John's, Newfoundland and Labrador, Canada.

Mee, J.A., F. Noddin, J.R. Hanisch, W.M. Tonn, and C.A. Paszkowski. 2013. Diets of sexual and sperm-dependent asexual dace (*Chrosomus* spp.): relevance to niche differentiation and mate choice hypotheses for co-existence. Oikos 122: 998–1008. https://doi.org/10.1111/j.1600-0706.2012.00178.x

Mee, J.A., and L. Rowe. 2010. Distribution of *Phoxinus eos*, *Phoxinus neogaeus*, and their asexually-reproducing hybrids (Pisces:Cyprinidae) in Algonquin Provincial Park, Ontario. Plos One 5: e13185. https://doi.org/10.1371/journal.pone.0013185

Naestad, F., and J.E. Brittain. 2010. Long-term changes in the littoral benthos of a Norwegian subalpine lake following the introduction of the European minnow (*Phoxinus phoxinus*). Hydrobiologia 642: 71–79. https://doi.org/10.1007/s10750-010-0160-8

Page, L.M., and B.M. Burr. 1991. A Field Guide to the Freshwater Fishes: North America North of Mexico. Houghton Mifflin, Boston, Massachusetts, USA.

Pinfold, G. 2011. Economic value of wild Atlantic Salmon. Gardner Pinfold Consultants Inc., Halifax, Nova Scotia, Canada.

Scott, W.B., and E.J. Crossman. 1964. Fishes Occurring in the Fresh Waters of Insular Newfoundland. Queen's Printer and Controller of Stationary, Ottawa, Ontario, Canada.

Scott, W.B., and E.J. Crossman. 1998. Freshwater Fishes of Atlantic Canada. Galt House Publications Ltd., Oakville, Ontario, Canada.

Stasiak, R.H. 1972. The morphology and life history of the finescale dace, *Pfrille neogaea*, in Itasca State Park, Minnesota. Ph.D. thesis, University of Minnesota, Minneapolis, Minnesota, USA.

Stasiak, R.H. 1980. *Phoxinus neogaeus* Cope. Page 336 *in* Atlas of North American Freshwater Fishes. *Edited by* D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer. North Carolina State Museum Natural History, Raleigh, North Carolina, USA.

Stasiak R.H. 2011. Reproduction, age, and growth of the finescale dace, *Chrosomus neogaeus*, in Minnesota, Transactions of the American Fisheries Society 107: 720–723. http://doi.org/fftzz9

Stasiak, R., and G.R. Cunningham. 2006. Finescale Dace (*Phoxinus neogaeus*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Accessed 10 October 2019. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5206787.pdf.

van Zyll de Jong, M.C., R.J. Gibson, and I.G. Cowx. 2004. Impacts of stocking and introductions on freshwater fisheries of Newfoundland and Labrador, Canada. Fisheries Management and Ecology 11: 183–193. https://doi.org/10.1111/j.1365-2400.2004.00390.x

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Albinism in Orange-footed Sea Cucumber (*Cucumaria frondosa*) in Newfoundland

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Abstract
Orange-footed Sea Cucumber (*Cucumaria frondosa*; Echinodermata: Holothuroidea) is a dark-brown species that is broadly distributed in North Atlantic and Arctic waters. Here, we document the rare occurrence of colour morphs showing various degrees of albinism, from totally white to faint orange pigmentation. These unusually coloured individuals were found across a broad distribution range in eastern Canada and northeastern United States, with their occurrence in Newfoundland samples ranging from 0.2% to 0.5%. Two fully albino individuals were noticeably smaller than other colour morphs. The occurrence of rare, unusually coloured sea cucumbers is important from an ecological standpoint and may also have commercial implications.

Key words: Orange-footed Sea Cucumber; *Cucumaria frondosa*; albinism; colour diversity; Holothuroidea; sea cucumber; North Atlantic

Introduction
Unusually coloured and albino (white) sea cucumbers are rare in nature and typically have higher market value, particularly in Asia. Albino individuals have sold at auction for US$23 000/kg (normal value US$2000–2500/kg for the species; Tse 2015). To date, published records of albinism in holothuroid echinoderms (nomenclature according to World Register of Marine Species; WoRMS 2019) include Japanese Sea Cucumber (*Apostichopus japonicus*) in the temperate Western Pacific (Lin *et al.* 2013), White Teatfish (*Holothuria fuscogilva*) in the tropical Indo-Pacific (Friedman and Tekanene 2005), Brown Sea Cucumber (*Isostichopus fuscus*) in the tropical eastern Pacific (Fernández-Rivera Melo *et al.* 2015), Four-sided Sea Cucumber (*Isostichopus badionotus*) in the Caribbean (Wakida-Kusunoki *et al.* 2016), Climbing Sea Cucumber (*Ocnus planci*) in the temperate and tropical Atlantic (Casellato *et al.* 2006), along with some anecdotal reports and pictures of white sea cucumbers scattered in the literature (Trefry 2001; Feindel *et al.* 2011; Benoît 2016).

Colour variants, including complete lack of colour, in *A. japonicus* have been described (Yang *et al.* 2015). The body wall of albino *A. japonicus* adults contains ~0.24% melanin compared with ~3.12% in normal adults (Zhao *et al.* 2015). As albinism is known to occur in only a limited number of individuals in any given species (0.00001–0.1%; Mouahid *et al.* 2010), a directed search for these could fuel overexploitation in some already overfished or vulnerable species (Purcell *et al.* 2014). Albinism may also affect the behaviour, growth rates, and physiology of sea cucumbers, although these effects remain incompletely understood (Lin *et al.* 2013; Bai *et al.* 2016; Xia *et al.* 2017).

Orange-footed Sea Cucumber (*Cucumaria frondosa*, Gunnerus 1767) is the most common sea cucumber along the eastern Canadian coast, with a distribution spanning the North Atlantic, Arctic, and Barents Sea (Paulay and Hansson 2013). A commercial fishery for *C. frondosa* is rapidly developing in several countries (e.g., Canada, United States, Russia, Greenland, and Iceland), which makes it one of the most important wild sea cucumber fisheries in the world (Therkildsen and Petersen 2006; Nelson *et al.* 2012). As of 2016, market values for *C. frondosa* ranged from $120–140/kg (Hansen 2016) up to about $300/kg (Guangzhou market, China; J.-F.H. pers. obs.); a separate market for unusual colour morphs has not yet developed.

Here, we describe colour morphs reported for wild *C. frondosa* populations from northeastern North America. We also report the results of a survey of *C. frondosa* populations from the Grand Banks of Newfoundland to determine the relative abundance of colour morphs to improve ecological knowledge of this important commercial species.

Methods

Records of unusually coloured *C. frondosa* were collated from numerous sources, including specimens collected by hand, SCUBA, and fishing vessels across various locations in eastern Canada (e.g., the estuary and Gulf of St. Lawrence, Quebec; Saint-Pierre Bank and southeastern coast of Newfoundland; Figure 1, Table 1).

Two batches of sea cucumbers (n = 600) were examined in June and July 2017 to establish the percentage of orange and white individuals relative to normally coloured ones (dark-brown and grey-brown); no colour standards were used. Samples were obtained from the commercial fishery (trawled using modified scallop gear) in the Grand Banks area of Newfoundland, Canada. No restrictions are placed on animal size, shape, or colour in the fishery; thus, harvests are usually a good representation of local populations. Total wet weights of sea cucumbers, as well as the contracted lengths and widths were measured from fully contracted individuals according to Singh *et al.* (2001). These measurements were taken for all white and orange individuals and from 150 haphazardly selected dark-brown and grey-brown individuals. For white and orange individuals collected in the Grand Banks area of Newfoundland in 2013, two additional measurements were included. Internal organ colours were also compared in pale versus normal individuals.

Results

Summary of colour morphs in northeastern North America

Four main colour variants have been reported for *C. frondosa* in northeastern North America: dark-brown, grey-brown, orange, and albino (i.e., white and off-white individuals; Figure 2). Dark-brown and grey-brown are the most common colours for this species and, thus, represent normally coloured individuals (Figure 2a,b). The tentacles and tube feet of dark-brown and grey-brown *C. frondosa* are dark-brown and dark-orange to brown, respectively. Orange-tinged tube feet are common, hence the common name (Paulay and Hansson 2013). Orange and white individuals are the rarest colour morphs and can be described as a gradient of little to no melanin pigment deposition (Figure 2c–g). The tentacles and tube feet of orange and white individuals are typically pale orange and white, respectively.

Frequency of colour morphs in Newfoundland trawls

All four colour morphs were found off the Grand Banks, Newfoundland (trawled at 40–70 m depth) and in coastal areas near the Avalon Peninsula (collected by SCUBA at <10 m). The survey from the Grand Banks area revealed that orange-coloured individuals made up 0.5% of the population (n = 3 in 600), but that white individuals were rarer in that sample (n = 1 in 600, <0.2%). The internal organs (muscle bands, gonad, and intestine) of these white and orange individuals were the same colour as those of dark-brown and grey-brown individuals. Orange individuals were also similar in size to brown individuals (mean wet

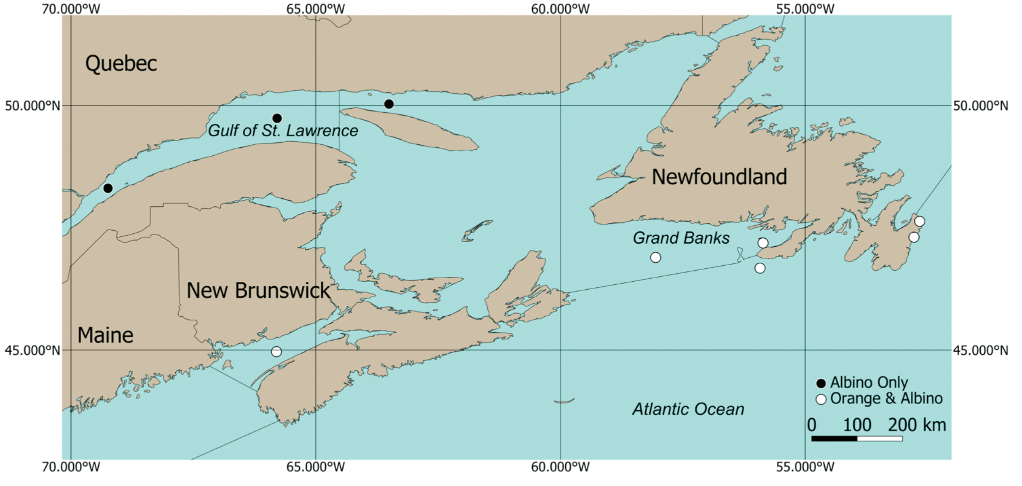

FIGURE 1. Locations in northeastern North America where unusually coloured Orange-footed Sea Cucumbers (*Cucumaria frondosa*) were observed and/or collected.

weight 246 ± 87 [SD] g versus 235 ± 74 g; Table 2). The mean wet weight of the two white individuals, including the one in our 2017 survey and another from 2013 (B. Gianasi pers. comm. October 2017), was 78.6 ± 3.4 g (versus mean wet weight of 235 g in normally coloured individuals; Table 2).

TABLE 1. Locations in North America where unusually coloured Orange-footed Sea Cucumber (*Cucumaria frondosa*) occur, based on reports from the literature and the present study.

Province or state, country	Region	Coordinates	Colour observed	No. (total sampled)	Date	Source
Maine, USA	NA	NA	Orange	NA	NA	Feindel *et al.* 2011
	NA	NA	Albino	NA	NA	Feindel *et al.* 2011
Newfoundland, Canada	Fortune Bay, Grand Banks	47.18597933°N, 55.86135864°W	Orange	3 (600)	2017	E. Montgomery (current study)
		47.18597933°N, 55.86135864°W	Albino	1 (NA)	2017	E. Montgomery (current study)
	St. Pierre Bank, Grand Banks	46.67205647°N, 55.92315674°W	Orange	3 (NA)	2017	E. Montgomery (current study)
		46.67205647°N, 55.92315674°W	Albino	NA	2017	E. Montgomery (current study)
	Unnamed site, Grand Banks	46.89023157°N, 58.05450439°W	Orange	3 (NA)	2013	B. Gianasi (current study)
		46.89023157°N, 58.05450439°W	Albino	1 (NA)	2013	B. Gianasi (current study)
	Logy Bay	47.6295369°N, 52.66073227°W	Orange	NA	NA	Memorial Field Services
		47.6295369°N, 52.66073227°W	Albino	NA	NA	Memorial Field Services
	Bay Bulls	47.3048439°N, 52.77677536°W	Orange	NA	NA	Memorial Field Services
		47.3048439°N, 52.77677536°W	Albino	NA	NA	Memorial Field Services
Quebec, Canada	Mingan Archipelago	50.02538762°N, 63.50372314°W	Albino	NA	1990s	J.-F. Hamel
	Gaspé Peninsula	49.73513141°N, 65.78887939°W	Albino	NA	1990s	J.-F. Hamel
	Les Escoumins	48.30512072°N, 69.24407958°W	Albino	NA	1990s	J.-F. Hamel
New Brunswick, Canada	Bay of Fundy	44.96479793°N, 65.80261230°W	Orange	NA	NA	S. Robinson (DFO)
		44.96479793°N, 65.80261230°W	Albino	NA	NA	S. Robinson (DFO)

Note: DFO = Department of Fisheries and Oceans, NA = data not available.

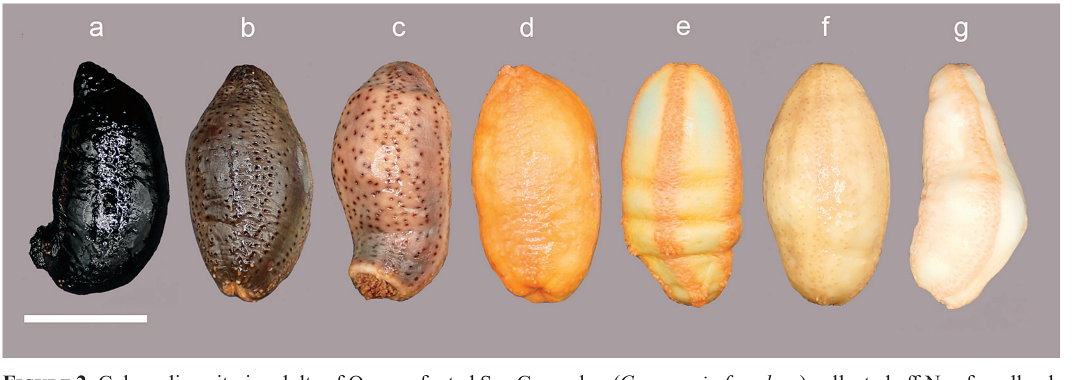

FIGURE 2. Colour diversity in adults of Orange-footed Sea Cucumber (*Cucumaria frondosa*) collected off Newfoundland, eastern Canada. a and b. Typical colours: dark-brown and grey-brown. c to g. Increasing discolouration/albinism: pale brown, orange, pale orange, beige, and white. Sea cucumbers that match c, d, or e are considered "orange", and those like f and g are considered "white". Photos were taken with uniform illumination and have not been edited for brightness, contrast, or colour. Scale bar represents 5 cm for a–f and 3 cm for g. Photos: E. Montgomery.

TABLE 2. Size of individuals of Orange-footed Sea Cucumber (*Cucumaria frondosa*) sampled in southeastern Newfoundland during the present study. Mean values for orange and white colour morphs are pooled across individuals collected in this area, 2013–2017. Mean values for fully pigmented morphs were obtained from individuals collected in 2017.

Colour morph	*n*	Mean weight, g ± SD	Mean contracted length, cm ± SD
White (fully albino)	2	78.7 ± 3.4	8.2 ± 1.5
Orange (partly albino)	9	246.3 ± 87.1	12.7 ± 1.9
Dark-brown/ grey-brown (fully pigmented)	150	235.1 ± 74.0	13.3 ± 0.5

Discussion

Four main colour morphs of the body wall have been reported for *C. frondosa* from northeastern North America. However, it is important to note that a continuum of degree of pigmentation exists in this species, ranging from dark-brown to white. White and orange individuals from Newfoundland had normally coloured internal structures and organs, suggesting that this species may display leucism (partial or complete loss of pigment), rather than true albinism (no pigment deposition). In fact, some of the dark individuals housed in the laboratory for several months displayed a tendency to bleach over time (B. Gianasi pers. comm. 2017).

In the present study, white and orange individuals were seen and collected in all known populations of *C. frondosa* sampled in eastern Canada, suggesting that loss or decrease of pigmentation is not geographically constrained. An anecdotal reference to unusually coloured individuals is also made in a fisheries report from Maine (Feindel *et al.* 2011), further supporting the suggestion that the phenomenon likely occurs across populations of *C. frondosa* in North America, northern Europe, and the Arctic, as a gene flow study of So *et al.* (2011) indicates a supply source along southeastern Newfoundland. Further study will be needed to confirm the factors involved in pigment absence and/or loss in this species, as the phenomenon seems to be geographically widespread.

We noted that different colour morphs of *C. frondosa* were collected in Newfoundland from different depths. Dark-brown sea cucumbers occurred in shallow water <10 m deep (collected by SCUBA) and grey-brown individuals in deeper water (40–70 m; collected by trawl) where less ultraviolet (UV) light penetrates, and weaker pigment protection may be required, as also proposed for *A. japonicus* (Jiang *et al.* 2015). Also of note is the fact that white individuals were present in all sampled locations, mixed with the normally coloured morphs (Figure 1). Despite this, it remains possible that these individuals may be more susceptible to UV light than normally coloured individuals and may seek cover more readily than darker individuals. In the lower subtidal area of the St. Lawrence Estuary and the Mingan Archipelago of Quebec, pale individuals were reported mainly from discrete areas at the base of rocks or under dense algal cover (J.-F.H. pers. obs.), suggesting that they are actively seeking shelter against exposure to strong light, similar to increased covering behaviour reported in albino urchins in the Caribbean (Kehas *et al.* 2005).

Paler sea cucumbers reported from the Bay of Fundy, New Brunswick, did not appear to differ in size from dark-brown and brown individuals (S. Robinson pers. comm. October 2017), which is consistent with the current samples. Although any size difference remains to be confirmed with further sampling, white sea cucumbers stand out against the background substrate colour, which may generate more stress and, together with decreased UV protection, might explain why they would be generally smaller than normally coloured individuals (Table 2). Their relatively smaller size may also be explained by metabolic factors, as white sea cucumbers have previously been reported as less efficient at protein metabolism than other colour morphs (e.g., *A. japonicus*, Bai *et al.* 2016).

Our data document the presence of uncommon colour morphs of *C. frondosa* across most of its eastern Canadian distribution (Figure 1) and other areas from its general geographic distribution. This deserves further investigation from both ecological and economical perspectives.

Author Contributions

Writing – Original Draft: E.M. and T.S.; Writing – Review & Editing: E.M., T.S., J.-F. H., and A.M. Investigation: E.M., T.S., J.-F. H., and A.M.; Formal Analysis: E.M. and T.S.; Funding Acquisition: A.M.

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Literature Cited

Bai, Y., L. Zhang, S. Xia, S. Liu, X. Ru, Q. Xu, T. Zhang, and H. Yang. 2016. Effects of dietary protein levels on the growth, energy budget, and physiological and immunological performance of green, white and purple color morphs of sea cucumber, *Apostichopus japonicus*. Aquaculture 450: 375–382. https://doi.org/10.1016/j.aquaculture.2015.08.021

Benoît, G. 2016. An albino sea cucumber! Is that possible? Musée du Fjord, La Baie, Quebec, Canada. Accessed January 2019. http://museedufjord.com/en/an-albino-sea-cucumber- is-that-possible.

Casellato, S., L. Massiero, and S. Soresi. 2006. Un caso di albinismo in *Ocnus planci* (Brandt, 1835) (Echinodermata: Holothuroidea) nelle "tegnue" dell'Alto Adriatico. Biologia Marina Mediterranea 13: 1059–1062. https://doi.org/10.7325/galemys.2012.n02

Feindel, S., T. Bennett, and K. Kanwit. 2011. The Maine sea cucumber (*Cucumaria frondosa*) fishery. Department of Marine Resources, Augusta, Maine, USA. Accessed January 2019. https://www.maine.gov/dmr/science-research/species/cukes/documents/feindeletal2011.pdf.

Fernández-Rivera Melo, F.J., H. Reyes-Bonilla, A. Cantú, and J. Urías. 2015. First record of albinism in the brown sea cucumber *Isostichopus fuscus* in the Gulf of California, Mexico. Marine Biodiversity Records 8: e14. https://doi.org/10.1017/s1755267214001353

Friedman, K., and M. Tekanene. 2005. White teatfish at Kiribati sea cucumber hatchery: local technicians getting them out again. SPC Beche-de-Mer Information Bulletin 21: 32–33. Accessed 24 May 2019. https://tinyurl.com/y26jnjok.

Hansen, J. 2016. Sea cucumber facility in Hackett's Cove hoping to entice Chinese market. CBC Radio-Canada, Ottawa, Ontario, Canada. Accessed January 2019. https://www.cbc.ca/news/canada/nova-scotia/sea-cucumber-plant-china-market-marine-animal-1.3699286.

Jiang, S., S. Dong, Q. Gao, Y. Ren, and F. Wang. 2015. Effects of water depth and substrate color on the growth and body color of the red sea cucumber, *Apostichopus japonicus*. Chinese Journal of Oceanology and Limnology 33: 616–623. https://doi.org/10.1007/s00343-015-41 78-7

Kehas, A.J., K.A. Theoharides, and J.J. Gilbert. 2005. Effect of sunlight intensity and albinism on the covering response of the Caribbean Sea urchin *Tripneustes ventricosus*. Marine Biology 146: 1111–1117. https://doi.org/10.1007/s00227-004-1514-4

Lin, C., L. Zhang, S. Liu, S. Gao, Q. Xu, and H. Yang. 2013. A comparison of the effects of light intensity on movement and growth of albino and normal sea cucumbers (*Apostichopus japonicus* Selenka). Marine and Freshwater Behaviour and Physiology 46: 351–366. https://doi.org/10.1080/10236244.2013.841350

Mouahid, G., R.M. Nguema, M.A. Idris, M.A. Shaban, S. Al Yafee, J. Langand, M. Verdoit-Jarraya, R. Galinier, and H. Moné. 2010. High phenotypic frequencies of complete albinism in wild populations of *Biomphalaria pfeifferi* (Gastropoda: Pulmonata). Malacologia 53: 161–166. https://doi.org/10.4002/040.053.0109

Nelson, E.J., B.A. MacDonald, and S.M. Robinson. 2012. A review of the Northern sea cucumber *Cucumaria frondosa* (Gunnerus, 1767) as a potential aquaculture species. Reviews in Fisheries Science 20: 212–219.

Paulay, G., and H. Hansson. 2013. *Cucumaria frondosa* (Gunnerus, 1767). *In* World Register of Marine Species. Flanders Marine Institute, Ostend, Belgium. Accessed January 2019. http://www.marinespecies.org/aphia.php?p=taxdetails&id=124612.

Purcell, S.W., B.A. Polidoro, J.-F. Hamel, R.U. Gamboa, and A. Mercier. 2014. The cost of being valuable: predictors of extinction risk in marine invertebrates exploited as luxury seafood. Proceedings of the Royal Society B 281: 20133296. https://doi.org/10.1098/rspb.2013.3296

Singh, R., B.A. MacDonald, P. Lawton, and M.L.H. Thomas. 2001. The reproductive biology of the dendrochirote sea cucumber *Cucumaria frondosa* (Echinodermata: Holothuroidea) using new quantitative methods. Invertebrate Reproduction and Development 40: 125–141. https://doi.org/10.1080/07924259.2001.9652713

So, J.J., S. Uthicke, J.-F. Hamel, and A. Mercier. 2011. Genetic population structure in a commercial marine invertebrate with long-lived lecithotrophic larvae: *Cucumaria frondosa* (Echinodermata: Holothuroidea). Marine Biology 158: 859–870. https://doi.org/10.1007/s00227-010-1613-3

Therkildsen, N.O., and C.W. Petersen. 2006. A review of the emerging fishery for the sea cucumber *Cucumaria frondosa*: biology, policy, and future prospects. SPC Beche-de-Mer Information Bulletin 23: 16–25. Accessed 24 May 2019. https://tinyurl.com/y5mp97wd.

Trefry, S. 2001. *Parastichopus californicus*: Race Rocks Taxonomy, Pearson College, Victoria, British Columbia, Canada. Accessed January 2019. http://www.racerocks.com/racerock/eco/taxalab/saraht.htm.

Tse, C. 2015. Albino sea cucumbers, a delicacy, could become a lot less rare. New York Times, Aug. 6. Accessed January 2019. https://sinosphere.blogs.nytimes.com/2015/08/06/albino-sea-cucumbers-a-delicacy-could-become-a-lot-less-rare/.

Wakida-Kusunoki, A., A. Poot-Salazar, and R.J.D. Mena-Loria. 2016. First record of albinism in three-rowed sea cucumber, *Isostichopus badionotus*. Bulletin of Marine Science 92: 285–290. https://doi.org/10.5343/bms.2015.1051

WoRMS (World Register of Marine Species). 2019. An Authoritative Classification and Catalogue of Marine Names. Flanders Marine Institute, Ostend, Belgium. http://www.marinespecies.org.

Xia, S.D., M. Li, L.B. Zhang, M. Rahman, Q.Z. Xu, L.N. Sun, S.L. Liu, and H.S. Yang. 2017. Growth, immunity and ammonia excretion of albino and normal *Apostichopus japonicus* (Selenka) feeding with various experimental diets. Aquaculture Nutrition 2017: 1–9. https://doi.org/10.1111/anu.12646

Yang, H., J.-F. Hamel, and A. Mercier. 2015. The Sea Cucumber *Apostichopus japonicus*: History, Biology and Aquaculture. Academic Press, New York, New York, USA.

Zhao, H., C. Muyan, and H. Yang. 2015. Albinism. Pages 211–226 *in* The Sea Cucumber *Apostichopus japonicus*: History, Biology and Aquaculture. *Edited by* H. Yang, J.-F. Hamel, and A. Mercier. Academic Press, New York, New York, USA.

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Wintercresses (*Barbarea* W.T. Aiton, Brassicaceae) of the Canadian Maritimes

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Abstract
We conducted a review of herbarium collections of the Wintercress genus (*Barbarea* W.T. Aiton) from the Maritime provinces. Most specimens previously determined to be the regionally rare native species Erect-fruit Wintercress (*Barbarea orthoceras* Ledebour) are in fact the uncommon exotic Small-flowered Wintercress (*Barbarea stricta* Andrzejowski). The latter species is here reported as new to Atlantic Canada, where it is scattered but widespread in the three Maritime provinces. Only three collections (two from New Brunswick and one from Nova Scotia) were confirmed as *B. orthoceras*. Its known range extent and area of occupancy in the Maritimes has been significantly revised, and *B. orthoceras* is now considered potentially extirpated in New Brunswick and extremely rare in Nova Scotia. One collection from Nova Scotia was referred to another rare exotic species, Early Wintercress (*Barbarea verna* (Miller) Ascherson), which represents the first record for the Maritimes.

Key words: Cruciferae; Brassicaceae; new record; floristics; *Barbarea stricta*; *Barbarea orthoceras*; *Barbarea verna*; conservation; Maritimes; Canada; wintercress

Introduction

The wintercress genus (*Barbarea* W.T. Aiton) has long been a source of confusion in North America, in part due to taxonomy and to somewhat variable species with overlapping morphology (Fernald 1909; Mulligan 2002; Al-Shehbaz 2010). The sole native North American member of the genus, Erect-fruit Wintercress (*Barbarea orthoceras* Ledebour), was at one point considered a native form of the Eurasian species Bitter Wintercress (*Barbarea vulgaris* W.T. Aiton) or Small-flowered Wintercress (*Barbarea stricta* Andrzejowski; discussed in Fernald 1909). Fernald (1909), who concluded reports of *B. stricta* were misidentified individuals of *B. vulgaris* with appressed fruit, excluded the former species from the North American flora. Mulligan (1978) reported the first confirmed North American records of *B. stricta* based on specimens collected from Quebec in 1944, although the species was not included in *The Flora of Canada* (Scoggan 1978). *Barbarea stricta* has subsequently been documented in Ontario (based on a 1922 specimen; Dorofeev 1998), Colorado, Connecticut, Maine, Michigan, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, and Wisconsin (Al-Shehbaz 2010). Prior to our study, only two species of *Barbarea* were listed in the flora of the Canadian Maritimes (New Brunswick [NB], Nova Scotia [NS], and Prince Edward Island [PEI]): *B. vulgaris* and *B. orthoceras* (Roland and Smith 1969; Scoggan 1978; Zinck 1998; Hinds 2000; Munro *et al.* 2014).

Barbarea vulgaris is a common and widespread weedy species of Eurasian origin, well documented from throughout NB, NS, and PEI (Erskine 1960; Roland and Smith 1969; Zinck 1998; Hinds 2000; AC CDC 2019; Figure 1). *Barbarea orthoceras* is native to boreal North America and eastern and central Asia (Al-Shehbaz 2010). Haines (2011) considers *B. orthoceras* a calciphile associated in New England with high-pH bedrock or till, although a variety of habitats, including grasslands, forests, boggy ground, and railroad embankments are reportedly suitable (Al-Shehbaz 2010). Though relatively secure in the western and northern portion of its range, *B. orthoceras* is rare in eastern North America and is of conservation concern in all jurisdictions of occurrence east of Ontario (NatureServe 2017). As of 2000, it was reported in the Maritimes from five NB locations on “stream banks, sandy beaches, gravel river strands, and rocky shores” (Hinds 2000: 225). An additional nine NB collections and two NS collections initially identified as *B. orthoceras* were deposited at regional herbaria between 2001 and 2015 (AC CDC 2019; Figure 2), but in 2015 D.M.M. suspected some Maritimes records involved *B. stricta*, so we undertook a thorough specimen review to determine the regional status of *B. orthoceras*, *B. stricta,* and *B. vulgaris*.

Methods

Approximately 170 specimens from four regional herbaria (E.C. Smith Herbarium—Acadia University [ACAD], New Brunswick Museum [NBM], Nova Scotia Museum of Natural History [NSPM], Connell Memorial Herbarium—University of New Brunswick [UNB]) and one national herbarium (Canadian Museum of Nature [CAN]) were examined by C.J.C. in 2018. Specimens from Agriculture and Agri-Food Canada's National Collection of Vascular Plants [DAO] were unavailable for examination due to facility renovations. Plants were determined based on the treatments in Al-Shehbaz (2010) and Haines (2011). A simplified key is presented here:

1a. Stylar beaks narrow, longer than 1.5 mm (Figure S1); auricles of distal leaves glabrous..... .... *B. vulgaris*

1b. Stylar beaks stout, less than 1.5 mm long (Figure S2); auricles of distal leaves at least sparsely ciliate 2

2a. Uppermost leaves dentate (Figure S3); petals less than 4.5 mm long (Figure S4); fruit mostly shorter than 28 mm long........................ *B. stricta*

2b. Uppermost leaves pinnatifid (Figure S5); petals greater than 5 mm long; fruit mostly greater than 31 mm long.................................... 3

3a. Basal leaves with 1–4 pairs lateral lobes; fruit usually under 40 mm long; fruiting pedicels narrower than fruit .... *B. orthoceras*

3b. Basal leaves with 4–10 pairs lateral lobes; fruit usually greater than 53 mm long; fruiting pedicels as broad as fruit .... *B. verna*

Clear determinations could be made for most specimens, but some collections presented conflicting morphology, as is mentioned of NB (Hinds 2000), New England (Al-Shehbaz 2010), and Michigan (Voss

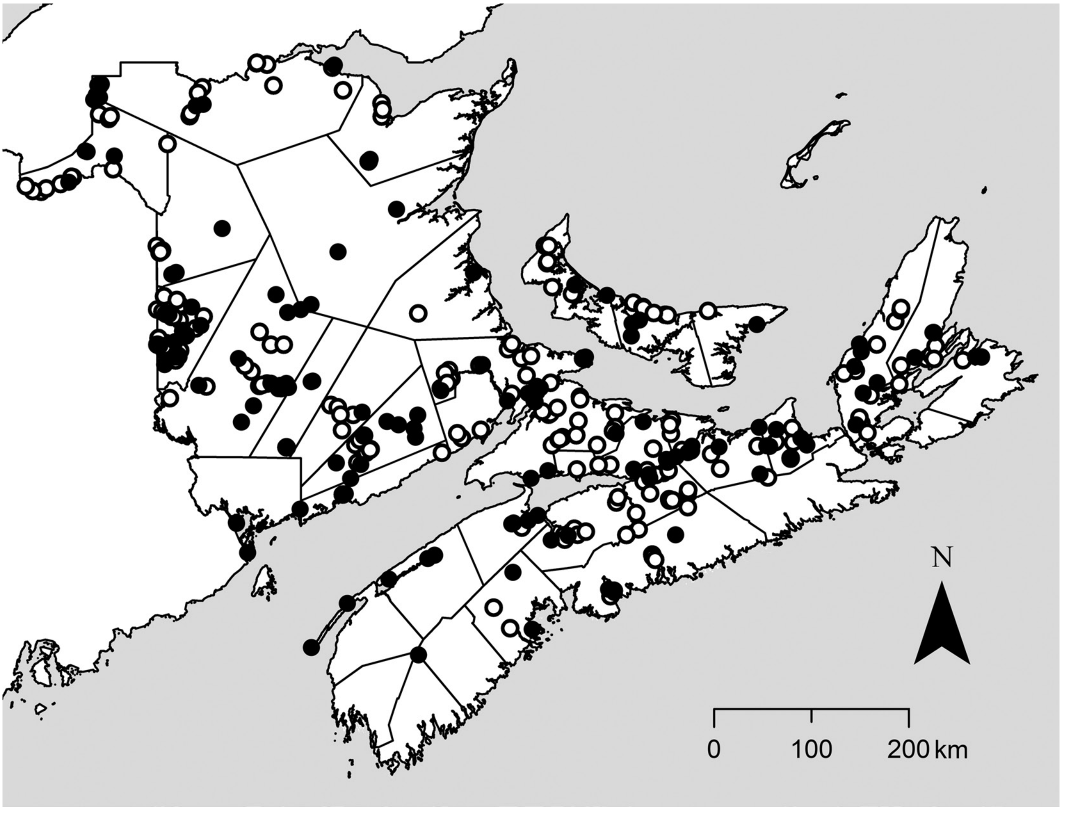

FIGURE 1. Distribution of Bitter Wintercress (*Barbarea vulgaris*) in the Canadian Maritimes based on specimens (solid circles) and Atlantic Canada Conservation Data Centre sight records (hollow circles) determined and verified during the present study.

and Reznicek 2012) material. We sent a small subset of six specimens to Ihsan Al-Shehbaz, Missouri Botanical Garden, and he confirmed all six as the species initially determined by C.J.C.

All records in this paper are either supported by voucher specimens or are photographic or sight records made by Atlantic Canada Conservation Data Centre (AC CDC) botanists.

Results and Discussion

Barbarea vulgaris W.T. Aiton

Barbarea vulgaris remains the most frequently encountered and widespread species of *Barbarea* in the Maritimes (Figure 1). As a weedy species, *B. vulgaris* is found in a variety of anthropogenic habitats such as fields and roadsides (Erskine 1960; Roland and Smith 1969; Hinds 2000). It is also frequent on river shores, where it can co-occur with *B. stricta* and potentially with *B. orthoceras*. The taxon is morphologically variable, and though many varieties have been described (treated in Fernald 1909), none are presently recognized in North America (Al-Shehbaz 2010). Some specimens present mixed or intermediate morphology in style length, uppermost leaf shape, and auricle pubescence. Hinds (2000) reported apparently intermediate NB specimens and suspected hybridization might be involved. Hybrids of *B. vulgaris* and *B. stricta* (= *B. × schulzeana* Haussknecht) are recorded for Europe, although occurrences are very infrequently recorded and highly sterile (Rich 1987). If hybrids were also sterile in the Maritimes, we might expect a lower frequency of plants intermediate between *B. vulgaris* and *B. orthoceras* than has been observed. These intermediates may thus be morphological extremes of the highly variable *B. vulgaris*.

Barbarea orthoceras Ledebour

We found that only one specimen initially identified as *B. orthoceras* was determined correctly. The remainder were reassigned to *B. stricta* or in very few cases *B. vulgaris*. An additional *B. orthoceras* record was discovered upon redetermination of a specimen originally identified as *B. vulgaris*. The two specimens now confirmed for NB were collected in 1944 along water-runs in an old pasture on Grand Manan Island (*C.A. Weatherby & Una F. Weatherby 7343*), and in 1964 on a roadside at the edge of a Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) forest in Kings County (*P.R. Roberts*

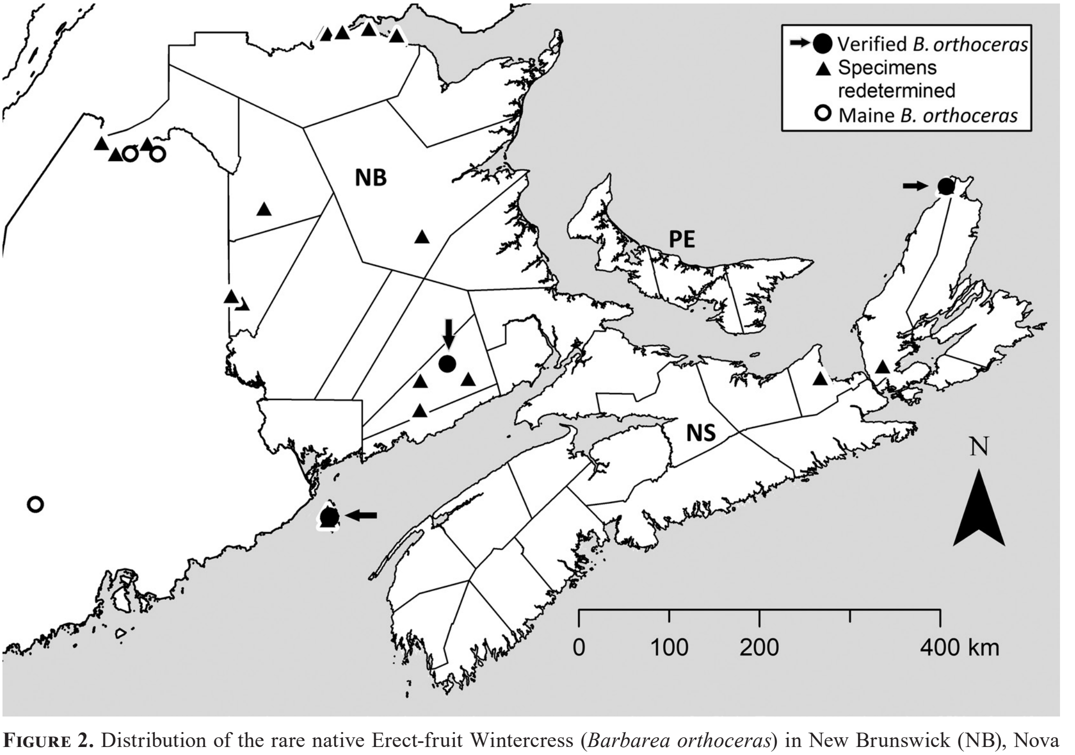

FIGURE 2. Distribution of the rare native Erect-fruit Wintercress (*Barbarea orthoceras*) in New Brunswick (NB), Nova Scotia (NS), and Prince Edward Island (PE) based on specimens determined and verified during the present study. Historical records from Maine provided by the Maine Natural Heritage Program were not verified, but one Maine collection at the New Brunswick Museum was redetermined as *B. orthoceras*.

& N. Bateman 64-361). C.S.B. discovered the first and only known NS population on a steep, seepy ravine slope under shrubs in northern Cape Breton in 2016 (collection number *8978*).

Barbarea orthoceras was first reported for NB based on two specimens revised by H.J. Scoggan in 1955 (*R. Chalmers 305a* [now determined as *B. stricta*] and *C.A. Weatherby and Una F. Weatherby 7343*). Scoggan appears unlikely to have considered *B. stricta* as a possible identity because it was not confirmed in North America until much later (Mulligan 1978). Indeed, his key in Scoggan (1978) describes the petals in *B. orthoceras* as "at most 5 mm long", a key character of *B. stricta* (Al-Shehbaz 2010). Hinds (2000) similarly described the petals of *B. orthoceras* as "less than 5 mm long". In fact, the petals are 5–7 mm long in *B. orthoceras*, which is the most reliable character separating it from *B. stricta* (I. Al-Shehbaz pers. comm. 8 May 2018).

One historical collection of *B. orthoceras* (initially misidentified as *B. vulgaris* and later as *B. stricta*) was uncovered from Fort Kent, Maine (*G.U. Hay, s.n.*), along the Saint John River across from Madawaska County, NB. The species is known from two additional historical records in northern Maine, however all recent collections of potential *B. orthoceras* in the state have turned out to be *B. stricta* (L. St. Hilaire and D. Cameron pers. comm. 20 February 2019). All recent records from extensive AC CDC fieldwork along northern NB rivers have also been *B. stricta*, suggesting that, if *B. orthoceras* is present on rivers in the region, it is quite rare. However, the now-confirmed records of *B. orthoceras* from pasture and roadsides in NB suggest it could be overlooked in disturbed sites because of assumptions that *Barbarea* in ruderal habitats must be *B. vulgaris* or *B. stricta*, and because botanists tend to spend less time in ruderal habitats.

Speculation aside, our study greatly decreases the known range extent and area of occupancy for *B. orthoceras* in the Maritime provinces (Figure 2). No recent records exist in NB, where its provincial status has been changed from imperilled/vulnerable (S2S3) to possibly extirpated (SH). It has been confirmed as extremely rare in NS and remains unknown on PEI.

Barbarea stricta Andrzejowski

This study confirmed the presence of *B. stricta* in Atlantic Canada, where it is scattered but widely distributed in NB, NS, and PEI (Figure 3). Haines (2011) and Cayouette (1984) describe *B. stricta* as having invaded river shores, lake shores, and wet, disturbed areas in New England, and Quebec respectively, and it has mostly been collected from similar habitats in the Maritimes. Many *B. stricta* specimens examined in this study had morphology that was at the larger extremes for the species (as also reported in Al-Shehbaz 2010), which is potentially suggestive of genetic influence from the larger *B. orthoceras*. The morphology of these plants might also be explained by the founder principle (Mayr 1942) if North American populations happened to have been founded by unusually large individuals. The morphological similarity of *B. orthoceras* and *B. stricta* would make hybridization difficult to demonstrate without molecular investigation.

We failed to locate historical specimens of *B. stricta* in NS or PEI, suggesting it may have dispersed more recently to these provinces. However, it was introduced in NB as early as 1877 (*R. Chalmers 305a*; now the earliest Canadian record), where collections were misidentified as *B. orthoceras*, or more rarely as *B. vulgaris*. Early introduction of *B. stricta* and overlapping habitat requirements of *Barbarea* species suggests ample opportunity for hybridization in NB. However, because Hinds (2000) appears not to have considered *B. stricta* as a possibility in identifying NB material, his specimens of "intermediate morphology" between *B. vulgaris* and *B. orthoceras* may simply have represented *B. stricta*.

Barbarea verna (Miller) Ascherson

We referred one collection from Kentville, NS (*J.S. Erskine s.n.*) to Early Wintercress (*Barbarea verna* (Miller) Ascherson). Originally identified as *B. vulgaris*, it was distinguished by its leaves with five to seven pairs of lateral lobes, pinnatifid uppermost leaves, and conspicuously ciliate leaf auricles (Al-Shehbaz 2010; Haines 2011). In fruit, *B. verna* can also be distinguished by its large fruit (5.3–7 cm), and pedicels as broad as the fruit they subtend (Al-Shehbaz 2010). This European species is cultivated as a salad plant in North America, where it escapes to disturbed habitats such as fields and meadows (Mulligan 2002; Haines 2011). This represents the first Maritimes record of this rarely reported introduction, otherwise known in Canada only from Newfoundland and British Columbia (Brouillet *et al*. 2010+).

Voucher specimens

Barbarea orthoceras Ledebour—NEW BRUNSWICK: Charlotte Co., Grand Manan, Between Long Pond & Red Pt., weed along water-runs in old pasture, 6 August 1944, *C.A. Weatherby and U.F. Weatherby 7343* (CAN); Kings Co., Lower Millstream, roadside at Black Spruce forest edge, 28 May 1964, *P.R. Roberts & N. Bateman 64-361* (UNB); NOVA SCOTIA: Inverness Co., Pleasant Bay, Lower Delaneys Brook, 46.966519°N, 60.654339°W, steep, seepy ravine slope under shrubs, not seen elsewhere between High Capes & Delaneys Point, with Red-osier Dogwood (*Cornus sericea* L.), Tall Meadow-rue (*Thalictrum pubescens* Pursh), 14 July 2016, *C.S. Blaney 8978* (NSPM);

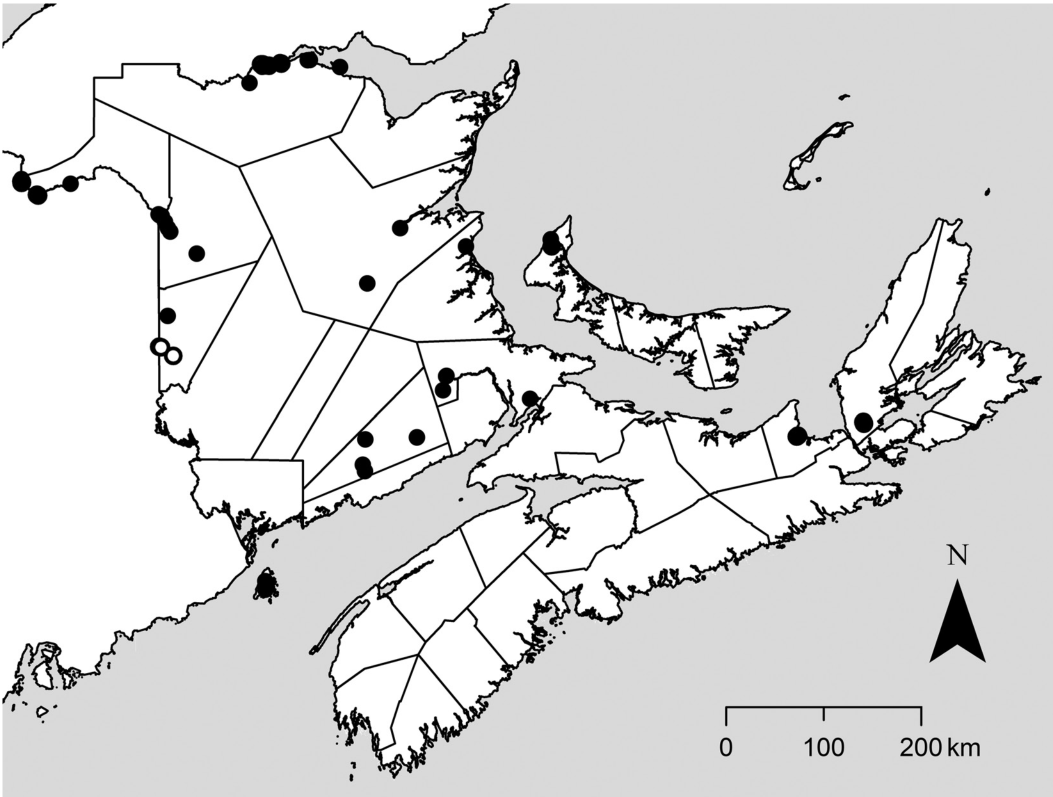

FIGURE 3. Distribution of the uncommon exotic species Small-flowered Wintercress (*Barbarea stricta*) in the Canadian Maritimes based on specimens (solid circles) and Atlantic Canada Conservation Data Centre photographic or sight records (hollow circles; the western sample is shown in Figure S3) determined, verified, or revised during the present study.

MAINE: Aroostook Co., Fort Kent, 8 July 1904, *G.U. Hay s.n.* (NBM).

Barbarea stricta Andrzejowski—NEW BRUNSWICK: Madawaska Co., St. Francis River, 47.182855°N, 68.896639°W, wet mud, in grassy meadow along shore of floodplain island, 11 July 2013, *D.M. Mazerolle DM4032* (NBM, UNB, DAO); Madawaska Co., St. Francis River, 47.285603°N, 69.050753°W, sandy riverbank with sparse alders, 9 July 2013, *C.S. Blaney & D.M. Mazerolle 8267* (NBM); Madawaska Co., St. Francis River, 47.276528°N, 69.049497°W, sandy-bouldery shore under Eastern White Cedar (*Thuja occidentalis* L.), 9 July 2013, *C.S. Blaney 8268* (NBM); Madawaska Co., St. Francis River, 47.26046°N, 69.050219°W, silty sand-gravel rivershore, 9 July 2013, C.S. Blaney 8270 (NBM); Restigouche Co., Campbellton, 20 July 1877, *R. Chalmers 305a* (CAN); Victoria Co., Grand Falls, 47.05527°N, 67.759561°W, 31 July 2018, *D.M. Mazerolle DM7808* (NBM); Restigouche Co., Heron Island, 47.9823°N, 66.11649°W, sandy hummocks, 29 September 1982, *H.R. Hinds 5798* (UNB); Restigouche Co., Eel River, 48.02520°N, 66.39349°W, gravel shore, 5 August 1982, *H.R. Hinds 5400* (UNB); Restigouche Co., Morrissey Rock, 47.983327°N, 66.832622°W, alongside railway tracks, 10 August 1965, *P.R. Roberts & B. Pugh 65-5384* (UNB); Restigouche Co., Restigouche River, 47.990321°N, 66.769302°W, sandy floodplain terrace above river bank, on island in upper estuary near head of tide, 18 September 2013, *D.M. Mazerolle DM4143* (NBM); Restigouche Co., Tidehead, 47.985532°N, 66.767721°W, silty bar in fresh tidal zone, 18 September 2013, *C.S. Blaney 8485* (NBM); Restigouche Co., Eel River, 48.023715°N, 66.412898°W, graminoid floodplain meadow on elevated terrace along brackish tidal river, 26 August 2015, *D.M. Mazerolle DM6967* (NBM, UNB); Restigouche Co., Upsalquitch River, 47.883333°N, 66.951000°W, 12 July 1957, *E.C. Smith 16312* (ACAD); Victoria Co., Arthurette, 46.81718°N, 67.43563°W, gravelly north shore, 27 July 1982, *H.R. Hinds 5361* (UNB); Victoria Co., Grand Falls, 47.059342°N, 67.778800°W, 31 July 2018, *C.J. Chapman 1152* (NBM); Victoria Co., Grand Falls, 47.064978°N, 67.788144°W, 31 July 2018, *C.J. Chapman 1158* (UNB); Northumberland Co., Upper Blackville Bridge, 46.629606°N, 65.865519°W, eroding sandy-gravel shore slope, 14 August 2007, *C.S. Blaney & D. Whittam 6646* (UNB); Northumberland Co., Beaubears Island, Miramichi, 46.978856°N, 65.561207°W, On open backshore of east point of island, 7 September 2005, *D. McLeod & C. Merrithew 5271* (UNB); Carleton Co., Big Presque Isle Stream, 46.424062°N, 67.703127°W, moist depression in densely vegetated weedy Balsam Poplar (*Populus balsamifera* L.)/Black Ash (*Fraxinus nigra* Marshall) floodplain, 7 July 2015, *D.M. Mazerolle DM6711* (NBM, UNB); Kent Co., Kouchibouguac NP, 46.86312°N, 64.95513°W, garbage dump, 11 June 1977, *B. Lyons & D. LaFontaine 564* (UNB, ACAD); Kings Co., Hatfield Point, 45.63523°N, 65.88335°W, rocky and gravelly shore, 28 June 1980, *H.R. Hinds 3234* (UNB); Kings Co., Hammond River, 45.471532°N, 65.9056750°W, rich soil in understorey of Silver Maple (*Acer saccharinum* L.) floodplain forest, on floodplain island, 23 August 2017, *D.M. Mazerolle DM7598* (NBM); Westmorland Co., North River, 46.038486°N, 65.138669°W, rich, silty upper river bank, 19 July 2017, *C.S. Blaney 9148* (NBM); Westmorland Co., North River, 46.041878°N, 65.135242°W, silty river bank, 19 July 2017, *C.S. Blaney 9153* (NBM); Westmorland Co., Petitcodiac River, 45.949465°N, 65.166692°W, muddy gravel river bar, 8 September 2017, *C.S. Blaney 9198* (NBM); NOVA SCOTIA: Antigonish Co., Antigonish Harbour, 45.659103°N, 61.895856°W, open, cattle-grazed White Spruce (*Picea glauca* (Moench) Voss) forest on gypsum at edge of saltmarsh, 30 June 2014, *C.S. Blaney 8575* (ACAD); Antigonish Co., Antigonish Harbour, 45.658474°N, 61.899508°W, muddy edge of brackish marsh, 30 June 2014, *C.S. Blaney 8578* (ACAD, NSPM, DAO, UNB); Inverness Co., Glenora, 45.742390°N, 61.293412°W, edge of rich shrubby floodplain terrace, 31 July 2015, *D.M. Mazerolle DM6879* (ACAD, NSPM, DAO); PRINCE EDWARD ISLAND: Prince Co., Miminegash River, 46.860973°N, 64.169513°W, forb and graminoid floodplain meadow, 28 July 2017, *D.M. Mazerolle DM7483* (ACAD, DAO).

Barbarea verna (Miller) Ascherson—NOVA SCOTIA: Kings Co., Kentville, sandy grassy slope, 22 May 1950, *J.S. Erskine s.n.* (NSPM).

Author Contributions

Writing—Original Draft: C.J.C.; Writing—Review & Editing: C.S.B., D.M.M., and C.J.C.; Conceptualization: C.S.B. and D.M.M.; Investigation: C.J.C.; Methodology: C.J.C.; Funding Acquisition: C.S.B., D.M.M., and C.J.C.

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Literature Cited

AC CDC (Atlantic Canada Conservation Data Centre). 2019. Digital database of species occurrence records for the Maritime provinces. Atlantic Canada Conservation Data Centre, Sackville, New Brunswick, Canada.

Al-Shehbaz, I.A. 2010. *Barbarea*. Pages 460–463 *in* Flora of North America North of Mexico. Volume 7. *Edited by* Flora of North America Editorial Committee. Flora of North America Association, New York and Oxford.

Brouillet, L., F. Coursol, M. Favreau, M. Anions, P. Bélisle, and P. Desmet. 2010+. VASCAN, the database of vascular plants of Canada. Accessed 10 May 2018. http://data.canadensys.net/vascan.

Cayouette, J. 1984. Nouvelles stations du *Barbarea stricta* Andrz. au Québec. Naturaliste canadien 111: 207–209.

Dorofeev, V.I. 1998. The four new species of Brassicaceae for North America. Botanicheskiĭ Zhurnal 83: 133–135.

Erskine, D.S. 1960. The Plants of Prince Edward Island. Plant Research Institute, Research Branch, Canada Department of Agriculture. Publication 1088. https://doi.org/10.5962/bhl.title.53729

Fernald, M.L. 1909. The North American species of *Barbarea*. Rhodora 11: 134–141.

Haines, A. 2011. Flora Novae Angliae, A Manual for the Identification of Native and Naturalized Higher Vascular Plants of New England. Yale University Press, New Haven, Connecticut, USA.

Hinds, H.R. 2000. Flora of New Brunswick, Second Edition: A Manual for Identification of the Vascular Plants of New Brunswick. Department of Biology, University of New Brunswick, Fredericton, New Brunswick, Canada.

Mayr, E. 1942. Systematics and the Origin of Species. Columbia University Press, New York, USA.

Mulligan, G.A. 1978. *Barbarea stricta* Andrz., a new introduction to Quebec. Naturaliste canadien 105: 298–299.

Mulligan, G.A. 2002. Weedy introduced mustards (Brassicaceae) of Canada. Canadian Field-Naturalist 116: 623–631. Accessed 12 October 2019. https://biodiversitylibrary.org/page/35151869.

Munro, M.C., R.E. Newell, and N.M. Hill. 2014. Nova Scotia Plants: 3-14 Brassicaceae, mustard family. Nova Scotia Museum, Halifax, Nova Scotia. Accessed 10 May 2018. https://ojs.library.dal.ca/NSM/article/view/5478.

NatureServe. 2017. NatureServe Explorer: an online encyclopedia of life. Version 7.1. NatureServe, Arlington, Virginia, USA. Accessed 10 May 2018. http://explorer.natureserve.org.

Rich, T.C.G. 1987. The genus *Barbarea* R.Br. (Cruciferae) in Britain and Ireland. Watsonia 16: 389–396.

Roland, A.E., and E.C. Smith. 1969. The Flora of Nova Scotia. Nova Scotia Museum, Halifax, Nova Scotia, Canada.

Scoggan, H.J. 1978. The Flora of Canada, Part 3: Dicotyledonae (Saururaceae to Violaceae). National Museums of Canada, Ottawa, Canada. https://doi.org/10.5962/bhl.title.122890

Voss, E.G., and A.A. Reznicek. 2012. Field Manual of Michigan Flora. University of Michigan Press, Ann Arbor, Michigan, USA. https://doi.org/10.3998/mpub.345399

Zinck, M. 1998. Roland's Flora of Nova Scotia. Nimbus Publishing, Halifax, Nova Scotia, Canada.

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SUPPLEMENTARY MATERIAL:

FIGURE S1. Bitter Wintercress (*Barbarea vulgaris*), with characteristic slender, relatively long stylar beaks (>1.5 mm long).

FIGURE S2. Small-flowered Wintercress (*Barbarea stricta*), with short and stout stylar beaks (<1.5 mm long) and appressed siliques.

FIGURE S3. Small-flowered Wintercress (*Barbarea stricta*), with dentate upper stem leaves and ciliate auricles.

FIGURE S4. Small-flowered Wintercress (*Barbarea stricta*), with relatively short petals (<4.5 mm long).

FIGURE S5. Large-fruit Wintercress (*Barbarea orthoceras*), with pinnatifid uppermost stem leaves. Specimen: National Herbarium of Canada, Canadian Museum of Nature (CAN 60422).

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Note

Summer movements of a radio-tagged Hoary Bat (*Lasiurus cinereus*) captured in southwestern Ontario

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Abstract
Hoary Bat (*Lasiurus cinereus*) is a migratory species known to travel long distances during migration. Little is known about its movement patterns during other periods. An adult male Hoary Bat that we radio-tagged in southwestern Ontario in summer was tracked using the Motus Wildlife Tracking System. It travelled a minimum of 827 km in a circular route over a 2-week period and was last recorded 46 km from the original capture site. Hoary Bat is highly vulnerable to being killed at wind turbines and its propensity to travel great distances during summer and migration may exacerbate the impacts of wind farms.

Key words: Hoary Bat; *Lasiurus cinereus*; summer movement; Motus; radio-tracking; southwestern Ontario

Hoary Bat (*Lasiurus cinereus*) is widely distributed throughout the Western Hemisphere, and may be common in the Great Lakes Region. However, it is among the least frequently encountered species in studies of regional bat communities (e.g., Jung *et al.* 1999).

Hoary Bat travels long distances through its life cycle (Cryan *et al.* 2014). Migratory movements of this species have mostly been inferred from the seasonal distribution of museum specimens (Cryan 2003; Cryan *et al.* 2014), but there are several biases in these data. Kurta (2010) demonstrated that studies based on museum specimens did not match actual distribution and sex ratios of Hoary Bats captured by mist-netting in Michigan. This species is frequently studied through acoustic inventories (e.g., Barclay *et al.* 1999) and mortality studies at wind power facilities (e.g., Kunz *et al.* 2007). Such studies provide no information on individual movement patterns, which can only be determined through physical handling and tracking of individuals. Only one study has documented the long-distance movements of Hoary Bats in North America (Weller *et al.* 2016), and it was conducted in autumn rather than summer.

The non-migratory movements of males have not been well documented. Banfield (1974) stated that males seem to wander erratically during spring and summer and do not associate with females while the latter are caring for their young. Here we provide data on the short-term movements of a radio-tracked male Hoary Bat during mid-summer.

On 9 July 2016, we captured an adult male Hoary Bat in a 12-m triple high mist net near a Little Brown Myotis (*Myotis lucifugus*) maternal roost near Branchton, Ontario (43.2986°N, 80.2900°W). The Hoary Bat was 29.2 g at the time of capture and had a forearm length of 51 mm. A Nanotag radio transmitter (Lotek, Newmarket, Ontario, Canada) was affixed to the back of the bat by shaving a small area and applying a small amount of Osto-Bond (Montreal Ostomy Inc., Vaudreuil-Dorion, Quebec, Canada) glue to the bat and the tag. The mass of the tag reported by the manufacturer was 0.33 g, representing 1.1% of the body mass of the bat, less than the maximum of 5% recommended by Aldridge and Brigham (1988). This brand of skin cement is effective for adhesion of the tag to the bat for at least several days (Carter *et al.* 2009), and the transmitter battery life is expected to be as long as 21 days. Once the glue had dried, the bat was released at the capture site.

We attempted to relocate the bat by driving roads within 5 km of the capture site for seven days after capture, using two 4-element Yagi antennae fixed in opposite directions to the roof of a truck and connected to an SRX800 receiver (Lotek). The bat was

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never detected from the ground; thus, tracking its movements relied on detections on the Motus Wildlife Tracking System.

The Motus system is an international collaborative research network that uses coordinated automated radio telemetry arrays to study movements of small animals (Taylor *et al.* 2017); it has been used for tracking migratory bats (Lagerveld *et al.* 2017). Bird Studies Canada maintains an array of more than 100 automated radio telemetry stations in Ontario, and The Ohio State University maintains other stations in Ohio used by this study. Although these do not provide complete coverage of all areas and are not suitable for precise triangulation, detections show large landscape movements. Detection of tags at a receiver station could be within 15 km of the station depending on station strength and whether the animal is flying in the open or near obstructions (Taylor *et al.* 2017). The nearest receiver station to the capture site (Onondaga) was ~2 km south, but it was not activated until 12 July 2016 (seven days after we tagged the bat); the bat was never detected at this station.

Figure 1 depicts the movements of the bat, although it did not necessarily travel in a straight line between stations. The specific locations of the stations where it was detected are provided in Table 1 along with the dates and times when the bat was detected. Over two weeks, the Hoary Bat travelled a minimum distance of 827 km and was last detected only 46 km from the banding location. The landscape that it moved through was predominantly agricultural with scattered remnants of forest and wetland.

The male Hoary Bat made significant movements within short periods (Table 1): the longest were a minimum of 253 km over one night and 316 km over three nights (although it is unknown how long the

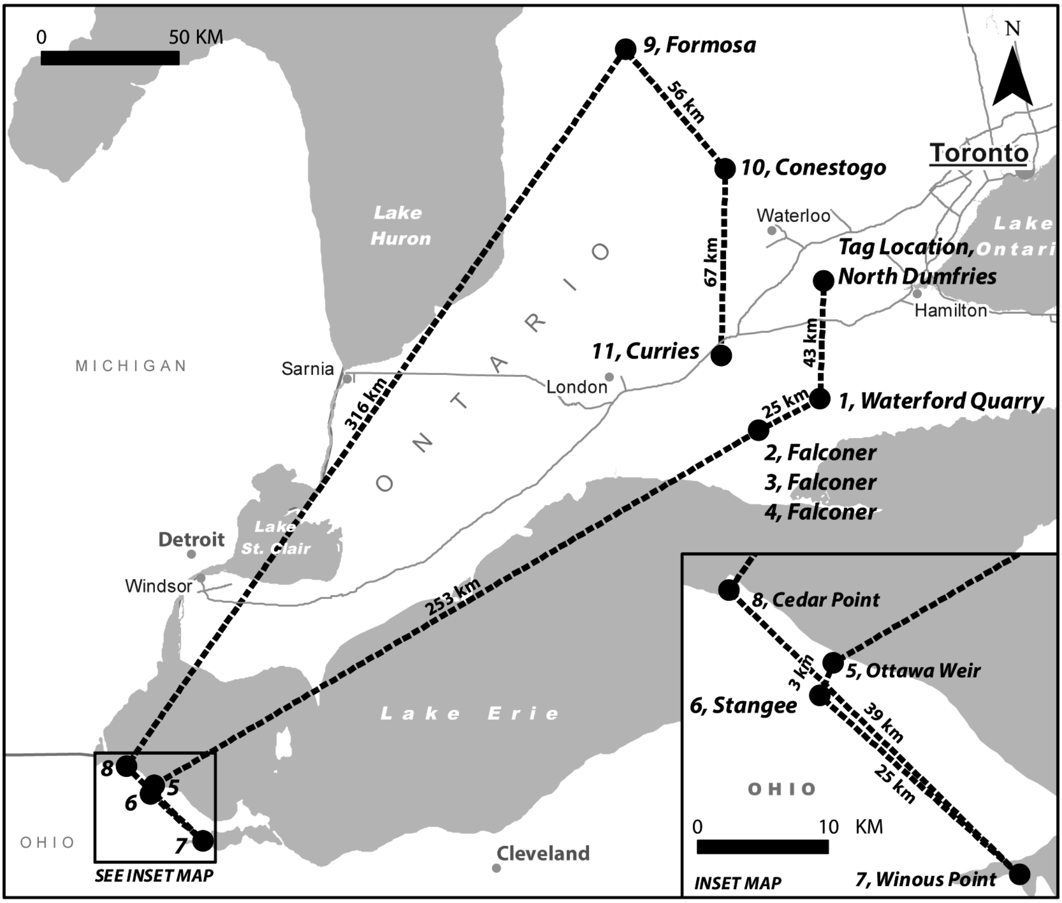

FIGURE 1. The map indicates the location where the male Hoary Bat (*Lasiurus cinereus*) was tagged on 9 July 2016 (North Dumfries) and its subsequent detections at the various Motus stations: 1. Waterford Quarry; 2, 3, 4. Falconer; 5. Ottawa Weir; 6. Stangee; 7. Winous Point; 8. Cedar Point; 9. Formosa; 10. Conestogo; 11. Curries. The inset map shows its movements in Ohio on 19 July 2016.

TABLE 1. Movements of a radio-tagged Hoary Bat (*Lasiurus cinereus*) over a 2-week period in July 2016 in southwestern Ontario.

Motus station*	Date and time detected	Distance from last station, km	Cumulative distance travelled, km
North Dumfries (tagging location)	9 July, 2350	0	0
1. Waterford Quarry	14 July, 1943–2200	43	43
2. Falconer	15 July, 2229–2303	25	68
3. Falconer	16 July, 2005	0	68
4. Falconer	18 July, 1912–1929	0	68
5. Ottawa Weir	19 July, 1728–1730	253	321
6. Stangee	19 July, 1732–1743	3	324
7. Winous Point	18 July, 1731–1736	25	349
8. Cedar Point	19 July, 1743–1744	39	388
9. Formosa	22 July, 1954–1955	316	704
10. Conestogo	22 July, 2129–2133	56	760
11. Curries	23 July, 2229–2349 24 July, 0156–0201	67	827

*Numbers correspond to those on the map in Figure 1.

bat took to fly these distances). The movements were not in a clear latitudinal direction. The bat initially moved to the southwest along or over Lake Erie, then flew quickly back to the northeast along or over Lake Huron and started another trip toward the southwest. It spent some time north of the Long Point area at Falconer and in the Cedar Point area of Ohio and was last detected at the Curries station (also near Long Point). The bat was detected consistently early in the night and often during daylight hours. If the bat was not moving at this time, we would have expected it to be detected repeatedly at individual stations until it moved out of the detection range. The bat did not appear to return to the location where it was captured during our sample period, because it was never detected at the Onondaga or other nearby stations.

Our study reports the first documented movements of an adult male Hoary Bat during the summer months. It has been widely believed that Hoary Bat makes long-distance movements during migration, but concrete evidence of this is sparse; even less information is available on local summer movements, such as those documented here. The few recoveries of banded Hoary Bats show maximum distances between banding and recovery sites of 150–450 km, representing more local movements (Davis 1969, 1970), although isotope analysis has shown that Hoary Bats make long-distance seasonal movements (Arias 2014; Baerwald *et al*. 2014).

In autumn in California, Weller *et al.* (2016) recovered three adult male Hoary Bats with global positioning system tags. One remained sedentary during the study, one made local movements of less than 100 km, and the third travelled over 1000 km in a month. Similar to the bat that we tracked, it moved in a circular manner and ended up less than 150 km from the original capture location. Results from this observation and Weller *et al.* (2016) indicate that male Hoary Bats may occasionally make circular or other long-distance movements lasting several days and covering distances as great as 1000 km. Although sample size is still very small (two of four tracked bats), this indicates that these bats have a large home range and, therefore, habitat protection or conservation for the species must similarly be on a large scale. The purpose of these flights is uncertain: bats may be searching for females to mate with before migration (Weller *et al.* 2016), although this bat was not scrotal (showing signs of sexual reproduction by having distended testes). More studies that use the Motus system or other methods capable of tracking Hoary Bats are recommended to better understand the space use by this fast, high-flying bat.

Hoary Bats are frequently killed at wind power facilities, particularly during late summer and autumn migration (Arnett *et al.* 2007; Bird Studies Canada *et al.* 2016). Hayes *et al.* (2015) concluded that Hoary Bats make up approximately 40–50% of all bat mortalities at wind farms; in Canada, this figure is 30.9% (Bird Studies Canada *et al*. 2016). Cryan (2011) estimated that as many as 225 000 Hoary Bats might be killed annually at North American wind farms, and it is predicted that the Hoary Bat population could decline by 90% in the next 50 years because of mortality related to wind turbines (Frick *et al.* 2017). Over the landscape that this bat travelled, a considerable number of wind turbines are in operation. Ontario has the greatest wind power generation in Canada with more than 4781 MWh of annual power production as of 2016 (Canadian Wind Energy Association 2017); many of the turbines are in southwestern Ontario. This bat either avoided those turbines or flew through them without being killed during the period that it was tracked. Our data provide evidence that Hoary Bats are at risk of encountering a large number of wind turbines during their summer movements, not just during migration.

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Literature Cited

Aldridge, H.D.J.N., and R.M. Brigham. 1988. Load carrying and maneuverability in an insectivorous bat: a test of the 5% "rule" of radio-telemetry. Journal of Mammalogy 69: 379–382. https://doi.org/10.2307/1381393

Arias, L. 2014. Using stable isotope analysis to study altitudinal and latitudinal bat migration. Ph.D. thesis, Indiana State University, Terre Haute, Indiana, USA.

Arnett, E.B., D.B. Inkley, D.H. Johnson, R.P. Larkin, S. Manes, A.M. Manville, R. Mason, M. Morrison, M.D. Strickland, and R. Thresher. 2007. Impacts of wind energy facilities on wildlife and wildlife habitat. Technical review 07-2. Wildlife Society, Bethesda, Maryland, USA. Accessed 7 May 2017. https://wildlife.org/wp-content/uploads/2014/05/Wind07-2.pdf.

Baerwald, E.F., W.P. Patterson, and R.M.R. Barclay. 2014. Origins and migratory patterns of bats killed by wind turbines in southern Alberta: evidence from stable isotopes. Ecosphere 5: 1–17. https://doi.org/10.1890/ES13-00380.1

Banfield, A.W.F. 1974. The Mammals of Canada. National Museums of Canada, Ottawa, Ontario, Canada.

Barclay, R.M.R., J.H. Fullard, and D.S. Jacobs. 1999. Variation in the echolocation calls of the hoary bat (*Lasiurus cinereus*): influence of body size, habitat structure, and geographic location. Canadian Journal of Zoology 77: 530–534. https://doi.org/10.1139/z99-008

Bird Studies Canada, Canadian Wind Energy Association, Environment Canada, and Ontario Ministry of Natural Resources. 2016. Wind energy bird and bat monitoring database: summary of the findings from post-construction monitoring reports. Port Rowan, Ontario, Canada. Accessed 26 September 2019. https://docs.wind-watch.org/Bird-Studies-CAN-Jul2016_Wind.pdf.

Carter, T.C., T.J. Sichmeller, and M.G. Hohmann. 2009. A field- and laboratory-based comparison of adhesives for attaching radiotransmitters to small insectivorous bats. Bat Research News 50: 81–85.

Canadian Wind Energy Association. 2017. Wind is Canada's largest source of new electricity generation for more than a decade. Canadian Wind Energy Association, Ottawa, Ontario, Canada. Accessed 3 October 2018. https://canwea.ca/news-release/2017/01/31/wind-energy-continues-strong-growth-canada-2016/.

Cryan, P.M. 2003. Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. Journal of Mammalogy 84: 579–593. https://doi.org/10.1644/1545-1542(2003)084<0579:sdomtb>2.0.co;2

Cryan, P.M. 2011. Wind turbines as landscape impediments to the migratory connectivity of bats. Environmental Law Review 41: 355–370. Accessed 6 July 2017. http://elawreview.org/articles/volume-41/issue-41-2/wind-turbines-as-landscape-impediments-to-the-migratory-connectivity-of-bats/?hilite="cryan".

Cryan, P.M., C.A. Stricker, and M.B. Wunder. 2014. Continental-scale, seasonal movements of a heterothermic migratory tree bat. Ecological Applications 24: 602–616. https://doi.org/10.1890/13-0752.1

Davis, W.H. 1969. A recovery of a banded Hoary Bat. Bat Research News 10: 41.

Davis, W.H. 1970. Recovery of a banded *Lasiurus cinereus*. Bat Research News 11: 30.

Frick, W.F., E.F. Baerwald, J.F. Pollock, R.M.R. Barclay, J.A. Szymanski, T.J. Weller, A.L. Russell, S.C. Loeb, R.A. Medellin, and L.P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. Biological Conservation 209: 172–177. https://doi.org/10.1016/j.biocon.2017.02.023

Hayes, M.A., P.M. Cryer, and M.B. Wunder. 2015. Seasonally-dynamic presence-only species distribution models for a cryptic migratory bat impacted by wind energy development. PLoS One 10: e0132599. https://doi.org/10.1371/journal.pone.0132599

Jung, T.S., I.D. Thompson, R.D. Titman, and A.P. Applejohn. 1999. Habitat selection by forest bats in relation to mixed-wood stand types and structure in central Ontario. Journal of Wildlife Management 63: 1306–1319. https://doi.org/10.2307/3802849

Kunz, T.H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R.P. Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife Management 71: 2449–2486. https://doi.org/10.2193/2007-270

Kurta, A. 2010. Reproductive timing, distribution, and sex ratios of tree bats in Lower Michigan. Journal of Mammalogy 91: 586–592. https://doi.org/10.1644/09-mamm-a-308.1

Lagerveld, S., R. Janssen, J. Manshanden, A.-J. Haarsma, S. De Vries, R. Brabant, and M. Scholl. 2017.

Telemetry for migratory bats—a feasibility study. Technical report. Wageningen University, Den Helder, Netherlands. https://doi.org/10.18174/417092

Taylor, P.D., T.L. Crewe, S.A. Mackenzie, D. Lepage, Y. Aubry, Z. Crysler, G. Finney, C.M. Francis, C.G. Guglielmo, D.J. Hamilton, R.L. Holberton, P.H. Loring, G.W. Mitchell, D.R. Norris, J. Paquet, R.A. Roncini, J.R. Smetzer, P.A. Smith, L.J. Welsh, and B.K. Woodworth. 2017. The Motus Wildlife Tracking System: a collaborative research network to enhance the understanding of wildlife movement. Avian Conservation and Ecology 12: 8. https://doi.org/10.5751/ace-00953-120108

Weller, T.J., K.T. Castle, F. Liechti, C.D. Hein, M.R. Schirmacher, and P.M. Cryer. 2016. First direct evidence of long-distance seasonal movements and hibernation in a migratory bat. Scientific Reports 6: 34585. https://doi.org/10.1038/srep34585

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A reconnaissance survey for Collared Pika (*Ochotona collaris*) in northern Yukon

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Abstract
Collared Pika (*Ochotona collaris*) is a cold-adapted Beringian species that occurs on talus slopes and is sensitive to climate warming. Collared Pikas are patchily distributed throughout the sub-Arctic mountains of northwestern Canada and Alaska; however, information on their occurrence in the northern part of their distributional range is limited. In particular, no survey information is known from the southern Richardson Mountains and the Nahoni Mountains. We conducted aerial- and ground-based surveys to document Collared Pika occurrence and general habitat suitability in northern Yukon. We flew 505 km of aerial survey (not including ferrying to targetted survey areas) and performed ground surveys at 22 sites within the Richardson Mountains (including a portion of Dàadzàii Vàn Territorial Park) and the Nahoni Mountains in and adjacent to Ni'iinlii Njik (Fishing Branch) Territorial Park. Overall, suitable habitat for Collared Pikas was patchy in the mountains of northern Yukon—talus was sparse and many patches of talus appeared to be unsuitable. Collared Pikas were detected at eight of 22 (36%) sites visited, representing important new records for the species in the northern portion of their range. Our reconnaissance provides a first approximation of habitat suitability for Collared Pikas of the mountains of northern Yukon, as well as new records for the species in the region. These data are useful in better determining the contemporary distribution of Collared Pika through species distribution modelling, and may serve to identify areas for more detailed survey and monitoring initiatives for this climate-sensitive mammal.

Key words: Collared Pika; Dàadzàii Vàn Territorial Park; distributional range; Ni'iinlii Njik (Fishing Branch) Territorial Park; *Ochotona collaris*

Introduction
Collared Pika (*Ochotona collaris*) is a small, cold-adapted mammal that is Beringian in origin (Lanier and Olson 2013; Lanier *et al*. 2015) and patchily distributed throughout the sub-Arctic mountains of Alaska and northwestern Canada (MacDonald and Jones 1987). Collared Pika are closely associated with talus (i.e., boulder fields) that is interspersed by alpine meadows (MacDonald and Jones 1987; Franken and Hik 2004; Morrison and Hik 2007). Talus provides Collared Pikas with critical protection from predators and inclement weather; as such, they are rarely found far from this habitat. However, not all talus is suitable for Collared Pika. In Tombstone Territorial Park (central Yukon, Canada), for instance, Collared Pika occupancy was positively associated with large patches of talus that had an average rock size of 30–100 cm, and where *Dryas* spp. and *Carex* spp. were available within and adjacent to the patch (L.M. Andresen *et al.* unpubl. data). Given that talus is naturally patchy on the landscape, Collared Pikas have a fragmented distribution. They have limited dispersal ability and are subject to metapopulation dynamics—whereby local populations may periodically become extinct—leaving apparently suitable habitat variably occupied (Franken and Hik 2004; Morrison and Hik 2007).

In Canada, Collard Pika has been assessed as a species of Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), largely because of the threat of climate change (COSEWIC 2011). The region where the Collared Pika occurs is "experiencing climate-driven shifts in habitat, temperature, and precipitation at faster rates than elsewhere in Canada" (COSEWIC 2011). Climate-induced shrubification of alpine tundra (Danby and Hik 2007; Myers-Smith *et al.* 2011) is of chief concern regarding the persistence of Collared Pika populations, as is the depth and duration of snowpack (Morrison and Hik 2007). Local populations of Collared Pikas in southwestern Yukon have declined due to variability in snowpack (Morrison and Hik 2007). This demonstrated sensitivity to climate-induced changes to their habitat, coupled with poor dispersal ability and the fragmented nature of their habitats, make Collared Pikas particularly vulnerable to climate change (Morrison and Hik 2007, 2008; COSEWIC 2011). As such, Collared Pika may be a useful bioindicator of climate change impacts to alpine ecosystems (Morrison and Hik 2008).

To assess the range-wide impact of climate change on Collared Pika, wildlife managers require better information on the current species distribution. Precise location data also may be used to develop accurate spatial distribution models that can then be used to predict changes in distribution under different climate change scenarios (e.g., Li *et al.* 2015; Struebig *et al.* 2015). Detailed monitoring and systematic surveys of Collared Pika have occurred in southwestern Yukon (Morrison and Hik 2008) and Tombstone Territorial Park (Kukka *et al.* 2014); however, information on their occurrence in the northern part of their distributional range is limited. In particular, no survey information was known from the southern Richardson Mountains and the Nahoni Mountains (i.e., Ni'iinlii Njik [Fishing Branch] Territorial Park).

The purpose of this study was two-fold: 1) to survey for the presence of Collared Pika in the northern portion of their range, and 2) to conduct a rapid assessment of the habitat suitability for this species in the Richardson Mountains (including Dàadzàii Vàn Territorial Park) and in the Nahoni Mountains (including in Ni'iinlii Njik [Fishing Branch] Territorial Park) in northern Yukon. To do so, we undertook a reconnaissance survey for Collared Pika and their habitat, using aerial- and ground-based surveys. Our aim was to provide new information on Collared Pikas in the northern portion of their distributional range so that these data can inform habitat modelling, monitoring, and management planning, initiatives for this species at risk.

Methods

We surveyed for Collared Pikas and their habitat in northern Yukon, Canada, during 3–6 July 2018. Specifically, we searched for suitable habitat in the Richardson Mountains east and north of Eagle Plains, Yukon (including a portion of Dàadzàii Vàn Territorial Park), as well as in the Nahoni Mountains (including Ni'iinlii Njik [Fishing Branch] Territorial Park), south of Old Crow, Yukon (Figure 1). We used an AStar helicopter (AS350B3; Eurocopter, Marignane, France) to provide an aerial overview of the habitat conditions in the survey area, and to locate the apparently most suitable habitat for ground-based surveys. We flew 100–400 m above ground level at slow speeds (i.e., 100–120 km/h) in suitable terrain (i.e., mountains) and searched for areas of extensive talus slopes and investigated these more closely. Based on occupancy models developed for Collared Pika in Tombstone Territorial Park (L.M. Andresen *et al.* unpubl. data) that identified predictive habitat covariates, we created four habitat suitability ranks to apply to observed talus slopes (Table 1). We applied these to broadly characterize the suitability of the talus as Collared Pika habitat.

At select sites (n = 22) we landed and searched talus areas for Collared Pika presence. We attempted to select the most suitable talus sites for ground surveys (i.e., habitat suitability rank 3 or 4; Table 1); however, where no such habitat was apparent we elected to search lower ranked areas of talus to ensure that we covered the possibility that Collared Pikas were selecting these sites based on their availability. At each site 4–5 observers searched separate talus patches for approximately 30–60 minutes to detect the presence of Collared Pikas. We walked along the perimeter of the talus patch, and also traversed portions of the talus to intersect potential Collared Pika territories. Pikas (*Ochotona* spp.) are highly territorial and vocalize when conspecifics or other species (including humans) enter their territory (Conner 1984; Trefry and Hik 2009). As such, we largely relied on acoustically detecting Collared Pika (Moyer-Horner *et al.* 2012). We also used binoculars to periodically scan for Collared Pika within the talus; however, Collared Pika are cryptically-coloured to match talus, and may be difficult to visually observe if they are not moving or vocalizing. Finally, pikas build easily recognizable hay piles and latrines within the talus (MacDonald and Jones 1987), and we also used these signs to detect their presence (Morrison and Hik 2008; Moyer-Horner *et al.* 2012; L.M. Andresen *et al.* unpubl. data). For each site surveyed we assigned a habitat suitability rank of 1–4 (poor to excellent; Table 1).

Results and Discussion

We flew 505 km of survey effort for Collared Pika in northern Yukon (not including ferrying to targetted survey areas). This effort included low-level aerial survey of 158 and 178 km of potential Collared Pika habitat (i.e., mountain slopes) in the southern and northern Richardson Mountains, respectively, and 169 km of potential habitat in Ni'iinlii Njik (Fishing Branch) Territorial Park (Figure 1).

While some mountains observed had large patches of talus (e.g., approximately ≥5 ha; Figure 2), in general we did not observe extensive boulder fields in the same relative abundance as that found in Tombstone Territorial Park, likely because much of the Richardson and Nahoni mountains were unglaciated during the Last Glacial Maximum (Catto 1996). Quantity of talus, in general, was greatest during our survey in the northern Richardson Mountains, in and adjacent to Dàadzàii Vàn Territorial Park, with much of that observed being ranked as 3–4 (good–excellent) as Collared Pika habitat. In contrast, quantity of talus was low in the southern Richardson Mountains, and its suitability as Collared Pika habitat was ranked only as 1–2 (poor-marginal). Mountain peaks there were low and rounded and most talus observed was small (<30 cm) and unsuitable as Collared Pika habitat. Potential Collared Pika habitat was variable in the Nahoni Mountains, with some local areas having abundant talus of suitable characteristics (rank 2–4; marginal-excellent) and other areas have little talus available. Overall, we would rate the northern Richardson Mountains being most suitable as Collared Pika habitat in the areas we surveyed, although local areas in the Nahoni Mountains were also suitable. We observed little suitable Collared Pika habitat in the southern Richardson Mountains.

We detected Collared Pika presence at nine of 22

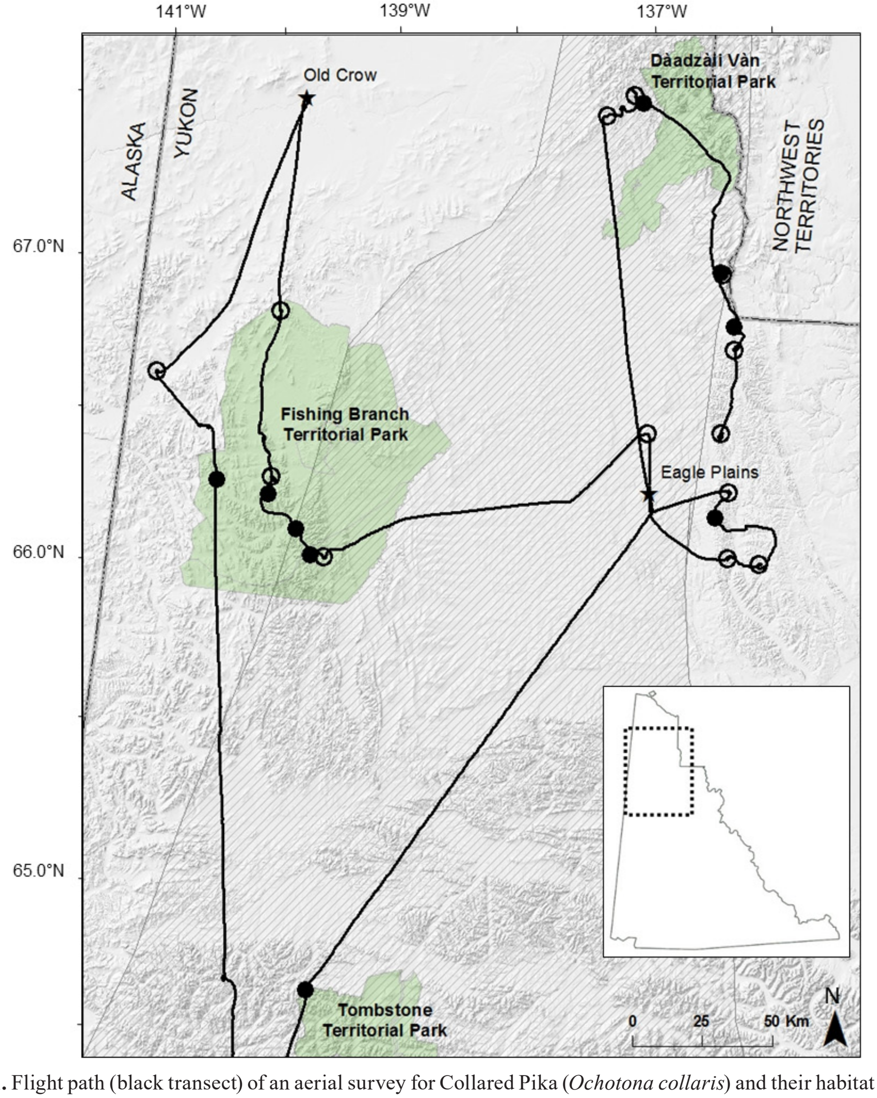

FIGURE 1. Flight path (black transect) of an aerial survey for Collared Pika (*Ochotona collaris*) and their habitat in northern Yukon. Closed circles are sites surveyed on the ground where Collared Pika was detected, and open circles where they were not detected. The stippled polygon represents the putative distributional range of Collared Pika (Lanier and Hik 2016). Stars indicate human settlements. Site numbers are in Table 2. The insert shows the study area situated within Yukon, Canada.

TABLE 1. Description of habitat suitability ranks given to areas surveyed for Collared Pika (*Ochotona collaris*) in northern Yukon, July 2018.

Habitat suitability rank	General description
1	Poor habitat quality: Average rock size <30 cm or >100 cm with many smaller rocks that fill in the interstitial spaces between the larger rocks.
2	Marginal habitat quality: Average rock size 30–100 cm, but with areas of extensive shrub cover in and around the talus, or with no to small amounts of *Dryas* spp. cover adjacent to talus, or many smaller rocks that fill in the interstitial spaces between the larger rocks.
3	Good habitat quality: Average rock size 30–50 cm; large area covered by talus slopes that are interspersed with non-shrubby patches of vegetation including *Dryas* spp.
4	Excellent habitat quality: Average rock size 50–100 cm; large area covered by talus slopes that are interspersed with non-shrubby patches of vegetation including extensive *Dryas* spp. cover.

FIGURE 2. Photograph of site 8 (see Table 2)—an example of the site characteristics where Collared Pika (*Ochotona collaris*) were observed in northern Yukon, Canada. Photo: J.H. Skevington.

sites surveyed on the ground (Table 2; Figure 1). One of these sites was just outside the northern boundary of Tombstone Territorial Park, where Collared Pika are already known and monitored (Kukka *et al.* 2014; Figure 1). We detected Collared Pika at three of five and one of seven sites surveyed in the northern and southern Richardson Mountains, respectively, and four of eight sites in the Nahoni Mountains (Figure 1). At two sites (sites 4 [Figure 3a] and 11; Table 2) we detected only old sign of Collared Pika, indicating that the population may have been extirpated. This included the single site where we detected Collared Pika in the southern Richardson Mountains (site 4, Table 2). Although our survey was not designed to estimate the density of Collared Pika at our sites, it appeared that they persisted at low densities at all the sites where they were detected. In only one instance did we detect more than a single individual at a site. In suitable habitat in southwestern Yukon, Collared Pika density is estimated at <1 to 4 individuals per ha (Morrison and Hik 2007).

Habitat suitability was variable among the 22 sites we surveyed on the ground, with 36% of them having poor-marginal (1–2 ranks) and 64% having good-excellent (3–4 ranks) habitat suitability ranks (Table 2). Collared Pikas were detected at only one of eight sites that were of poor-marginal habitat suitability, but they were detected at seven of 14 sites we classified as being of good-excellent habitat suitability (Figures 2 and 3). Anecdotally, the most limiting habitat features at the sites we surveyed were likely the average rock size being <50 cm, coupled with many sites having extensive shrubby vegetation in and around the talus (as opposed to *Dryas* spp. and other forage plants; L.M. Andresen *et al.* unpubl. data). The elevation where we detected Collared Pika was variable with a mean of 961.1 ± 175.8 m (SD; range = 685–1329 m; Table 2).

Other mammals or their sign (e.g., burrows, diggings, dens, scat, antlers) detected at our survey sites for Collared Pika included Grizzly Bear (*Ursus arctos*), Wolverine (*Gulo gulo*), Dall's Sheep (*Ovis dalli*), Caribou (*Rangifer tarandus*), Muskox (*Ovibos moschatus*), Moose (*Alces americanus*), Arctic Ground Squirrel (*Urocitellus parryii*), and small rodents (likely Singing Vole [*Microtus miurus*], Tundra Vole [*Microtus oeconomus*], Northern Red-backed Vole [*Myodes rutilus*], or Brown Lemming [*Lemmus trimucronatus*]; Table 2). Notably, we did not observe any sign of Hoary Marmot (*Marmota caligata*) during our survey. Moreover, Arctic Ground Squirrels were surprisingly not abundant at any of the sites we surveyed north of the Ogilvie Mountains, where there they are often on mountains associated with Collared Pika (T.S.J. pers. obs.). We detected Arctic Ground Squirrels at only six of 21 (29%) sites that were surveyed north of the Ogilvie Mountains.

Our reconnaissance of the mountains of northern Yukon provides a first approximation of habitat suitability for Collared Pikas, as well as important new records for the species, in the northern portion of their distributional range. These data are useful in determining the contemporary distribution of Collared Pika through species distribution modelling and may serve to identify areas for more detailed survey and monitoring initiatives for this

TABLE 2. Description of sites surveyed for Collared Pika (*Ochotona collaris*) in northern Yukon, 3–6 July 2018.

Site	Habitat rank*	Collared Pika detected	Detection type†	Location	Elevation (m)	Other mammals observed‡
1	3	Yes	1, 2	64.77657°N, 139.08717°W	1329	1, 2, 3, 6, 7
2	1	No	—	66.24000°N, 136.09439°W	1092	1, 2, 7
3	3	No	—	66.22826°N, 135.84087°W	771	1, 5, 7
4	2	Yes	3	66.36445°N, 136.21266°W	944	3, 5, 7
5	1	No	—	66.44556°N, 136.11227°W	851	1, 2, 7
6	1	No	—	66.62994°N, 136.20248°W	1205	1, 2, 7
7	2	No	—	66.89725°N, 136.13144°W	565	1, 3, 5, 7
8	3	Yes	2	66.96921°N, 136.14555°W	927	1, 2, 3, 7
9	4	No	—	67.13135°N, 136.26424°W	1011	1, 2, 3, 4, 7
10	3	Yes	2	67.13584°N, 136.27515°W	862	5, 6
11	4	Yes	3	67.65533°N, 137.01370°W	1047	1, 2, 3, 5, 6, 7
12	3	No	—	67.67641°N, 137.08986°W	941	2, 3, 7
13	4	No	—	67.60668°N, 137.31078°W	957	1, 2, 3, 7
14	2	No	—	66.61674°N, 136.79306°W	873	3
15	3	No	—	66.13930°N, 139.29184°W	994	1, 6, 7
16	3	Yes	2	66.14023°N, 139.39793°W	817	1, 5, 6, 7, 8
17	3	Yes	2	66.21690°N, 139.53180°W	685	5, 6, 7
18	4	Yes	1, 2, 3	66.31663°N, 139.78535°W	1120	1, 2, 3, 6, 7
19	1	No	—	66.37148°N, 139.77873°W	871	1, 5
20	2	No	—	66.89491°N, 139.85330°W	984	1, 2, 5, 6, 7
21	1	No	—	66.65713°N, 140.79265°W	680	5, 7
22	3	Yes	2	66.34312°N, 140.20544°W	919	5, 7

*See Table 1 for habitat suitability rank descriptions.
†Detection types as follows: 1 = visual, 2 = acoustic, 3 = sign (haypiles or latrines).
‡Codes for other mammals as follows: 1 = Grizzly Bear (*Ursus arctos*), 2 = Dall's Sheep (*Ovis dalli*), 3 = Caribou (*Rangifer tarandus*), 4 = Muskox (*Ovibos moschatus*), 5 = Moose (*Alces americanus*), 6 = Arctic Ground Squirrel (*Spermophilius parryii*), 7 = voles or lemmings, 8 = Wolverine (*Gulo gulo*).

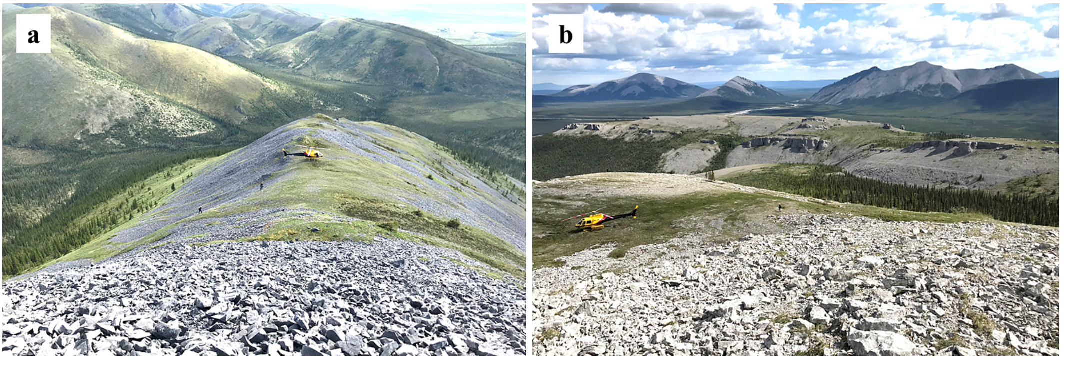

FIGURE 3. Photographs of the general habitat conditions at select survey sites for Collared Pika (*Ochotona collaris*) in the southern Richardson Mountains (a is site 4) and Nahoni Mountains (b is site 15) in northern Yukon, Canada. Photos: J.H. Skevington.

climate-sensitive mammal. We suggest that Collared Pika presence and habitat suitability was good in the northern Richardson Mountains, moderate-to-good in the Nahoni Mountains, and poor in the southern Richardson Mountains. We emphasize, however, that our work is preliminary in nature and our ability to thoroughly survey our target areas was limited; thus, this region would benefit from further survey effort. Preliminary habitat suitability mapping in northern Yukon, using imagery from remote sensing to map large patches of talus, would likely be helpful in determining other sites with a high probability of Collared Pika occurrence. We suggest that the northern Richardson Mountains (in and adjacent to Dàadzàii Vàn Territorial Park) would be an important area to focus future survey efforts, perhaps in conjunction with similar surveys for other small mammals of conservation interest in the region (e.g., collared lemmings [*Discrostonyx* spp.]; Jung *et al.* 2014).

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Literature Cited

Catto, N.R. 1996. Richardson Mountains, Yukon-Northwest Territories: the northern portal of the postulated 'ice-free corridor'. Quaternary International 32: 3–19. https://doi.org/10.1016/1040-6182(95)00062-3

Conner, D.A. 1984. The role of an acoustic display in territorial maintenance in the pika. Canadian Journal of Zoology 62: 1906–1909. https://doi.org/10.1139/z84-280

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2011. COSEWIC assessment and status report on the Collared Pika *Ochotona collaris* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario, Canada.

Danby, R.K., and D.S. Hik. 2007. Variability, contingency and rapid change in subarctic alpine tree line dynamics. Journal of Ecology 95: 352–363. https://doi.org/10.1111/j.1365-2745.2006.01200.x

Franken, R.J., and D.S. Hik. 2004. Influence of habitat quality, patch size and extinction dynamics of collared pika *Ochotona collaris*. Journal of Animal Ecology 73: 889–896. https://doi.org/10.1111/j.0021-8790.2004.00865.x

Jung, T.S., B.G. Slough, D.W. Nagorsen, and P.M. Kukka. 2014. New records of the Ogilvie Mountains Collared Lemming (*Dicrostonyx nuntakensis*) in central Yukon. Canadian Field-Naturalist 128: 265–268. https://doi.org/10.22621/cfn.v128i3.1605

Kukka, P.M., A. McCulley, M. Suitor, C.D. Eckert, and T.S. Jung. 2014. Collared pika (*Ochotona collaris*) occupancy in Tombstone Territorial Park, Yukon: 2013 survey results. Yukon Department of Environment Survey Report SR-14-01, Whitehorse, Yukon, Canada.

Lanier, H.C., and D.S. Hik. 2016. *Ochotona collaris*. The IUCN Red List of Threatened Species 2016: e.T41257A45182533. https://doi.org/10.2305/IUCN.uk.2016-3.rlts.t41257a45182533.en

Lanier, H.C., R. Massati, Q. He, L.E. Olson, and L.L. Knowles. 2015. Colonization from divergent ancestors: glaciation signatures on contemporary patterns of genomic variation in collared pikas (*Ochotona collaris*). Molecular Ecology 24: 3688–3705. https://doi.org/10.1111/mec.13270

Lanier, H.C., and L.E. Olson. 2013. Deep barriers, shallow divergences: reduced phylogeographic structure in the collared pika (Mammalia: Lagomorpha: *Ochotona collaris*). Journal of Biogeography 40: 466–476. https://doi.org/10.1111/jbi.12035

Li, R., M. Xu, M. Hang, G. Wong, S. Qiu, X. Li, D. Ehrenfeld, and D. Li. 2015. Climate change threatens giant panda protection in the 21st Century. Biological Conservation 182: 93–101. https://doi.org/10.1016/j.biocon.2014.11.037

MacDonald, S.O., and C. Jones. 1987. *Ochotona collaris*. Mammalian Species 281: 1–4. https://doi.org/10.2307/3503971

Morrison, S.F., and D.S. Hik. 2007. Demographic analysis of a declining pika *Ochotona collaris* population: linking survival to broad-scale climate patterns via spring snowmelt patterns. Journal of Animal Ecology 76: 899–907. https://doi.org/10.1111/j.1365-2656.2007.01276.x

Morrison, S.F., and D.S. Hik. 2008. When? Where? And for how long? Census design considerations for an alpine lagomorph, the collared pika (*Ochotona collaris*). *In* Lagomorph Biology. *Edited by* P.C. Alves, N. Ferrand, and K. Hackländer. Springer, Berlin, Heidelberg, Germany.

Moyer-Horner, L., M.M. Smith, and J. Belt. 2012. Citizen science and observer variability during American pika surveys. Journal of Wildlife Management 76: 1472–1479. https://doi.org/10.1002/jwmg.373

Myers-Smith, I.H., B.C Forbes, M. Wilmking, M. Hallinger, T. Lantz, D. Blok, K.D Tape, M. Macias-Fauria, U. Sass-Klaassen, E. Lévesque, S. Boudreau, P. Ropars, L. Hermanutz, A. Trant, L. Siegwart Collier, S. Weijers, J. Rozema, S.A. Rayback, N.M. Schmidt, G. Schaepman-Strub, S. Wipf, C. Rixen, C.B. Menard, S. Venn, S. Goetz, L. Andreu-Hayles, S. Elmendorf, V. Ravolainen, J. Welker, P. Grogan, H.E. Epstein, and D.S. Hik. 2011. Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters 6: 045509. https://doi.org/10.1088/1748-9326/6/4/045509

Struebig, M.J., M. Fischer, D.L.A. Gaveau, E. Meijaard, S.A. Wich, C. Gonner, R. Sykes, A. Wilting, and S. Kramer-Schadt. 2015. Anticipated climate and land-cover changes reveal refuge areas for Borneo's orangutans. Global Change Biology 21: 2891–2904. https://doi.org/10.1111/gcb.12814

Trefry, S.A., and D.S. Hik. 2009. Eavesdropping on the neighbourhood: collared pika (*Ochotona collaris*) responses to playback calls of conspecifics and heterospecifics. Ethology 115: 928–938. https://doi.org/10.1111/j.1439-0310.2009.01675.x

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Note

Occurrence of the rare marine littoral millipede, *Thalassisobates littoralis* (Diplopoda: Nematosomatidae), in Canada

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Abstract

The first Canadian occurrence of the rare, marine littoral millipede, *Thalassisobates littoralis*, is reported from Campobello Island in the outer Bay of Fundy, New Brunswick. One of only a few North American occurrences, this is the most northerly to date from the continent.

Key words: New Brunswick; marine habitat; marine millipede; dispersal; anthropochorus species; *Thalassisobates littoralis*

World-wide, *Thalassisobates littoralis* (Silvestri, 1903) (no common name) is one of the few marine littoral millipedes and is considered rare (Blower 1985; Barber 2009). The species occurs under stones and seaweed, in rock crevices or shingle in or above the tidal zone, and sometimes in coastal caves (Enghoff 1987; Cawley 1997). *Thalassisobates littoralis* has a wide but scattered distribution, with reports (often single) from the coasts of Europe, the Balearic Islands, Algeria, and the eastern United States (Enghoff 2013). The centre of its distribution appears to be the western Mediterranean basin (Kime 1999), with Kime (1999) suggesting that *T. littoralis* may have been introduced to northwestern Europe. Reporting the first North American occurrences, Enghoff (1987) speculated that the species was of European origin, but was uncertain whether its amphi-Atlantic distribution was natural or the result of human introduction. He noted that all amphi-Atlantic millipedes previously reported from North America, with one possible exception, can be regarded as introductions to the continent and that the direction of the Gulf Stream is not conducive to the natural dispersal of *T. littoralis* from Europe to North America. Thus, not unreasonably, *T. littoralis* has been considered of anthropochorus origin in North America (Kime 1999; Golovatch and Kime 2009).

Previously, *T. littoralis* has been recorded in North America only from the southwest shore of Chincoteague Island, Virginia, in 1964, from an unknown locale in Massachusetts (date unknown; Enghoff 1987), and, more recently (2005–2009), from six of the 34 islands that make up the Boston Harbor Recreation Area (Boston Harbor Islands 2014). Here, I document the first occurrence of *T. littoralis* from Canada and the most northerly to date on the North American continent.

On 24 September 2017, I found *T. littoralis* to be present, but patchily distributed, along a cobble shoreline at Herring Cove, in Herring Cove Provincial Park, Campobello Island, New Brunswick (44.85956°N, 66.93188°W), along the western shore of the Bay of Fundy. Millipedes were present under patches of decomposing Bladderwrack (*Fuscus vesiculosus*) above and below the high-water mark (Figure 1a). Where present, millipedes were abundant (Figure 1b). In a sample of 104 specimens, 55 females and 49 males were present, close to a 1:1 sex ratio. The whole body of a single male (Figure 1c) and a series of views of the male peltogonopods, diagnostic for *T. littoralis*, are shown in Figure 1d–f. Voucher specimens have been deposited in the New Brunswick Museum (NBM 10776).

After the discovery of *T. littoralis* on Campobello Island, two other cobble beach sites in New Brunswick were searched along the western coast of the Bay of Fundy (Alma, 45.596739°N, 64.948728°W, and Browns Beach, West Quaco, 45.319236°N, 65.551114°W), for *T. littoralis* without success. Further field investigations will be required to determine

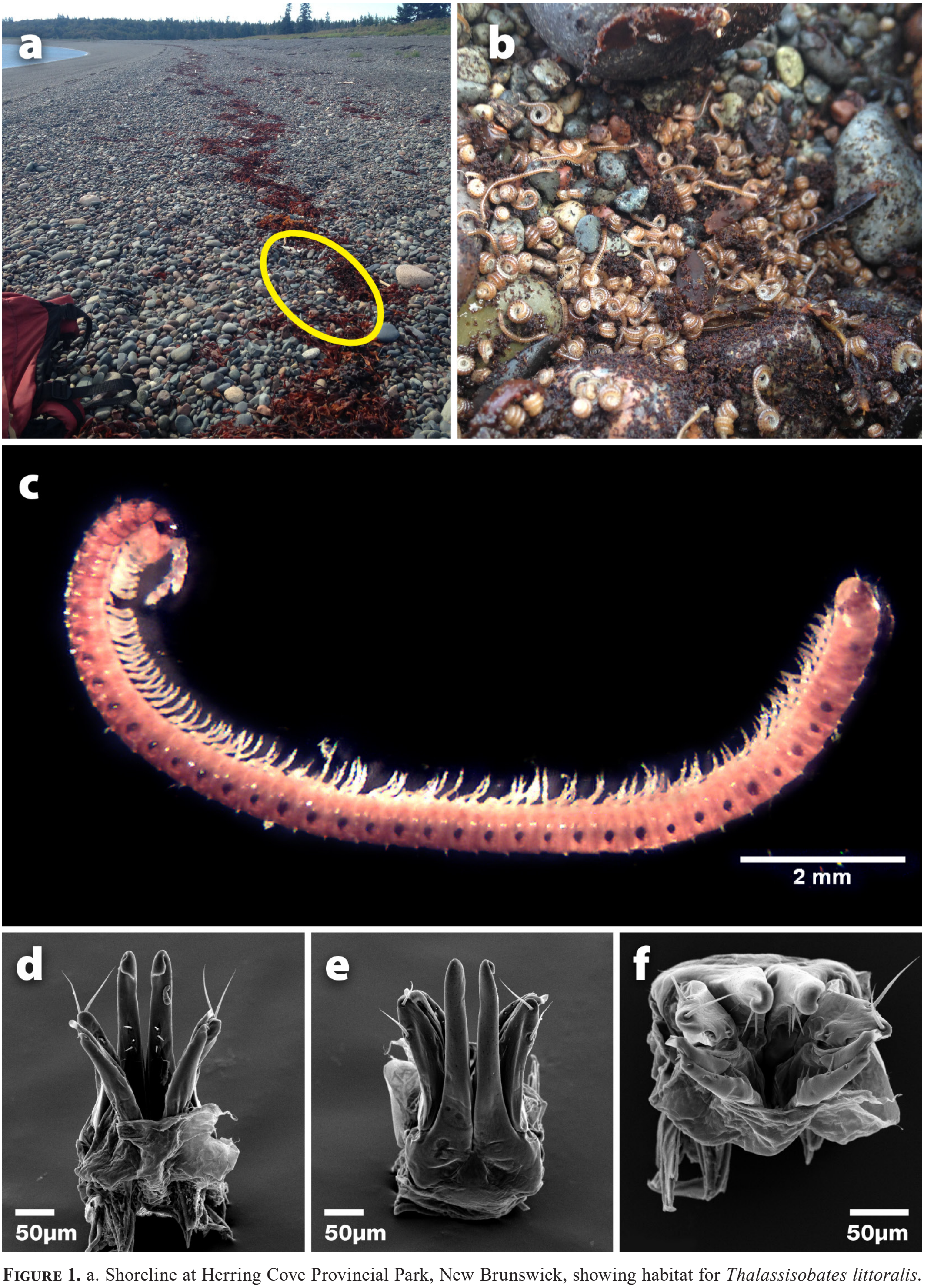

Figure 1. a. Shoreline at Herring Cove Provincial Park, New Brunswick, showing habitat for *Thalassisobates littoralis*. b. Concentration of millipedes under Bladderwrack (*Fuscus vesiculosus*). c. Habitus of male *T. littoralis*; scanning electron microscope images show d. superior, e. inferior, and f. distal views of the diagnostic peltogonopods. Photos: a–b. D.F. McAlpine. Photos: c–f. Nhu Trieu.

the full distribution and true abundance of *T. littoralis* in Atlantic Canada.

Acknowledgements

I thank Amber McAlpine-Mills for help in the field, investigating sites at Alma and West Quaco, New Brunswick. I also thank Nhu Trieu, of the University of New Brunswick Microscopy and Microanalysis Facility, for providing Figure 1c–f.

Literature Cited

Barber, A.D. 2009. Littoral myriapods: a review. Soil Organisms 81: 735–760.

Blower, J.G. 1985. Millipedes. E.J. Brill, London, United Kingdom.

Boston Harbor Islands. 2014. All taxa biodiversity inventory: list of specimens: *Thalassisobates littoralis*. President and Fellows of Harvard College, Boston, Massachusetts, USA. Accessed 14 October 2019. http://140.247.96.247/boston_islands/mantisweb/specimen_list_bhi.php?id=59261.

Cawley, M. 1997. Distribution records for uncommon millipedes (Diplopoda) including *Thalassisobates littoralis* (Silvestri) new to Ireland. Irish Naturalist Journal 25: 380–382.

Enghoff, H. 1987. *Thalassisobates littoralis* (Silvestri—an amphiatlantic millipede (Diplopoda, Julida, Nematosomatidae). Entomologist's Monthly Magazine 123: 205–206.

Enghoff, H. 2013. New montane, subterranean congeners of a littoral millipede, genus *Thalassisobates* (Diplopoda: Julida: Nemasomatidae). Journal of Natural History 47: 1613–1625. https://doi.org/10.1080/00222933.2012.759289

Golovatch, S.I., and R.D. Kime. 2009. Millipede (Diplopoda) distributions: a review. Soil Organisms 81: 565–597.

Kime, R.D. 1999. The continental distribution of British and Irish millipedes. Bulletin of the British Myriapod Group 15: 33–76.

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A practical technique for preserving specimens of duckmeal, *Wolffia* (Araceae)

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Abstract

Making identifiable herbarium vouchers of the minute aquatic vascular plant duckmeal, *Wolffia* (Lemnoideae; Araceae) has typically required plants to be preserved in transparent, space-consuming vials that are fragile, difficult to work with, and labourious to prepare. An alternative technique for dry-mounting *Wolffia* within a layer of transparent, acid-free glue presents a promising alternative. Although the largely water-filled individual plants still compress substantially, this preparation technique results in specimens that retain their colour, size, and, most important, their shape. This greatly enhances the possibility of confident identification and simplifies both specimen preparation and storage.

Key words: *Wolffia*; Lemnoideae; Araceae; herbarium specimen preparation; storage

Introduction

Dore (1957) described the difficulty collectors face in securing voucher specimens of duckmeal (*Wolffia* spp., Lemnoideae, Araceae; also known as watermeal) in a condition that permits their re-examination and identification. Three species of this minute, simple plant, which is uncommon to rare throughout most of its Canadian range, typically form dense, floating mats (Figure 1) consisting of thousands and even millions of individuals (Brunton 2018; Brunton and Bickerton 2018). At least two *Wolffia* species (Figure 2) are native in southern Ontario and Quebec (Crow and Hellquist 2000). Individuals of this, the smallest flowering plant in the world, shrivel up into greenish-brown dust when air dried as conventional vascular plant herbarium specimens (Figure 3). This deformation eliminates the possibility of further identification, which is heavily dependent on plant shape characteristics (Crow and Hellquist 2000). Accordingly, the potential use of such material for taxonomic or phytogeographic analysis is substantially reduced.

Dore's (1957) solution to that curatorial challenge was to place *Wolffia* samples in a preservative fluid (alcohol) in a sealed glass vial, which was then attached to a standard herbarium sheet. Although this technique permits the voucher plants to retain their shape and size, it is an involved process that results in a slurry of colourless plants floating in a cumbersome, fragile vessel that takes up considerable space in a conventional herbarium arrangement. Individual plants also move freely within the vial and are difficult to follow or relocate. Unless the vial is opened (necessitating repetition of the entire voucher preparation process), the view of individual plants is also obscured and distorted by the glass container. There is a risk of breakage or leakage of the vials, as is evident in Dore's collection preserved in the Agriculture and Agri-Food Canada herbarium (DAO). In addition, the alcohol-filled vials are sealed with a flame or heat, a process that requires some experience and poses potential hazards (P.M. Catling pers. comm. 14 March 2019). Although preferable to simply drying plants into an unrecognizable condition, the vial solution is a cumbersome and unsatisfying curatorial response.

The easy availability of high-quality digital imagery in the field now provides a practical enhancement of the traditional air-dried voucher technique, because hard-copy images of fresh (pre-dried) voucher material can be affixed to the voucher sheet. However, photographs are only two-dimensional representations and cannot be used for detailed morphological studies.

Discussions with numerous field botanists in eastern Canada have confirmed that the difficulty in securing reasonable quality *Wolffia* vouchers significantly discourages their collection. This represents a floristic and conservation problem in Ontario and Quebec where Northern Duckmeal (*Wolffia borealis* (Engelmann) Landolt & Wildi ex Gandhi, Wiersema & Brouillet) (= *Wolffia punctata* Grisebach) and Co-

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FIGURE 1. Dense duckmeal (*Wolffia* spp.) mat completely covering creek surface. 8 August 2011, Beachburg, Renfrew County, Ontario. Photo: D.F. Brunton.

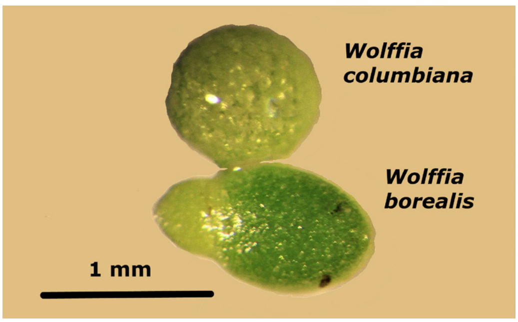

FIGURE 2. Fresh (live) Ontario native duckmeal (*Wolffia*) species. 31 July 2011, Peterborough County, Ontario, D.F. Brunton & K.L. McIntosh 17,896B. Photo: D.F. Brunton.

lumbia Duckmeal (*Wolffia columbiana* H. Kirsten) (= *Wolffia arrhiza* auct., non (L.) Horkel) are almost always regionally uncommon (Dore 1957; Soper 1962; Oldham 2017) and the possibly introduced Papillate Watermeal (*Wolffia brasiliensis* Weddell) is rare (Thomson 2005). Both *W. borealis* and *W. columbiana* are considered rare and of conservation concern in Quebec (Tardif *et al.* 2005). In addition, populations are increasingly being found beyond *Wolffia*'s traditional northern limit along the southern edge of the Canadian Shield in Ontario (Soper 1962), suggesting ongoing range expansion (Brunton 2018).

Does this change represent climate change? Increased populations of certain waterfowl species? Transportation by human activity? All of the above? That is not clear, but the range of *Wolffia* unquestionably is enlarging in Canada and new *Wolffia* occurrences must be recorded with voucher specimens to document this and assess its implications. Accordingly, a practical procedure for producing informative vouchers is an important part of addressing these questions.

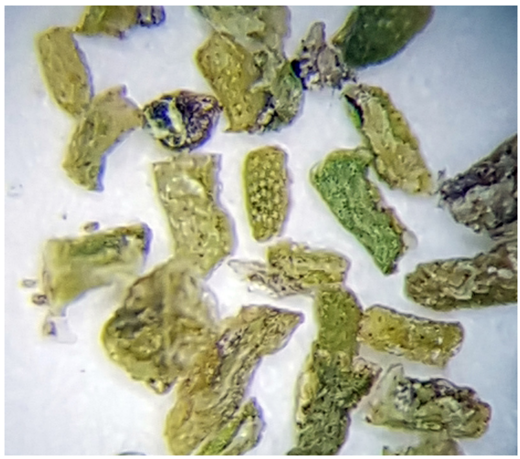

FIGURE 3. Shrivelled air-dried Northern Duckmeal (*Wolffia borealis*). 31 July 2011, Peterborough County, Ontario, D.F. Brunton & K.L. McIntosh 17,896B. Photo: D.F. Brunton.

The dry-mounted specimen preparation technique described in this paper is an adaptation of the method described by Brunton (1990) for securing mass samples of even smaller and more fragile megaspores of the aquatic lycophyte *Isoetes* (quillwort) in a readily examinable state. This new dry-mounting procedure has been used to prepare samples in approximately two dozen *Wolffia* collections to date. It has resulted in vouchers of superior quality and utility in comparison to most vouchers prepared using traditional methods.

Methods

A small (5–10 mL) sample of fresh *Wolffia* plants is placed in a plastic or glass vial with enough of the water-diluted (ca. 75% of full strength), acid-free glue commonly used in herbarium specimen preparation to maintain the sample free floating. The glue used here was commercially available Weldbond Universal Adhesive (Frank T. Ross & Sons Ltd., Markham Ontario, Canada). No attempt was made to assess the performance of other commercial brands of adhesive, but it is suspected that any water-soluble white herbarium glue would perform comparably. The sample is left to soak for ~48 h. The container is covered to prevent the glue from drying and solidifying. Because *Wolffia* plants are exceedingly buoyant, the slurry of plants is stirred periodically (two or three times in the course of the soaking period) to ensure thorough contact with the glue solution.

After about 25–30 h, the colour of the glue solution takes on a distinctively green cast. The *Wolffia* plants also appear to be less buoyant, floating lower in the solution and remaining submerged slightly longer when stirred. This is interpreted as indicating that the plants have become slightly waterlogged and that the glue has penetrated their tissues.

After ~48 h the slurry is spread (poured) onto a sheet of plain paper (a heavier gauge, pH neutral paper is recommended) or directly onto a herbarium sheet (White 100 Percent Rag Bond – neutral pH 20 or 24 lb; Herbarium Supply Co., Bozeman, Montana, USA) in as thin a layer as possible and allowed to air dry. Concentrations of plants on the mounting sheet can be thinned by gently passing a dissection needle or probe through them. This must be done immediately after the slurry has been poured, however, as the solution becomes too tacky for smooth manipulation within as little as 10 min. The sample (Figure 4) is dry and ready for examination or processing as a herbarium specimen within about 2 h.

Results

Applying this voucher preparation technique to over 30 samples of native Ontario *Wolffia* involving

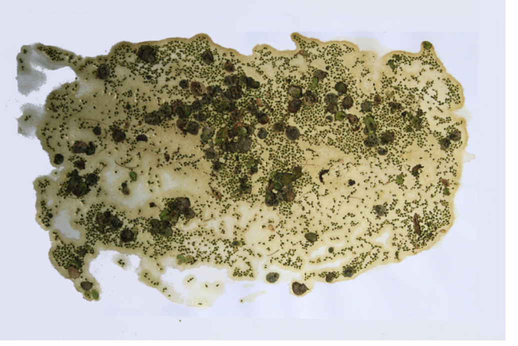

FIGURE 4. Sample of dried, glue-impregnated Columbia Duckmeal (*Wolffia columbiana*); larger intermixed plants are *Spirodella polyrhiza* (L.) Schleiden. 25 August 2017, Renfrew, Renfrew County, Ontario, D.F. Brunton & K. Fleming 19,783. Photo: D.F. Brunton.

23 separate collections (Appendix 1) has produced encouraging results. Although the dry, glue-impregnated plants are completely deflated and flattened, they have, for the most part, retained their original size, shape, and colour (Figure 5). Some aspects of their morphology remain evident: for example, the punctate (dotted) surface of *W. borealis* is clearly visible in the dried plants.

Rehydrating shrivelled, long-dried herbarium material may also be worthwhile. In the two samples tested, the glue solution did not become as green as it did with fresh material, suggesting that the rehydrating plants do not become as completely saturated. Nonetheless, the rehydrated material was more distinguishable than it would have been if specimens had only been air dried.

It is recommended that collectors making *Wolffia* vouchers include a packet of air-dried plants ("green dust") prepared in the traditional way as well. This typically indistinguishable air-dried material is potentially useful for chemical and molecular analyses. Ideally, photos of fresh plants should be included in the voucher. When used in combination with glue-impregnated plants, these additional specimen components provide the most complete vouchers possible for multidisciplinary investigations.

More extensive experimentation would refine the technique described here. It may well provide similarly satisfying results, for example, for other aquatic plants that occur in vast numbers of minute individuals, such as duckweed (*Lemna)*, duck-meat (*Spirodela*), and mud-midget (*Wolffiella*). A variation on this technique to accommodate larger specimens might also prove useful for the preservation of exceptionally delicate and/or fragile water nymph (*Najas*)*,* ditch-grass (*Ruppia*), horned pondweed (*Zannichellia*), and

FIGURE 5. Close-up of glue-impregnated Columbia Duckmeal (*Wolffia columbiana*) retaining shape and size. 25 August 2017, Renfrew, Renfrew County, Ontario, D.F. Brunton & K. Fleming 19,783. Photo: D.F. Brunton.

pondweed (*Potamogeton* and *Stuckenia*) plants in a more natural form. As currently understood, however, this technique provides a logistically simple, space-efficient, permanent preservation alternative for making *Wolffia* vouchers, for which there is an immediate need. The technique has the added benefit of being hazard free for the preparator and posing no curatorial risks to associated herbarium material.

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Literature Cited

Brunton, D.F. 1990. A device for the protection of spore samples from *Isoetes* (Isoetaceae) voucher specimens. Taxon 39: 226–228. https://doi.org/10.2307/1223021

Brunton, D.F. 2018. The changing distribution and extraordinary abundance of *Wolffia* in Ontario. Field Botanists of Ontario Newsletter 30(2). Accessed 15 March 2019. https://www.researchgate.net/publication/326719302_Wolffia_in_Ontario_FBO_2018.

Brunton, D.F., and H. Bickerton. 2018. New records for the

Eastern Mosquito-fern (*Azolla cristata*: Salviniaceae) in Canada. Canadian Field-Naturalist 132: 350–359. https://doi.org/10.22621/cfn.v132i4.2033

Crow, G.E., and C.B. Hellquist. 2000. Aquatic and wetland plants of northeastern North America, Volume Two Angiosperms: Monocotyledons. University of Wisconsin Press, Madison, Wisconsin, USA.

Dore, W.G. 1957. *Wolffia* in Canada. Canadian Field-Naturalist 71: 10–16. Accessed 15 March 2019. https://www.biodiversitylibrary.org/item/89178#page/22.

Oldham, M.J. 2017. List of the vascular plants of Ontario's Carolinian Zone (Ecoregion 7E). Ontario Ministry of Natural Resources and Forestry, Peterborough. https://doi. org/10.13140/RG.2.2.34637.33764

Soper, J.H. 1962. Some genera of restricted range in the Carolinian flora of Canada. Transactions of the Royal Canadian Institute 34 (Part 1): 3–56.

Tardif, B., G. Lavoie, et Y. Lachance. 2005. Atlas de la biodiversité du Québec. Ministère du Développement durable, de l'Environnement et des Parcs, Direction du développement durable, du patrimone écologique et des Parcs, Québec, Canada. Accessed 15 March 2019. https://tinyurl.com/y3794fcj.

Thomson, E.R. 2005. Papillate Watermeal, *Wolffia brasiliensis*, in eastern Ontario: an addition to the Flora of Canada. Canadian Field-Naturalist 119: 137–138. https://doi.org/10.22621/cfn.v119i1.97

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Appendix 1: *Wolffia* specimens prepared, partly or entirely, using the Weldbond technique. Herbarium acronyms of Thiers (continuously updated).

Wolffia borealis

Ontario: City of Ottawa, 45.36843°N, 75.79522°W, west end of Turtle Bay, southwest portion of Mud Lake, Britannia Conservation Area, D.F. Brunton 17,106, 7 September 2007 (DFB);

Ontario: City of Ottawa, 45.33572°N, 75.92777°W, in Shirley's Brook along south side of Trillium Woods, South March Highlands, Kanata, D.F. Brunton 17,125, 5 October 2007 (DFB);

Ontario: City of Ottawa, 45.39846°N, 75.96812°W, south end of Constance Lake by inlet of Constance Creek, West Carleton, D.F. Brunton 18,036, 13 August 2011 (CAN, DFB);

Ontario: City of Ottawa, 45.34581°N, 75.86959°W, abandoned sewage treatment plant 395 m south southeast of Range Road/Carling Avenue intersection, Nepean, D.F. Brunton 18,913A, 8 October 2014 (WIN, DFB);

Ontario: Frontenac County, 44.27868°N, 76.59344°W, west side of Collins Creek north side of Creeksford Road, Kingston, D.F. Brunton 18,050A, 24 August 2011 (WIN, DFB);

Ontario: Peterborough County, 44.76643°N, 78.49064°W, west side of White's Lake Road, north side of Crystal Lake, Galway & Cavendish Township, D.F. Brunton and K.L. McIntosh 17,986B, 12 July 2011 (DFB);

Ontario: Peterborough County, 44.38742°N, 77.97751°W, east side of mill pond by outlet, north side of Highway 7, east end of Norwood, Asphodel Township, D.F. Brunton 19,916, 6 September 2017 (DFB).

Wolffia columbiana

Ontario: City of Ottawa, 45.36843°N, 75.79522°W, west end of Turtle Bay, southwest portion of Mud Lake, Britannia Conservation Area, D.F. Brunton 17,107, 7 September 2007 (DFB);

Ontario: City of Ottawa, 45.33572°N, 75.92777°W, in Shirley's Brook along south side of Trillium Woods, South March Highlands, Kanata, D.F. Brunton 17,126, 5 October 2007 (DFB);

Ontario: City of Ottawa, 45.39846°N, 75.96812°W, south end of Constance Lake by inlet of Constance Creek, West Carleton, D.F. Brunton 18,035, 13 August 2011 (CAN, DFB);

Ontario: City of Ottawa, 45.34581°N, 75.86959°W, abandoned sewage treatment plant 395 m south-southeast of Range Road/Carling Avenue intersection, Nepean, D.F. Brunton 18,913B, 8 October 2014 (WIN, DFB);

Ontario: Frontenac County, 44.27868°N, 76.59344°W, west side of Collins Creek north side of Creeksford Road, Kingston, D.F. Brunton 18,050B, 24 August 2011 (WIN, DFB);

Ontario: Peterborough County, 44.38742°N, 77.97751°W, east side of mill pond by outlet, north side of Highway 7, east end of Norwood, Asphodel Township, D.F. Brunton 19,917, 6 September 2017 (DFB);

Ontario: Peterborough County, 44.76643°N, 78.49064°W, west side of White's Lake Road, north side of Crystal Lake, Galway & Cavendish Township, D.F. Brunton and K.L. McIntosh 17,986B, 312 July 2011 (WIN, UBC, DFB);

Ontario: Renfrew County, 45.5128°N, 76.7591°W, 650 m north of Highway 60 at southeast corner of Clubhouse Lake, west side of Renfrew Golf Club, Horton Geographic Township, D.F. Brunton and K. Fleming 19,873, 27 August 2017 (DFB).

Literature Cited

Thiers, B. [continuously updated]. Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. Accessed 15 March 2019. http://sweetgum.nybg.org/science/ih/.

The Canadian Field-Naturalist

Note

Sighting rates and prey of Minke Whales (*Balaenoptera acutorostrata*) and other cetaceans off Cormorant Island, British Columbia

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Abstract
From June to August 2012, we conducted over 500 h of visual surveys from Cormorant Island, British Columbia, to determine behaviour and habitat use patterns of nearby cetaceans. Seven species were documented, but Minke Whales (*Balaenoptera acutorostrata*) were by far the most common and were observed lunge feeding at the surface on 15 occasions. In addition, this species was documented surface lunge feeding on Pacific Herring (*Clupea pallasi*) and Pacific Sand Lance (*Ammodytes personatus*) on 32 occasions during vessel-based cetacean surveys around Cormorant Island between 2010 and 2014. Although Minke Whales are relatively uncommon in British Columbia, these results indicate that they can regularly be found in specific feeding areas during the summer.

Key words: Minke Whale; *Balaenoptera acutorostrata*; habitat use; feeding ground; Pacific Herring; *Clupea pallasi*; Pacific Sand Lance; *Ammodytes personatus*; Cormorant Island; British Columbia

The coastal waters of the eastern North Pacific are home to several species of cetaceans. Many have been exploited by humans and conservation concerns have made them the focus of extensive field studies in recent decades (Ford 2014). Important foraging habitats considered critical for recovery have been identified for depleted populations of Killer Whale (*Orcinus orca*), Humpback Whale (*Megaptera novaeangliae*), and Fin Whale (*Balaenoptera physalus*), and some populations of these species have become increasingly abundant and widespread in coastal waters in recent years (Ford *et al*. 2009, 2013, 2017; Nichol *et al*. 2018; Towers *et al.* 2015, 2018, 2019). Although the distribution and behaviour of less common cetacean species have been recorded (Ford 2014), the foraging ecology and habitat use patterns of some, such as Minke Whale (*Balaenoptera acutorostrata*), remain poorly understood.

Minke Whale is a small, migratory baleen whale that normally occurs in coastal waters of the eastern North Pacific between spring and fall (Towers *et al.* 2013). Despite a lack of human exploitation history in these waters, Minke Whales are relatively rare along the west coast of North America. Ship-based cetacean surveys between California and Washington have documented Minke Whales 18 times between 1991 and 2008 (Barlow and Forney 2007; Barlow 2010). Further north, in the coastal waters of British Columbia, surveys conducted by Williams and Thomas (2007) and Ford *et al.* (2010) detected only a combined total of 35 Minke Whales during 34 290 km of survey effort.

Directed photo-identification research on Minke Whales in British Columbia and Washington has also documented relatively few unique individuals with totals of only 38 identified between 1977 and 1987 (Dorsey *et al.* 1990) and 44 between 2005 and 2012 (Towers *et al.* 2013). Photo-identification data have not been compared between these periods, but at least one individual identified in the 1980s was also documented in the 2010s (J.R.T. unpubl. data). Several other individuals documented on more than one occasion show high degrees of inter- and intra-annual fidelity to certain coastal areas over long periods (Dorsey *et al*. 1990; Towers *et al*. 2013).

The feeding behaviour of Minke Whales can be difficult to determine because most of it occurs below the water surface. However, in Washington, Minke Whales have been reported surface feeding on Pacific Herring (*Clupea pallasi*) and Pacific Sand Lance (*Ammodytes personatus*) on 10 and two occasions, respectively (Hoelzel *et al.* 1989). Few data on Minke Whale prey have been reported in western Canada, but Minke Whales have also been observed lunge feeding at the surface around Cormorant Island off northeastern Vancouver Island (Towers *et al.* 2013).

The waters around Cormorant Island are relatively shallow compared to depths of other nearby waterways and the substrate is made up of glaciofluvial gravels and sand. Large tidal fluctuations (5 m) and varied bathymetry in this area result in strong currents (<10 km/h = <5 kts with anything over 2 kts generally considered to have an impact on the movements and behaviour of most commercial and recreational vessel traffic as well as most fish and marine mammals) and upwellings. These environmental variables combine to create favourable habitat for an array of marine species, including several cetaceans in addition to Minke Whales.

To study the behaviour and occurrence of these species non-invasively, we conducted systematic shore-based cetacean observations from Cormorant Island in the summer of 2012 while making concurrent underwater acoustic recordings. This note presents the visual results of this study combined with data from surface predation events by Minke Whales that were opportunistically documented from small research vessels around Cormorant Island from 2010 to 2014. The acoustic results of this study are reported in Nikolich and Towers (2018).

Visual observations of cetaceans were made from the north shore of Cormorant Island at 50°36.140′N, 126°56.820′W (Figure 1). Observers used naked eyes and 15 × 80 binoculars (Steiner, Greely, Colorado, USA) with built in magnetic (M) compass and reticle bar mounted on a leveled tripod (Velbon, Tokyo, Japan) to detect cetaceans over an arc of 160° (272°M–072°M). Visual surveys were conducted by two or more alternating observers for up to 13 h/day when Beaufort sea state levels were ≤2 (see http://www.wdcs.org/submissions_bin/WDCS_Shorewatch_Seastate.pdf for explanation of Beaufort sea

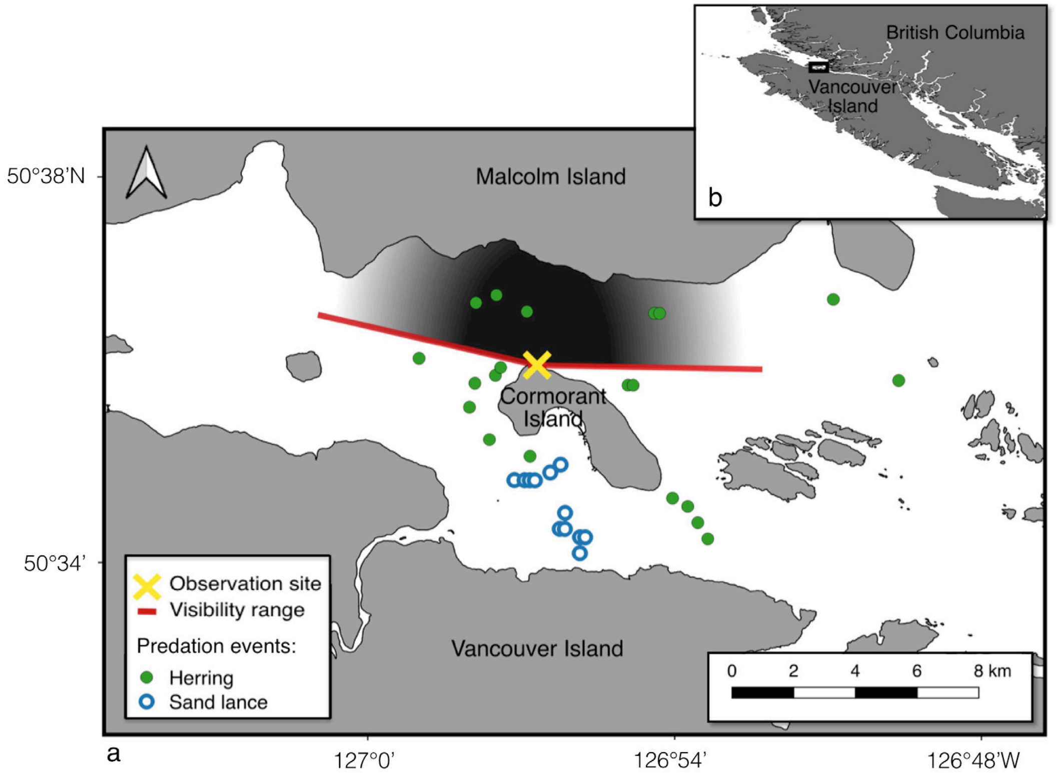

FIGURE 1. The study area off northeastern Vancouver Island, with a. showing the point on Cormorant Island from which observations were made, the arc of visibility, and the locations of Minke Whale (*Balaenoptera acutorostrata*) predation events and prey species documented from research vessels from 2010 to 2014 in relation to b. the south and central coasts of British Columbia.

states). Data, including Beaufort sea state, tide height, and notes on visibility, were recorded every 30 minutes of survey effort. The time, compass bearing, and reticle distance were recorded each time a cetacean surfaced (Nikolich and Towers 2018), but when Minke Whales and other species were present in the study area, priority was given to recording the surfacings of Minke Whales. The behaviour of cetaceans was noted when apparent, and an effort was made to identify individual whales visually when they were within range. Individual Minke Whale identifications were based on unique natural markings as described and shown in Towers (2011). To reduce any biases arising from animals being missed when sighting effort was focussed in another section of the study area, cetacean occurrence is portrayed in this paper as presence per unit effort (PPUE). A unit of effort was classified as 55–60 minutes of uninterrupted visual surveys and PPUE was defined as the number of effort units that the species was present divided by the total number of effort units.

Between 11 June and 15 August 2012, weather conditions allowed for observers to make shore-based visual surveys on 54 days: 20 in June, 19 in July, and 15 in August (Figure 2). In total, 513 units of visual survey effort were conducted. Seven species of cetaceans were documented: Minke Whale, Humpback Whale, Fin Whale, Bigg's Killer Whale (*Orcinus orca*; also known as West Coast Transient population), Dall's Porpoise (*Phocoenoides dalli*), Harbour Porpoise (*Phocoena phocoena*), and Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*; Figure 2). Minke Whales had the highest PPUE (0.44), as they were observed during 224 units of effort (Figure 2; Table 1). Six previously known and individually recognizable Minke Whales were visually identified (M001, M002, M003, M004, M006, and M022; Towers 2011). Harbour Porpoises were the second most commonly present species in the study area followed by Humpback Whales and Dall's Porpoises (Figure 2; Table 1). The species with the lowest PPUE was Fin Whale (Figure 2; Table 1). All species were documented transiting; although most species likely foraged at depth in the study area, only Minke Whales, Humpback Whales, and Bigg's Killer Whales were observed feeding at the surface. Bigg's Killer Whales were documented preying on a Dall's Porpoise on one occasion, and Minke and Humpback Whales were observed feeding on small schooling fish on 15 and two occasions, respectively. No relation between tidal activity and the foraging behaviour or occurrence of any species was detected.

Between 10 September 2010 and 7 August 2014, predation at the surface by Minke Whales around Cormorant Island was also opportunistically documented from small research vessels on 32 occasions (Figure 3; Table 2). Prey species were visually identified from photographs, video, or samples of remains collected near the surface with a dip-net after the feeding event. Of the predation events, 20 were on Pacific Herring and 12 were on Pacific Sand Lance (Figures 1 and 3; Table 2). Of the six photo-identified Minke Whales involved in these events (Table 2), five were visually documented during the shore-based component of this study.

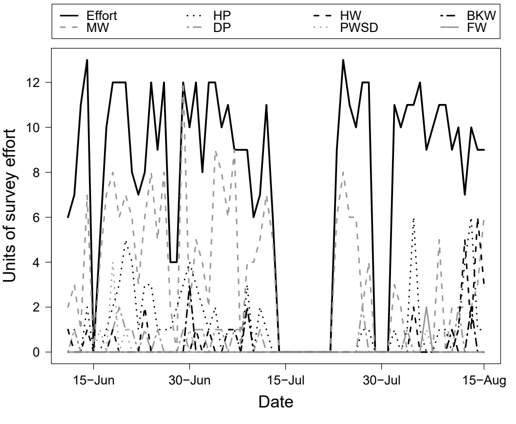

FIGURE 2. Units of survey effort and the presence per unit effort (PPUE) of each species of cetacean sighted between 11 June and 15 August 2012 off Cormorant Island, British Columbia. MW = Minke Whale (*Balaenoptera acutorostrata*), HP = Harbour Porpoise (*Phocoena phocoena*), HW = Humpback Whale (*Megaptera novaeangliae*), DP = Dall's Porpoise (*Phocoenoides dalli*), PWSD = Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*), BKW = Bigg's Killer Whale (*Orcinus orca*), and FW = Fin Whale (*Balaenoptera physalus*).

TABLE 1. Occurence of cetaceans and presence per unit effort (PPUE) based on sightings from the north shore of Cormorant Island, British Columbia, 11 June to 15 August 2012.

	MW	HP	HW	DP	PWSD	BKW	FW
Days observed	45	39	14	20	5	4	1
Sightings	1551	109	113	35	23	40	3
Units present	224	80	27	23	8	8	2
PPUE	0.44	0.16	0.05	0.04	0.02	0.02	0

Note: BKW = Bigg's Killer Whale (*Orcinus orca*), DP = Dall's Porpoise (*Phocoenoides dalli*), FW = Fin Whale (*Balaenoptera physalus*), HP = Harbour Porpoise (*Phocoena phocoena*), HW = Humpback Whale (*Megaptera novaeangliae*), MW = Minke Whale (*Balaenoptera acutorostrata*), and PWSD = Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*).

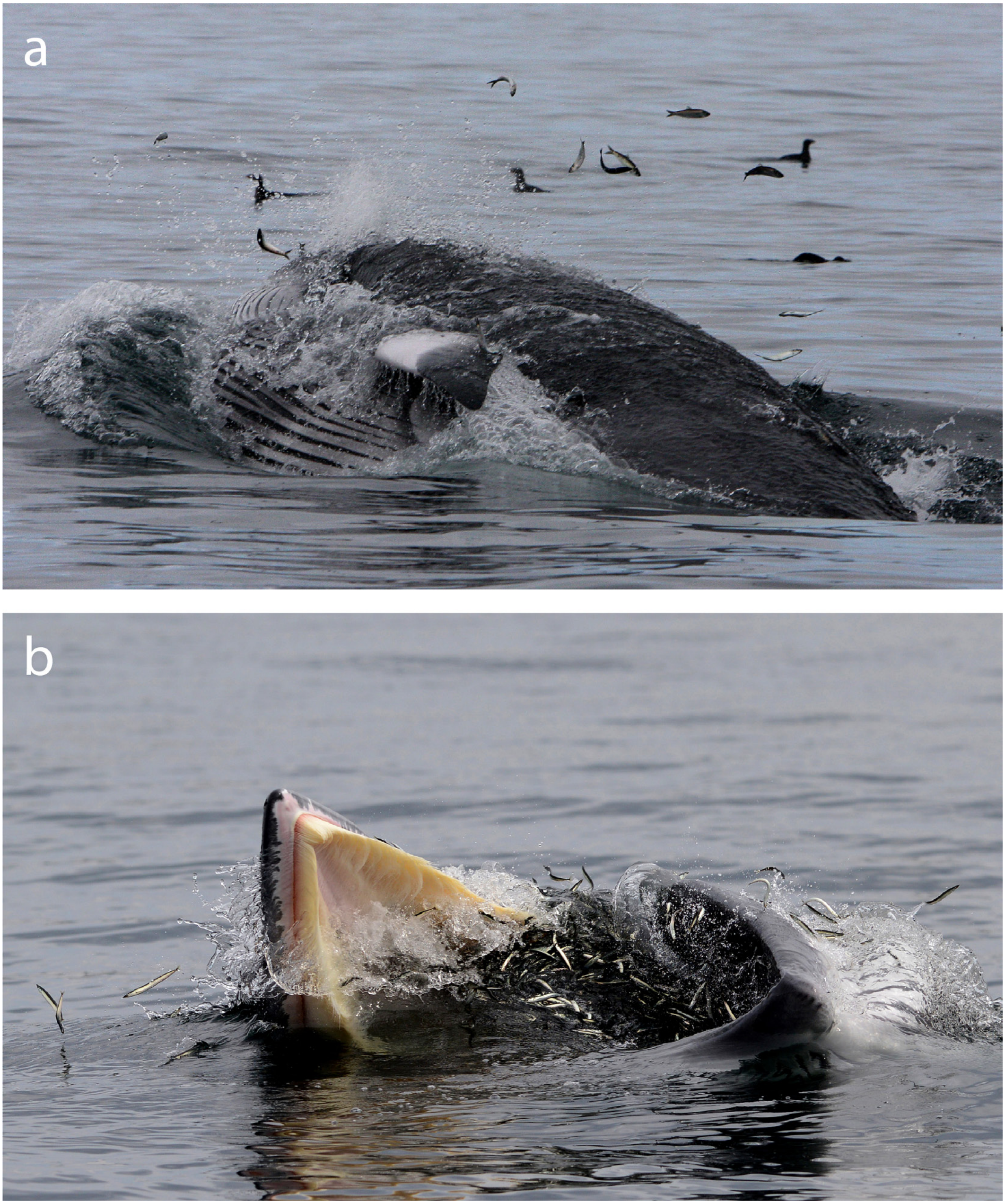

Figure 3. Minke Whale (*Balaenoptera acutorostrata*) M001 lunging on a. juvenile Pacific Herring (*Clupea pallasi)* on 18 July 2011 and b. juvenile Pacific Sand Lance (*Ammodytes personatus*) on 11 June 2014. Photos: Jared Towers.

Of the other species documented in this study, all but Bigg's Killer Whales are also known to feed on Pacific Herring (Walker *et al.* 1998; Morton 2000; Nichol *et al.* 2013; McMillan *et al.* 2018; Towers *et al.* 2018). Among them, at least the second, third, and fourth most commonly observed species in this study, Harbour Porpoise, Humpback Whale, and Dall's Porpoise also feed on Pacific Sand Lance (Walker *et al.* 1998; Nichol *et al.* 2013; Marine Education and Research Society unpubl. data). All species documented are relatively common in many coastal regions of the eastern North Pacific with the exception of Fin Whale. This species is rarely observed in the inshore waters around Vancouver Island and the individual

TABLE 2. Dates of foraging events by identified Minke Whales (*Balaenoptera acutorostrata*) around Cormorant Island, British Columbia, from 2010 to 2014, and prey species consumed: Pacific Herring (*Clupea pallasi*) and Pacific Sand Lance (*Ammodytes personatus*).

Date	Individual whale	Prey species
10 Sep. 2010	M004	Pacific Herring
10 Sep. 2010	M006	Pacific Herring
18 Jul. 2011	M001	Pacific Herring
27 Jul. 2011	M006	Pacific Herring
1 Aug. 2011	M022	Pacific Herring
18 Sep. 2011	M007	Pacific Herring
18 Sep. 2011	M007	Pacific Herring
15 Jul. 2012	M001	Pacific Sand Lance
15 Jul. 2012	M004	Pacific Sand Lance
15 Jul. 2012	M001	Pacific Sand Lance
15 Jul. 2012	M002	Pacific Sand Lance
16 Jul. 2012	M001	Pacific Sand Lance
16 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
18 Jul. 2012	M004	Pacific Sand Lance
20 Jul. 2012	M022	Pacific Herring
25 Jul. 2012	M001	Pacific Herring
26 Aug. 2012	M006 or M004	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
17 Jun. 2013	M001	Pacific Herring
11 Sep. 2013	M001	Pacific Herring
11 Jun. 2014	M001	Pacific Sand Lance
11 Jun. 2014	M001	Pacific Sand Lance
14 Jun. 2014	M006	Pacific Herring
1 Jul. 2014	M022	Pacific Herring
1 Jul. 2014	M022	Pacific Herring
31 Jul. 2014	M006	Pacific Herring
7 Aug. 2014	M001	Pacific Herring

observed is likely the same one photographed nearby the previous day as reported in Towers *et al.* (2018).

Although the species observed in this study are widely distributed throughout the eastern North Pacific (Ford 2014), the high rates of Minke Whale sightings compared with other cetacean species and numerous predation events recorded confirm this area as an important summer feeding ground for some individual Minke Whales that show intra- and inter-annual fidelity to these waters. To our knowledge, no other shore-based cetacean study in the eastern North Pacific has documented such high rates of Minke Whale occurrence, and the feeding observations reported here are among the first of this species in western Canada.

The environmental variables in the waters around Cormorant Island that create favourable habitat for Minke Whales and their prey are not unlike those documented in Minke Whale habitat in other regions. Minke Whale occurrence is positively correlated with shallow water that is near deeper water in Washington (Hoelzel *et al.* 1989) and Scotland (Robinson *et al.* 2009). The dynamic bottom topography of such areas often result in strong currents that drive upwelling and increase ocean productivity (Croll *et al.* 2005; Tynan *et al.* 2005). In addition, the sand and gravel substrate around Cormorant Island and in other areas where Minke Whales are often found in the western and eastern North Atlantic (Naud *et al.* 2003; MacLeod *et al.* 2004; Robinson *et al.* 2009; de Boer 2010) can provide suitable burrowing or rearing habitat for Minke Whale prey, such as Pacific Sand Lance (Bizzarro *et al.* 2016) and Pacific Herring (Hay and McCarter 2006), respectively. Further studies on Minke Whales off Cormorant Island could focus on relations between their occurrence and temporal fluctuations in the abundance and distribution of their prey and other environmental variables.

Author Contributions

Writing – Original Draft: J.T.; Writing – Review & Editing: J.T., C.M., and R.P.; Conceptualization: J.T.; Investigation: J.T., C.M., and R.P.; Methodology: J.T. and C.M.; Formal Analysis: J.T., C.M., and R.P.; Funding Acquisition: J.T.

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Literature Cited

Barlow, J. 2010. Cetacean abundance in the California current estimated from a 2008 ship-based line-transect survey. Technical memorandum NOAA-TM-NMFS-SWFSC-456. United States Department of Commerce, National Oceanic and Atmospheric Administration, La Jolla, California, USA.

Barlow, J., and K. Forney. 2007. Abundance and population density of cetaceans in the California current ecosystem. Fishery Bulletin 105: 509–26.

Bizzarro, J.J., A.N. Peterson, J.M. Blaine, J.P. Balaban, H.G. Greene, and A.P. Summers. 2016. Burrowing behaviour, habitat, and functional morphology of the Pacific sand lance (*Ammodytes personatus*). Fishery Bulletin 114: 445–460. https://doi.org/10.7755/fb.114.4.7

Croll, D.A., B. Marinovic, S. Benson, F.P. Chavez, N. Black, R. Ternullo, and B.R. Tershy. 2005. From wind to whales: trophic links in a coastal upwelling system. Marine Ecology Progress Series 289: 117–130. https://doi.org/10.3354/meps289117

de Boer, M.N. 2010. Spring distribution and density of minke whale *Balaenoptera acutorostrata* along an offshore bank in the central North Sea. Marine Ecology Progress Series 408: 265–274. https://doi.org/10.3354/meps08598

Dorsey, E.M., S.J. Stern, A.R. Hoelzel, and J. Jacobsen. 1990. Minke whale (*Balaenoptera acutorostrata*) from the west coast of North America: individual recognition and small-scale site fidelity. Report of the International Whaling Commission (special issue) 12: 357–368.

Ford, J.K.B. 2014. Marine Mammals of British Columbia. Royal BC Museum, Victoria, British Columbia, Canada.

Ford, J.K.B., R.M. Abernethy, A.V. Phillips, J. Calambokidis, G.M. Ellis, and L.M. Nichol. 2010. Distribution and relative abundance of cetaceans in western Canadian waters from ship surveys, 2002–2008. Canadian technical report of fisheries and aquatic sciences 2913. Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada.

Ford, J.K.B., J.F. Pilkington, A. Reira, M. Otsuki, B. Gisborne, R.M. Abernethy, E.H. Stredulinsky, J.R. Towers, and G.M. Ellis. 2017. Habitats of special importance to resident Killer Whales (*Orcinus orca*) off the west coast of Canada. Canadian Science Advisory Secretariat research document 2017/035. Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Ford, J.K.B., A.L. Rambeau, R.M. Abernethy, M.D. Boogaards, L.M. Nichol, and L.D. Spaven. 2009. An assessment of the potential for recovery of Humpback Whales off the Pacific coast of Canada. Canadian Science Advisory Secretariat research document 2009/015. Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Ford, J.K.B., E.H. Stredulinsky, J.R. Towers, and G.M. Ellis. 2013. Information in support of the identification of critical habitat for transient Killer Whales (*Orcinus orca*) off the west coast of Canada. Canadian Science Advisory Secretariat research document 2012/155. Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Hay, D.E., and P.B. McCarter. 2006. Herring spawning areas of British Columbia: a review, geographic analysis and classification. Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia, Canada.

Hoelzel, A.R., E.M. Dorsey, and S.J. Stern. 1989. The foraging specializations of individual minke whales. Animal Behaviour 38: 786–794. https://doi.org/10.1016/s0003-3472(89)80111-3

Macleod, K., R. Fairbairns, A. Gill, B. Fairbairns, J. Gordon, C. Blair-Myers, and E.C.M. Parsons. 2004. Seasonal distribution of minke whales *Balaenoptera acutorostrata* in relation to physiography and prey off the Isle of Mull, Scotland. Marine Ecology Progress Series 277: 263–274. https://doi.org/10.3354/meps277263

McMillan, C.J., J.R. Towers, and J. Hildering. 2018. The innovation and diffusion of "trap feeding," a novel humpback whale foraging strategy. Marine Mammal Science 35: 779–796. https://doi.org/10.1111/mms.12557

Morton, A. 2000. Occurrence, photo-identification and prey of Pacific white-sided dolphins (*Lagenorhyncus obliquidens*) in the Broughton Archipelago, Canada 1984–1998. Marine Mammal Science 16: 80–93. https://doi.org/10.1111/j.1748-7692.2000.tb00905.x

Naud, M., B. Long, J. Brêthes, and R. Sears. 2003. Influences of underwater bottom topography and geomorphology on minke whale (*Balaenoptera acutorostrata*) distribution in the Mingan Island (Canada). Journal of the Marine Biological Association of the United Kingdom 83: 889–896. http://doi.org/dskq9c

Nichol, L.M., R.M. Abernethy, B.M. Wright, S. Heaslip, L.D. Spaven, J.R. Towers, J.F. Pilkington, E.H. Stredulinsky, and J.K.B. Ford. 2018. Distribution, movements and habitat fidelity patterns of Fin Whales (*Balaenoptera physalus*) in Canadian Pacific Waters. Canadian Science Advisory Secretariat research document 2017/004. Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Nichol, L.M., A.M. Hall, G.M. Ellis, E. Stredulinsky, M. Boogaards, and J.K.B. Ford. 2013. Dietary overlap and niche partitioning of sympatric harbor porpoises and Dall's porpoises in the Salish Sea. Progress in Oceanography 115: 202–210. https://doi.org/10.1016/j.pocean.2013.05.016

Nikolich, K., and J.R. Towers. 2018. Vocalizations of common minke whales (*Balaenoptera acutorostrata*) in an eastern North Pacific feeding ground. Bioacoustics. https://doi.org/10.1080/09524622.2018.1555716

Robinson, K.P., M.J. Tetley, and E.G. Mitchelson-Jacob. 2009. The distribution and habitat preference of coastally occurring minke whales (*Balaenoptera acutorostrata*) in the outer southern Moray Firth, northeast Scotland. Journal of Coastal Conservation 13: 39–48. https://doi.org/10.1007/s11852-009-0050-2

Towers, J.R. 2011. Minke Whales of the Straits off Northeastern Vancouver Island (Second Edition). Marine Education and Research Society, Alert Bay, British Columbia, Canada.

Towers, J.R., G.M. Ellis, and J.K.B. Ford. 2015. Photo-identification catalogue and status of the northern resident Killer Whale population in 2014. Canadian technical report of fisheries and aquatic sciences 3139. Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Towers, J.R., M. Malleson, C.J. McMillan, J. Cogan, S. Berta, and C. Birdsall. 2018. Occurrence of fin whales (*Balaenoptera physalus*) between Vancouver Island and continental North America. Northwestern Naturalist 99: 49–57. https://doi.org/10.1898/nwn17-16.1

Towers, J.R., C.J. McMillan, M. Malleson, J. Hildering, J.K.B. Ford, and G.M. Ellis. 2013. Seasonal movements and ecological markers as evidence for migration of common minke whales photo-identified in the eastern North Pacific. Journal of Cetacean Research and Management 13: 221–229.

Towers, J.R., G.J. Sutton, T.J.H. Shaw, M. Malleson, D. Matkin, B. Gisborne, J. Forde, D. Ellifrit, G.M. Ellis, J.K.B. Ford, and T. Doniol-Valcroze. 2019. Photo-identification catalogue, population status, and distribution of Bigg's killer whales known from coastal waters of British Columbia, Canada. Canadian technical report of fisheries and aquatic sciences 3311. Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Tynan, C.T., D.G. Ainley, J.A. Barth, T.J. Cowles, S.D. Pierce, and L.B. Spear. 2005. Cetacean distributions relative to ocean processes in the northern California Current system. Deep-Sea Research II 52: 145–167. https://doi.org/10.1016/j.dsr2.2004.09.024

Walker, W.A., M.B. Hanson, R.W. Baird, and T.J. Guenther. 1998. Food habits of the harbor porpoise, *Phocoena phocoena*, and the Dall's porpoise, *Phocoenoides dalli*, in the inland waters of British Columbia and Washington. Pages 63–75 *in* Marine Mammal Protection Act and Endangered Species Act Implementation Program 1997. AFSC processed report 98-10. National Marine Fisheries Service, Seattle, Washington, USA.

Williams, R., and L. Thomas. 2007. Distribution and abundance of marine mammals in the coastal waters of British Columbia, Canada. Journal of Cetacean Research and Management 9: 15–28.

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Use of salmon (*Oncorhynchus* spp.) by Brown Bears (*Ursus arctos*) in an Arctic, interior, montane environment

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Abstract
Salmon (*Oncorhynchus* spp.) is a key dietary item for temperate coastal Brown Bears (*Ursus arctos*) across much of their circumpolar range. Brown Bears living in Arctic, interior, and montane environments without large annual runs of salmon tend to be smaller bodied and occur at much lower densities than coastal populations. We conducted ground and aerial surveys to assess whether Brown Bears fished for salmon above the Arctic Circle, in and around Gates of the Arctic National Park and Preserve. Here, we document the use of salmon by interior Brown Bears in the Arctic mountains of the central Brooks Range of Alaska. We believe our findings could be important for understanding the breadth of the species' diet across major biomes, as well as visitor safety in the park and Brown Bear conservation in the region.

Key words: Alaska; Brown Bear; diet; fishing; mountains; *Oncorhynchus* spp.; salmon; *Ursus arctos*; Brooks Range

Introduction

In temperate environments, Brown Bears (*Ursus arctos*) feed extensively on salmon (*Oncorhynchus* spp.; Hilderbrand *et al.* 1999a; Mowat and Heard 2006). The abundance of salmon in some river systems and their high nutritional value allow Brown Bears in these areas to grow much larger and live at much higher densities than Brown Bear populations without predictable access to seasonal marine resources (Hilderbrand *et al.* 1999a,b; Mowat and Heard 2006). For example, Brown Bears living in interior regions are often much smaller than coastal conspecifics and occur at much lower densities (Hildebrand *et al.* 2018a,b). Substantively lower resource availability is thought to be a major determinant of both body size and population density (Hilderbrand *et al.* 1999a,b; Mowat and Heard 2006). Bears use terrestrial protein sources (Caribou [*Rangifer tarandus*], Arctic Ground Squirrels [*Spermophilus parryii*], and Moose [*Alces americanus*]), as well as plants, nuts, and other foods when access to marine resources, such as salmon, is limited (Welch *et al.* 1997; Rode *et al.* 2001; Gau *et al.* 2002; Mowat and Heard 2006), in areas such as the Arctic, interior, montane environments of the central Brooks Range of Alaska.

Reports from local aircraft pilots of Brown Bears congregating along Arctic rivers during August and September have been received by the National Park Service (NPS) as early as 2008, although use of salmon by Brown Bears has never been reported in the central Brooks Range or in many other Arctic regions (e.g., MacHutchon and Wellwood 2003; Mowat and Heard 2006). In 2014, the NPS initiated a Brown Bear monitoring project. Global positioning system (GPS) data collected by that project indicated that Brown Bears in the interior mountains of the Brooks Range did indeed spend extended periods along larger river corridors from July through September.

Our goal was to document the timing and location of salmon use by Brown Bears in the central Brooks Range by direct observation. A better understanding of Brown Bear resource use in the region could be useful in determining the breadth of the species' diet across major biomes, as well as locally, for visitor management and Brown Bear conservation.

Methods

We conducted a survey of Brown Bears fishing in and around Gates of the Arctic National Park and Preserve (GANPP; Figure 1). GANPP encompasses an interior Arctic ecosystem characterized by the mountainous terrain of the Brooks Range, extensive spruce (*Picea* spp.) forests and lowland riparian areas on the range's southern flanks, and tundra on its northern side (Wilson *et al.* 2014). The headwaters of three major river systems begin in GANPP:

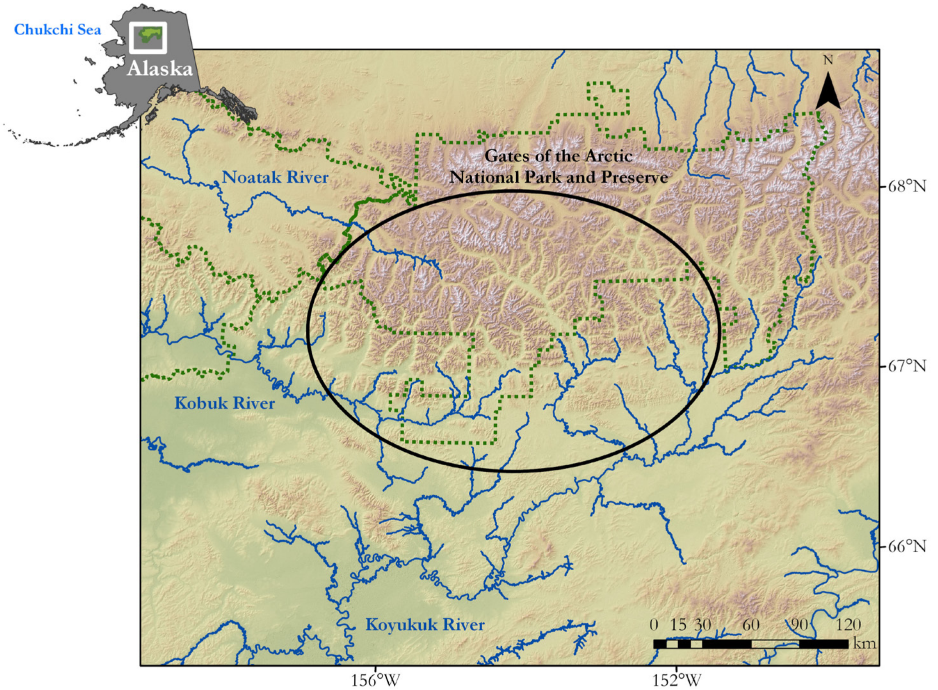

FIGURE 1. Study area (black oval) in the central Brooks Range mountains in Arctic Alaska.

the Kobuk, Koyukuk, and Noatak rivers. The Kobuk River drains west about 550 km (river length) to the Chukchi Sea (part of the Arctic Ocean) with most of the major tributaries arising in the southern Brooks Range. The Koyukuk River, a major tributary of the Yukon River, drains southwest for 1870 river-km from GANPP to the Bering Sea. The Noatak River drains northwest about 660 river-km to the Chukchi Sea, with all of its major tributaries arising in the northern Brooks Range.

Site-specific salmon escapement numbers are not available for our study areas, as these counts usually focus on commercial fisheries in salt water and specific freshwater streams important for sport or subsistence fishing. However, each of GANPP's three main rivers has runs of Chum Salmon (*Oncorhynchus keta*) and Chinook Salmon (*Oncorhynchus tshawytscha*) from mid-July to early September (O'Brien and Berkgiler 2005).

We visited one tributary in each of GANPP's three main river systems to document use of salmon by Brown Bears in the region. The specific locations visited were determined from GPS collared bears (n = 33) or reports by pilots and were accessible by wheeled or float plane. (For more information about our collaring efforts, which were in accordance with the guidelines of the American Society of Mammalogists [Sikes and Gannon 2011] and approved by United States Geological Survey and NPS Institutional Animal Care and Use Committees [IACUCs; 2014-1 and 2014A2, respectively], see Hilderbrand *et al.* 2018a.)

In 2016, we surveyed 8 km of the Kobuk River system (Table 1). In 2017, we surveyed 2 km of the Noatak River system and 8 km of the Koyukuk River system (Table 1). Our surveys involved walking along river banks and/or floating down streams in a raft to identify signs of bears fishing (e.g., fish carcass, scat, or observations of bears fishing) and document the presence of salmon species. Along the Noatak River system, we used a vantage point above an area that we suspected bears used for fishing to look for bears using a 20 × 60 spotting scope.

Results

During each stream visit, we observed bears fishing or identified recent signs of fishing activity (i.e., salmon gill plate, mandible, carcass, or bear scat with fish remains in it; Table 1). On the Kobuk River system, 17 August 2016, we found a large pile of fresh gill plates (Figure 2) along a sharp bend in the river where a deep pool had formed. Although we did not observe a bear fishing, we surmised that bears were diving for the salmon carcasses that we observed lying at the bottom of the pool.

On the Koyukuk River system, 2 August 2017, we observed an adult male fishing by "snorkeling" upstream in ~1.5 m of water and another adult male fish-

TABLE 1. Observations of Brown Bears (*Ursus arctos*) using salmon (*Oncorhynchus* spp.) in the central Brooks Range, Alaska, 2016–2017.

River system	Observation	Dates	Notes
Kobuk	Salmon gill plates	17 August 2016	Fresh pile of plates found adjacent to a deep pool formed at bend in river
	Fresh bear tracks	1–4, 17, 29 August 2016 9–10 September 2016	Single bears and family groups
	1 bear*	29 August 2016	Adult fishing near Chum Salmon
Koyukuk	1 bear*	4 August 2016	Adult fishing near Chum Salmon
	1 male bear	2 August 2017	Large male snorkeling upstream in 1.5 m of water
	1 male bear	2 August 2017	Large male fishing along a shallow side stream
	1 male bear	21 August 2017	Large male fishing along a shallow portion of river
	Salmon gill plates	22 August 2017	Fresh pile of plates found along bank of river
Noatak	3 bears	28 July 2017	A Brown Bear family group fishing at the confluence
	11 bears	29 August 2017	8 independent bears and 1 sow with 2 2-year-old cubs fishing along 2 km of river
	1 male bear	30 August 2017	Male bear fishing along a shallow side stream

*Aerial survey; all other observations were made during ground-based surveys.

ing along a shallow (<0.5 m) portion of the stream.

On 29 August 2017, we spent 4 h observing bears fishing from a vantage point above the Noatak River. We observed 11 bears (eight independent adults and one female with two 2-year-old cubs) using ~2 km of stream. Each adult was observed catching at least one salmon. Most bears either walked upstream along the bank or in the stream to locate and catch spawning Chum Salmon (Figure 3). All bears fished along a small (<250 m) section of stream and were often close to other bears.

We also documented the presence and spawning activity of Chum Salmon at each stream.

FIGURE 2. Salmon remains (jaws and gill plates) found along a tributary of the Koyukuk River, Alaska, 22 August 2017. Piles such as these were common along well-worn game trails at the river edge. Photo: Matthew Cameron, National Park Service.

Discussion

Our surveys substantiate earlier reports that interior, montane Brown Bears in the Arctic fish for salmon. Although the Brown Bears we studied lived about 400 km inland (or 550–1800 river-km from the coast), Chum Salmon were present and used by Brown Bears. Our findings build on past research that evaluated broad diet patterns of Brown Bears across North America (Mowat and Heard 2006). Even though salmon occur in streams throughout the Brooks Range, Mowat and Heard (2006) reported no use of salmon by Brown Bears in the central Brooks Range. Our observations of Brown Bears fishing for salmon across multiple river systems throughout the central Brooks Range provide evidence that salmon are not only used by bears here, but are likely an important seasonal food resource in the region.

Many interior populations of Brown Bears rely solely on terrestrial food resources, such as green vegetation, berries, and ungulates to satisfy their nutritional requirements (Gau *et al.* 2002; MacHutchon and Wellwood 2003; Mowat and Heard 2006). However, if available, some interior bear populations consume salmon (Belant *et al.* 2006). In the Arctic interior, food is even more limited for bears, as the growing season is short and ungulate densities are quite low and sparsely distributed over vast areas (Gasaway *et al.* 1992). Thus, where salmon resources are available, they likely play an important dietary role for bears living in the Arctic interior and may alter their distribution, body size, and population density (Hilderbrand *et al.* 1999a; Deacy *et al.* 2016, 2019).

FIGURE 3. A Brown Bear (*Ursus arctos*) successfully acquiring a salmon (*Oncorhynchus* spp.) from a tributary of the Noatak River, central Brooks Range Alaska, 30 August 2017. Photo: Mathew Sorum, National Park Service.

Consumption of salmon by Brown Bears provides a direct avenue for nutrient and energy transfers from marine to lotic to terrestrial systems (Hilderbrand *et al.* 1999c). Inputs of marine-derived nutrients into a terrestrial system creates cascading effects across trophic levels via increased productivity (Mathewson *et al.* 2003; Winder *et al.* 2005), and the effects are likely compounded in a nutrient-limited system, such as GANPP. Ultimately, this relationship creates biological hotspots with higher productivity, species diversity, and richness (Naiman *et al.* 2002). Identification of these areas is important for conservation and preservation of these important ecological systems. For example, areas of congregating Brown Bears in this low-density system may warrant additional hunting and/or visitation restrictions in the future to avoid overhunting and/or disturbance during the critical period of hyperphagia.

Identification and further elucidation of the relation between salmon and bears in interior ecosystems will improve the understanding and management of population dynamics of both predators and their prey. Future research should consider estimating the composition of salmon in the diet of Brown Bears and the influence of salmon on seasonal distribution and habitat selection patterns of bears.

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Literature Cited

Belant, J.L., K. Kielland, E.H. Follmann, and L.G. Adams. 2006. Interspecific resource partitioning in sympatric ursids. Ecological Applications 16: 2333–2343. https://doi.org/10.1890/1051-0761(2006)016[2333:irpisu]2.0.co;2

Deacy, W., W. Leacock, J.B. Armstrong, and J.A. Stanford. 2016. Kodiak brown bears surf the salmon red wave: direct evidence from GPS collared individuals. Ecology 97: 1091–1098. https://doi.org/10.1890/15- 1060.1

Deacy, W.W., W. Leacock, J.A. Stanford, and J.B. Armstrong. 2019. Variation in spawning phenology within salmon populations influences landscape-level patterns of brown bear activity. Ecosphere 10: eo2575. https://doi.org/10.1002/ecs2.2575

Gasaway, W.C., R.D. Boertje, D.V. Grangaard, D.G. Kelleyhouse, R.O. Stephenson, and D.G. Larsen. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Monographs 120: 3–59.

Gau, R.J., R. Case, D.F. Penner, and P.D. McLoughlin. 2002. Feeding patterns of barren-ground grizzly bears in the central Canadian Arctic. Arctic 55: 339–344. https://doi.org/10.14430/arctic717

Hilderbrand, G.V., D.D. Gustine, B.A. Mangipane, K. Joly, W. Leacock, L.S. Mangipane, J. Erlenbach, M.S. Sorum, M.D. Cameron, J.L. Belant, and T. Cambier. 2018a. Body size and lean mass of brown bears across and within four diverse ecosystems. Journal of Zoology 305: 53–62. https://doi.org/10.1111/jzo. 12536

Hilderbrand, G.V., D.D. Gustine, B. Mangipane, K. Joly, W. Leacock, L. Mangipane, J. Erlenbach, M.S. Sorum, M.D. Cameron, J.L. Belant, and T. Cambier. 2018b. Plasticity in physiological condition of female brown bears across diverse ecosystems. Polar Biology 41: 773–780. https://doi.org/10.1007/s00300-017-2238-5

Hilderbrand, G.V., T.A. Hanley, C.T. Robbins, and **C.C. Schwartz.** 1999c. Role of brown bears (*Ursus arctos*) in the flow of marine nitrogen into a terrestrial ecosystem. Oecologia 121: 546–550. https://doi.org/10.1007/s004420050961

Hilderbrand, G.V, S.G. Jenkins, C.C. Schwartz, T.A. Hanley, and C.T. Robbins. 1999b. Effect of seasonal differences in dietary meat intake on changes in body mass and composition in wild and captive brown bears. Canadian Journal of Zoology 77: 1623–1630. https://doi.org/10.1139/z99-133

Hilderbrand, G.V, C.C. Schwartz, C.T. Robbins, M.E. Jacoby, T.A. Hanley, S.M. Arthur, and C. Servheen. 1999a. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. Canadian Journal of Zoology 77: 132–138. https://doi.org/10.1139/cjz-77-1-132

MacHutchon, G.A., and D.W. Wellwood. 2003. Grizzly bear food habits in northern Yukon, Canada. Ursus 14: 225–235.

Mathewson, D.D., M.D. Hocking, and T.E. Reimchen. 2003. Nitrogen uptake in riparian plant communities across a sharp ecological boundary of salmon density. BMC Ecology 3: 4–15. https://doi.org/10.1186/1472-6785-3-4

Mowat, G., and D.C. Heard. 2006. Major components of grizzly bear diet across North America. Canadian Journal of Zoology 84: 473–489. https://doi.org/10.1139/z06-016

Naiman, R.J., R.E. Bilby, D.E. Schindler, and J.M. Helfield. 2002. Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. Ecosystems 5: 399–417. https://doi.org/10.1007/s10021-001-0083-3

O'Brien, J.P., and B.L. Berkgiler. 2005. Abundance and run timing of adult salmon in Henshaw Creek, Kanuti National Wildlife Refuge, Alaska, 2004: 23. Alaska fisheries data series 2005-15. United States Fish and Wildlife Service, Fairbanks, Alaska, USA.

Rode, K.D., C.T. Robbins, and L.A. Shipley. 2001. Constraints on herbivory by grizzly bears. Oecologia 128: 62–71. https://doi.org/10.1007/s004420100637

Sikes, R.S., and W.L. Gannon. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92: 235–253. https://doi.org/10.1644/10-mamm-f-355.1

Welch, C.A., J. Keay, K.C. Kendall, and C.T. Robbins. 1997. Constraints on frugivory by bears. Ecology 78: 1105–1119. https://doi.org/10.1890/0012-9658(1997)078[1105:cofbb]2.0.co;2

Wilson, R.R., D.D. Gustine, and K. Joly. 2014. Evaluating potential effects of an industrial road on winter habitat of caribou in north-central Alaska. Arctic 67: 472–482. https://doi.org/10.14430/arctic4421

Winder, M., D.E. Schindler, J.W. Moore, S.P. Johnson, and W.J. Palen. 2005. Do bears facilitate transfer of salmon resources to aquatic macroinvertebrates? Canadian Journal of Fisheries Aquatic Science 62: 2285–2293. https://doi.org/10.1139/f05-136

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Note

Roman Snail, *Helix pomatia* (Mollusca: Helicidae), in Canada

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Abstract
Populations of Roman Snail, *Helix pomatia*, a large European land snail, are reported for the first time in Canada from disturbed habitats in two distant locations: Sarnia, Ontario and Montrose, British Columbia. As Roman Snail is an edible species subject to international commercial trade, its deliberate, but illegal, introduction into Canada and intentional or unintentional releases are possible sources of these populations.

Key words: Mollusca; terrestrial snail; gastropod; new provincial records; Ontario; British Columbia; biogeography

The genus *Helix* L., 1758, in its modern, restricted sense, is a group of large-bodied land snails of Europe, some parts of western Asia, and North Africa (Schileyko 2006; Mumladze *et al.* 2008; Fiorentino *et al.* 2016). Larger land snails, including species of the genus *Helix* and its type species, *Helix pomatia* L., 1758 (Figure 1), are among those that have been consumed by humans for millennia (Bar 1977; Lubell 2004).

The range of *H. pomatia*, Roman or Burgundy Snail, includes central and southern Europe, but also extends into western and northwestern Europe to coastal areas of countries on the Baltic Sea and west to France and England (Kerney 1999; Neubert 2013, 2014), with the ancestral range in the Balkan region (Fiorentino *et al.* 2016). The presence of this species in Britain is generally believed to represent a Roman introduction (Taylor 1910; Kerney 1966, 1999); the Romans went so far as importing, breeding, and rearing snails in “cochlearia” (Taylor 1900). The original geographic range of *H. pomatia* may have been central European, with its spread into western Europe a result of ancient introductions by humans (Taylor 1910).

Recently, introductions have been reported as far east as European Russia (Sysoev and Schileyko 2009; Egorov 2015). In the United States, perhaps the first established population was noted in Jackson, Michigan, in 1937 (Archer 1937; Pilsbry 1939), but *H. pomatia* is now also known from Wisconsin, New York, Massachusetts, Indiana, Pennsylvania, Florida, and California (GBIF 2017; NatureServe 2019). The presence of this species in Canada has gone unreported in the literature, and we document here the occurrence of *H. pomatia* in British Columbia and Ontario.

Specimens were collected opportunistically by us or our contacts and are vouchered in the Mollusc Collection of the New Brunswick Museum, Saint John (NBM). Shell height (H) and diameter (or width; D) of unbroken, apparently mature specimens were measured using a digital caliper, to the nearest 0.1 mm.

Helix pomatia was first observed at Canatara Park in Sarnia, Ontario, on 10 May 2013 by J.K. (Figure 1a). Three live specimens and one empty shell were collected on 31 May 2013. Canatara is a multi-use municipal park of ~80 ha that is surrounded by urban lands. The south portion (~25 ha), where Roman Snails were found, was once a landfill site, which has regenerated over many decades. It consists of old field, thickets, and woodland with a high proportion of non-native invasive plant species. Roman Snails were found in dry meadow co-dominated by goldenrods (*Solidago* sp.) and Canada Thistle (*Cirsium arvense* (L.) Scopoli) with some Garlic Mustard (*Alliaria petiolata* (M. Bieberstein) Cavara & Grande). The snails were often seen under debris, such as boards, or climbing on vegetation up to 30 cm above the ground. The non-native, European Grove Snail, *Cepaea nemoralis* (L., 1758), was abundant in Canatara Park.

At Montrose, British Columbia (BC), S. Munch (pers. comm. 2015) had observed *H. pomatia* on his property since moving there in 2002. The habi-

FIGURE 1. Roman Snail, *Helix pomatia*. a. Canatara Park, Sarnia, Ontario. b. Shells from Sarnia, Ontario (left; NBM 010198) and Montrose, British Columbia (right; NBM 010200). Photo: a. J. Kamstra. Photo: b. R. Forsyth.

tat is an open area that includes lawn and tall uncut grass with small Trembling Aspen (*Populus tremuloides* Michaux), spruce (*Picea* A. Dietrich sp.), and Western Red Cedar (*Thuja plicata* Donn ex D. Don). The maximum number of snails encountered at one time was 15–20 individuals in a 9 × 9 m area.

We are also aware that *H. pomatia* has persisted for several years at Revelstoke, BC (H. Douglas pers. comm. 2014), but have little information about its presence there.

No native or introduced land snail in Canada approaches the size of *H. pomatia*, which is one of the largest of the European *Helix* species (up to 50 mm; Kerney and Cameron 1979). The only other established, large helicid species in Canada is Brown Gardensnail, *Cornu aspersum* (Müller, 1774), more commonly known as *Helix aspersa,* but that species is easily recognized by its smaller shell, different pattern of shell pigmentation, and different sculpture, among other characters (Kerney and Cameron 1979). *Helix lucorum* L., 1758, which can grow to be larger than *H. pomatia*, might be confused with *H. pomatia*, although it has markedly more prominent banding. Indeed, Burke (2013) figured a specimen of *H. lucorum* that he misidentified as *H. pomatia.*

Based on our own observations and correspondence with the discoverer of the Montrose population of *H. pomatia*, we believe that both this and the Sarnia population have persisted for several years (at least 13 years at Montrose) and that this species can be added to the growing list of introduced terrestrial molluscs in Canada. Variation in shell sizes suggests that different generations exist.

Throughout its range in Europe, *H. pomatia* inhabits milder coastal areas as well as mountainous regions with more continental climates. Thus, the successful establishment of this species in Canada is not a surprise. However, as climate change brings milder winters, in the future, we might expect increasingly more successful introductions of terrestrial molluscs in different parts of the country. Novel records of introduced terrestrial molluscs in Canada continue to be discovered, even in areas that are rather well explored (e.g., Forsyth 1999, 2008; Reise *et al.* 2000; Forsyth *et al.* 2001, 2016; Maunder *et al.* 2017). The discovery of *H. pomatia* at Montrose and Revelstoke adds a second introduced snail species known from the BC interior but not from the milder south coast region of BC. More surveys for terrestrial molluscs around populated centres, such as those of Forsyth (1999) who focussed on the Vancouver and Victoria regions, would be useful in the BC interior. Similar to BC, southern Ontario has been rather well explored for terrestrial snails. The great extent of modified habitats there allows for the foothold of many synanthropic, introduced species. The possible invasiveness of *H. pomatia* is not known. Apparently the species persists but had not spread far from Jackson, Michigan, even 80 years after it was first discovered (Atkinson 2019). At the Sarnia site, the species has not become appreciably more abundant in the five years since it was first discovered, in contrast to the highly invasive *Cepaea nemoralis*.

Most non-native terrestrial snails and slugs are likely accidentally introduced with plants, soil, and debris, or movements of other materials. However, for *H. pomatia*, the source of the introductions is uncertain. It seems likely that someone raising Roman Snail deliberately or unintentionally released several individuals. Roman Snail is an edible species that has international commercial value and is sold for both food and the pet trade. It is listed for sale on various websites, such as My Happy Snails (https://www.myhappysnails.com/), based in Ukraine, which will ship abroad to willing buyers. It is possible that Roman Snail was deliberately imported into Canada, although the importing of any species of *Helix* into Canada is prohibited (D. Mooij pers. comm. 2019). The Sarnia location is only about 150 km from where *H. pomatia* occurs in Michigan, but it seems unlikely that the Sarnia snails originated from that location, given the presence of an international border, a water barrier, and the distance.

Voucher specimens

Canada: Ontario: Lambton County: Sarnia: Canatara Park: ca. 43.0°N, 82.4°W, *leg.* James Kamstra, 31 May 2013 (NBM 010198, 1 specimen). British Columbia: Kootenay-Boundary Regional District: Montrose, ca. 49.1°N, 117.6°W, *leg.* Steven Munch, summer and fall 2015 (NBM 010200, 33 specimens; Figure 1b). British Columbia: Columbia-Shuswap Regional District: Revelstoke, 12 June 2014 (NBM 010199, 1 specimen).

Canadian shells (Figure 1a) can be described as follows. The shell is large (H = 33.6–42.0 mm, D = 30.46–39.37 mm; mean H/D = 1.05, SD = 0.05, n = 27) and rather globular with a conical spire. It is pale grey-brown, with lighter and darker colabral streaks and, in general, two to five spiral bands, which are sometimes rather weakly marked or absent. There are ~4 convex whorls, with the last whorl descending in full-grown specimens. The periphery is rounded, medial on the last whorl. The protoconch is smooth. The teleoconch has irregular, low, somewhat riblet-like colabral ridges and spiral rows of weak granules. The aperture is large, subovate-rounded, and showing the external shell colour through the shell wall. The outer lip is scarcely thickened and narrowly outwardly flared. The columellar lip is pinkish-brown, expanded, and almost sealing the umbilicus, which is a narrow slit.

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Literature Cited

Archer, A.F. 1937. *Helix pomatia* Linné in Jackson, Michigan. Nautilus 51: 61–63.

Atkinson, J.W. 2019. Exotic, invasive and pest snails and land slugs of Michigan. Michigan State University Snail Laboratory, Lansing, Michigan, USA. Accessed 13 March 2019. https://msu.edu/~atkinso9/pestsnailpage.htm.

Bar, Z. 1977. Human consumption of land snails in Israel. Basteria 31: 53–58.

Burke, T.E. 2013. Land Snails and Slugs of the Pacific Northwest. Oregon State University Press, Corvallis, Oregon, USA.

Egorov, R. 2015. *Helix pomatia* Linnaeus, 1758: the history of its introduction and recent distribution in European Russia. Malacologica Bohemoslavia 14: 91–101.

Fiorentino, V., G. Manganelli, F. Giusti, and V. Ketmaier. 2016. Recent expansion and relic survival: phylogeography of the land snail genus *Helix* (Mollusca, Gastropoda) from south to north Europe. Molecular Phylogenetics and Evolution 98: 358–372. https://doi.org/10.1016/j.ympev.2016.02.017

Forsyth, R.G. 1999. Distributions of nine new or little-known exotic land snails in British Columbia. Canadian Field-Naturalist 113: 559–568. Accessed 3 October 2019. https://biodiversitylibrary.org/page/34235429.

Forsyth, R.G. 2008. First record of the European land snail *Trochulus striolatus* in British Columbia, Canada (Pulmonata: Hygromiidae). Festivus 40: 76–78.

Forsyth, R.G., J.M.C. Hutchinson, and H. Reise. 2001. *Aegopinella nitidula* (Draparnaud, 1805) (Gastropoda: Zonitidae) in British Columbia—first confirmed North American record. American Malacological Bulletin 16: 65–69.

Forsyth, R.G., J.E. Maunder, D.F. McAlpine, and R.G. Noseworthy. 2016. Distributional status of an introduced land snail *Discus rotundatus* (Rotund Disc, Mollusca: Discidae) in Canada. Canadian Field-Naturalist 130: 235–246. https://doi.org/10.22621/cfn.v130i3.1887

GBIF (Global Biodiversity Information Facility). 2017. GBIF backbone taxonomy. Checklist dataset. *Helix pomatia* Linnaeus, 1758. Accessed 9 February 2019. https://doi.org/10.15468/39omei

Kerney, M.P. 1966. Snails and man in Britain. Journal of Conchology 26: 3–14.

Kerney, M.P. 1999. Atlas of the Land and Freshwater Molluscs of Britain and Ireland. Harley Books, Colchester, Essex, United Kingdom.

Kerney, M.P., and R.A.D. Cameron. 1979. A Field Guide to the Land Snails of Britain and North-west Europe. Collins, London, United Kingdom.

Lubell, D. 2004. Prehistoric edible land snails in the circum-Mediterranean: the archaeological evidence. Pages 77–98 *in* Petits animaux et sociétés humaines du complément alimentaire aux ressources utilitaires. XXIV[e] rencontres internationales d'archéologie et d'histoire d'Antibes. *Edited by* J-J. Brugal and J. Desse. Éditions APDCA, Antibes, France.

Maunder, J.E., R.G. Noseworthy, J.M.C. Hutchinson, and H. Reise. 2017. Terrestrial molluscs of the Province of Newfoundland and Labrador, Canada. Part 1: Boettgerillidae. Check List 13: 277–284. https://doi.org/10.15560/13.4.277

Mumladze, L., D. Tarkhnishvili, and B.M. Pokryszko. 2008. A new species of the genus *Helix* from the Lesser Caucasus (SW Georgia). Journal of Conchology 39: 483–487.

NatureServe. 2019. *Helix pomatia*—Linnaeus, 1758. Nature Serve Explorer, v. 7.1. Accessed 14 March 2019. http://explorer.natureserve.org/servlet/NatureServe?searchName=Helix+pomatia.

Neubert, E. 2011. *Helix pomatia. In* The IUCN Red List of Threatened Species. International Union for Conservation of Nature and Natural Resources, Cambridge, United Kingdom. e.T156519A4957463. https://doi.org/10.2305/iucn.uk.2011-1.rlts.t156519a4957463.en

Neubert, E. 2014. Revision of *Helix* Linnaeus, 1758 in its eastern Mediterranean distribution area, and reassignment of *Helix godetiana* Kobelt, 1878 to *Maltzanella* Hesse, 1917 (Gastropoda, Pulmonata, Helicidae). Contributions to Natural History [Natural History Museum Bern] 26: 1–200.

Pilsbry, H.A. 1939. Land Mollusca of North America (North of Mexico), Volume I, Part 1. Monograph 3. Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania, USA.

Reise, H., J.M.C. Hutchinson, R.G. Forsyth, and T.J. Forsyth. 2000. The ecology and rapid spread of the terrestrial slug *Boettgerilla pallens* in Europe with reference to its recent discovery in North America. Veliger 43: 313–318.

Schileyko, A.A. 2006. Treatise on Recent terrestrial pulmonate molluscs, part 13. Helicidae, Pleurodontidae, Polygyridae, Ammonitellidae, Oreohelicidae, Thysanophoridae. Ruthenica Supplement 2: 1765–1906.

Sysoev, A., and A. Schileyko. 2009. Land Snails and Slugs of Russia and Adjacent Countries. Pensoft, Sofia, Bulgaria.

Taylor, J.W. 1900. A Monograph of the Land and Freshwater Mollusca of the British Isles. Structural and General Volume. Part VII. Taylor Brothers, Leeds, United Kingdom.

Taylor, J.W. 1910. A Monograph of the Land and Freshwater Mollusca of the British Isles. Zonitidæ. Endodontidæ. Helicidæ. Part XVII. Taylor Brothers, Leeds, United Kingdom.

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First record of Paintedhand Mudbug (*Lacunicambarus polychromatus*) in Ontario and Canada and the significance of iNaturalist in making new discoveries

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Abstract

Paintedhand Mudbug (*Lacunicambarus polychromatus* (Thoma, Jezerinac & Simon 2005)) (Decapoda: Cambaridae) was recently discovered at three locations in Windsor, Ontario. These represent the first reports of this burrowing crayfish in Canada. iNaturalist, a nature app and website designed to record photo-based observations of plants and animals, was instrumental in facilitating this discovery. We discuss the importance of collaborative platforms, such as iNaturalist, for linking naturalists and citizen scientists to taxonomic experts around the globe.

Key words: Cambaridae; crayfish; Decapoda; iNaturalist; *Lacunicambarus polychromatus*; new distribution record; Ontario; Paintedhand Mudbug

Introduction

Paintedhand Mudbug (*Lacunicambarus polychromatus*) is a burrowing crayfish in the family Cambaridae that was newly described in 2005 (Thoma *et al.* 2005). Until recently, it was included in the genus *Cambarus* Erichson, 1846, in the rejected subgenus *Tubericambarus* Jezerinac, 1993 (Crandall and De Grave 2017). Phylogenetic analyses of mitochondrial DNA (mtDNA) sequence data combined with morphological and ecological characteristics have, however, indicated that *L. polychromatus* and several closely related species of burrowing crayfish are monophyletic and distinct from *Cambarus* (Glon *et al.* 2018). As a result, the subgenus *Lacunicambarus* Hobbs, 1969 has been resurrected and redescribed at the generic level to accommodate them (Glon *et al.* 2018).

Lacunicambarus polychromatus is known from throughout much of the North American midwest east of the Mississippi River (with the exception of a recent record from Missouri; Missouri Statewide Historical Crayfish Database 2019), as well as parts of Kentucky and Tennessee (see Figure 2 in Thoma *et al.* 2005). Throughout its range, *L. polychromatus* is commonly found in burrows in low-lying habitats close to the water table, including the banks and floodplains of lakes and rivers, roadside ditches, and wetlands (Thoma *et al.* 2005). The recent recognition of *L. polychromatus*, stemming in part from historical confusion with the closely related Devil Crayfish (*Lacunicambarus diogenes*), has led to a relative paucity of correctly identified records of this species in museum collections and databases. The full extent of the range of *L. polychromatus*, therefore, remains undetermined, and no records of this species have been reported previously from Canada.

Methods

On 26 May 2017, members of the Committee on the Status of Species at Risk in Ontario (COSSARO) visited the Ojibway Prairie Provincial Nature Reserve (42.263°N, 83.071°W) in Windsor, Ontario, along with several staff from the Ontario Ministry of Natural Resources and Forestry and the Ojibway Nature Centre, City of Windsor. During the visit,

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a large adult burrowing crayfish was encountered above ground during the daytime. The individual was photographed and the photos (Figure 1) were uploaded to iNaturalist (see https://inaturalist.ca/observations/6501788), a web-based application designed to capture and share photo-based records of plants and animals. At the time of the observation, the crayfish was identified as *L.* aff. *diogenes* (see Glon *et al.* 2018), a species known to occur in Ontario, Canada (Crocker and Barr 1968; Guiasu *et al.* 1996; Hamr 1998). Six months later, the iNaturalist record was discovered by M.G.G., an expert on the taxonomy of *Lacunicambarus* currently working on revising the genus, who suspected that it was more likely to be *L. polychromatus*. Additional photos were uploaded to the record allowing for confirmation that the species was indeed *L. polychromatus*, a species not previously reported for Canada.

On 15 May 2018, C.D.J. and M.G.G. returned to the original location to conduct additional surveys for the species and to collect a voucher specimen and tissue samples for DNA analysis. Burrows were searched for in ditches and along watercourses, and a hand-pumping technique, which included pouring additional water into the burrows, was used to bring the crayfish to the surface. Surveys for burrowing crayfish were also conducted on the same day at four additional locations in the Windsor area (Figure 2, Table 1). When burrows were located, the technique described above was used to extract crayfish. Voucher specimens were collected at each location where crayfish were found and have been deposited at the Royal Ontario Museum, Toronto, Ontario. A tissue sample was also taken from the Ojibway Prairie specimen for mtDNA sequencing.

Results

The surveys on 15 May 2018 at Ojibway Prairie Provincial Nature Reserve were successful in confirming the presence of *L. polychromatus*. At this location, burrows were found along a shallow ditch running along the northern edge of the nature reserve not far from where the specimen was located in 2017. The nature reserve is 105 ha in size and includes a

FIGURE 1. Paintedhand Mudbug (*Lacunicambarus polychromatus*) recorded on 26 May 2017 at Ojibway Prairie Provincial Nature Reserve, Windsor, Ontario. Distinguishing characteristics of the species are indicated by lines: closed areola (a, c); deflected rostrum (b1); suborbital angle (b2); dorsal surface of the palm of the chela with mesial quarter to third studded with tubercles not forming distinct rows (d). Photos: Colin D. Jones.

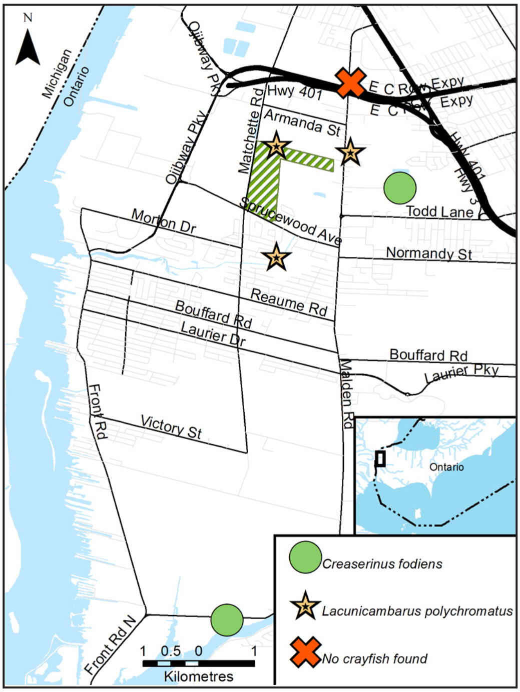

FIGURE 2. The six survey sites in the Windsor, Ontario, area. Stars indicate the three locations where Paintedhand Mudbug (*Lacunicambarus polychromatus*) was detected. Circles indicate the two locations where Digger Crayfish (*Creaserinus fodiens*) was found. The × indicates a location where no crayfish burrows or crayfish were found. The hatched area represents the Ojibway Prairie Provincial Nature Reserve.

combination of native tallgrass prairie and prairie/savanna habitat. It is part of a complex of closely situated natural areas located in the City of Windsor that together protect nearly 350 ha of native prairie, savanna, and forest.

A single specimen of *L. polychromatus* was collected, preserved in 95% ethanol and deposited at the Royal Ontario Museum (ROMIZ L5261). The GenBank accession numbers for 12S (MH878691), 16S (MH878723), and partial CO1 (MH882991) have been previously reported in Glon *et al.* (2019).

On the same day, *L. polychromatus* was also collected from a nearby site, Vince Marcotte Park (42.245°N, 83.071°W). Unlike the natural habitat of the nature reserve, the burrows at Vince Marcotte Park were located on the manicured lawn of the park bordering Turkey Creek. There were many burrows at this location and two specimens of *L. polychromatus* were collected and deposited at the Royal Ontario Museum (Table 1, Figure 2).

On 15 May 2018, three additional sites were surveyed (Table 1). At one site, no crayfish burrows were located. At the other two sites, crayfish burrows were found and hand-pumped. The species present, however, was Digger Crayfish (*Creaserinus fodiens*), which was first discovered in Ontario, Canada, in 1863 and is often found living in burrows adjacent to those of *L. polychromatus* in the United States (Cottle 1863; Hobbs 1974).

Following the discovery that *L. polychromatus* occurs in the Windsor area (Table 1), an additional photo-based record was uploaded to iNaturalist from a third location adjacent to Ojibway Prairie. An individual was found by Steve Marks above ground, at night, and backdated to 24 May 2016 (see https://inaturalist.ca/observations/17855665). The location is a residential yard bordered by a shallow drainage ditch adjacent to a dry-moist old field. Crayfish burrows are periodically found in the manicured lawn and along the banks of the ditch at this location, but no attempts have been made to survey for crayfish.

Discussion

The Ojibway Prairie complex in extreme southwestern Ontario supports a number of plant and animal species that are restricted to this unique portion of the province, not to mention the entire country (Oldham 1992; Paiero *et al.* 2010; Pratt 2018). The discovery of *L. polychromatus* here represents the first record of the species in Canada. The closest known occurrences are in adjacent Michigan, where it has been known since it was first described (Thoma *et al.* 2005); thus, it is not entirely surprising that it was eventually recorded across the Detroit River in the Windsor area. *Lacunicambarus polychromatus* is almost certainly native to Canada, rather than being a recent colonizer or introduction, and its presence has likely gone undetected because of historical confusion about the taxonomy of *Lacunicambarus*. Additional surveys will be required throughout southwestern Ontario to delineate the full extent of the species' range in Canada. We also suggest that preserved specimens ascribed to "*C. diogenes*" (i.e., *L.* aff. *diogenes*) be re-examined, particularly if they were collected before *L. polychromatus* was described in 2005, to determine if the latter species is more widely distributed in Ontario than the observations documented herein led us to believe. Such information will also be critical in making an accurate assessment of the species' conservation status provincially and nationally.

Lacunicambarus polychromatus can be differentiated from all other Canadian crayfishes by its closed areola (Figure 1a,c); strongly deflected rostrum (in lateral view; Figure 1b1); presence of a suborbital angle (Figure 1b2); Form I male gonopods with two terminal elements directed caudally at approxi-

TABLE 1. Records of Paintedhand Mudbug (*Lacunicambarus polychromatus*) from Ontario, Canada, including locations where the species was searched for unsuccessfully. Repositories include both iNaturalist (for photo-based records) and the Royal Ontario Musuem (ROM). Catalog numbers for iNaturalist refer to the unique record number and are accessible online by adding the catalog number to the end of the URL, https://inaturalist.ca/observations/.

Date	Location	Latitude, °N	Longitude, °W	Habitat	Details	Observers	Repository	Catalog no.
24 May 2016	Lambton St., Windsor	42.262	83.059	Suburban yard bordering drainage ditch	Incidental; one *L. polychromatus* photographed	S.M.	iNaturalist	17855665
26 May 2017	Ojibway Prairie Provincial Nature Reserve, Windsor	42.263	83.071	Native tallgrass prairie	Incidental; one *L. polychromatus* photographed	C.D.J., M.G.G., K.C., S.M.P., P.D.P., T.J.P., + COSSARO members	iNaturalist	6501788
15 May 2018	Ojibway Prairie Provincial Nature Reserve, Windsor	42.263	83.071	Shallow ditch bordering native tallgrass prairie	Targetted search; burrows detected and pumped; one *L. polychromatus* collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5261 12590089
15 May 2018	Vince Marcotte Park, Windsor	42.245	83.071	Urban park lawn bordering creek	Targetted search; burrows detected and pumped; two *L. polychromatus* collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5262 ROMIZ L5263 12590307
15 May 2018	Continental Ave., Windsor	42.273	83.059	Roadside ditch bordering small field in industrial area	Targetted search; no burrows or crayfish detected	M.G.G., C.D.J.	n/a	n/a
15 May 2018	Spring Garden Natural Area, Windsor	42.256	83.051	Wooded swamp	Targetted search; burrows detected and pumped; one *Creaserinus fodiens* (Digger Crayfish) collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5265 12590235
15 May 2018	River Canard Park, Amherstburg	42.186	83.079	Roadside ditch bordering recreational park	Targetted search; burrows detected and pumped; one *Creaserinus fodiens* collected	M.G.G., C.D.J.	ROM iNaturalist	ROMIZ L5264 12590320

mately 90° relative to the gonopod shaft, the distal most of which (central projection) is markedly shorter than the proximal one (mesial process); and dorsal surface of the palm of the chela with mesial quarter to third studded with tubercles not forming distinct rows (Figure 1d). Although colouration is subject to variation and is not always a reliable character, *L. polychromatus* typically exhibits striking orange and red highlights along its rostral margins, chelae, and the dorsoposterior margins of its abdominal somites and blue or green shades across its body (Figure 1a–d). This crayfish is almost always collected from burrows, but it is occasionally encountered in open waters or even on land, particularly after heavy rain. Burrows with recent activity have fresh mud at the opening (Figure 3) often forming a chimney (Figure 4). The burrows themselves are not, however, diagnostic to species, and there are several species of burrowing crayfish.

iNaturalist was instrumental in facilitating the discovery of this species in Canada. Had it not been for iNaturalist, its presence may have remained undetected. As iNaturalist grows in popularity, more and more amateur naturalists and citizen scientists are uploading their photos and seeking confirmation of their identification. For example, in the 10 years since its inception in 2008 over 7 000 000 observations have been contributed by 224 334 users (iNaturalist 2019). In 2018 alone, the total number of observations more than doubled to well over 15 000 000 and the number of users also more than doubled to an astonishing 501 308 (iNaturalist 2019; also see Martin 2018 for a summary of Canadian records). At the same time, more and more taxonomic experts are becoming involved in iNaturalist by offering their expertise at providing or correcting identifications. This was certainly the case with the Ojibway Prairie record of *L. polychromatus* that would have been entered in field notes and potentially in databases as a record of *L.* aff. *diogenes.* In time, the photos may have been re-examined and re-determined as *L. polychromatus*, but iNaturalist has provided a platform that has greatly increased the ability of amateurs and experts to collaborate in real time. This collaboration is greatly increasing our collective knowledge of the distribution and, in fact, the conservation status of species.

There are other examples of this rapid increase in species discoveries. In Ontario alone, for example, at least 40 species of moths new to the province (at least 19 of which are new to Canada and one new to North America) have been discovered (M.V.B. Burrell pers. comm. 22 January 2019) through iNaturalist submissions since the recent publication of a comprehensive annotated Canadian Lepidoptera list (Pohl *et al.* 2018).

As species, such as Paintedhand Mudbug, are new-

FIGURE 3. Fresh mud at the opening of a crayfish burrow in Vince Marcotte Park, Windsor, Ontario, Canada (42.245°N, 83.071°W), 15 May 2018. Photo: Colin D. Jones.

FIGURE 4. A Paintedhand Mudbug (*Lacunicambarus polychromatus*) chimney in Muhlenberg County, Kentucky, USA (37.313°N, 87.201°W), 11 June 2018. Photo: Mael G. Glon.

ly discovered in Ontario, they are added to the provincial species list maintained by the Natural Heritage Information Centre (NHIC), Ontario Ministry of Natural Resources and Forestry, and are assigned a conservation status rank following methods developed by NatureServe (Faber-Langendoen *et al.* 2012; Master *et al.* 2012). Paintedhand Mudbug has been assigned a rank of S1S2 (critically imperilled to imperilled). The NHIC typically compiles observations of species with a conservation status rank of S3 (vulnerable) or higher. These observations then inform areas of conservation value (element occurrences) and are added to the provincial record where they are available to inform conservation, land-use, and natural resources management planning, policy, and legislation.

iNaturalist is also greatly increasing the ability to detect the introduction of exotic and potentially invasive species. A new and potentially invasive vascular plant species, Small-flowered Jewelweed (*Impatiens parviflora* de Candolle), for example, has been recently documented in Ontario through iNaturalist (Oldham 2018).

The growth and popularity of iNaturalist is not showing any signs of slowing down. With such growth, an increasing number of local, regional, and national discoveries will be made, such as the discovery of *L. polychromatus* in Canada. Such discoveries will assist in advancing our collective knowledge of the distribution and conservation status of species. The NHIC has created a project on iNaturalist that users can join allowing their personal observations of provincially rare species to be considered for incorporation into the provincial record (https://inaturalist.ca/projects/nhic-rare-species-of-ontario).

Author Contributions

Writing – Original Draft: C.D.J. and M.G.G.; Writing – Review and Editing: all; Conceptualization – C.D.J. and M.G.G.; Methods – M.G.G. and C.D.J.; Investigation – all.

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Literature Cited

Cottle, T.J. 1863. On the two species of *Astacus* found in Upper Canada. Canadian Journal of Industry, Science, and Art 45: 216–219.

Crandall, K.A., and S. De Grave. 2017. An updated classification of the freshwater crayfishes (Decapoda: Astacidea) of the world, with a complete species list. Journal of Crustacean Biology 37: 615–653. http://doi.org/dcw4

Crocker, D.W., and D.W. Barr. 1968. Handbook of the Crayfishes of Ontario. Royal Ontario Museum life sciences miscellaneous publications, University of Toronto Press, Toronto, Ontario, Canada. https://doi.org/10.5962/bhl.title.60758

Faber-Langendoen, D., J. Nichols, L. Master, K. Snow, A. Tomaino, R. Bittman, G. Hammerson, B. Heidel, L. Ramsay, A. Teucher, and B. Young. 2012. NatureServe conservation status assessments: methodology for assigning ranks. NatureServe, Arlington, Virginia, USA.

Glon, M.G., R.F. Thoma, M. Daly, and J.V. Freudenstein. 2019. *Lacunicambarus chimera*: a new species of burrowing crayfish (Decapoda: Cambaridae) from Illinois, Indiana, Kentucky, and Tennessee. Zootaxa 4544: 451–478. https://doi.org/10.11646/zootaxa.4544.4.1

Glon, M.G., R.F. Thoma, C.A. Taylor, M. Daly, and J.V. Freudenstein. 2018. Molecular phylogenetic analysis of the devil crayfish group, with elevation of *Lacunicambarus* Hobbs, 1969 to generic rank and a redescription of the devil crayfish, *Lacunicambarus diogenes* (Girard, 1852) comb. nov. (Decapoda: Astacoidea: Cambaridae). Journal of Crustacean Biology 38: 600–613. https://doi.org/10.1093/jcbiol/ruy057

Guiasu, R.C., D.W. Barr, and D.W. Dunham. 1996. Distribution and status of crayfishes of the genera *Cambarus* and *Fallicambarus* (Decapoda: Cambaridae) in Ontario, Canada. Journal of Crustacean Biology 16: 373–383. https://doi.org/10.1163/193724096x00162

Hamr, P. 1998. Conservation status of Canadian freshwater crayfishes. World Wildlife Fund Canada and Canadian Nature Federation, Toronto, Ontario, Canada.

Hobbs, H.H., Jr. 1974. A checklist of the North and Middle American crayfishes (Decapoda: Astacidae and Cambaridae). Smithsonian Contributions to Zoology 166: 1–161. https://doi.org/10.5479/si.00810282.166

iNaturalist. 2019. iNaturalist.org year in review 2018. iNaturalist. Accessed 17 January 2019. https://www.inaturalist.org/stats/2018.

Martin, A.E. 2018. iNaturalist Canada passes the 1 000 000 observation mark. Canadian Field-Naturalist 132: 434. https://doi.org/10.22621/cfn.v132i4.2305

Master, L., D. Faber-Langendoen, R. Bittman. G.A. Hammerson, B. Heidel, L. Ramsay, K. Snow, A. Teucher, and A. Tomaino. 2012. NatureServe conservation status assessments: factors for evaluating species and ecosystem risk. NatureServe, Arlington, Virginia, USA.

Missouri Department of Conservation. 2019. Missouri statewide historical crayfish database. Missouri Department of Conservation, Resource Science Division, Columbia, Missouri, USA.

Oldham, M.J. 1992. Rare vascular plants of Ojibway Prairie and vicinity, Windsor, Ontario. Unpublished report. Ontario Ministry of Natural Resources, Aylmer, Ontario, Canada.

Oldham, M.J. 2018. Two new and potentially invasive vascular plant species recently documented in Ontario through citizen science and social media. Unpublished report. Ontario Ministry of Natural Resources, Peterborough, Ontario, Canada.

Paiero, S.M., S.A. Marshall, P.D. Pratt, and M. Buck. 2010. Insects of Ojibway Prairie, a southern Ontario tallgrass prairie. Pages 199–225 *in* Arthropods of Canadian Grasslands (Volume 1): Ecology and Interactions in Grassland Habitats. *Edited by* J.D. Shorthouse and K.D. Floate. Biological Survey of Canada, Canada. https://doi.org/10.3752/9780968932148.ch9

Pohl, G.R., J.-F. Landry, B.C. Schmidt, J.D. Lafontaine, J.T. Troubridge, A.D. Macaulay, E.J. van Nieukerken, J.R. DeWaard, J.J. Dombroskie, J. Klymko, V. Nazari, and K. Stead. 2018. Annotated checklist of the moths and butterflies (Lepidoptera) of Canada and Alaska. Pensoft Publishers, Sofia, Bulgaria.

Pratt, P.D. 2018. Provincially rare vascular plants and wildlife of the Ojibway Prairie complex (version APR2018). Ojibway Nature Centre, Department of Parks, Windsor, Ontario. Accessed 22 January 2019. http://www.ojibway.ca/raresp.htm.

Thoma, R.F., R.F. Jezerinac, and T.P. Simon. 2005. *Cambarus* (*Tubericambarus*) *polychromatus* (Decapoda: Cambaridae), a new species of crayfish from the United States. Proceedings of the Biological Society of Washington 118: 326–336. http://doi.org/dg6mcq

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Note

Duckling mortality at a river weir

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Abstract
River weirs are low-head dams that dissipate energy by creating hydraulic recirculation zones at their base. These recirculation zones are a major cause of human drownings and have been referred to as "drowning machines". We observed an event that allowed us to add ducklings to the list of weir victims. As a Mallard (*Anas platyrhynchos*) hen and her brood floated over the Calgary weir, the mother flew safely over the hydraulic recirculation. The ducklings drifted into the recirculation and three quickly passed through; four were stalled, repeatedly recirculated, and died. We observed other regional weirs where adult birds commonly flew over the hazard. We did not observe any other waterfowl drifting into recirculation zones, and we found no prior report of this lethal hazard. Although mortality might be rare at each weir, with hundreds of thousands of low-head dams worldwide, the collective hazard could be substantial. Weirs can be designed to eliminate the lethal recirculation zone, and the apparent hazard to ducklings could provide another motivation to redesign or modify these common structures.

Key words: Bow River; dams; mortality; waterfowl

Human developments impose many lethal challenges on wildlife. Avian mortality can follow collisions with windows, towers, power lines, airplanes, or wind turbines (Weir 1976; Avery *et al.* 1980). Alterations to streams, ponds, and lakes impose additional challenges for waterfowl, including the flooding of nests and increased predator access (Mauser *et al.* 1994; Flint and Grant 1997). We are investigating the ecological consequences of weirs and other river dams (Rood *et al.* 2003, 2010) and observed another, apparently unreported, cause of waterfowl mortality.

Our observation was from the viewing platform at the weir across the Bow River in Calgary, Canada (Figure 1; 51°2.61′N, 114°0.85′W). This weir creates an elevated head pond upstream, which allows for off-stream water diversion for irrigation. The concrete weir produces a drop of about 2 m into the stilling pool, forming a hydraulic recirculation zone, which is also referred to as a "hydraulic jump" or "hole" (Figure 2; Makuk 1988; Bradshaw 2004). This recirculation zone dissipates energy to reduce erosion of the weir base and downstream channel. Because of the recirculation, buoyant objects that float over the sill are often stalled in the trough, and are retained there or plunge down into the seam created by falling water. These objects flow slightly downstream, then resurface because of their buoyancy while still within the turbulent recirculation zone. This imposes a repetitive and somewhat violent cycle, and the recirculation zone can thus be retentive, as revealed with sticks, logs, and a wheel in the trough of the Calgary weir (Figures 1 and 3).

With the hydraulic recirculation, low-head dams will often stop swimmers or stall and capsize small boats, and then recirculate the victims. The lethal hazard of these "drowning machines" is well recognized, as human drownings at river weirs continue to represent about a fifth of recent North American river fatalities (Walbridge 2000; Bradshaw 2004). The Calgary weir has been especially lethal, with at least 10 fatalities from 1982 through 2007, including four double drownings (Makuk 1988; Canadian River Safety 2019). Largely because of the drowning hazard, this weir was modified in about 2010 to divide the single major drop into a sequence of smaller irregular drops, eliminating the retentive hydraulic recirculation zone and creating the safer Harvie Passage paddling park.

While at that construction site on 4 June 2009, we observed a fatal wildlife incident. Near mid-day, a

FIGURE 1. The Calgary weir in June 2009 (discharge 109 m^3/s), displaying the river water flowing over the weir and into the hazardous hydraulic recirculation zone, with trapped sticks and a wheel. The structure on the far side allows offstream diversion into an irrigation canal. This system was subsequently modified with the Harvie Passage to produce safer paddling channels. Photo: Stewart Rood.

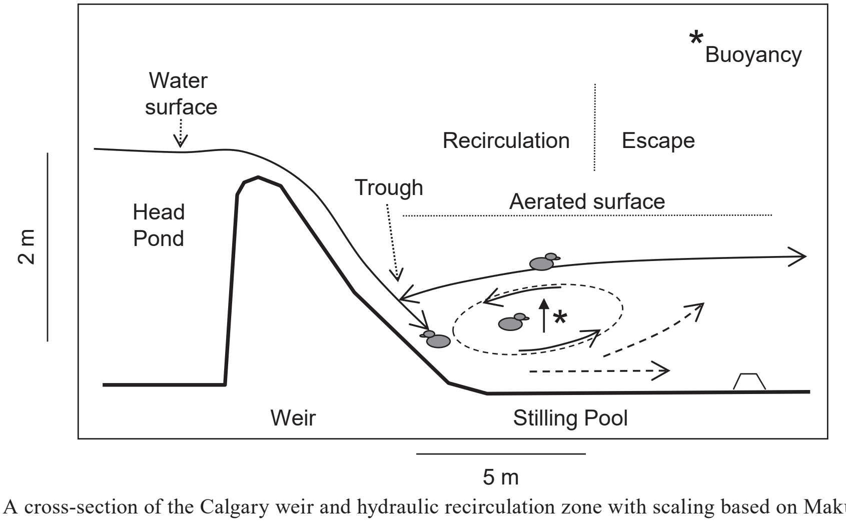

FIGURE 2. A cross-section of the Calgary weir and hydraulic recirculation zone with scaling based on Makuk (1988) and Golder (2002). The positions of the submerged ducklings are based on flume simulations with objects of similar buoyancy and observed emergence patterns. Note the exaggerated vertical scale.

Mallard (*Anas platyrhynchos*) hen and her brood of seven ducklings drifted slowly along the south bank (Figure 3). As water flowed over the weir, the ducklings turned upstream and appeared to paddle vigorously. As the hen floated over the sill, she rose with a few wing strokes and glided downstream beyond the recirculation zone. Some of the ducklings turned toward her and paddled vigorously downstream.

Paddling into the trough, three passed through fairly quickly, apparently aided by a break in the recirculation because of a tumbling log in the trough. The other four ducklings were stalled. Each was plunged down, and we observed three of the four resurface a few seconds later in the aerated surface, 3–4 m downstream. Despite paddling downstream, each was drawn back upstream into the trough and

FIGURE 3. A Mallard (*Anas platyrhynchos*) hen with seven ducklings approaching the hydraulic recirculation zone at the Calgary weir, 4 June 2009. Three of these ducklings survived, while four died. The hen is just rising and subsequently flew over the recirculation area. Photo: Stewart Rood.

again plunged under water. With each recirculation, the ducklings appeared to be weakened as they became less vigorous. We observed two ducklings recirculating three times and one four times, but did not observe the fourth over the next few minutes. After about five more minutes, one duckling emerging in the water downstream from the hydraulic recirculation area, drifting passively on its side, apparently dead. We observed no further evidence of the remaining three ducklings over an additional 30 min.

This incident demonstrates that a low-head dam can be lethal for ducklings. The mature hen was readily able to fly over the retentive hydraulic recirculation zone, but the ducklings were unable to fly and were, therefore, vulnerable. Of the seven ducklings, four apparently died, indicating that this powerful recirculation was quite hazardous.

This physical hazard from low-head dams may be very common; the design of these dams is fairly universal and consistently produces retentive and lethal hydraulic recirculation zones (Makuk 1988; Walbridge 2000; Bradshaw 2004). There are about 45 000 large dams world-wide (World Commission on Dams 2000) and low-head dams are probably about ten-fold more numerous (Chandler and Chapman 2003; Doyle *et al.* 2003). With this widespread occurrence and the apparent lethality for ducklings, we conclude that weirs could provide a substantial hazard for juvenile waterfowl.

To investigate whether this hazard is recognized in the field of ecology, we conducted Google Scholar and Web of Science literature searches with search term combinations including duck, duckling, mortality, death, hazard, dam, and weir. These revealed extensive reports on duckling mortality, including reviews and bibliographies, showing that duckling mortality is considerable (Ringleman and Longcore 1982; Savard *et al.* 1991; Flint and Grand 1997), largely as a result of predation (Talent *et al.* 1983; Mauser *et al.* 1994). Although many reports of hazards to waterfowl and other birds from various types of artificial structures exist (Weir 1976; Avery *et al.* 1980), we found no reference to the drowning hazard from river weirs. Wildlife biologists with Alberta Environment and Parks reported that they had never seen ducklings or goslings drifting over weirs, but were not surprised by the possibility, because waterfowl are abundant in head ponds above weirs in southern Alberta.

News and social media websites were another source of information. A Google search (September 2019) on "ducklings and weirs" revealed YouTube, Facebook, and news media videos, photographs, and reports of ducklings unable to follow the mother hen up and over weirs or stranded in troughs or drains below weirs. These ducklings were uninjured and were often assisted by observers or wildlife officers; for some repetitive cases, screens or other measures solved the stranding. We found no report of ducklings retained, injured, or killed in the hydraulic recirculation zone of a river weir.

Over five years, we visited other river weirs, including the 1-m-high Lethbridge Northern Irrigation District weir (49°39.9′N, 113°36.1′W), the 1.5-m City of Lethbridge weir on the Oldman River (49°40.9′N, 112°51.4′W), and the 3-m Carseland weir on the Bow River (50°49.5′N, 113°26.6′W). These weirs also produce retentive hydraulic recirculation zones and humans have drowned at the Lethbridge and Carseland weirs (Canadian River Safety 2019). We undertook 50, 6-hour observer-days at these three weirs during June from 2010 through 2015.

During these observations, water birds were common near each of the weirs, including the piscivorous American White Pelican (*Pelecanus erythrorhynchos*) and Double-crested Cormorant (*Phalacrocorax auritus*). In addition to Mallards, other ducks were abundant, including Common Merganser (*Mergus merganser*), Common Goldeneye (*Bucephala clangula*), occasional Wood Ducks (*Aix sponsa*), and other species. Canada Goose (*Branta canadensis*), including goslings, were also abundant, along with Ring-billed (*Larus delawarensis*) and other gulls. We commonly observed adults drifting toward the weirs, and they would consistently fly before drifting into the hydraulic recirculation zone. Ducklings or goslings were common, but we did not see any others drift over the weirs; thus, it is probably uncommon for waterfowl to drift into recirculation zones. We have repeatedly observed pelicans and some other birds fishing right below and even in the recirculation zone during summer intervals when river flows are lower and the hydraulic power and hazard are probably slight (Figure 4).

Following these observations, we suspect that the hazard to waterfowl varies considerably across weirs and with different river flows. A small weir on a small stream would produce a modest hydraulic recirculation zone that would be less capable of stopping and recirculating ducklings. The hydraulic force and hazard would increase with increasing drop height and stream discharge. The Carseland weir hydraulic system was very loud and this may have signaled its presence from 100 m or more upstream. Waterfowl were abundant in the upstream pond, but remained well away from that drop. With the reduced hazard of smaller weirs and noise cues of larger weirs,

FIGURE 4. The Lethbridge weir across the Oldman River in late summer when flows are low and the recirculation hazard is reduced. American White Pelicans (*Pelecanus erythrorhynchos*) are common, feeding on fish that are blocked by the weir from upstream passage. Photo: Stewart Rood.

it is possible that intermediate-sized weirs, such as the Calgary weir, might provide the greatest risk to ducklings.

The lack of prior reporting of duckling deaths in weir recirculation zones could indicate that this source of mortality is rare. Conversely, the lack of evidence may reflect ducklings' inconspicuous nature. Ducklings are small and cryptic, and hens encourage secretive behaviour (Mauser *et al.* 1994). Also, reducing the likelihood of observation, humans are discouraged from approaching river weirs by signage or fencing. Although stilling pools, the slow flowing zones downstream of weirs, are sometimes favoured for fishing, this is less common during the interval of turbid water and high flow rates in late spring and early summer, when ducklings are unable to fly and thus more vulnerable.

Although the extent of mortality is unknown, the prospective drowning hazard to waterfowl could provide one more reason to avoid weir designs that create "drowning machines". In addition, modifications to existing weirs to eliminate the hydraulic recirculation zone should reduce the risk for ducklings and possibly other wildlife, as well as humans. For example, the modifications to the Calgary weir to create the safer Harvie Passage might reduce future duckling mortality at this location where we observed the tragic drownings in 2009.

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Literature Cited

Avery, M.L., P.F. Springer, and N.S. Dailey. 1980. Avian mortality at man-made structures: an annotated bibliography (revised). United States Fish and Wildlife Service, Department of the Interior, Washington, DC, USA. FWS/OBS-80/54.

Bradshaw, S. 2004. River Safety: A Floater's Guide. Lyons Press, Guilford, Connecticut, USA.

Canadian River Safety. 2019. Map of incidents in Alberta. Canadian River Safety Project, Canada. Accessed September 2019. http://www.canadianriversafety.ca/w/core/index.php?title=Province:Alberta.

Chandler, J.A., and D. Chapman. 2003. Existing habitat conditions of tributaries formerly used by anadromous fish (appendix 2.1-2). Technical report FERC no. 1971. Idaho Power Company, Boise, Idaho, USA.

Doyle, M.W., E.H. Stanley, and J.M. Harbor. 2003. Channel adjustments following two dam removals in Wisconsin. Water Resources Research 39: 1011. https://doi.org/10.1029/2002WR001714

Flint, P.L., and J.B. Grand. 1997. Survival of spectacled eider adult females and ducklings during brood rearing. Journal of Wildlife Management 61: 217–221. https://doi.org/10.2307/3802430

Golder Associates. 2002. Pre-design of the preferred alternatives to modify the Western headworks weir in Calgary. Golder Associates Ltd., Calgary, Alberta, Canada.

Makuk, J.S. 1988. Multiple use of water resources: adapting weirs for recreation. M.Env. Design thesis, University of Calgary, Calgary, Alberta, Canada.

Mauser, D.M., R.L. Jarvis, and D.S. Gilmer. 1994. Survival of radio-marked mallard ducklings in northeastern California. Journal of Wildlife Management 58: 82–87. https://doi.org/10.2307/3809552

Ringleman, J.K., and J.R. Longcore. 1982. Survival of black ducks during brood rearing. Journal of Wildlife Management 46: 622–628. https://doi.org/10.2307/3808552

Rood, S.B., J.H. Braatne, and L.A. Goater. 2010. Favorable fragmentation: river reservoirs can impede downstream expansion of riparian weeds. Ecological Applications 20: 1664–1677. https://doi.org/10.1890/09-0063.1

Rood, S.B., C.R. Gourley, E.M. Ammon, L.G. Heki, J.R. Klotz, M.L. Morrison, D. Mosely, G.G. Scoppettone, S. Swanson, and P.L. Wagner. 2003. Flows for floodplain forests: a successful riparian restoration. BioScience 53: 647–656. http://doi.org/c4tvrc

Savard, J.-P.L., G.E.J. Smith, and J.N.M. Smith. 1991. Duckling mortality in Barrow's Goldeneye and Bufflehead broods. Auk 108: 568–577. https://doi.org/10.2307/4088097

Talent, L.G., R.L. Jarvis, and G.L. Krapu. 1983. Survival of mallard broods in south-central North Dakota. Condor 85: 74–78. https://doi.org/10.2307/1367893

Walbridge, C. 2000. The American Canoe Association's River Safety Report 1996–1999 (Second Edition). Menasha Ridge Press, Birmingham, Alabama, USA.

Weir, R.D. 1976. Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions. Department of Fisheries and the Environment, Canadian Wildlife Service, Ottawa, Ontario, Canada.

World Commission on Dams. 2000. Dams and Development: a New Framework for Decision-making. Earthscan Publications Ltd., London, United Kingdom.

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Book Reviews

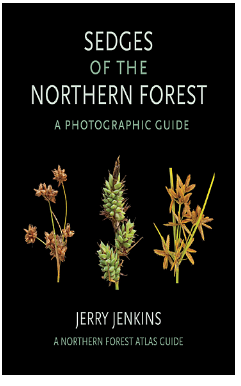
Book Review Editor's Note: *The Canadian Field Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those on any species (native or non-native) that inhabits Canada, as well 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 Pound.

Botany

Sedges of the Northern Forest: A Photographic Guide

By Jerry Jenkins. 2019. Cornell University Press. 96 pages, 16.95 USD, Paper.



Another regional guide to identification of sedges (Cyperaceae) has been published, this time covering the species found in what has been referred to as the "Northern Forest". This book—and it's companion "Quick Guide", a boxed set of two fold-out charts—joins several other excellent treatments of sedges from various parts of North America that have been published in recent years. The area covered by this book does not include much of the forest region Canadians generally would think of as "northern", which would be the boreal forest; rather, it covers mainly what we think of as the Great Lakes–St. Lawrence Forest Region in Ontario and Quebec, and the Acadian Forest Region in the Maritime Provinces (Rowe 1972).

As the title indicates, this book is a photographic guide. It is laid out in such a way that comparisons among similar species can be made easily. The use of a black background behind the images assists greatly in highlighting the important features, such as shape of the perigynium, venation on the perigynium surface, perigynium beak shape, size, and orientation, overall inflorescence and individual spike morphology, scale shape, colour, and size, and various other features that are critical for identification. The great majority of the species found in the region are included with photographs, but there are a few species for which only brief mention is made in the text that supplements the photographs; most of the species without photographs are rare, range-edge species within the region covered.

The book begins with a brief introduction explaining its role and ways to use it. This is followed by an illustrated glossary, the illustrations being simplified caricatures or outlines of the features being described. Throughout the book, some simple symbols and abbreviations are used to assist in interpretation of structures, such as symbols for the sex of the individual flowers or spikelets, and the cross-sectional shape of the achenes. A helpful section on vegetative features, arrangement of spikelets within the larger inflorescence, achene shapes, perianth bristles, etc. is followed by a quick guide to the genera found in the flora, the latter again accompanied by stylized illustrations. Then, the detailed treatment of genera and the sections and species within them (in *Carex*, for example) follows. All genera, and in the case of *Carex*, sections within the genus, are treated alphabetically. Following this, a section called "Quick Guides to *Carex*" provides more details on morphology of spikelets, including arrangement of the sexes within them, perigynia, achenes, and, to a lesser extent, leaf and sheath features. Short paragraphs supplement the photographs in this section and provide additional hints on identification including, where applicable, habitat notes. More detail on each species is found later in the text, but this section provides a quick reference to help in narrowing down which group within *Carex* a specimen belongs.

Almost half of the book is dedicated to photographs of the most important features that aid in the identification of individual species. Generally, the photographs focus on inflorescence, spikelet, flower, and achene features, but occasionally also include vegetative features. Key features are noted with the photographs (e.g., solitary spikelet, stems smooth, base of bract with lobes), and there are also paragraphs for each genus, section, or group of similar species highlighting distinctive features or providing brief notes on habitat preferences. The quality of the images generally is very good and the notes are helpful. In most cases, the photographs selected for inclusion convey a good representation of the characteristic appearance of the species. For difficult groups such as *Carex* section *Ovales*, a nice job has been done of grouping similar species together on the plates (e.g., species with perigynia >2 mm wide, species with perigynia covered by the scales). Another difficult group, the genus *Eleocharis*, has also been dealt with quite well, with good images and notes. One exception to the representation of species with typical photographs is the image of the upper part of the inflorescence of *Carex molesta*, which does not convey its typical appearance, at least to my eye. The spikelets usually are more closely aggregated into a cluster. Another exception is the inflorescence of *Carex lenticularis*, which normally shows a striking pattern of pale green perigynia among bicoloured black and green scales within the spikelets.

I did detect a number of typographical and formatting errors in the text, such as an incorrect symbol beside the inflorescence of *Carex exilis*, lack of italics here and there, the odd missing letter in a word, duplicated entries in the list of older names on p. 87, errors with the listing of *Carex appalachica* and *Carex radiata* in the list of older names, and so on, but in general the text and the plates are well put together. The author has included his own opinions on topics such as the flurry of nomenclatural changes that has occurred with *Carex* sectional names over the past few decades, the distinctness (or not) of certain species (e.g., *Carex tincta*), and similarities among unrelated species, all of which add some colour to the text. One such comment that has me scratching my head, though, is his perception that *Carex capillaris* is somewhat similar to *Carex eburnea*. Nevertheless, the great majority of the text contributes well to assisting the user to identify sedges.

Overall, this book is well conceived, and provides an excellent resource for field botanists who wish to get a better handle on the identification of species in this large and diverse family in the northeastern USA and southeastern Canada. Although the size is a bit cumbersome, I think that it could still be opened on a desk next to a specimen or adjacent to a dissecting scope and used effectively. I certainly recommend it field botanists and naturalists interested in improving their knowledge of this important family of flowering plants.

Literature Cited

Rowe, E.C. 1972. Forest Regions of Canada. Canadian Forestry Service Publication No. 1300. Fisheries and Environment Canada, Canadian Forest Service, Ottawa, Ontario, Canada.

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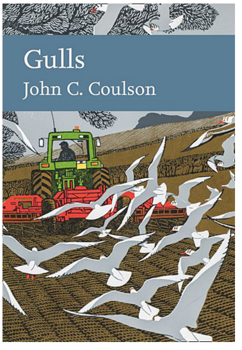
ORNITHOLOGY

Gulls

John C. Coulson. 2019. New Naturalist Library, HarperCollins Publishers. 495 pages, 108 charts and graphs, 35 maps, and 109 colour pictures, 135.99 CAD, Cloth.



This book is about the gulls of Great Britain and Ireland and to a lesser extent those of Western Europe, but it includes many generalisations that apply to gulls everywhere, gulls being a relatively uniform group of birds. A 42-page overview chapter deals with the taxonomy, biogeography, demography, plumage variation, and breeding biology within the Laridae. This is followed by comprehensive individual accounts for the nine species breeding regularly in Britain (about 25 pages each, but 64 on Black-legged Kittiwake [*Rissa tridactyla*]) and by chapters on rare species (17), on methods used to study gulls, on urban gulls (considered a big problem in Britain), and on conservation and management. There is a "selected bibliography" that is certainly sufficient to satisfy all but the most demanding reader (a full bibliography was considered too extensive to be included) and a few statistical appendices, as well as one dealing with the taxonomy of the Herring Gull (*Larus argentatus*) complex in Europe.

Compared to a similar area of Canada, Britain is relatively rich in gulls: only five species breed in the Maritimes, for instance. In addition, there has been a great deal of research on British gulls, especially Herring Gull, Lesser Black-backed Gull (*Larus fuscus*), and Black-legged Kittiwake. Consequently, the author has a lot of material to work with. Moreover, a substantial proportion of it was actually amassed by Coulson and his students (including Canadians John Chardine and Julie Porter) over a span of nearly 70 years. This is the summary of a lifetime's work by a very industrious and distinguished (and long-lived) scientist!

In his Foreword, Coulson mentions an early interest in banding. This seems to have continued because the book includes many maps of band recoveries and movements figure prominently in the species accounts. Where the author has researched the species extensively (Herring Gull, Black-legged Kittiwake) he gives many details from personal field experience. These anecdotes are among the most enlightening in the book. The methods chapter devotes several pages to banding as a research technique and includes a description of how the author discovered and developed the use of Darvic to make colour-fast plastic bands. This material is still used in many avian studies worldwide and has been an important component of my own research on auks. For many years, the Canadian Wildlife Service sourced its colour bands from John Coulson's technician at Durham University!

The book, printed in China, is nicely produced on glossy paper with excellent maps, charts, and photographs. John Coulson was a pioneer in the study of seabirds, especially long-term population studies. He was the source for many methods still current in the field. He writes with the authority appropriate to his seniority and lifetime of research. Yes, the accounts are a little parochial: we do know something about Herring Gulls and Black-legged Kittiwakes in North America, but Coulson makes no pretence that these are other than United Kingdom-based accounts. Despite its slightly narrow focus, *Gulls* is a must for anyone interested in any branch of Ornithology.

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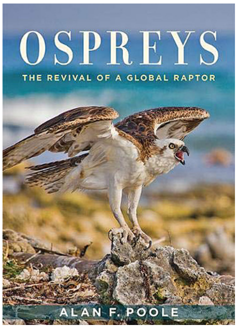
Ospreys: The Revival of a Global Raptor

By Alan F. Poole. 2019. John Hopkins University Press. 205 pages, 39.95 USD, Cloth or E-book.



Many of us are familiar with the catastrophic declines in Bald Eagle (*Haliaeetus leucocephalus*) and Peregrine Falcon (*Falco peregrinus*) populations owing to DDT and their subsequent recovery in at least parts of their ranges. But many may not be aware of the extent to which Osprey (*Pandion halieatus*) were similarly affected. Alan Poole is clearly an authority on the subject, having studied Ospreys in New England for over 35 years and authoring numerous scientific publications on the subject.

The title of this new offering is a bit of a misnomer, however, as the book covers a lot more ground than just the recovery of the species. An initial Introduction sets the stage and "A Hawk that Fishes" (Chapter 2) describes the Osprey's morphological adaptions, including differences among subspecies. The "Geography of Ospreys" (Chapter 3) summarizes the status of different Osprey populations across its global range, including Canada (citing several provincial atlassing efforts). Subsequent chapters cover foraging ecology, nesting behaviour, and migration, with the final two chapters discussing threats and solutions and the future outlook for Osprey. With such a cosmopolitan species and the breadth of topics he touches upon, Poole has done an admirable job constructing a cohesive narrative.

Poole's new book also brings into the discussion technological advances such as satellite telemetry, geolocators, and DNA evidence that have helped further our understanding of Ospreys over the last 30 years. Clearly willing to share the credit, he includes sidebar profiles on other Osprey researchers—reminding us how it takes a global village to understand this wide-ranging raptor. He also mentions where our understanding of Osprey is lacking, such as the period when young Osprey are learning to forage and during their first migration. I would like to have learned what factors exclude Osprey from breeding in tropical South America and Africa, given they overwinter there and reside year-round in Australia—but perhaps that will have to wait for Poole's next book.

Scientific chops notwithstanding, Poole's very readable prose makes it accessible for the layperson despite the quantity of information presented. For example, when discussing Osprey learning to fly, he remarks "As any human pilot will tell you – flying is easy; it's the landings that are tough" (p. 104) and mentions how human mothers with a houseful of rowdy teenagers might sympathize with female Ospreys at the nest. The book also benefits from over 100 excellent, decent-sized photographs and illustrations of Ospreys and their habitats, covering all manner of behaviour. Well laid-out maps showing Osprey movement patterns (from telemetry data) and several charts add to the fantastic visuals. On a very minor note, it would have been informative to have a density map of breeding Osprey in North America, but perhaps there are insufficient data. More Canadian content (and calling Nunavut a territory rather than a province on p. 44) would also have been welcome, but I suppose one can only ask so much with a global raptor. I do wish however, that all species names be capitalized or none; for example, Osprey is capitalized but Black Caiman and Agami Heron are not (p. 133).

My first childhood encounter with Ospreys was watching one catch a fish in a northern Ontario lake, only to see it lost to a marauding Bald Eagle. Since then, despite being a professional biologist, I have learned woefully little about this remarkable raptor. *Ospreys: The Revival of a Global Raptor* has greatly helped me address such gross negligence. I thoroughly enjoyed reading it and would highly recommend it to both novice naturalist and experienced birder alike.

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ZOOLOGY

The New Beachcomber's Guide to the Pacific Northwest

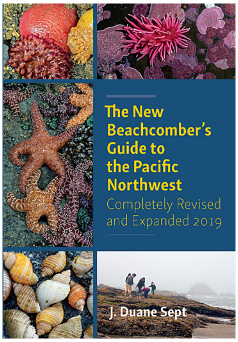
By J. Duane Sept. 2019. Harbour Publishing. 432 pages and 880 photographs, 32.95 CAD, Paper.

A Field Guide to Marine Life of the Protected Waters of the Salish Sea

By Rick M. Harbo. 2019. Harbour Publishing. Pamphlet, 7.95 CAD, Folding Guide.

A Field Guide to Marine Life of the Outer Coasts of the Salish Sea and Beyond

By Rick M. Harbo. 2019. Harbour Publishing. Pamphlet, 7.95 CAD, Folding Guide.



My recent move from Ontario to British Columbia (BC) introduced me to a number of new environs, each with their own suite of organisms. Mountains, glaciers, and temperate rainforests were all new to me. Perhaps most exciting of all were my first encounters with shoreline and intertidal life on the Pacific Ocean. Being more acquainted with the Carolinian Forest and Great Lakes shores, I was unable to identify most of what I saw. This similar situation must present itself to many who visit Canada's Pacific Coast or the United States' Pacific Northwest for the first time.

A series of new field guides, all by the same BC-based publisher, aim to provide a quick introduction to the species found on the shorelines and beaches of BC and the Pacific Northwest. Two different formats are employed. The first is a full field guide: *The New Beachcomber's Guide to the Pacific Northwest* by J. Duane Sept. This compact but hefty softcover book gives a detailed introduction to life in the intertidal zone. A brief opening chapter explains tides, shoreline zones, and microhabitats within the coastal ecosystem. What follows is 300+ pages of accounts of the most common invertebrate, algae, lichen, and plant species to be found on the beach. Each species is given one or two full colour photographs, a common name, scientific name, and brief outline of range, physical description, and life history notes. Species accounts proceed taxonomically with sections on sponges; anemones, hydroids, and jellies; comb jellies; worms; molluscs; lampshells; arthropods; bryozoans; echinoderms; tunicates; fish; seaweeds; plants; and lichens. No keys or identification guides are provided, so the book is best used by flipping through to find a photo that looks most like the strange creature you just found under a rock. For easier comparison, full colour plates of a range of limpets, snails, bivalves, and urchins are provided separately. This book is big, certainly bigger than a back pocket, but will likely provide greater chance of identification for those that must know about everything they find.

Parallel to, but separate from, this approach are the two pamphlets written by Rick Harbo: *A Field Guide to Marine Life of the Protected Waters of the Salish Sea* and *A Field Guide to Marine Life of the Outer Coasts of the Salish Sea and Beyond*. These two works take a similar approach to quick identification of intertidal life, but are definitely designed to be thrown into any pocket. In order to accommodate a drastic reduction in size, a more targetted region and fewer species are included. Both guides focus on the Salish Sea, the region roughly encompassing the marine region east of Vancouver Island, west of the lower BC mainland, and stretching down into Puget Sound in Washington State. The two guides roughly divide this region into an inner protected region and an outer coastal region. Understandably, there is some overlap in species. Like Sept's book, species accounts are presented taxonomically. Sticking with the condensed format however, fewer biological details are given for each species. Despite these restrictions, each species still gets a full colour photograph and over 75 species are included in each pamphlet.

All three of these publications can be valuable tools for those venturing out on the Pacific Coast. The cost is very reasonable and durable construction ensures that they should survive more than a few trips to the shore. The only difference is the relative size and biological depth that each provides. Certainly, any one of these works would be a valuable purchase for those, like me, who want to go to the shore and be able to identify most of the fascinating lifeforms that they will encounter.

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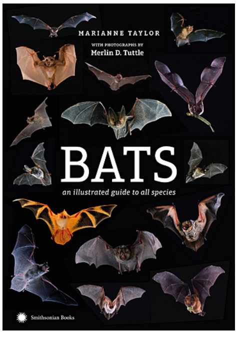
Bats: An Illustrated Guide to All Species

By Marianne Taylor. Photography by Merlin D. Tuttle. 2018. Smithsonian Books. 400 pages, 39.95 CAD, Cloth.



Part lavishly illustrated desktop field guide, part coffee table book, this stunning hardcover is a triumph of production quality. From the cover through to the index, this book has the look and feel of a text three times its price. Not only do the colour saturation and satisfying weight of paper stock do justice to the incredible images, the book is intuitively organized and rendered in exquisite detail.

Starting with a well written and accessible 50-page introduction section that offers an overview of everything from evolution, diversity, and biology to behaviour and bat-human relationships, the bulk of this book is in the species descriptions, organized by suborder, family, and species. As advertised, it covers the 1384 currently recognized bat species of the world, following the 2018 bat taxonomic review by Simmons and Cirranello (2019). Each species is represented by at least a portrait, as well as its distribution (details and map), physical description, and a few interesting facts. The length, weight, and IUCN status of each species is also provided.

Although lacking a species key and not designed as a true field guide, the level of detail in the family and genus descriptions is more reminiscent of a textbook than a popular science entry. While Taylor largely avoids jargon throughout, the long-form descriptions interspersed between the species accounts do have a noticeably different tone. Casual readers will likely enjoy the more accessible Introduction section and enjoy the book as a curio for its beautiful photography and interesting facts. There is certainly enough here for those with a keener interest, but they will have to seek out further reading on their own as the book provides no citations for the information presented.

The highlight of this book is certainly the photography, much of which captures night-time scenes. The bat portraits are all the more impressive for the way they capture the likeness of their subject. It should be said that this is a good resource to win over the bat-fearing folk among us—aside from a handful of very unusual looking adaptations, bats are by and large endearing creatures and Tuttle captures them with remarkable skill. Taking charismatic photos that show a bat's natural expression (i.e., avoiding squinting eyes from a nocturnal animal exposed to flash) is not an easy task, but the night-time photography, and especially the action shots, in this book are simply unparalleled.

If the author's and photographer's objectives were to create a spectacular photo inventory of bat species, prefaced by interesting front matter and interspersed with highly detailed family and genus descriptions, they have met and exceeded their goals. The care, time, and effort put into this book are obvious. Dr. Tuttle has studied and photographed bats for 60 years, and his photo collection combined with Taylor's clear writing are what make this book possible. The result is a gorgeous, informative catalogue of species which absolutely deserves a place on your bookshelf.

Literature Cited

Simmons, N.B., and A.L. Cirranello. 2019. Bat Species of the world: a taxonomic and geographic database. Accessed 2 October 2019. http://www.batnames.org.

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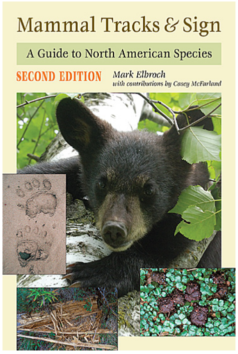
Mammal Tracks and Sign: A Guide to North American Species. Second Edition

By Mark Elbroch with contributions by Casey McFarland. 2019. Globe Pequot / Stackpole Books. 680 pages, 49.95 USD, Paper, 47.50 USD, E-book.



The first edition of this magnificent guide was published 16 years ago. As Mark Elbroch explains in his Preface, the second edition is less personal—though it retains personal stories as introductions to the chapters—and more rigorous in terms of added depth of detail. It contains less about the "tools of the trade" (p. v), because basic information is now readily available through increasing online resources. Some adjustments in species inclusion were made, primarily removing any south of Mexico. Surprisingly, the second edition is shorter than the first (by just over 100 pages), a result of being tightened up, with white space at a premium and photos sometimes smaller. In sum, if you have the first, you wouldn't be amiss to acquire this edition as well.

Senior author Elbroch and contributor Casey McFarland have extensive experience tracking animals. They are both certified Senior Trackers under the CyberTracker Conservation program, started in South Africa by biologist David Lieberman, who was inspired to develop CyberTracker freeware following his experiences with Kalahari Desert bushmen, whose lives depend on their ability. Elbroch is involved as well with Pathera, a big cat conservation organization, as Director of its Puma Program. His 10 books have been well received, the first edition of this guide being one of several of his books to win a National Outdoor Book Award.

The first chapter provides a brief and succinct introduction to this prodigiously illustrated and comprehensive guide. "Tracking is … field ecology", the authors note, that "grounds us in the natural history of a place" and provides "a natural bridge to science" (p. 2). Extensive, detailed knowledge is required to track successfully, but, they caution, one must always keep in mind the dangers of drawing conclusions without it.

A hundred pages are required in Chapter 2 to cover "Mammal Tracks and Track Patterns". Feet make tracks, Elbroch reminds us, and the first section of this chapter follows its opening story with descriptions and sketches of the morphology of mammalian feet. But the tracks these feet produce have their own, obverse morphology, and eight questions are presented that relate the tracks to the feet that created them. Track morphology can be affected by many things, including substrate (sand, soil, snow), sexual dimorphism (helpful in sexing individual animals), and the animal's age. The many types of locomotion (gaits, hops, gallops, etc.) are covered in detail, with diagrams and illustrations of each, before the discussion turns to interpretation of tracks. This is an imaginative, speculative process that requires the tracker "to build a working hypothesis and test it" against later observations of the animal's behaviour as evidenced in its tracks: "we either toss out our original hypothesis and create a new one, or continue to refine and support it" (p. 45). This lengthy chapter concludes with a "Reference guide to mammal tracks", 46 pages of plates of life-size tracks, each example—as throughout the book's illustrations—keyed to the long, final section of species accounts.

Seven subsequent chapters follow this format of text plus grouped illustrations, the latter having their own colour-coded page edges making these sections easy to find. In the course of their movements and other activities, mammals leave behind plenty of sign which offers rich and diverse clues to who they are and what they were doing. Thus, the emphasis shifts from tracks to sign, beginning with a discussion in Chapter 3 of the "Runs, Paths, and Eskers" created by the movements of animals. (Also known as trail castings, eskers are the backfilling materials deposited in snow tunnels created by the smallest mammals [p. 113].) Animals eat and then excrete, the subject of the fourth chapter. Scat is the primary topic, because urine, being hard to find, remains understudied generally. It can have its uses, however—Elbroch has an amusing account of tracking a Bobcat by sniffing the urine it had sprayed on "scent posts", moving and sniffing from post to likely post to figure out its movements (p. 445). The short Chapter 5, "Nests, Lodges, and Other Constructions", describes the often difficult to identify shelters animals "construct … from materials they collect and manipulate" (p. 178); the shelters are organized under the likely places to find them. The next three chapters cover sign left on the ground, beginning with discussion in Chapter 6 of "diverse signs" (p. 192) created in the course of bedding down, rooting around for food, taking a dust bath, or making below-ground dens. Signs are also left "on Fungi, Herbaceous Plants, and Cacti" (Chapter 7) and "on Trees and Shrubs" (Chapter 8). While these are generally the result of feeding (Chapter 7), they can also be produced by climbing, stripping off bark, browsing on twigs, and taking advantage of tree cavities (Chapter 8). Fourteen pages of colour plates are required to detail the "Sign on mast crops" alone. The penultimate chapter is not for the squeamish—it deals with "Interpreting Prey Remains" in gruesome, full-coloured detail. A suite of forensic skills is required when dealing with remains, one of the most difficult areas of tracking to decipher. This chapter is full of questions to consider and authoritative references to consult; techniques and data to aid with interpretation are offered, including, for example, a chart of the spread between upper and lower incisors of various mammals.

The topics of the preceding chapters are the basis for the rich data presented on each species described in Chapter 10, "Species Accounts". The *Revised Checklist of North American Mammals North of Mexico, 2014* (Bradley *et al*. 2014) provides the taxonomic orders for 261 pages of individual species accounts. This is the most technical part, with data presented in small print, including measurements of front and hind tracks, trail strides of various kinds, and other measurable elements, all organized along the lines of the chapter headings. Sketches and photographs abound. The species themselves are named but not described—the evidence they leave behind is the constant topic. The trails data sections are frequently followed by notes describing that species' movements under varying conditions.

By now, the reader can be forgiven for concluding—with good reason—that using tracks and sign is a more demanding and complex means of mammal identification than looking at the mammal itself. To summarize the authors, it's a matter of detective work, close observation, detailed and intricate knowledge, plus a healthy dose of humility—the capacity to accept and admit one's inevitable mistakes. Becoming a good tracker takes time, experience, and patience plus the helpful analyses presented in this excellent guide. It's on the heavy side for packing in the field, but it's well organized and indexed, so useful whether in the field or in the study. Anyone interested in the topic will learn from this book. It opens up a new universe for exploring the natural world for those coming fresh to the topic and no doubt contains much for those with experience. As the authors note early on, it's not only easy to get it wrong, but costly in terms of natural history. This guide will help.

A final note: Stackpole Books is to be congratulated on its publication of another fine field guide in its tracks and sign series. This one on mammals joins guides on birds (co-authored by Elbroch; Elbroch *et al*. 2001), reptiles and amphibians (Tkaczyk 2015), and insects (Eiseman *et al*. 2010), all similar in form and topics covered.

Literature Cited

Bradley, R.D., L.K. Ammerman, R.J. Baker, L.C. Bradley, J.A. Cook, R.C. Dowler, C. Jones, D.J. Schmidly, F.B. Stangl, Jr., R.A. Van Den Bussche, and B. Würsig. 2014. Revised Checklist of North American Mammals North of Mexico, 2014. Museum of Texas Tech University, Lubbock, Texas, USA. Accessed 7 November 2019. http://www.nsrl.ttu.edu/publications/opapers/ops/OP327.pdf.

Eiseman, C., and N. Charney. 2010. Tracks & Sign of Insects and Other Invertebrates: a Guide to North American Species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Elbroch, M., E. Marks, and C.D. Boretos. 2001. Bird Tracks & Sign: a Guide to North American Species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

Tkaczyk, F.A. 2015. Tracks & Sign of Reptiles & Amphibians: a Guide to North American Species. Stackpole Books, Mechanicsburg, Pennsylvania, USA.

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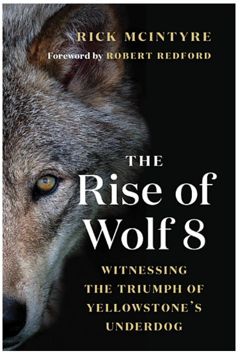
Ottawa, ON, and Corraville, PEI

The Rise of Wolf 8: Witnessing the Triumph of Yellowstone's Underdog

By Rick McIntyre. 2019. Greystone Books. 304 pages, 34.95 CAN, 26.95 USD, Cloth.



Rick McIntyre has spent over 40 years observing wolves in national parks, including Denali, Glacier, and Yellowstone. *The Rise of Wolf 8* is part one of a planned trilogy of his nearly 25 years of observing Yellowstone wolves. What is significant about this book is that the author is the source for this story. For the past 20 plus years, many people have written about McIntyre, his colleagues, and the Yellowstone wolves through interviews and television documentaries. But now we get to hear from the man himself. And the book doesn't disappoint. The profiles of individual wolves found in this book are unparalleled for a carnivore, especially here in North America where most carnivores are elusive, usually being active away from people, in forested areas, and at night. As Doug Smith says in the Afterword, "Rick has become a global ambassador for wolves … what you have just read is one of the most personal and in-depth insights into wolves ever produced" (p. 267). I agree! The only resource that I can compare it to is Jane Goodall's *The Chimpanzees of Gombe* (1986, Belknap Press), which describes the lives of individual chimpanzees in unprecedented detail. The same is true of McIntyre's observations of wolves; his knowledge of individuals provides a remarkable real-life narrative of wild wolves.

Hoping just to see a wolf during the first summer (1995) that they were reintroduced to the park (pp. 19–20), McIntyre observed a pack for hours on his first day there and went on to observe more wild wolves than any other human in history, as documented in the Afterword of this book (pp. 265–267). He has had over 100 000 wolf sightings as of January 2019 (p. 267), aided by radio-telemetry, spotting scopes, and a cadre of wildlife watchers and professionals assisting him. He once went out an indefatigable 6175 consecutive straight days into the park, saw wolves 892 days in a row, and has compiled a journal of over 12 000 pages (pp. 265–266)! Over the years, he has been a critical resource for thousands of people in observing wild wolves which is important because observing carnivores is a major economic driver in many regions (Way and Bruskotter 2012), with people specifically visiting regions where carnivores are protected to have "peak life experiences" (McIntyre 2016). Rick was an important source for my own book, *My Yellowstone Experience* (2013, White Cottage Publishing), so it is probably not surprising that I was revelling in the opportunity to review this book.

After a brief background describing his childhood and earlier park service jobs, mostly up in Alaska at Denali and in Texas at Big Bend, the book starts in 1994 in Yellowstone where McIntyre was the country's first "Wolf Interpreter" for the park service. There he primed about 25 000 park visitors that summer about the return of wolves to Yellowstone (p. 10). The next few chapters discuss the reintroduction project—some of the human actors involved as well as the early wolves, brought from Alberta (near Jasper National Park) to Yellowstone. We learn that Wolf 8 of the Crystal Creek pack was the smallest male brought to Yellowstone, a Coyote-like 72-pound (32.6-kg), grey coloured male (p. 15) called "the little guy" (p. 29). He was frequently picked on by his three larger brothers while they were held in an acclimation pen to reduce their homing instincts (Chapter 3).

The most important story in the book, and arguably one of the most important events in the annals of Yellowstone wolf reintroduction, was Wolf 8 leaving his birth pack as a 1.5-year-old to join up with Wolf 9 and her eight pups of the Rose Creek pack (Chapter 6). Wolf 9's mate #10 had been illegally killed outside the park in April 1995, so 9 and her pups were brought back to the park soon after and kept in an acclimation pen until October. Just before the planned release of the wolves, 8 showed up and greeted and fed two of the pups who had escaped the pen during a summer storm. Park employees immediately released the rest of the wolves and the ten wolves formed a cohesive pack led by step-father wolf 8 who protected his new pack (e.g., pp. 48–50) and regularly had to go out and hunt prey animals much bigger and stronger than he was (pp. 248–249). Wolf 8 proved his worth by eventually fathering 54 pups over his life (p. 232).

McIntyre moved full-time to Yellowstone in 1999 to immerse himself in the wolves' world (p. 182). Thus, *The Rise of Wolf 8* is highly personalized as it is about individual wolves, similar to *Wild Wolves We Have Known* which details the lives of famous wolves studied around the globe (Way 2016). But two things stand out in McIntyre's book: 1) it is about individual wolves studied in one area; and 2) studying individuals is becoming more and more frequent, despite the stereotype that biologists shouldn't ascribe names and emotions to their study subjects. Thus, this book normalizes the importance of individual—not just populations of—animals. We clearly see that wolves have individual personalities, are social, and love to play—all characteristics of higher-order animals like humans. We learn that play is vitally important for bonding within packs as well as preparing them for real world circumstances; McIntyre provides a list and vivid descriptions of these games throughout the book (e.g., pp. 210, 227, 228, 242).

The culmination of the book was "The Battle of Specimen Ridge" (Chapter 27) between Wolf 8's Rose Creek pack and his step-son 21's Druid Peak pack. McIntyre's Shakespearean description of the encounter is absolutely riveting. He noted that 8's determination to battle the much larger 21, who was undefeated in battle situations with other wolves (p. 263), was the bravest thing he had ever seen, "a fight that 21 could not lose and one 8 could not win" (p. 257). Wolves 8 and 21 were never known to have killed other wolves and there are repeated accounts throughout the book of them letting rivals go (p. 262). This is exceptional because they were both alpha wolves for years and wolves killing each other is the most common cause of death where people don't kill them (p. 179). Wolf 8 was battle-worn and had many debilitating injuries (pp. 247–248). Yet he soldiered on, fueled solely by willpower (p. 249), until June 2000 when he died from either an Elk's kick to his head or drowning soon afterward (p. 260). Dying in combat, McIntyre noted, was an honourable ending to his life—it was a good death (p. 261).

At the beginning of the book McIntyre noted (p. xix) that all the elements of a great tale are present, including warfare, betrayal, murder, bravery, compassion, empathy, and loyalty, yet a literary genius such as Dickens or Shakespeare was not available to write this story. I disagree. I believe that McIntyre himself was the perfect person to write this wonderful account. He combines his extraordinary level of observation of wolves with great storytelling (p. 265).

For fans of Yellowstone or wolves, this book is priceless, with a historic feel to it that is palpable. I wholeheartedly recommend it and believe that readers interested in nature, carnivores, and individual animals will be fascinated to learn about the wolves described here and in forthcoming volumes of McIntyre's planned trilogy. McIntyre (2016) has described viewing Yellowstone wolves as a "peak life experience". Reading this book and gaining the insights into Yellowstone wolves that McIntyre provided in unparalleled detail was a 'peak reading experience' for me! I eagerly await the next edition of the Yellowstone wolf saga.

Literature Cited

McIntyre, R. 2016. A peak life experience: watching wolves in Yellowstone National Park. Yellowstone Science 24: 44–46.

Way, J.G. 2016. [Book Review] Wild wolves we have known: stories of wolf biologists' favorite wolves. Canadian Field-Naturalist 130: 85–87. https://doi.org/10.22621/cfn.v130i1.1800

Way, J.G., and J.T. Bruskotter. 2012. Additional considerations for gray wolf management after their removal from Endangered Species Act protections. Journal of Wildlife Management 76: 457–461. https://doi.org/10.1002/jwmg.262

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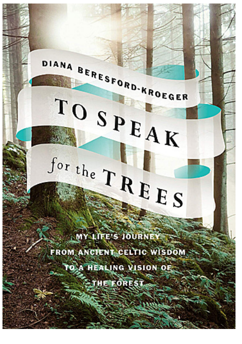
OTHER

To Speak for the Trees: My Life's Journey from Ancient Celtic Wisdom to a Healing Vision of the Forest

By Diana Beresford-Kroeger. 2019. Random House Canada. 289 pages, 32.00 CAD, Paper.



Diana Beresford-Kroeger is a name that has become increasingly well-known in recent years. Awareness and acceptance of her work has been a long time coming. Variously described as a classical botanist, medical biochemist, and protector of forests, Fellow of The Royal Canadian Geographical Society, and—in a delightful poke at the conservative elements that resist her message—"an enemy of the people" (https://www.insideottawavalley.com/news-story/5463236-diana-beresford-kroeger-is-now-an-enemy-of-the-public/; accessed 10 September 2019), she is at once grounded in local activities and at home in world-wide travels through various media. She has published some 300 scientific papers, but the public has come to know her through her previous half-dozen books (or more, depending how you count the editions), published over the past 20 years, and more recently the film *Call of the Forest*, now streaming on the Internet (https://www.youtube.com/watch?v=T0asL2LfPFk). Not bad for someone who echews email and social media as taking too much time from her real work (D. Beresford-Kroeger pers. comm. 13 August 2019)!

Trees have been at the centre of her explorations and writings, and she combines in her study and advocacy two broad and apparently disparate streams, the scientific fields of botany and biochemistry and the esoteric realm of ancient Celtic beliefs and practices regarding nature. Now, in her latest book, she relates the personal story behind this double expertise. *To Speak for the Trees* doesn't begin with the *Ancient Celtic Wisdom* noted in the subtitle; rather, it begins with an account of the difficult life of a misplaced soul whose journey began in trauma and tragedy. These hard beginnings contain the roots of the dual streams noted above. Her father's family came from a long lineage of wealth and status, her mother's from an even longer lineage dating back to the Celtic/Druidic world, based in Lisheens Valley, County Cork, Ireland. The former was the source of the trauma; tragedy—the deaths of her parents within months of each other when Diana was 12—propelled her initially into the world of science as shared with an uncle who took her in. The serendipitous discovery of her capacious intellect, revealed through her photographic memory, lifted her into deeper studies, at university but also while under the care of her Celtic relations with whom she spent her summers. That aging community decided she would be the ideal exponent of their traditional knowledge and proceeded to teach her everything they knew. Thus, her increasingly happier world came to be divided, productively, between science and indigenous Celtic lore.

The first six chapters cover all this and more. In Chapter 7, "But Where are the Trees?", the book moves on to its central substance, her love of, and life-long relationship with, trees and her increasing awareness of their absolute essentiality to the survival of other forms of life on earth. The title question for this chapter relates to her realization that the ancient forests of Ireland had largely disappeared. Thus began her quest to understand what happened and why, a quest that ultimately took her around the world, inspired a great deal of original research, and led to the insight—and she is marvellous at gaining insights—that if the trees disappear, we disappear, the dependency is that tight (p. 114). This fundamental principle is at the core of a life of activism and the development of her "global bioplan" (p. 159) for addressing climate change, the gravest single problem faced by humanity today. Her research results coalesced into this practical plan, one she lives, with her husband, Christian Kroeger, on 160 acres (64.75 hectares) of land they call Carriglaith, near Merrickville, south of Ottawa. Chapter 11, "My Own Work in My Own Way", recounts the story of developing this land into what amounts to a gene bank of trees hardy enough to live in northern climes as temperatures rise.

The paragraph above compresses the second half of Part One of the book. As her work progressed, she came to understand that she "could serve as a bridge between these two worlds, the ancient and the scientific" (p. 98). Her account is bravely personal, for she is frank about how the suppression she experienced growing up and into early adulthood continued through misogynistic workplaces and the reluctance of the scientific community to accept the esoteric and spiritual elements her research revealed. She took strength from these experiences, however, coming to realize that her background was essential to her ability to think for herself, to refuse to suffer fools gladly, to stand firm for her growing beliefs in the power of trees, and to bring this into form through her actions, from the land she and Christian manage to promoting her hard-won knowledge through the books and documentary noted above, to advising many groups and governments. Examples of her efforts are described in the final chapters of Part One, which concludes with her "Philanthropy of the Mind", the combination of her "scientific knowledge and … energy" (p. 76) that drives her and, she hopes, will inspire all of us to act.

In Part Two, she returns to her roots to provide us with "one more gift …: my annotation of the Ogham script, … the first alphabet of Europe, in which every letter is named for a tree or an important companion plant of trees" (p. 189). There are 20 letters, each receiving an account that mingles poetically scientific knowledge of the trees with ancient Celtic lore, starting with A/Ailm, Pine, and ending with Z/Straif, Blackthorn. Old uses, now largely lost, medicinal properties, and notes on the alphabet itself are melded into each of these brief notes.

This is a courageous, highly readable book, yielding insights of value and leaving us—field naturalists, researchers, nature lovers—with much to think about. The discoveries Diane Beresford-Kroeger has made are at last entering the mainstream, as a source of knowledge and inspiration for the increasing numbers of people concerned with the physical and future state of the planet.

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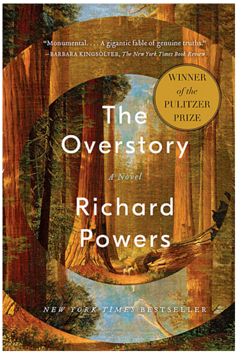
The Overstory: A Novel

By Richard Powers. 2018. W.W. Norton. 512 pages, 27.95 USD, Paper.



Readers of *The Canadian Field-Naturalist* might reasonably wonder why a novel would be reviewed in its pages. A precedent of sorts was set several issues ago with our first review—at least on my watch as Book Review Editor—of a book of poetry, Alice Major's *Welcome to the Anthropocene* (Citron 2017). But a novel? This isn't just any novel, however—it's a brilliant evocation of the life and times of trees as understood, misunderstood, used and abused, by the one species on Earth that supposes itself to be dominant—*Homo sapiens*, you and I and all the other 8 billion or so humans alive today. The entire book, from its title on out, is structured along the lines of and about trees. The title is a play on words, referring at a literal level to the overarching canopy of trees in a forest, the collective crowns of the tallest trees, while signalling the author's ambition to tell as fully as possible the richly complex story of trees as sentient beings and their interactions with humans.

This Powers does brilliantly, in language that flows with an unusually high degree of authenticity. The novel has four sections: Roots, Trunk, Crown, and Seeds. The first is the only one with subtitled chapters, nine of them, named for the characters introduced in each. I was a bit puzzled at first to read separate stories of such a disparate and seemingly disconnected group of people. Each however had some kind of connection to trees and these early chapters set the stage for Powers' interweaving, in various combinations, the stories of these people in ways that allow him to address his panoramic purpose. We humans take multifaceted approaches toward trees, whether as sources of food and medicines, shelter and fuel, beauty and meditative healing, or the many lines of work they provide, from scientific studies to logging and milling up construction materials. Powers addresses our approaches in ways that reveal our inherent, eternal conflicts arising from our need to preserve ourselves—read lifestyles, economies—and our yearning for connectivity and transcendence. Powers does not resolve these conflicts, however. While reading his book, it's possible to hate and fear the destruction our 'normal' lumbering practices are inflicting on the forests while having sympathy for the people whose jobs are at stake if those practices cease, to engage emotionally with the activists going to increasing lengths to end the destruction while gasping at some of their decisions. The world of science is also revealed as conflicted, especially in the characterization of 'maverick' versus conventional science through the career of Patricia Westerford and her supportive husband Dennis, based on the career pathway of the very real Diane Beresford-Kroeger and her husband Christian Kroeger. Powers has done his homework—he has a reputation as a prodigiously inquisitive researcher—yet weaves his learning into a highly imagined fictional form.

The author's deliberate unwillingness to missionize, to leave the reader pondering these dilemmas, is the strength and power of the book, and reason enough, I think, to review it in these pages. Powers claims his own life was changed as a result of researching and writing this, his twelfth novel. In a recent interview, he declared that "Trees are among the very largest, longest-lived, most successful, and most collaboratively social forms of life on the planet. They live, all at once, in the sky, on the surface, and under the ground … We will learn, as Thoreau says, to resign ourselves to the influence of the earth, or we will disappear" (Brady 2018). The clarity of his personal position notwithstanding, he has managed to resist judgement and condemnation while creating a credible and complex picture of human activities in relation to trees. A number of excellent novels dealing with nature and natural history have come out in recent years, and this is one of the best, shortlisted in 2018 for the Man Booker Prize, winner in 2019 of the Pulitzer Prize in Fiction. Powers sends readers a message worth the time spent to listen to it.

Literature Cited

Citron, M. 2017. [Book Review] Welcome to the Anthropocene. Canadian Field-Naturalist 131: 372–373. https://doi.org/10.22621/cfn.v131i4.2087

Brady, A. 2018. Richard Powers: writing 'The Overstory' quite literally changed my life. Chicago Review of Books. Accessed 7 September 2019. https://chireviewofbooks.com/2018/04/18/overstory-richard-powers-interview/.

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Prepared by Barry Cottam

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Plantes de l'enclave argileuse Barlow-Ojibway – 2 Québec 2018. Par Pierre Martineau. 2018. Éditions P. Martineau. 218 pages, 40.00 CAD, Cloth. Free PDF available at http://cikwanikaci.ca/volume/index.html or http://depositum.uqat.ca/785/1/MartineauPierre.pdf.

Darwin's Most Wonderful Plants: Darwin's Botany Today. By Kenneth Thompson. 2019. Profile Books. 256 pages, 8.99 GBP, Paper.

Joseph Banks' Florilegium: Botanical Treasures from Cook's First Voyage. By Mel Gooding, David Mabberley, and Joe Studholme. 2019. Thames and Hudson. 320 pages and 180 illustrations, 45.00 USD, Cloth.

Conservation & Ecology

†The Coastal Everglades: The Dynamics of Social-Ecological Transformation in the South Florida Landscape. Long-Term Ecological Research Network Series. Edited by Daniel L. Childers, Evelyn Gaiser, and Laura A. Ogden. 2019. Oxford University Press. 300 pages, 79.95 CAD, Cloth. Also available as an E-book.

Community Ecology. Second Edition. By Gary G. Mittelbach and Brian J. McGill. 2019. Oxford University Press. 432 pages, 50.00 CAD, Cloth. Also available as an E-book.

Working with Nature: Saving and Using the World's Wild Places. By Jeremy Purseglove. 2019. Profile Books. 288 pages, 32.99 AUD, Paper.

Green Growth That Works: Natural Capital Policy and Finance Mechanisms from Around the World. Edited by Lisa Mandle, Zhiyum Ouyang, James Salzman, and Gretchen C. Daily. 2019. Island Press. 368 pages, 39.95 USD, Paper.

The Plant Messiah: Adventures in Search of the World's Rarest Species. By Carlos Magdalena. 2018. Penguin. 240 pages, 9.99 GBP, Paper or E-book.

Wild Capital: Nature's Economic and Ecological Wealth. By Barbara K. Jones. 2019. University Press of Florida. 304 pages, 60.00 USD, Cloth.

After Geoengineering: Climate Tragedy, Repair, and Restoration. By Holly Jean Buck. 2019. Verso Books. 2019. 288 pages, 33.95 CAD, Cloth, 13.99 CAD, E-book.

How Did We Get into This Mess? Politics, Equality, Nature. By George Monbiot. 2017. Verso Books. 352 pages, 32.99 CAD, Cloth, 22.95 CAD, Paper, 13.99 CAD, E-book.

International Wildlife Management: Conservation Challenges in a Changing World. Edited by John L. Koprowski and Paul R. Krausman. 2019. Johns Hopkins University Press. 248 pages, 74.95 USD, Cloth or E-book.

The Anthropocene Disruption. By Robert William Sandford. 2019. Rocky Mountain Books (RMB). 168 pages, 20.00 CAD, Cloth.

Rivers of the Anthropocene. Edited by Jason M. Kelly, Philip Scarpino, Helen Berry, James Syvitski, and Michel Meybeck. 2017. University of California Press. 242 pages, 34.95 USD, Paper. Free PDF available at https://doi.org/10.1525/luminos.43

The Shock of the Anthropocene: The Earth, History and Us. By Christophe Bonneuil and Jean-Baptiste Fressoz. Translated by David Fernbach. 2017. Verso Books. 320 pages, 25.95 CAD, Paper, 13.99 CAD, E-book.

Changing Tides: An Ecologist's Journey to Make Peace with the Anthropocene. By Alejandro Frid. 2019. New Society Publishers. 208 pages, 19.99 CAD / USD, Paper, 13.99 CAD / USD, E-book.

Towards Zero Waste: How to Live a Circular Life. By Féidhlim Harty. 2019. Permanent Publications. 176 pages, 17.95 USD, Paper.

Entomology

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Gods, Wasps and Stranglers: The Secret History and Redemptive Future of Fig Trees. By Mike Shanahan. 2018. Chelsea Green Books. 208 pages, 14.95 USD, Paper.

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Ornithology

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Great Plains Birds. Discover the Great Plains Series. By Larkin Powell. 2019. Bison Books, University of Nebraska Press. 244 pages, 16.95 USD, Paper or E-book.

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The Art of the Bird: The History of Ornithological Art Through Forty Artists. By Roger J. Lederer. 2019. UCP. 224 pages and 200 colour plates, 35.00 USD, Cloth, 21.00 USD, E-book

Oceanic Birds of the World: A Photo Guide. By Steve N.G. Howell and Kirk Zufelt. 2019. Princeton University Press. 360 pages, 368 plates with 2200 colour photos, and 114 colour distribution maps, 35.00 USD, Paper.

Peterson Reference Guide to Sparrows of North America. By Rick Wright. 2019. Houghton Mifflin Harcourt. 443 pages, 35.00 USD, Cloth.

Ornithology: Foundation, Analysis, and Application. Edited by Michael L. Morrison, Amanda D. Rodewald, Gary Voelker, Melanie R. Colón, and Jonathan F. Prather. 2018. Johns Hopkins University Press. 1016 pages and 936 illustrations, 110.00 USD, Cloth. Also available as an E-book.

Henry Dresser and Victorian Ornithology: Birds, Books and Business. By Henry A. McGhie. 2017. Manchester University Press. 368 pages. 25.00 GBP, Cloth, 30.00 GBP, E-book.

RSPB Spotlight Ospreys. By Tim Mackrill. 2019. Bloomsbury Wildlife. 128 pages and 200 colour photos, 12.99 GBP, Paper. Also available as an E-book.

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Common Spiders of North America. By Richard A. Bradley. Illustrations by Steve Buchanan. 2019. University of California Press. 288 pages, 34.95 USD, Paper. Also available as an E-book. Cloth edition published in 2012.

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Upcoming Meetings and Workshops

The Committee on the Status of Endangered Wildlife in Canada

The next Wildlife Species Assessment Meeting of COSEWIC will be held 24–29 November 2019 at the Lord Elgin Hotel, Ottawa, Ontario. See how COSEWIC assigns the status to Canadian wildlife species, the first step in protection and recovery under the federal *Species at Risk Act*. Please contact ec.cosepac-cosewic.ec@canada.ca for the procedure to attend as an observer at least one week before the meeting begins. More information about COSEWIC is available at http://cosewic.ca.

The Society for Integrative & Comparative Biology Annual Meeting

The Society for Integrative & Comparative Biology Annual Meeting to be held 3–7 January 2020 at the JW Marriott Austin, Austin, Texas. Registration is currently open. More information is available at https://burkclients.com/sicb/meetings/2020/site/.

Science, Practice & Art of Restoring Native Ecosystems Conference

The Science, Practice & Art of Restoring Native Ecosystems Conference to be held 17–18 January 2020 at the Kellogg Center, East Lansing, Michigan. Registration is currently open. More information is available at https://conference.stewardshipnetwork.org/.

Midwest Fish & Wildlife Conference

The 80th Midwest Fish & Wildlife Conference to be held 22–29 January 2020 at the BOS Center, Springfield, Illinois. The theme of the conference is: 'Bringing Science Back to the Forefront of Resource Management'. Registration is currently open. More information is available at http://www.midwestfw.org/.

Forests Ontario Annual Conference

The annual conference of Forests Ontario to be held 14 February 2020 at the Nottawasaga Inn, Alliston, Ontario. The theme of the conference is: 'We the Forest'. Registration is currently open. More information is available at https://www.forestsontario.ca/community/annual-conference/.

Society for Range Management's Annual Meeting, Technical Training and Trade Show

The Society for Range Management's 73rd Annual Meeting, Technical Training and Trade Show to be held 16–20 February 2020 at the Sheraton Denver Downtown Hotel, Denver, Colorado. The theme of the conference is: 'Transformation & Translation'. Registration is currently open. More information is available at http://www.srm2020.org/.

Wetland Science Conference

The Wetland Science Conference, a program of the Wisconsin Wetlands Association, to be held 18–20 February 2020 at the Osthoff Resort, Elkhart Lake, Wisconsin. More information is available at https://conference.wisconsinwetlands.org/.

Sedges of the Northern Forest: downloadable digital resource (pdf)

A photographic "atlas" of the sedges of the northern forest was posted online (Version 1.3, 357 pages) in early 2019 by Jerry Jenkins at http://northernforest atlas.org/. The guide contains over 1400 high-resolution digital images of 223 Cyperaceae species occurring in the northeast (including both forest and wetland species). These are composite macro images that are "stacked" to obtain clarity throughout the entire depth of field. The result is a collection of crisp, magnified, almost 3D images that carefully illustrate the distinguishing characters of each species—inflorescences, perigynia, achenes, ligules, and even anthers. The stacked images themselves are a marvel, showing even familiar species anew, with rich detail and subtle beauty.

In itself, this free downloadable resource is not a sedge guide, although it accompanies a Cornell publication that has recently become available (also called *Sedges of the Northern Forest*; 2019, Cornell University Press, see review on pp. 172–173 of this issue of *The Canadian Field-Naturalist*). It is intended to be used together with its accompanying book, or with any of the other excellent field guides and floras recently released (e.g., *Field Guide to Wisconsin Sedges* [Hipp 2008]; *Field Manual of Michigan Flora* [Voss and Reznicek 2012]; *Sedges of Maine* [Arsenault *et al.* 2013]). While it has no keys, schematic diagrams of each genus or section (in the case of *Carex*) highlight main characters. Helpful field marks and key differences with similar species are described and often illustrated. For example, a brilliant comparative page of scaled photos of achenes of the challenging Ovales group is sure to be bookmarked on my copy—think of Peterson's famous watercolour plate of "Confusing Fall Warblers", but for Ovales sedges!

This is a beautiful, portable, searchable resource. As a pdf, it can easily be transferred to a phone or tablet, and taken into the field. When used with regional floras, it will aid both beginners and advanced professionals in the study of this ecologically important, diverse, yet often difficult group.

Literature Cited

Arsenault, M., G.H. Mittlehauser, D. Cameron, A.C. Dibble, A. Haines, S. Rooney, and J.E. Weber. 2013. Sedges of Maine—A Field Guide to Cyperaceae. University of Maine Press, Orono, Maine, USA.

Hipp, A.L. 2008. Field Guide to Wisconsin Sedges: an Introduction to the Genus *Carex* (Cyperaceae). University of Wisconsin Press, Madison, Wisconsin, USA.

Voss, E.G., and A.A. Reznicek. 2012. Field Manual of Michigan Flora. University of Michigan Press, Ann Arbor, Michigan, USA.

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Book Reviews

News and Comment

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