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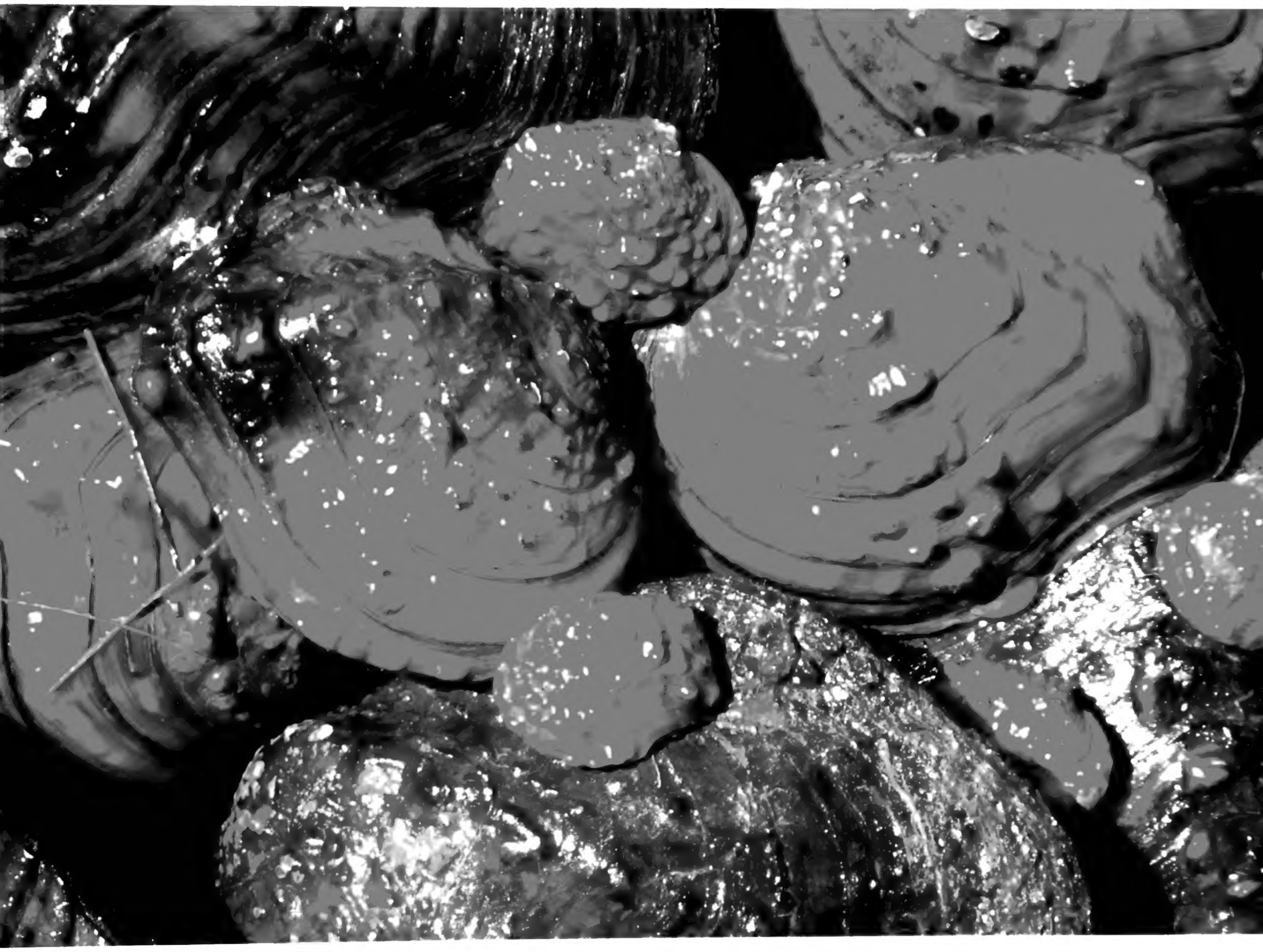

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COVER: A collection of Mapleleaf (*Quadrula quadrula*) from the Welland River, Ontario, August, 2008. See article in this issue pages 76–81 by Scott M. Reid, Victoria Kopf, Anita LeBaron, and Todd J. Morris. Photo by T. J. Morris.

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Influence of Environmental Variables on the Diel Movements of the Greenland Shark (*Somniosus microcephalus*) in the St. Lawrence Estuary

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The geographic distribution of the Greenland Shark (*Somniosus microcephalus*) extends from the Arctic Ocean to the North Atlantic Ocean. However, little is known about the habitat of this species, as it is generally found at great depths or in the High Arctic. In the St. Lawrence Estuary, Greenland Sharks undertake diel vertical movements into shallow water (≤ 30 m), but the reasons for these movements are unknown. To test the hypothesis that environmental variables drive the movements of this shark in the St. Lawrence Estuary, eight Greenland Sharks were tagged with acoustic telemetry transmitters during the summer of 2005. Three environmental factors, temperature, light, and tides, were associated with their movements. Movement patterns indicate a preference for deep, cold water during daylight hours and shallow, warmer water during the night. Ascending into shallow water mostly coincided with darkness and high tide. This improved understanding of the spatio-temporal distribution of the Greenland Shark will allow for assessment of the risk to these sharks from commercial fisheries, as occurs in the Greenland Halibut (*Reinhardtius hippoglossoides*) longline fishery. In addition, temperature-driven behavioural patterns may change as the thermal structure of the water column shifts due to global warming.

Key Words: Acoustic telemetry; depth; habitat; light; St. Lawrence River; temperature; tide; shark; Greenland Shark; *Somniosus microcephalus*

Introduction

The Greenland Shark (*Somniosus microcephalus*) is the largest arctic fish, reaching lengths up to 730 cm (Compagno 1984). Despite its size and widespread distribution, extending over the waters adjoining at least six countries in the North Atlantic and Arctic Oceans (Yano *et al.* 2007; Chernova *et al.* 2015), the Greenland Shark remains largely unknown. Little is known about its life cycle, habitat use, and the environmental factors that influence its movements. Most studies have focused on its geographic distribution, diet, and contaminant or parasite loads (MacNeil *et al.* 2012).

Because of the paucity of visual observations in surface waters until recently, the Greenland Shark was long considered a primarily cold water bathybenthic species, found at depths of up to 2200 m (Herdendorf and Berra 1995). In the St. Lawrence Estuary, Greenland Sharks undertake diel vertical movements into shallow depths (≤ 30 m) (Stokesbury *et al.* 2005), but the reasons for these movements are unknown. Although more recent studies indicate that Greenland Sharks show no temperature preference within the narrow range observed in the Arctic Ocean at Svalbard, Norway (Fisk *et al.* 2012), and Baffin Island, Canada (Skomal and Benz 2004), thermal preference may exist in the shallower waters of the St. Lawrence Estuary, where temperatures fluctuate by as much as 23°C (Stokesbury *et al.* 2005; JG, unpublished data).

Sightings of Greenland Sharks at shallow depths are not limited to the St. Lawrence. The species has been harvested by harpoon at the surface on Baffin Island (Beck and Mansfield 1969), and the Inuit from Cumberland Sound, Nunavut, occasionally observe these sharks from the surface as they swim along the sea floor (Idrobo 2008). However, this behaviour is associated with hunting activities when marine mammals are being butchered on the shore, which is not the case in the St. Lawrence since the Beluga (*Delphinapterus leucas*) fishery in Quebec was terminated in 1960. Natural encounters with scuba divers have also taken place in the Saguenay Fjord, Quebec (Harvey-Clark *et al.* 2005), and at Qaanaaq, Greenland (JG, unpublished data).

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The observed diel movements of the Greenland Shark are not unique for a shark of its size and northern distribution. A close relative, the Pacific Sleeper Shark (*Somniosus pacificus*), travels mainly below the photic zone during daylight hours and approaches the surface at night (Hulbert *et al.* 2006). The Sixgill Shark (*Hexanchus griseus*), another benthic species of comparable size found in cold water, has also been associated with nocturnal tides but at greater depths (Andrews *et al.* 2009). It remains to be determined whether Greenland Sharks respond to the same environmental stimuli as these two boreal deepwater species.

Several shark species follow circadian rhythms, remaining in deep water during the day and then ascending through the water column to shallower depths at night: Blue Shark (*Prionace glauca*; Carey and Scharold 1990), Bigeye Thresher (*Alopias superciliosus*; Nakano *et al.* 2003; Weng and Block 2004), Caribbean Reef Shark (*Carcharhinus perezii*; Chapman *et al.* 2007), Mako Shark (*Isurus oxyrinchus*; Klimley *et al.* 2002), Megamouth Shark (*Megachasma pelagios*; Nelson *et al.* 1997), Sixgill Shark (Andrews *et al.* 2009), and the Small-Spotted Catshark (*Scyliorhinus canicula*; Sims *et al.* 2006). However, studies on other shark species, including the Sixgill Shark (Hulbert *et al.* 2006) and the Greenland Shark (Skomal and Benz 2004; Stokesbury *et al.* 2005; Campana *et al.* 2013) point to conflicting diel movement patterns, and Stokesbury *et al.* (2005) observed Greenland Sharks swimming mostly close to the bottom rather than ascending vertically.

In the present study, we tested the hypothesis that environmental variables drive the movements of Greenland Shark in the St. Lawrence Estuary. To this end, we tagged eight Greenland Sharks with acoustic transmitters equipped with depth and temperature sensors and tracked their movements by telemetry during the summer of 2005.

Study Area

Greenland Sharks frequent four bays on the north shore of the St. Lawrence Estuary in the region of Baie-Comeau, Quebec, Canada (Figure 1). These boreal bays are characterized by a seasonally dynamic littoral environment offering a wide variety of known prey species of the Greenland Shark including fish, crustaceans, molluscs, and marine mammals. Baie des Anglais (station 1; 49.268°N, 68.127°W), the largest of the four bays, is 4.4 km long and 4.0 km wide with a maximum depth of 90 m. Baie du Garde-Feu (station 2; 49.281°N, 68.051°W) is 1.0 km long by 0.5 km wide with a maximum depth of 70 m. Baie-Saint-Pancrace (station 3; 49.287°N, 68.046°W) has the second largest

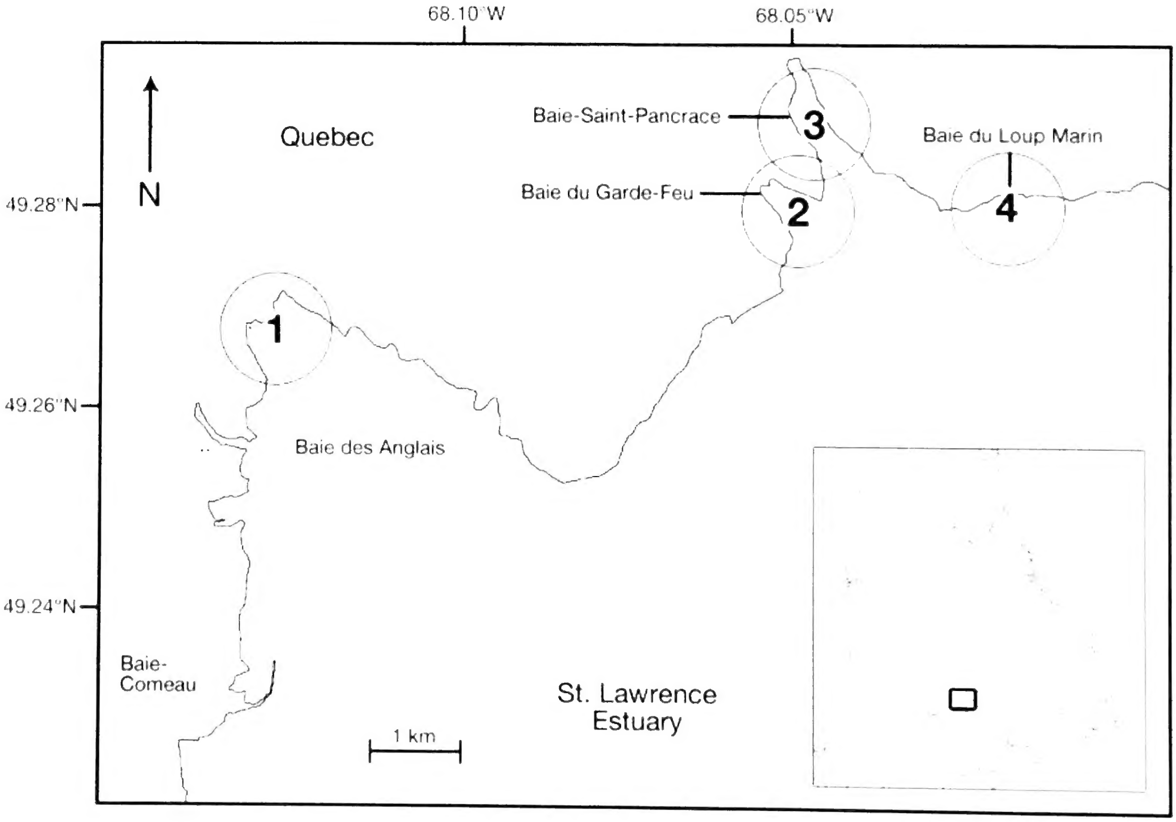

FIGURE 1. Location of acoustic sampling stations in the St. Lawrence Estuary near Baie-Comeau, Quebec. Circles indicate maximum range (600 m) of each receiver.

surface area and is also the narrowest bay (approximately 1.5 km long by 0.25 km wide); its maximum depth is also 70 m. Baie du Loup Marin (station 4; 49.280°N, 68.009°W) is only 0.03 km long by 0.2 km wide. Baie du Loup Marin is different from the other bays because of its steep incline (≥ 40°) and depth (> 150 m). The three other bays are characterized by a more gradual incline (≤ 25°). All four bays open on the St. Lawrence Estuary, which is approximately 56 km wide at the city of Baie-Comeau. The maximum depth of the Laurentian Channel, which lies at the centre of the estuary, is 350 m.

Methods

Acoustic Telemetry

To record the movements of Greenland Sharks, we deployed acoustic transmitter tags on eight sharks (unknown sex, mean length 3 m) at station 3 on 18 and 19 June 2005. To reduce the risk of injury to the sharks and divers, no shark was captured or restrained. Acoustic coded tags (V16 transmitters; Vemco, Halifax, Nova Scotia, Canada) were attached to the sharks by a scuba diver equipped with a Hawaiian sling type spear. A metal dart retained the transmitter in the shark's superficial tissue. The tag was attached to a fastener by a crimped 10-cm stainless steel wire (tensile strength 90.9 kg).

Tags transmitted a unique code, so that each shark could be identified. The tags were also equipped with sensors to measure the shark's depth (m) and water temperature (°C) at the shark's location. Tags were programmed to transmit data at 69 kHz every 60 s during the sampling period from 19 June to 19 August 2005. Transmissions were detected by receivers up to 600 m away depending on environmental conditions and bathymetry. Signals received by hydroacoustic receivers were date- and time-stamped and archived to memory. Four passive ultrasonic receivers (VR2; Vemco) were installed 6 m off the bottom in the four bays. Data recorded by the receivers were downloaded at the end of the sampling period with a laptop computer (VR1 PC interface; Vemco).

Environmental Data

Online tidal data, obtained from Fisheries and Oceans Canada (station 2840, Baie-Comeau), comprised two variables: high tide included data from 3 h before and 3 h after high water, and low tide included data from 3 h before and 3 h after low water. This distinction was made to create a time-buffer period and, thus, make allowance for sharks adjusting to the water movement of flow and ebb tides.

Surface water temperatures were obtained from an Institut Maurice Lamontagne (IML, Fisheries and Oceans Canada) thermograph network buoy off Baie-Comeau (49.202°N, 68.057°W). These data were used to monitor temperature at 1 m depth throughout the study period.

Light levels for the Baie-Comeau area were classified as "night" or "day" based on hourly data from Mobile Geographics LLC (tides.mobilegeographics.com/locations/332.html). Lunar phases obtained from the National Aeronautics and Space Administration (http://eclipse.gsfc.nasa.gov/SKYCAL/SKYCAL.html) were classified as "full moon" (7 days before to 7 days after the full moon or start of first quarter to start of last quarter) or "new moon" (7 days before to 7 days after the new moon or start of last quarter to start of first quarter).

Results

Detections per Shark

The acoustic receivers detected 96 653 signals from the eight Greenland Sharks over 62 days, from 19 June to 19 August 2005 (Table 1). All of the sharks transmitted signals on the same schedule, but the distribution of recorded signals was irregular. Lapses in signals for all sharks confirm that they left the zones covered by the receivers every day over the course of the summer. Shark 3 was detected most often (30 195 detections), whereas shark 2 was detected the least (1376). Shark 2 was also the only shark that did not remain in the study area until the end of the sampling period; it was last detected on June 21. Few signals from all sharks were detected from 19 June to 12 July. However, an increase

TABLE 1. Period of deployment and data collection for acoustic receivers in four bays off Baie-Comeau, Quebec, in summer 2005. Detections of Greenland Sharks (*Somniosus microcephalus*) (n = 96 653) ceased when the receivers were removed on 8, 20, and 21 August 2005.

Station no.	Deployment and recovery dates (d/m/y) (d/m/y)	Location	Receiver depth (m)	Dates of first and last detected signals (d/m/y)	Total signals detected
1	19/6/2005	49.267596°N	20	20/6/2005	77 379
	08/8/2005	68.127496°W		08/8/2005	
2	19/6/2005	49.287314°N	30	19/6/2005	
	08/8/2005	68.045956°W		08/8/2005	3 171
3	19/6/2005	49.280448°N	15	23/6/2005	
	20/8/2005	68.009428°W		19/8/2005	15 653
4	19/6/2005	49.280868°N	25	15/7/2005	
	21/8/2005	68.051043°W		19/8/2005	450

in detected signals began on 13 July, at which time six of the eight sharks traveled to station 1 (Figure 2).

Detections per Station

Station 1 (Baie des Anglais; depth 20 m) recorded the largest number of signals (80%; *n* = 77 379) and station 4 (Baie du Loup Marin; depth 25 m) recorded the least (0.47%; *n* = 450). Only two sharks (1 and 6) visited all four stations, and only station 2 (Baie du Garde-Feu; depth 30 m; *n* = 3171) was visited by all eight sharks. All sharks displayed similar movement patterns, swimming in and out of the stations at various speeds from the head of the bays to open water. Shark 1 made a return trip between stations 1 and 4 over a period of 29 h allowing us to calculate a long-distance average speed. Because it did so while transiting through stations 2 and 3, its minimum average cruising speed if swimming forward in a linear and continuous movement would have been approximately 0.3 m/s over a total distance traveled of 26 km. With the exception of shark 2, which left the study area shortly after being tagged, all sharks remained in close proximity to each other, traveling individually or in loose groups as

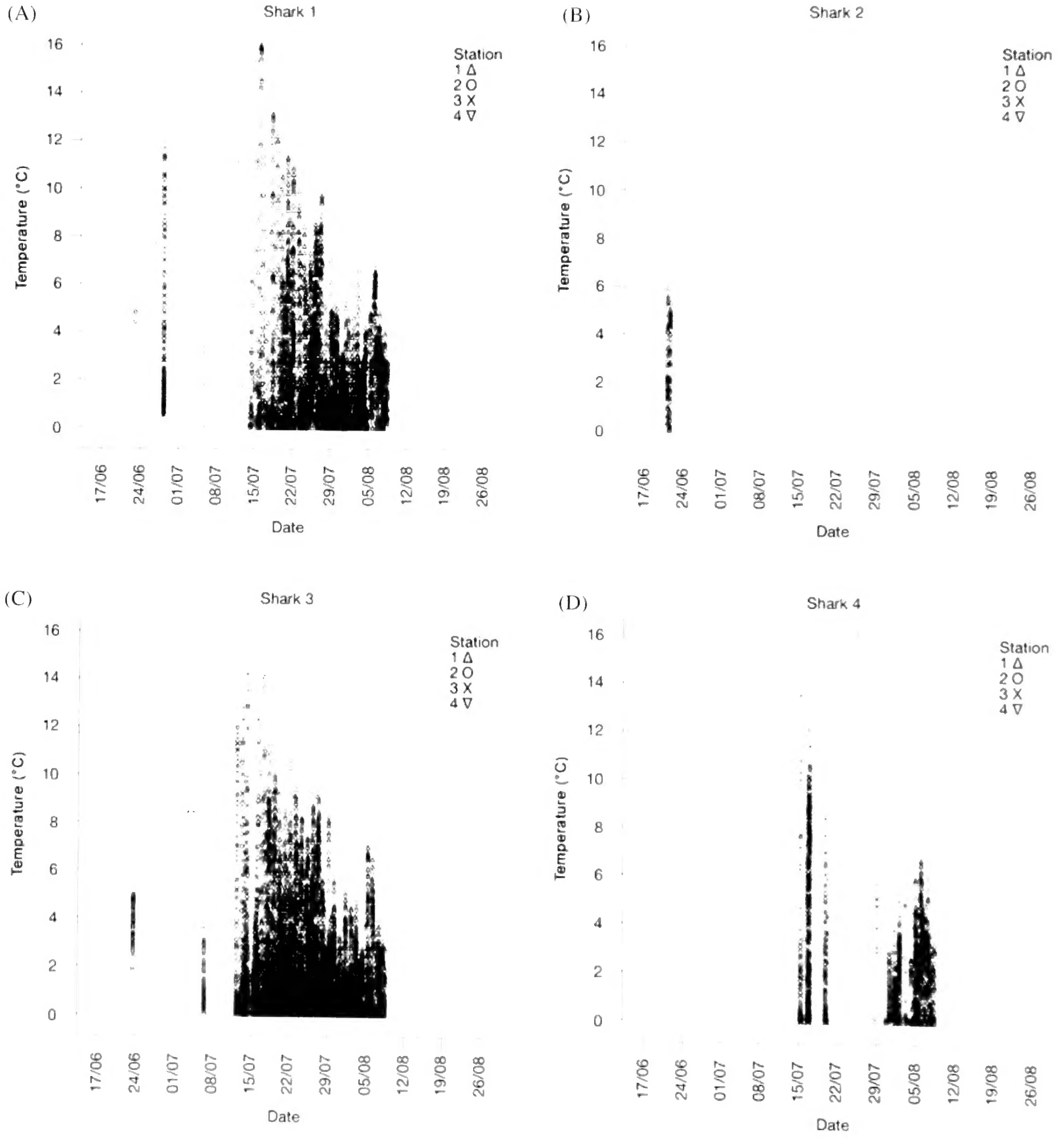

FIGURE 2. Temperature signals (°C) detected (*n* = 47 892) for all Greenland Sharks (*Somniosus microcephalus*) at all stations off Baie-Comeau, Quebec, from 19 June to 19 August 2005. *(Continued on next page.)*

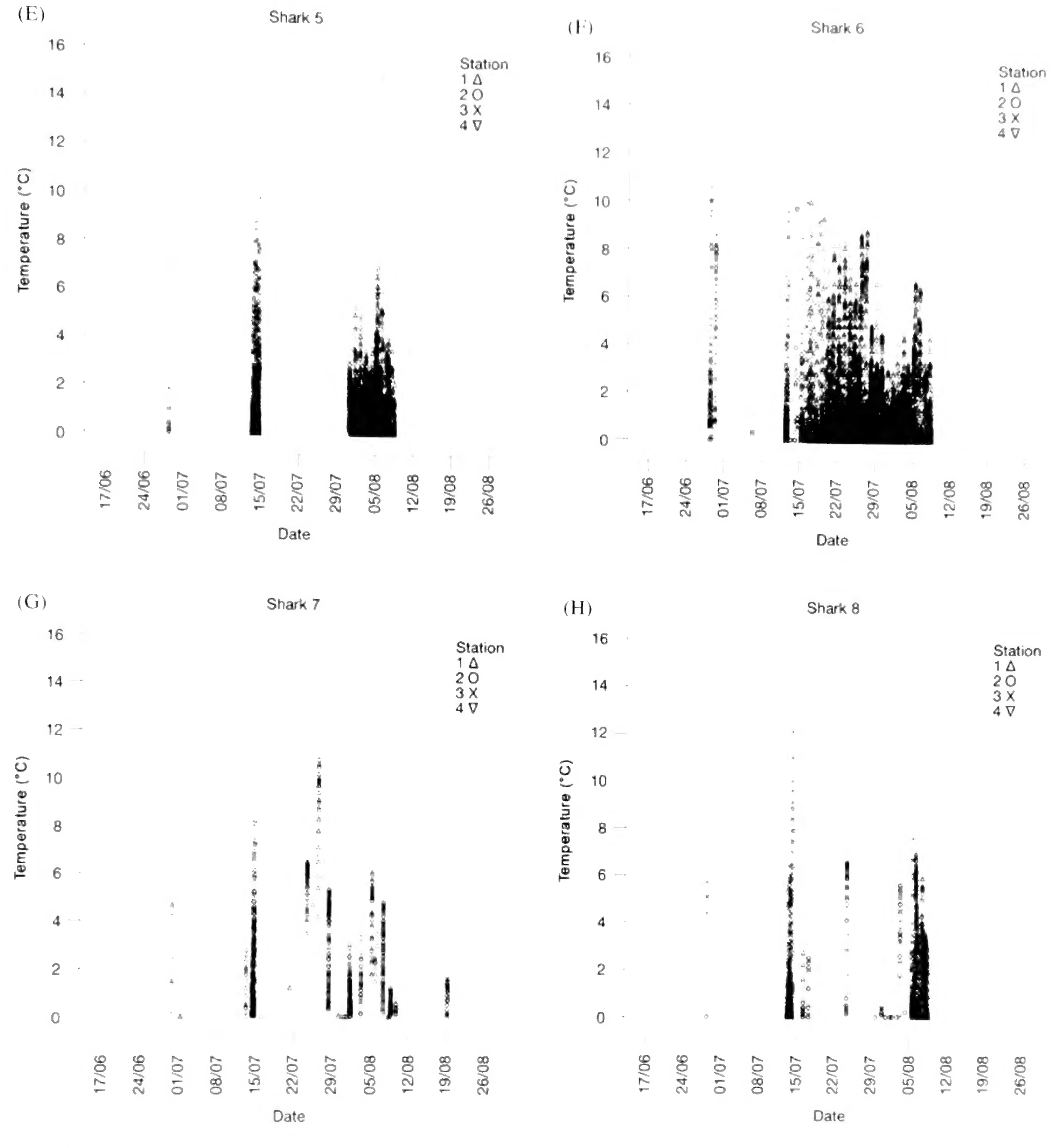

FIGURE 2 *(continued)*. Temperature signals (°C) detected ($n = 47\,892$) for all Greenland Sharks (*Somniosus microcephalus*) at all stations off Baie-Comeau, Quebec, from 19 June to 19 August 2005.

they repeatedly transited in and out of the same stations from mid-July to the end of the study period.

Temperature

All sharks experienced the coldest ambient water temperatures during daylight hours (Figure 3). For sharks 1, 3, 4, 5, and 6, the number of detections progressively increased as average water temperatures began to decrease in mid-July (Figure 2). The maximum temperature of 16.1°C was recorded for shark 1 at station 1 (Baie des Anglais) on 15 July at 0712 (Figure 2). This is near to the maximum (17.7°C) recorded by the IML buoy at a depth of 1 m later that same day. However, the IML buoy was located nearly 9 km from our receiver at the head of Baie des Anglais. Data from the stationary IML buoy also show that water temperatures at the surface decreased by as much as 6°C overnight. The minimum temperature of −1.6°C was recorded for shark 1 at station 1 on 1 August at 2258.

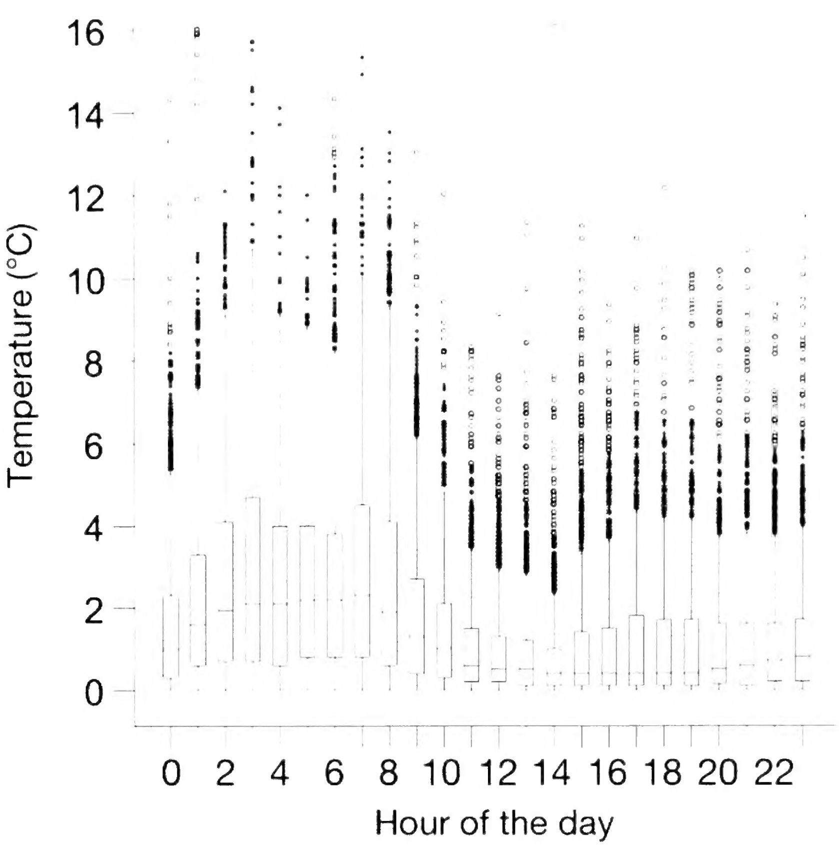

FIGURE 3. Hourly temperatures ($n = 47{,}892$) recorded for all Greenland Sharks (*Somniosus microcephalus*) at all stations off Baie-Comeau, Quebec, from 19 June to 19 August 2005. Box plots show median values (solid horizontal line), 50th percentile values (box outline), minimum and maximum values (whiskers), and outlier values (circles).

All sharks were rarely exposed to temperatures higher than 12°C (Figure 2), and remained only a few minutes in warmer water near the surface before heading back to deeper water offshore.

With the exception of shark 2, which left the study area shortly after being tagged, all sharks exhibited movement profiles that reflected diel temperature and depth differences. The sharks' incursions into shallow, warmer water at stations 1, 2, and 3 occurred throughout the day, although they were deeper during daylight hours, and typically lasted less than 30 minutes (Figure 4). The sharks returned to deeper, colder, and darker water after reaching the surface or the head of the bays. Their movements into shallow water at station 4, the only station located by a deep wall, were of even shorter duration, as there was no gradual slope to slow the sharks' movements in and out of shallow depths. The warmest temperature averages were reached between 0000 and 0800, when light levels at the surface were lowest (Figure 3).

Average temperatures transmitted by the tags at the first three stations were similar, ranging from 1.3°C to 1.8°C. Station 4, which had a steeper incline and greater depth than the other stations, had average tag readings of 0.4°C.

Light

The shallowest mean depths were recorded at night (Table 2). The back-and-forth movement pattern from deep to shallow water remained constant but mean depths progressively decreased as darkness set in (Figure 5). Signal detections were sporadic and showed no stable pattern while sharks transited between stations until mid-July. However, a steady diel vertical movement pattern associated with the daytime period became apparent from 20 to 27 July for sharks 1, 3, 4, 6, 7, and 8, and for shark 4 from 4 to 7 August, when their movements were mostly restricted to station 1. These six sharks exhibited the same diel vertical movement pattern; most of their signals detected at shallow depths coincided with high tide at night (Figures 6 and 7). There was no such pattern for signals detected at shallow depths during daylight hours. Although the nocturnal pattern observed from 20 to 27 July coincided with a full moon, the minimum average depths recorded for new moon (31.3 m) and full moon (30.9 m) phases over the course of the study were very similar; hence, nocturnal light levels did not appear to affect diel ver-

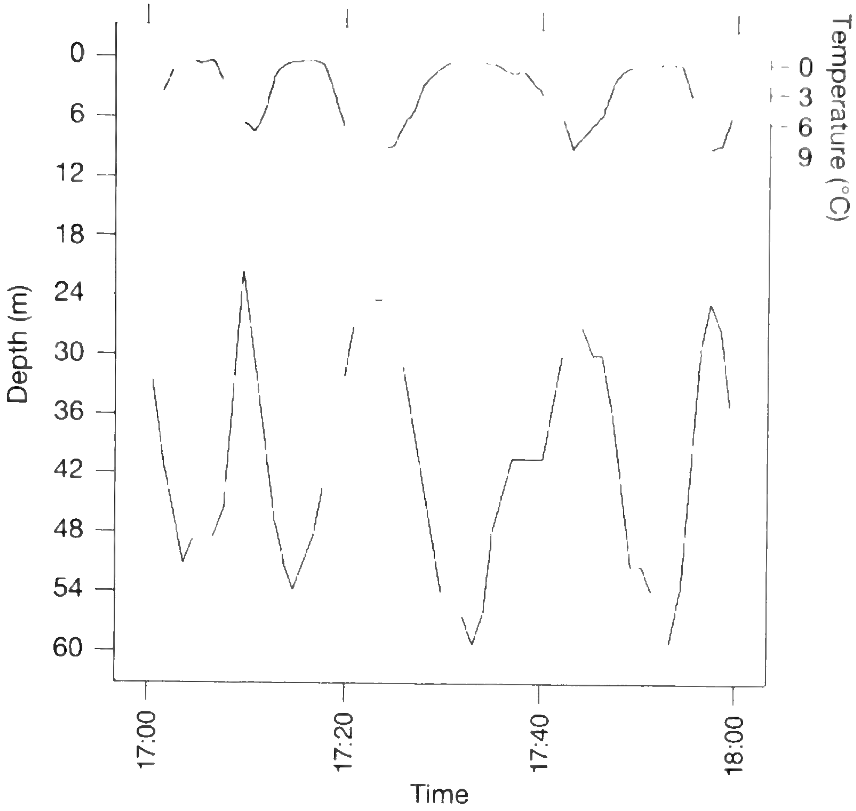

FIGURE 4. Depth (lower lines) and water temperature (upper lines) recorded for Greenland Shark (*Somniosus microcephalus*) 4 at station 1 (Baie des Anglais) on 16 July 2005, from 1700 to 1800.

tical movements. The difference between the number of signals detected for both lunar phases varied by 0.5% based on an equal number of nights for each variable. Regardless of the lunar phase, the shallowest depths and warmest temperatures were recorded between 0000 and 0800 when ambient light levels were lowest (Figures 3 and 5).

Tide

The warmest temperatures and shallowest depths recorded for sharks 1, 3, 4, 6, 7, and 8 coincided with high tide at night or early in the morning when ambient light levels underwater were still low (Figures 6 and 7).

Depth

Temperature and depth were inversely related for all sharks (Figures 3 and 5). Sharks 1, 2, 3, and 6 swam all the way to the surface (0 m) during the day and at night (Tables 2 and 3). The deepest recorded depth was 119.9 m, which was the deepest point within the range of station 4.

TABLE 2. Mean night-time depth and temperature range experienced by eight Greenland Sharks (*Somniosus microcephalus*) tagged off Baie-Comeau, Quebec, in summer 2005.

Tide	Number of detections	Depth (m)			Temperature (°C)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
High	15 333	0.0	119.9	28.7	−1.6	14.8	1.9
Low	15 121	1.8	118.1	33.5	0.3	16.1	1.3

TABLE 3. Mean daytime depth and temperature range experienced by eight Greenland Sharks (*Somniosus microcephalus*) tagged off Baie-Comeau, Quebec, in summer 2005.

Tide	Number of detections	Depth (m)			Temperature (°C)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
High	31 381	0.0	86.4	35.9	−0.5	15.3	1.2
Low	34 818	0.0	114.6	36.4	−0.4	16.0	1.3

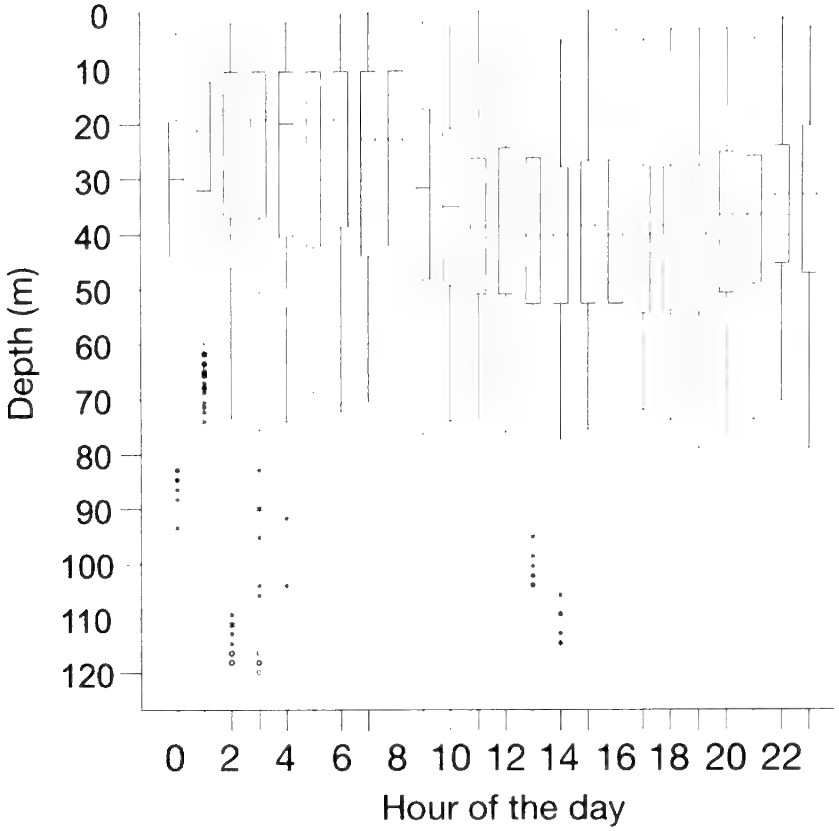

FIGURE 5. Hourly depths (n = 48 761) recorded for all Greenland Sharks (*Somniosus microcephalus*) at all stations off Baie-Comeau, Quebec, from 19 June to 19 August 2005. Box plots show median values (solid horizontal line), 50th percentile values (box outline), minimum and maximum values (whiskers), and outlier values (circles).

Discussion

In this study, we tracked eight Greenland Sharks fitted with acoustic transmitters for 60 days off the port city of Baie-Comeau, Quebec. Most signals (n = 89 608; 92.7%) were detected from 13 July to 8 August when six of the eight sharks (sharks 1, 3, 4, 5, 6, and 7) progressively transited upriver to station 1 from stations 2, 3, and 4. Most of these signals were produced by sharks 1, 3, 5, and 6 (n = 78 369). This group movement to the bay with the quickest access to deep, cold water coincided with the onset of the warmest surface water temperatures of the summer (up to 21.5°C). However, several days without any signals detected before and after this movement show that the sharks spent most of the sampling period beyond the range of the receivers (Figure 2). Nonetheless, the data obtained suggest that, in addition to water temperature, at least two other environmental factors, light and tide, may influence the short incursions of Greenland Sharks into shallow water at night.

Temperature

Previous research on Greenland Shark distribution has been conducted mainly in the Arctic Ocean and adjacent seas where water temperatures remain cold year round and vary little with depth (−1.8°C to −0.5°C; Skomal and Benz 2004). However, wider temperature variations off boreal Baie-Comeau during our study (−1.6°C to 21.5°C) appear to affect the movements of Greenland Sharks at shallow depths. Campana *et al.* (2013) also recorded wide temperature fluctuations surrounding tagged Greenland Sharks in the northwest Atlantic (2.6–17.2°C) but did not observe diel vertical migrations.

Sharks tagged in Baie-Comeau reached the shallowest average depths at night when surface waters were colder and darker than during daylight hours (Figures 3 and 5). This suggests that Greenland Sharks are sensitive to warmer surface temperatures and choose to move into shallow water when temperatures there are coolest (although they are much warmer than those at depth). The duration and number of movements into shallow water could, thus, be partly determined by water temperature. Data analysis over 60 minutes (16 July, 1700–1800) (Figure 4) shows that one of the sharks swam through temperature gradients of 10°C three times. The movements of six of the eight sharks were similar except for speed and the number of incursions inside the bays.

Hulbert *et al.* (2006) found that the movements of the Pacific Sleeper Shark consisted of systematic vertical

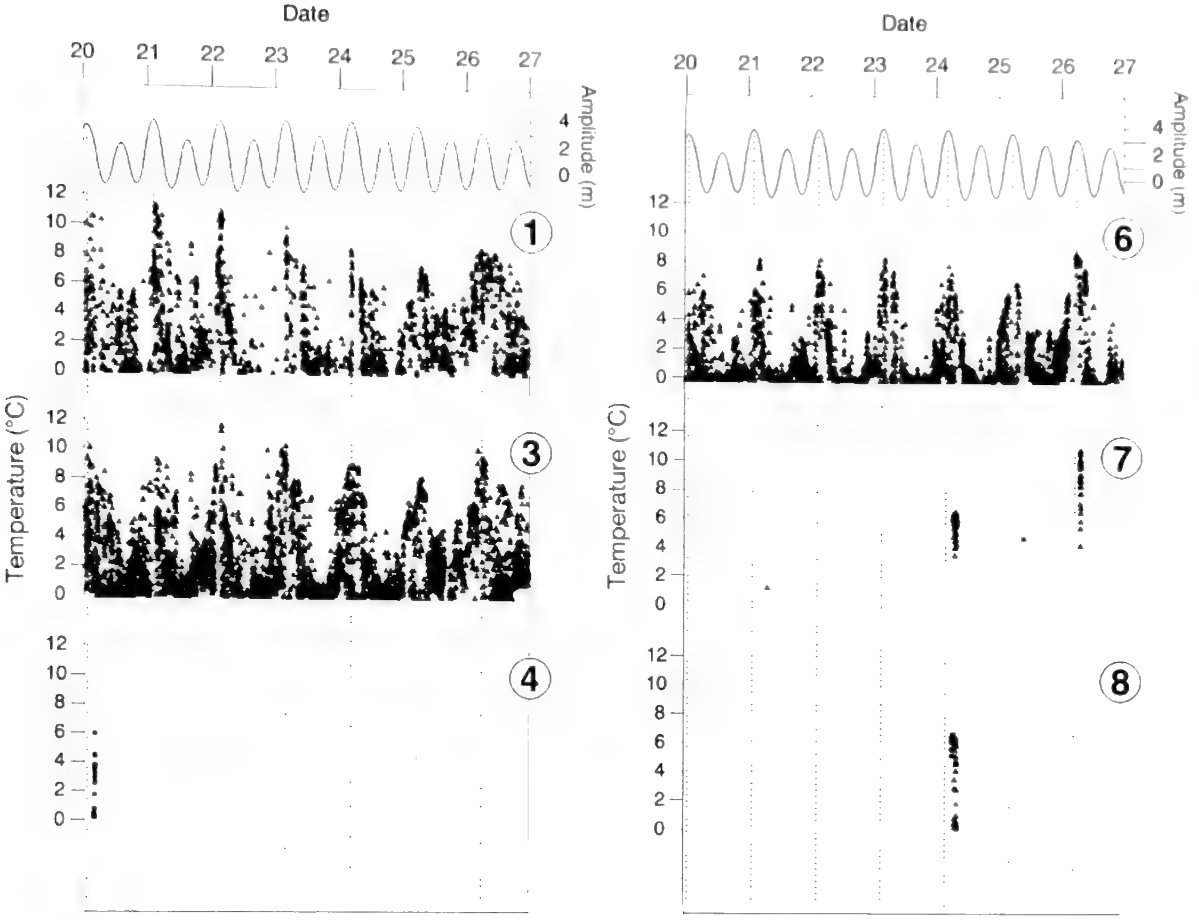

Figure 6. Tidal cycle (amplitude; lines) and temperature signals (points) from Greenland Sharks (*Somniosus microcephalus*) 1, 3, 4, 6, 7, and 8 at all stations from 20 to 27 July 2005. Dotted vertical lines indicate high tide at night.

oscillations with short transitions. Similarly, the sharks in our study as well as those studied by Stokesbury *et al.* (2005) spent little time in warmer water before moving to colder water offshore, demonstrating a preference for water in the 1–2°C range (Figure 3). Swimming in cold water could also allow the Greenland Shark to regulate its body temperature. The Small-Spotted Catshark hunts in warmer water at night and then returns to deep water during the day, where colder temperatures help with digestion (Sims *et al.* 2006). If the Greenland Shark is more scavenger than active predator, cold water may slow the digestive process thus compensating for a slower metabolic rate and sporadic feeding.

Light

Hulbert *et al.* (2006) reported uninterrupted sequences of diel vertical movements of the Pacific Sleeper Shark lasting up to 330 h (about 14 days), although most lasted 25 h or less. The longest sequence of signal detections in our study, which was interrupted by the removal of three acoustic receivers, lasted 27 days and may have been triggered by environmental conditions (Figure 2).

In the Arctic Ocean, the Greenland Shark experiences extended periods of darkness because of the depths it frequents (1200 m or more) (Yano *et al.* 2007), ice cover, and the high latitude. This suggests that vision often plays only a minor role during the shark's search for prey. This view is supported by anatomical studies indicating that most arctic Greenland Sharks have severely limited vision as a result of parasitism (Borucinska *et al.* 1998). Hulbert *et al.* (2006) contend that foraging of the Pacific Sleeper Shark is primarily guided by olfactory cues.

It is not known whether the Greenland Shark hunts at night or during the day nor whether it feeds opportunistically over a daily period. Inuit hunters have long attracted sharks to the surface by projecting light into ice holes (Idrobo 2008), presumably to simulate sunlight passing through a seal's breathing hole. Overwintering Belugas, restricted to ice holes, may also be preyed upon by Greenland Sharks (MacNeil *et al.* 2012).

Intense light levels could reduce the shark's stealth advantage as it swims toward potential prey at the surface, as well as hinder its vision, since it spends most of

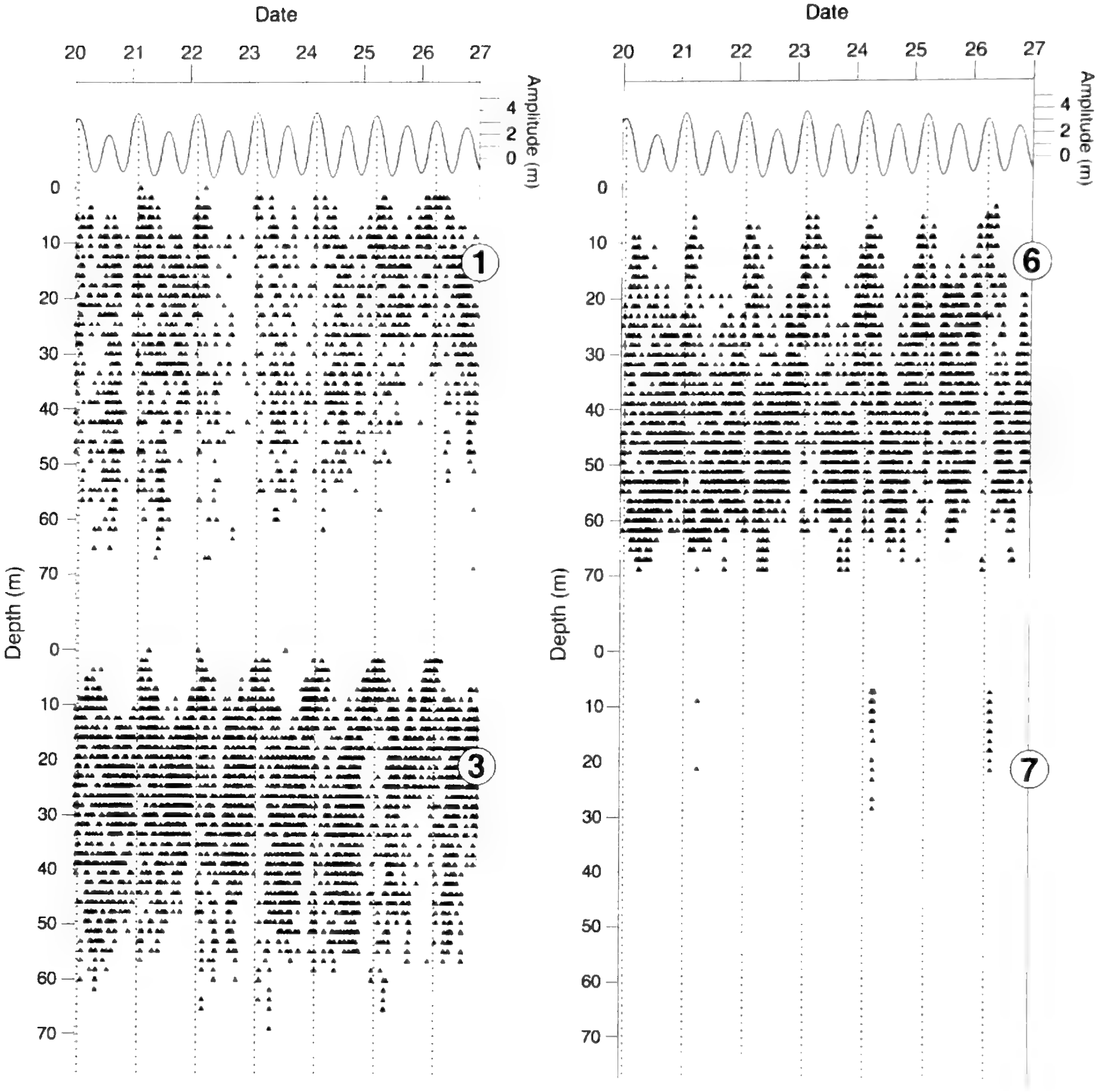

FIGURE 7. Tidal cycle (amplitude; lines) and depth signals (points) from Greenland Sharks (*Somniosus microcephalus*) 1, 3, 6, and 7 at all stations from 20 to 27 July 2005. Dotted vertical lines indicate high tide at night.

its existence in low-light conditions or in total darkness below the photic zone (< 200 m). Winter conditions in the St. Lawrence Estuary are similar to those of the Arctic, but for the rest of the year, the Greenland Shark may travel from total darkness to a highly luminous environment on a daily basis. However, the intensity of ambient light appears to have an effect on the movements of Greenland Sharks as shown by the negative relation between shark depths and light (Figure 5). This may be caused by a number of factors. The shark could be attracted by the seasonal abundance of prey, such as Snow Crabs (*Chionoecetes opilio*), at shallow depth. However, as the Greenland Shark is a generalist feeder as well as a scavenger, it may be sampling the water column rather than following a particular prey species. Unlike the prey of the Pacific Sleeper Shark, which feeds throughout the water column (Hulbert *et al.* 2006), fish and invertebrate prey of Greenland Sharks, including Greenland Halibut (*Reinhardtius hippoglossoides*), Atlantic Wolffish (*Anarhichas lupus*), redfish (*Sebastes* spp.), cephalopods, and various crabs are mostly benthic or demersal species that do not have diel vertical movements from bottom to surface. Fish remains found in the stomachs of Greenland Sharks are often whole (Castro 2011), which would indicate that prey was sucked off the bottom through the shark's downward-facing mouth.

Diel movements may also be due to physiological constraints, including light aversion and temperature tolerance. Because many of its prey species are found in both deep and shallow water, the Greenland Shark may selectively spend most of the day in deep water under dark conditions to avoid higher light levels in shallow water.

Unlike arctic populations of Greenland Sharks and Pacific Sleeper Sharks, in which most individuals are affected by the copepod *Ommatokoita elongata*, an ocular parasite (Borucinska *et al.* 1998; Benz *et al.* 2002), fewer than 10% of the more than 100 sharks we observed in the St. Lawrence between 2003 and 2012 and none of the tagged sharks in this study hosted this parasite. Although vision is not believed to play a significant role in the foraging behaviour of arctic populations of sleeper sharks, we have repeatedly observed and filmed Greenland Sharks visually avoiding divers and objects, such as boulders, in the St. Lawrence (Harvey-Clark *et al.* 2005). If their undamaged eyes are not used as mere light sensors, as has been suggested for arctic populations (Borucinska *et al.* 1998), vision may in fact play a more predominant role in the St. Lawrence. Because the eyes of the Greenland Shark are mostly accustomed to darkness even in the St. Lawrence, they could in turn be more sensitive to the higher levels of ambient light near or at the surface (Stokesbury *et al.* 2005).

Light aversion affecting vertical movements has also been proposed for the Sixgill Shark (Bigelow and Schroeder 1948; Compagno 1984). This may explain why the sharks in this study appeared to need a transition period, as their shallowest average depths occurred between 0000 and 0800, at least 3 h after night had set in and 3 h after sunrise (Figure 5). The sharks progressively left the deeper, darker areas offshore to reach shallow water during the night, with some occasionally swimming all the way to the surface. The reverse phenomenon occurred after sunrise when the number of signals detected at shallow depths gradually decreased as light levels increased.

Daytime turbidity may also affect sharks' depth distribution. Our observations while deploying acoustic transmitters mostly took place under dark conditions at depths greater than 10 m or when visibility was reduced because of plankton blooms, pollen accumulations at the surface, or increased freshwater runoff from local tributaries. Therefore, the shark may also be present, albeit in lower numbers, at shallow depths during daylight hours when the sky is overcast or during conditions of increased turbidity. Varying levels of ambient light could, thus, be partly responsible for daytime detections of Greenland Sharks in shallow water in the Baie-Comeau area.

Tide

Tides appeared to influence movements of the sharks. Diel vertical movement profiles show that the shallowest depths and the warmest temperatures were mostly recorded during high tide at night and early in the morning (Figures 6 and 7). Conversely, the average depths and temperatures recorded during high tide in daylight hours were deeper and colder (Figure 8). This could indicate that the sharks remained on the outer edge of receiver range and that they were not letting themselves be carried into shallow areas by the rising tide. There is, thus, the appearance of habitat selection, as the sharks' shallow water movements associated with high tide were mostly nocturnal. At night, the influx of colder offshore water, as well as the absence of sunlight, produced a cooling effect on surface waters, as recorded by the IML buoy, thus rendering shallow depths more hospitable to the Greenland Shark. The Sixgill Shark is also known to move closer to the surface during high tide at night (Andrews *et al.* 2009).

Depth

The effect of tide cycles at the study site (tidal range ≤ 3.5 m) is small considering that the range of depths sharks reached daily often surpassed 70 m. For all sharks, the shallowest depths were recorded between 0000 and 0800 (Figure 5). In every case, sharks that reached the surface or shallows at the head of the bays immediately headed back into deeper water.

The acoustic system we used did not measure the distance between the transmitter and the receiver, which makes it difficult to evaluate the actual position of the shark in relation to the sea floor. However, more than 95% of the sharks sighted while scuba diving (> 100 encounters since 2003) swam no more than 2 m off the bottom, at depths ranging from 6 m to 40 m. Also, the location of Greenland Sharks in the water column is likely to be directly associated with that of their mostly benthic prey (Ridoux *et al.* 1998; Fisk *et al.* 2002; Yano *et al.* 2007; Leclerc *et al.* 2012). Stomach contents from St. Lawrence Greenland Sharks as well as their highly abraded rostrum suggest that they feed on prey and animal remains found on the sea floor (Harvey-Clark *et al.* 2005). This evidence suggests that recorded depths were near the bottom and that the sharks rarely swam vertically up the water column. Our observations differ from those of Skomal and Benz (2004) in that their specimens tagged in the Arctic swam vertically from deep water offshore. They also differ from Hulbert *et al.* (2006), who suggest that the Pacific Sleeper Shark does not follow bottom contours exclusively while foraging.

Biological Factors

Greenland Sharks may enter shallow bays for many reasons, including to pursue prey, to reproduce, or to rid themselves of parasites that are sensitive to reductions in salinity caused by the many freshwater tributaries in the Baie-Comeau area.

All but one of the tagged sharks (shark 2), as well as dozens of other Greenland Sharks of both sexes consisting of mature males and immature females that were observed and recorded by scuba divers, appeared to be aggregating (including nose to tail swimming) over a period of several weeks. In addition, philopatry of

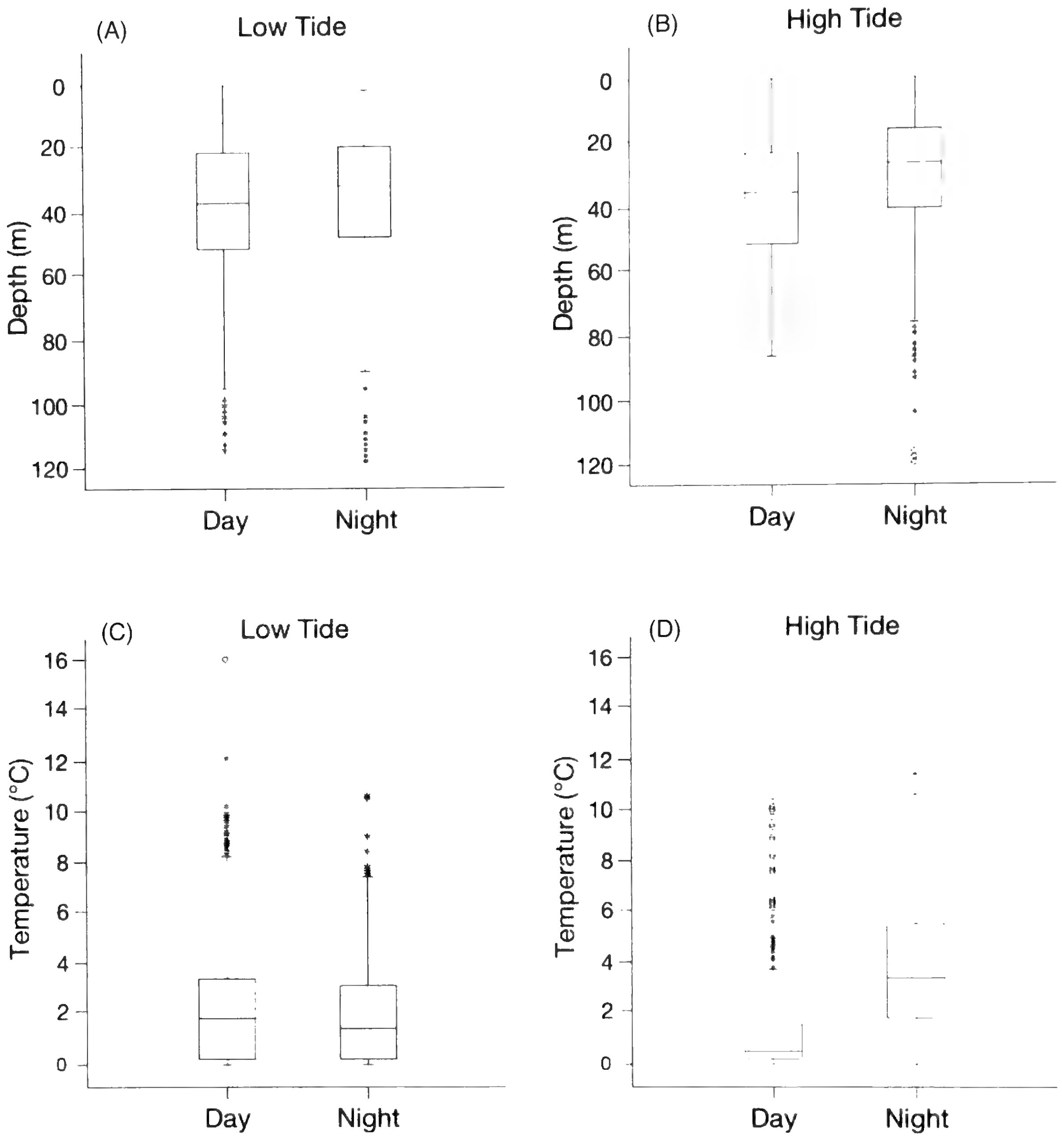

FIGURE 8. Daily depth (n = 48 761) at (A) low and (B) high tide, and temperature (n = 47 892) at (C) low and (D) high tide for all Greenland Sharks (*Somniosus microcephalus*) at all stations off Baie-Comeau, Quebec, from 19 June to 19 August 2005. Box plots show median values (solid horizontal line), 50th percentile values (box outline), minimum and maximum values (whiskers), and outlier values (circles).

Greenland Sharks observed over a period of 4 years in the Baie-Comeau area, including some of the sharks tagged in 2005 as well as sharks recorded during dives, could be partly a result of the permanent or seasonal presence of specific prey, such as the Snow Crab and Greenland Halibut; this phenomenon is known in other species, including the White Shark (*Carcharodon carcharias*) (Klimley *et al.* 1992, 2001) and the Sixgill Shark (Andrews *et al.* 2010).

However, the known local prey items of the Greenland Shark are found on the bottom, from surface waters to the deepest parts of the Laurentian Channel. Possible exceptions are pinnipeds, but very few were observed during the study period. Although remains of Grey Seals (*Halichoerus grypus*) and Harbour Seals (*Phoca vitulina*) have repeatedly been recovered from Greenland Shark specimens in the St. Lawrence, and considering that the Greenland Shark may actively prey on seals in the Greenland Sea (Leclerc *et al.* 2012), it has not been determined whether seals from the St. Lawrence are taken as carrion, in which case feeding would have taken place on the sea floor.

Although no juvenile sharks were seen at shallow depths in the Baie-Comeau area between 2003 and 2015, observed philopatry may be associated with pupping (Hueter *et al.* 2004; Feldheim *et al.* 2014; Hussey *et al.* 2014) taking place beyond the range of scuba divers. Despite the visual absence of juveniles, since 2003, we have observed at least three females that appeared gravid (Harvey-Clark *et al.* 2005; JG and CHC, unpublished data).

Conclusions

Three environmental factors, temperature, light, and tides, were found to influence the movements of the Greenland Shark. Movement patterns indicated a preference for deep, cold water during daylight hours and for shallow, warmer water at night. Ascending movements into shallow water mostly coincided with darkness and high tide. This improved understanding of the spatio-temporal distribution of the Greenland Shark should allow for improved assessment of risks to this species in the St. Lawrence Estuary, such as those arising from commercial fisheries, which have been occurring for over a century (JG, unpublished data). A better understanding of the influence of physical variables could also help predict the effects of climate change on the overall distribution and temperature-driven behavioural patterns of the Greenland Shark as the thermal structure of the water column shifts due to global warming.

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Lack of Response to Olfactory Lures Among Mammals in Riparian Habitat in Southern Wisconsin

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Non-invasive mammal surveys often employ olfactory stimuli on the assumption that they will attract mammals and increase the success of monitoring projects. However, information on the effectiveness of scent lures is variable and often relies on data generated from mammal tracks or sign, which can be challenging to quantify. Therefore, we sought to determine whether certain olfactory stimuli are more effective than others at eliciting a response from mammals along riparian corridors in southern Wisconsin, using camera traps to monitor response to four scents and a control of de-ionized water. We recorded the number of times each species responded as well as the length of time spent investigating scents (Muskrat gland, mink gland, Red Fox urine, crayfish oil) and the control. We recorded 2812 passes by 16 mammal species during our 12-month study, with Virginia Opossum (*Didelphis virginiana*), Woodchuck (*Marmota monax*), Eastern Gray Squirrel (*Sciurus carolinensis*), Eastern Fox Squirrel (*Sciurus niger*), Raccoon (*Procyon lotor*), Coyote (*Canis latrans*), and White-tailed Deer (*Odocoileus virginianus*) observed on cameras most frequently. However, 72% of observations involved mammals passing through without investigating any scents or the control, and among the 28% of observations where mammals did investigate, we found no significant differences in their response to specific scents or the control or in response by season. Further analysis revealed no significant differences in the time mammals spent investigating individual scents or the control. The lack of response suggests that factors other than scent may have attracted wildlife to our stations. Although under some circumstances olfactory attractants may increase the level of response to monitoring stations, we suggest that attraction to our stations was largely a behavioural response to novel stimuli in the environment.

Key Words: Mammals; Virginia Opossum; Woodchuck; Eastern Gray Squirrel; Eastern Fox Squirrel; Raccoon; Coyote; White-tailed Deer; riparian habitat; camera traps; olfactory stimuli; scent; lures; attractants; behavioural response; Wisconsin

Introduction

Olfaction is an important mechanism by which mammals sense their environment (Vaughan *et al.* 2010). Although it can play a critical role in food acquisition, it is also important for communication via scent cues in urine, scat, and gland secretions. Past studies have investigated mammal response to olfactory stimuli or have used scent lures to attract mammals for other objectives. These studies include assessments of urban mammal and nuisance mammal response to food scent (e.g., Andelt and Woolley 1996; Campbell and Long 2008), response of prey to predator scent (e.g., Gorman 1984; Sullivan *et al.* 1985; Caine and Weldon 1989; Swihart *et al.* 1991; Russell and Banks 2007), studies of kin recognition (Johnston 2003) and territoriality (e.g., Arnold *et al.* 2011; Shivik *et al.* 2011), and population estimates (e.g., Mowat and Strobeck 2000; Mowat and Paetkau 2002).

Despite a significant amount of research, the response of mammal species to various olfactory stimuli remains poorly understood. This could be due to the lack of uniformity in methods employed and, thus, difficulty in comparing results across studies. Nonetheless, as indicated by Shumake (1977), assessing the effectiveness of olfactory cues to enhance the success of surveys and wildlife management strategies is important and can improve the efficacy of research efforts. Likewise, Schlexer (2008) noted that the use of lures in wildlife management will be handicapped until quantifiable testing of traditional mammal attractants supplants anecdotal conjecture. Thus, studies that quantify the response of mammals to various olfactory cues are potentially valuable to wildlife managers and researchers.

The results of past research on wildlife response to scent lures are variable. A number of authors have reported high wildlife visitation rates at scent lure locations. Monterrosso *et al.* (2011) reported that "investigative behavior" of olfactory attractants by some Iberian carnivores occurred frequently (in up to 75–81% of detections). Several studies have reported that Coyotes (*Canis latrans*) also often responded to particularly attractive lures: 41.8% (Turkowski *et al.* 1983) and 45.7% response (Martin and Fagre 1988). Mowat and Strobeck (2000) successfully obtained Grizzly Bear (*Ursus arctos*) hair samples at 48–73% of scent/bait stations sampled. However, a number of authors have reported that response to scent lures was low for a variety of species, including Coyotes (16–20% average visit rate per night of scent station deployment; Roughton and Bowden 1979) and weasels (8% site visitation; Mowat and Paetkau 2002), as well as several mammal species in Louisiana (4.6–11.8% annual visitation rates; Linscombe *et al.* 1983) and Florida (1–27% 2-year visitation rates; Conner *et al.* 1983).

Within-study variability has also been found in the response of different species to olfactory lures. Chamberlain *et al.* (1999) reported that scent lures were effective for Coyotes and Gray Foxes (*Urocyon cinereoargenteus*), but less so for Bobcats (*Lynx rufus*). Variation in response to olfactory lures was recorded among species detected (and type of lure used) during an Iberian carnivore community study (Monterroso *et al.* 2011). Furthermore, dissimilarity both within and across studies was reported in the response to scent lures by species in similar taxonomic groups. For example, Portella *et al.* (2013) found that no felids visited scent/hair snare stations deployed in southern Brazil, while Weaver *et al.* (2005) found this method effective for Ocelots (*Leopardus pardalis*) in southern Texas. Mowat and Paetkau (2002) used fish oil to attract mustelids to hair sampling stations, and found it was effective for American Martens (*Martes americana*) but less effective for smaller weasel species (Long-tailed Weasel [*Mustela frenata*] and Ermine [*M. erminea*]).

Although past attempts to quantify wildlife response to olfactory lures exist, much of this research has analyzed data generated from tracks or wildlife sign. Unfortunately, such data can be of limited value if track quality is poor or tracks are from species that are difficult to identify from sign (e.g., carnivores; Zielinski and Schlexer 2009). However, camera traps, used increasingly in wildlife biology (O'Connell *et al.* 2011), can generate more definitive data for species identification than tracks, scat, or other sign. Further, camera traps have advantages over traditional trapping methods, in that they are generally less invasive and can be particularly effective for studying cryptic species (Wearn *et al.* 2013). They also reduce risk to researchers, as there is no direct contact with wild animals. Camera traps with the ability to record video footage are especially useful for investigating questions related to wildlife behaviour, although, to date, few studies have used camera traps to quantify the response of wildlife to scent lures or to gauge the intensity of response by measuring time spent investigating lures (e.g., Batter 2011; Monterroso *et al.* 2011; Juslin 2011; Portella *et al.* 2013).

Given these knowledge gaps, our objective was to exploit advancements in camera trap technology, including video capability, to investigate whether specific olfactory cues elicit a response among mammals along riparian corridors. We also hoped to assess potential differences in the intensity of that response and whether variation occurred by species or season. To meet our objective, we employed common food, gland, and urine scents that we believed mammals in the riparian habitat would naturally encounter. We hypothesized that mammals in riparian habitats would exhibit a stronger response to deployed scents than a control (i.e., they would respond more often to scents and spend more time investigating scents than the control). We further hypothesized that among the scents offered, some would elicit a stronger response than others, and that this response would vary by species and by season.

Study Area

The response of mammals to olfactory stimuli at experimental locations was monitored for 12 months (May 2012 to May 2013) at five locations in Jefferson and Walworth Counties in southern Wisconsin, USA. The landscape associated with the five monitoring locations contained a mix of open canopy and lightly wooded habitats along perennial streams. The proportion of open and wooded land cover varied by location, although was similar across specific sites where we deployed camera traps. Associated streams varied in the velocity of water flow and substrate composition, although all streambeds possessed a mix of cobble and silt. We conducted our experiments on private rural land with limited human activity to reduce the potential for camera trap theft. We also chose study sites that would allow us to construct our monitoring stations within 3 m of a stream and immediately adjacent to obvious wildlife activity (i.e., animal trails). We followed the recommendation of Sargeant *et al.* (1998) and separated our experimental monitoring locations by more than 2 km to reduce the likelihood of recording the same individuals at multiple sites; our study locations were separated by 5–26 km. Major highways and roads also separated sites from each other, further decreasing the likelihood of individual animals traveling between them.

Methods

Experimental Set-up

Each experimental monitoring location included a camera trap to record mammal response to four scent lures: crayfish oil, Red Fox urine, Muskrat gland, and mink gland, along with a control of de-ionized water. All scents were purchased from a commercial vendor (F&T Fur Harvester's Trading Post, Alpena, Michigan, USA). We chose to use commercially purchased scents because research suggests that some mammals respond more strongly to aged versus fresh urine (Price 1977), and we were most interested in assessing scent lures that were easily obtainable by researchers. We placed 15–20 mL of each scent or the control individually into 50-mL vials. We capped each vial with a screw top lid, punctured with an equal number of holes to allow scent dispersal, but to reduce the likelihood of scent dehydration. Each vial, the top of which was visible to any passing mammal, was seated in a 30.5-cm length of polyvinyl chloride (PVC) pipe that was separated from adjacent pipes by 60 cm and staked perpendicular to the ground, which raised scents above ground level. Raising the scents made it easier to determine whether a response was elicited, as passing animals typically lifted their head to investigate scent vials. A single camera trap (Ltl Acorn 5210A, Old Boys Outdoors, Stone Mountain, Georgia, USA) with infrared flash, set to record 15-s video clips when triggered, was locked in a steel security box and lag-screwed to a tree 2.5 m from scent and control vials.

We visited experimental monitoring locations about once a week to replace and rotate scent and control vials, swap camera memory cards, and assess battery life. On arrival, we removed old scent and control vials from PVC tubes and replaced them with fresh vials. To control for possible location bias associated with the order in which the scent and control vials were deployed in front of camera traps, we also rotated vials one position clockwise roughly every 7 days. We randomly determined the original order of scent and control vial deployment in front of camera traps at the start of the study. We kept this order consistent across all monitoring locations and followed the same vial rotation order throughout the study. We wore nitrile gloves in the field when handling vials and camera traps to reduce the transfer of human scent to survey equipment.

On removal from the field, vials were washed with laboratory detergent (Alconox, Inc., White Plains, New York, USA) and rinsed with de-ionized water for later reuse. Care was taken to ensure that a given vial was used to hold only a single scent type or the control throughout the study to avoid incidental transfer of scent and cross-contamination of stimuli.

Video Scoring and Data Analysis

We uploaded video clips about once a week, immediately after returning from monitoring locations in the field. We then reviewed video footage and recorded the responses of all detected mammals to scent and control vials. For every occasion that an individual mammal passed in front of the camera trap, we recorded species and date and counted the number of times it responded to a scent or the control. If multiple animals passed through simultaneously, the response of each was scored separately. We also recorded passes that did not include any response to a scent or the control. This allowed us to quantify both response to olfactory stimuli and the number of times individuals passed through the monitoring location without responding. We then used a standard stopwatch to determine the amount of time (to the nearest 0.1 s) individual animals spent investigating a scent or the control.

We considered a "response" to be the movement of an animal's head toward a vial elevated on a PVC pipe (i.e., the individual's nose was clearly in contact with or immediately adjacent to a specific scent or the control). Because we could not accurately identify individual animals of the species detected, we quantified the number of responses during single "pass events," rather than quantifying responses by individually identified animals. We arbitrarily considered passes to be unique events if they were separated by at least 2 minutes.

We used contingency table analysis to determine whether there were significant differences between the number of responses of each species to individual scent types or the control (Zar 2010). We analyzed only species with expected values of five or more responses, which included Virginia Opossum (*Didelphis virginiana*), Woodchuck (*Marmota monax*), Eastern Gray Squirrel (*Sciurus carolinensis*), Eastern Fox Squirrel (*Sciurus niger*), Raccoon (*Procyon lotor*), Coyote (*Canis latrans*), and White-tailed Deer (*Odocoileus virginianus*). We also used contingency table analysis to determine whether the number of responses to individual scents or the control differed by season. Because count data were not normally distributed and samples were related, a Wilcoxon signed rank test was conducted to determine whether the number of occasions when individuals responded to any of the scents or the control differed from the number of occasions when they did not respond (Zar 2010).

Because time, recorded in seconds, was not normally distributed, we log transformed data to obtain normality and one-way ANOVA (all animals combined) was used to determine if differences existed in time spent investigating any of the four scents versus the control (e.g., did mammals spend more time investigating crayfish oil than the control?). Two-way ANOVA was also performed on the transformed data to compare the amount of time spent investigating scents and the control by each species (e.g., did species A spend more time investigating all scents and the control than species B?). We conducted contingency table analyses in Excel (Microsoft, Redmond, Washington, USA), whereas we conducted Wilcoxon signed rank tests and ANOVA in SPSS (IBM, Armonk, New York, USA).

Results

We recorded 2812 passes by 16 mammal species during our 12-month study (Table 1). In addition, an unidentified rodent (likely a mouse, *Peromyscus* sp.) was frequently detected. Because of its small size, we are not certain whether it reliably triggered the camera trap during all passes and, therefore, it was excluded from our tallies. Some species, such as Raccoon (n = 1241), White-tailed Deer (n = 246), and Virginia Opossum (n = 243), were recorded frequently.

A response was observed in 798 cases for an overall response rate of 28% for all species combined (Table 1). The Wilcoxon signed rank test indicated that the number of passes during which an animal responded was significantly less than the number of passes when no response was recorded (two-tailed test: $t = -2.542$; $P = 0.011$; $\alpha = 0.05$). We arbitrarily eliminated those species that exhibited a response rate below 10% (Table 1). The six species remaining (Eastern Gray and Eastern Fox Squirrels were combined) responded at a rate of 38% and the Wilcoxon signed rank test indicated no difference between passes with a response and those without a response (two-tailed test: $t = -1.599$; $P = 0.110$).

TABLE 1. All species of mammals photographed by camera traps from May 2012 to May 2013, including the number of responses to at least one scent or control vial and "no response" recorded for passing individuals, Jefferson and Walworth Counties, Wisconsin, USA.

Species	No. passes where response observed	No. passes where no response observed	% response
Virginia Opossum (*Didelphis virginiana*)	61	182	25.10
Eastern Chipmunk (*Tamias striatus*)	1	39	2.50
Squirrels (*Sciurus* spp.)*	40	666	5.67
Woodchuck (*Marmota monax*)	18	57	24.00
Common Muskrat (*Ondatra zibethicus*)	5	4	55.56
Eastern Cottontail (*Sylvilagus floridanus*)	3	21	12.50
Raccoon (*Procyon lotor*)	472	769	38.03
Striped Skunk (*Mephitis mephitis*)	0	17	0.00
American Badger (*Taxidea taxus*)	0	4	0.00
Long-tailed Weasel (*Mustela frenata*)	1	1	50.00
American Mink (*Neovison vison*)	6	39	13.33
Red Fox (*Vulpes vulpes*)	7	14	33.33
Coyote (*Canis latrans*)	51	29	63.75
Domestic Cat (*Felis catus*)	2	57	3.39
White-tailed Deer (*Odocoileus virginianus*)	131	115	53.25
Total	798	2014	28.38

**S. carolinensis* and *S. niger.*

Contingency table analysis of the same six species revealed no difference in the number of responses to individual scents or control vials (χ^2 calculated value = 30.9671; df = 20; χ^2 critical value = 31.410; $\alpha = 0.05$; Table 2). Contingency table analysis also did not show a difference between responses to scent and control vials by season (χ^2 calculated value = 18.4867; df = 12; χ^2 critical value = 21.026; Table 3).

One-way ANOVA, which considered the summed response of all species to scent and control vials, did not detect an overall difference in the time spent investigating individual scents or the control (F = 1.9063; df = 4, 3980; P = 0.1065). Two-way ANOVA showed a significant difference in the amount of time individual species spent investigating all vials (F = 14.609; df = 5, 1482; $P < 0.001$), but no difference in time spent

TABLE 2. Observed (Obs.) and expected (Exp.) values calculated by contingency table analysis to assess species-specific response to control and scent vials. Only the six species that exhibited the greatest response are included.

	Control		Crayfish oil		Muskrat gland		Fox urine		Mink gland		
Species	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Total
White-tailed Deer (*Odocoileus virginianus*)	66	57.78	67	58.18	59	62.68	51	57.59	61	67.77	304
Raccoon (*Procyon lotor*)	191	183.23	181	184.48	190	198.76	180	182.61	222	214.91	964
Virginia Opossum (*Didelphis virginiana*)	8	17.11	13	17.22	25	18.56	23	17.05	21	20.06	90
Woodchuck (*Marmota monax*)	3	4.75	2	4.78	6	5.15	5	4.74	9	5.57	25
Coyote (*Canis latrans*)	18	22.81	30	22.96	30	24.74	22	22.73	20	26.75	120
Sciurus spp.*	9	9.31	4	9.38	10	10.10	13	9.28	13	10.92	49
Total	295		297		320		294		346		1552

**S. carolinensis* and *S. niger.*

TABLE 3. Observed (Obs.) and expected (Exp.) values associated with contingency table analysis to test for seasonal response to control and scent vials.

Season	Control		Crayfish oil		Muskrat gland		Fox urine		Mink gland		
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Total
Spring	51	60.60	59	61.21	74	66.66	68	60.60	69	71.92	321
Summer	166	150.66	148	152.17	154	165.73	135	150.66	195	178.78	798
Fall	67	68.34	67	69.03	75	75.18	78	68.34	75	81.10	362
Winter	16	20.39	29	20.59	27	22.43	19	20.39	17	24.20	108
Total	300		303		330		300		356		1589

investigating individual scent or the control vials (F = 0.761; df = 4, 1482; P = 0.551). We also detected no significant interaction between the independent variables: species and scent (F = 0.409; df = 2, 1482; P = 0.990). Each species treated the scent and the control equally, but there was a significant difference in the amount of time certain species spent investigating all scent and control vials, collectively. A post-hoc analysis (Tukey's test) revealed that squirrels (*Sciurus* spp.) spent less time investigating all scent and control vials than the others species included in our analysis.

Discussion

Although we hypothesized that mammals would respond more strongly to scent vials than the control vial and that certain scents would elicit a greater response than others, our data do not to support this. Only four of 16 identified mammal species responded to at least one scent or control vial on 50% or more passes through the monitoring locations. Furthermore, our results do not support the hypothesis that response to scents or the control varies significantly by species or season. The longer time spent investigating scent and control vials by most mammals we analyzed compared to squirrels may have been a result of inherently greater curiosity or food response (e.g., Raccoon; reviewed by Davis 1907), stronger territorial response (e.g., Red Fox [*Vulpes vulpes*], Coyote; Allen *et al.* 1999), or minimal neophobia (i.e., fear of novel stimuli).

Similar to our results, Thorson *et al.* (1998) found that Fox Squirrels (*Sciurus niger*) did not respond to experimentally applied scent (i.e., urine of Red Fox, Raccoons, and White-tailed Deer). However, there is great variability in the response of prey to the olfactory cues of other species, including the cues of predators (reviewed by Swihart *et al.* 1991; Apfelbach *et al.* 2005). This variation appears to be influenced by factors such as the species under investigation and the type of cue available for assessment. Several studies have reported a low rate of mammal response to olfactory lures, which corroborates our findings (Roughton and Bowden 1979; Linscombe *et al.* 1983; Mowat and Paetkau 2002). Others have also failed to detect a preferential response to specific scent lures by species under investigation. For example, little variation in the response of Coyotes to different deployed scents has been reported (Linhart *et al.* 1977; Roughton and Bowden 1979; Bullard *et al.* 1983), a phenomenon also observed in other carnivores during field trials (e.g., Travaini *et al.* 1996; Batter 2011). Yet, conflicting outcomes exist across published results. Some studies have found that Raccoons do not exhibit a preferential response to certain attractants (i.e., scents or bait; Nottingham *et al.* 1989; Kavanaugh and Linhart 2000), while others report that Raccoons respond frequently to specific food scents and bait, such as fruit (Campbell and Long 2008) or fish (Campbell and Long 2007). These latter studies suggest that perhaps the food scent we employed (crayfish oil) was not preferentially attractive enough. It is noteworthy that we found no evidence that the species we analyzed exhibited neophobia toward our deployed scents. This is evident because individuals frequently passed through scent station locations, regardless of whether they responded to the experimental olfactory cues we deployed, and corroborates past findings specific to Coyotes (Windberg 1996).

Although scent lures may help attract some species during surveys, our data indicate that responses may not always relate to specific scent lures. We observed that if an individual responded to one scent in our experimental array, it was also likely to investigate the other scents and the control, but we found that no single scent was more effective than others or the control at eliciting a response. We believe we observed a general behavioural response to the presence of novel stimuli (i.e., the scent stations) rather than an olfactory response. The possibility also exists that mammals were attracted to the general experimental locations we established because of the combination of scents provided, but did not further investigate individual scents on arrival. Unfortunately, our data do not provide an opportunity to address this effectively.

Regardless, the response of individuals to the deployed scent and control vials that we observed was low overall (i.e., mammals passed through without investigating scent or control vials significantly more often than they stopped to investigate). Our findings, coupled with the large variation in the reported effectiveness of scent lures, may challenge the usefulness of olfactory attractants during surveys. Rather than deploying scent lures, it may be more effective to concentrate efforts on selection of high-quality camera locations by identifying appropriate habitat or detecting evidence of a target species through knowledge of its natural history. We found that camera traps with video capability were particularly useful in quantifying responses at stations where attractants were deployed. Our ability to record video clips enabled us to count the number of responses and the duration of time spent investigating a given scent station. This allows for a more sophisticated assessment of a species' interest than counting photographs or tracks associated with scent stations.

Past research supports the assertion that mammals respond to scent lures. However, the effectiveness of mammal attractants (olfactory, auditory, visual) may depend on study context (i.e., target species, study goals, geographic location, prey, and scents naturally present at study sites). Mammals that were not among those that we detected may show a greater response to scent lures or to specific scent types. For example, felids in both captive and field settings will investigate various scent lures (McDaniel *et al.* 2000), including cologne (Thomas *et al.* 2005), although variability in the responses to other types of scents exists (Anile *et al.* 2012). Food bait might elicit a stronger response than scent alone for certain species, as was found for Canada Lynx (*Lynx canadensis*) in Minnesota (Moen and Lindquist 2006). Length of study could also influence visitation rates, as some species could become conditioned to the continued presence of scent lures over time (Robson and Humphrey 1985). The use of olfactory stimuli may be more effective for species that naturally exist in low densities and are otherwise very difficult to detect (i.e., wild felids), compared to the relatively abundant mammal species that we studied. Further research focused on the efficacy of other olfactory attractants and various combinations of attractant methods (i.e., novel visual or auditory stimuli) will aid in filling knowledge gaps.

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Note

Ross's Goose (*Chen rossi*) Nesting Colony at East Bay, Southampton Island, Nunavut

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Nissley, Clark, Christopher Williams, and Kenneth F. Abraham. 2016. Ross's Goose (*Chen rossi*) nesting colony at East Bay, Southampton Island, Nunavut. Canadian Field-Naturalist 130(1): 22–24.

Most Ross's Geese (*Chen rossi*) nest in the central arctic of North America, but the range has expanded eastward in the last two decades. In summer 2014, we discovered a cluster of 48 nesting pairs of Ross's Geese at East Bay Migratory Bird Sanctuary, Southampton Island, Nunavut. The Ross's Goose colony was between an upland Lesser Snow Goose (*Chen caerulescens caerulescens*) nesting area and a low-lying Cackling Goose (*Branta hutchinsii*) and Atlantic Brant (*Branta bernicla*) nesting area, in a zone dominated by ponds and lakes and interspersed with areas of moss and graminoids. Our discovery documents a previously unknown level of nesting of Ross's Geese at East Bay and corroborates unpublished evidence of growing numbers of the species on Southampton Island and expansion of its breeding range.

Key Words: Ross's Goose; *Chen rossi*; nesting; Southampton Island; East Bay Migratory Bird Sanctuary; Nunavut

Introduction

Field studies and aerial surveys have documented large populations of nesting Lesser Snow Geese (*Chen caerulescens caerulescens*), Atlantic Brant (*Branta bernicla hrota*), and Cackling Geese (*Branta hutchinsii*) on Southampton Island, Nunavut (Sutton 1932; Barry 1962; Kerbes 1975; Abraham and Ankney 1986; Kerbes *et al.* 2006, 2014). The largest numbers occupy portions of East Bay Migratory Bird Sanctuary, the Harry Gibbons Migratory Bird Sanctuary, and other lowland areas. In contrast, evidence of nesting by Ross's Geese (*Chen rossi*) comes from finding three nests prior to 1980, two in 1957 (Barry and Eisenhart 1958) and one suspected nest in 1979 (Abraham and Ankney 1986), but mainly from the capture of locally hatched young during the banding of molting geese in late summer in the last two decades (Abraham and Ankney 1986; Canadian Wildlife Service, unpublished data).

Study Area

In summer 2014, we conducted a goose study in the East Bay Migratory Bird Sanctuary at the same East Bay area of earlier studies (Abraham and Ankney 1986). The area extended west to 82.03187°W and east to 81.77023°W (Figure 1). East Bay Migratory Bird Sanctuary is a habitat dominated by ponds and lakes. It includes four general zones: tidal, rock dominated (minimal vegetation), pond and lake dominated (moss and graminoid vegetation), and upland (dominated by Entire-leaved Mountain Avens, *Dryas integrifolia*-Vahl, and Dwarf Willow, *Salix herbacea* L.). At the western limits of the study area, the pond and lake dominated zone extends further inland. The plant community here has been influenced by grazing and grubbing by both Lesser Snow Geese and Cackling Geese in recent decades (Abraham *et al.* 2012).

Methods

Searching for nests was done systematically on foot, using multiple searches of the entire study area during the incubation period to ensure that we found late-nesting and re-nesting geese. We recorded latitude, longitude, and microhabitat measurements at each nest. Nests were identified by observing the incubating female. To confirm that the nests were those of Ross's Geese rather than Lesser Snow Geese, we measured egg size using calipers (to the nearest ±0.1 mm) following Alisauskas *et al.* (1998). We candled a sample of eggs to determine development stage. We estimated the various forms of ground cover within 1 m of nests, and water within 10 m selecting from 25%, 50%, 75%, or 100%. We also classified dominant vegetation or ground cover within 10 m of each nest, as moss, graminoids, willow, dead moss, bare ground, or rock. We obtained banding records of Ross's Geese and Lesser Snow Geese from the Canadian Wildlife Service (J. O. Leafloor, personal communication).

Results

We found a small colony of 48 nesting pairs of Ross's Geese at the head of East Bay (Figure 1). Nine Ross's Goose nests were discovered on 26 June and an additional 39 were found on 2 July. All nests discovered or re-visited on 2 July were either hatching or in the last 4 days of incubation. The average clutch size at the time of discovery was 3.1 eggs. We measured 110 eggs from 34 Ross's Goose nests. Average egg length was 72.46 ± 2.27 mm and average width was 48.45 ± 1.37 mm (com-

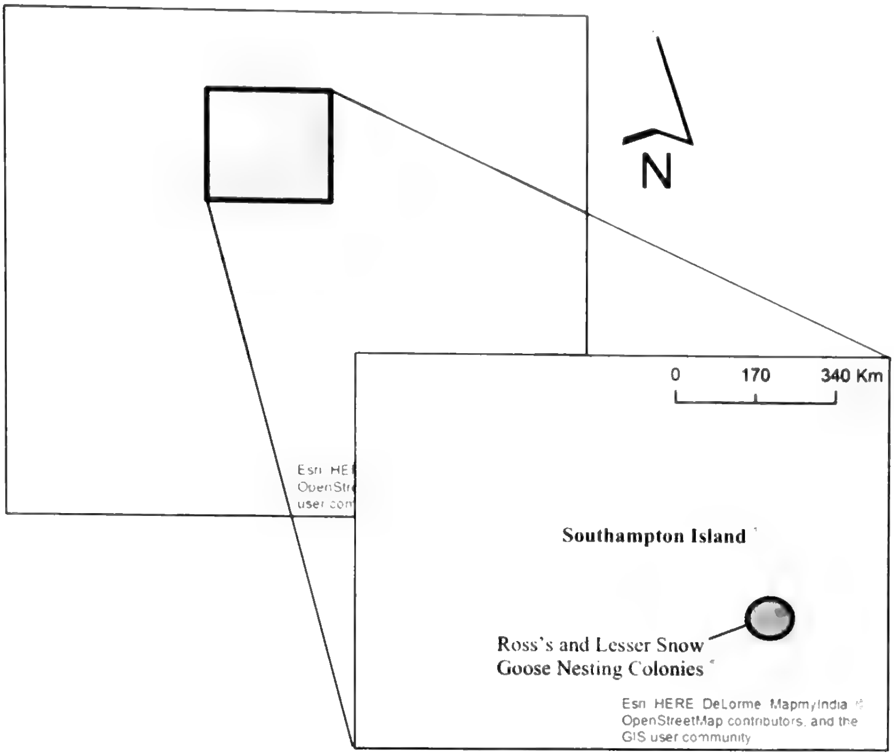

FIGURE 1. Map of Southampton Island and East Bay, Nunavut, including the previously unknown Ross's Goose (*Chen rossi*) colony.

pared with 71.8 ± 3.2 mm long by 48.4 ± 1.6 mm wide) corroborating our visual identification of the females and pairs as Ross's Geese and not Lesser Snow Geese whose egg size is reported as 78.4 ± 3.2 mm long by 52.7 ± 1.6 mm (Alisauskas *et al.* 1998).

Ross's Geese nested chiefly in the pond and lake dominated zone, sandwiched between an upland nesting area mostly occupied by nesting Lesser Snow Geese, and a low-lying area mostly occupied by nesting Cackling Geese and Atlantic Brant. Conspecific inter-nest distances were lower for Ross's Geese (mean = 30.41 ± 2.62 m, $n = 48$) than Lesser Snow Geese (mean = 83.52 ± 4.96 m, $n = 228$) or Cackling Geese (mean = 99.37 ± 2.62 m, $n = 578$).

The average vegetation composition within a 1-m radius of the nest was 48% live moss, 35% graminoid (mainly Hoppner's Sedge, *Carex subspathacea* Wormskjold), 11% dead moss, 4% rock, 2% willow, and <1% bare ground. Nest material was a combination of down, moss, graminoids, and willow. The dominant form of vegetation within 10 m of the nest was moss for 18 of the nests and graminoids for 29. In addition, on average, 52% of the area within a 10 m radius of the nests was water.

Discussion

North American Ross's Geese nest mostly in the Queen Maud Gulf Sanctuary but growing numbers are nesting in the western Hudson Bay region and numbers are reported to be increasing in the Foxe Basin region on Baffin Island and on Southampton Island (Moser 2001; Kerbes *et al.* 2006; Caswell 2009; Alisauskas *et al.* 2012). Although this is the first documentation of a Ross's Goose nesting colony on Southampton Island, the number and regularity of Ross's Goose captures during annual banding by the Canadian Wildlife Service suggest that it may be just one of many similar small colonies or clusters of Ross's Geese scattered among the much more numerous Lesser Snow Geese nesting on the island. Current estimation techniques for "light geese" on Southampton Island do not include separate estimates of Ross's Geese as in some other nesting areas (e.g., West Hudson Bay, cf. methods outlined in Kerbes *et al.* 2006, 2014).

We recommend more detailed monitoring on Southampton Island to allow discovery and enumeration of other nesting clusters of Ross's Geese. This is a necessary precursor to understanding their use of habitat in relation to that of other nesting goose species and their relation to habitat alterations that have occurred.

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Distribution and Ecology of a New Species of Water-lily, *Nymphaea loriana* (Nymphaeaceae), in Western Canada

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Nymphaea loriana Wiersema, Hellq. & Borsch (Lori's Water-lily) is a newly described, Canadian endemic species that has been found in central Manitoba and east-central Saskatchewan. To assess the status of a species, data regarding its distribution, population size, habitat, and search effort are needed. The purpose of this paper is to document these factors for this species. The extent of occurrence of *N. loriana* is approximately 15 100 km^2 but the known area of occupancy is a mere 20 km^2. The estimated population size of *N. loriana* is about 750 individual plants, although more may exist on poorly explored rivers and lakes within the extent of occurrence and possibly in northeastern Ontario. *Nymphaea loriana* occurs in fresh, stagnant, or slowly moving water in boreal lakes and rivers and is typically associated with *N. leibergii* (Dwarf Water-lily), *Schoenoplectus tabernaemontani* (Soft-stemmed Bulrush), *Potamogeton natans* (Floating-leaved Pondweed) and *Nuphar variegata* (Variegated Pond-lily). Potential threats to the persistence of this species include low water quality resulting from mining, forestry, and agriculture, and changes to water flow because of dam construction and climate change. Monitoring known populations and searching for additional ones may be needed to assess the status of this species.

Key Words: Lori's Water-lily; *Nymphaea loriana*; new species; Manitoba; Saskatchewan; conservation; distribution; ecology; endemic; rare

Introduction

Nymphaea loriana (Lori's Water-lily), is a newly described vascular plant found only in Manitoba and Saskatchewan, Canada (Figure 1). Taxonomic study of herbarium specimens of the water-lily genus for *Flora of North America North of Mexico,* volume 3 (Wiersema 1996, 1997) led to the discovery of plants from western Canada with unusual morphologies that were suspected of being hybrids between *N. leibergii* Morong (Dwarf Water-lily) and *N. odorata* Aiton (Fragrant Water-lily). Fieldwork to locate the unusual plants and subsequent DNA and other analyses occurred sporadically between 1996 and 2008 (Borsch *et al.* 2014). Morphological and molecular investigations have confirmed that *N. loriana* arose via hybridization between *N. leibergii* and *N. odorata* (Borsch *et al.* 2014). A detailed taxonomic description of this new species along with a new key to the *Nymphaea* of Canada is included in Borsch *et al.* (2014).

Canada is required to "monitor, assess and report regularly on the status of all wild species" to fulfill legal obligations under the Accord for the Protection of Species at Risk (CESCC 2011). Information on the status of species is then used by organizations, such as the International Union for Conservation of Nature and the Committee on the Status of Endangered Wildlife in Canada to identify and prioritize species for legal protection and conservation work. One of the main problems involved in achieving this goal is the lack of scientific data about wild species. As *N. loriana* is a newly recognized species, data on its distribution, population size, and habitat are needed to assess its status provincially, nationally, and globally. The objective of this paper is to provide some of the information needed for status assessment, identify areas where additional field surveys are needed, and assess any potential threats to its persistence.

FIGURE 1. Flower of *Nymphaea loriana* (Lori's Water-lily). Photo: Manitoba Museum.

Methods

Examination of herbarium specimens indicated three areas in Canada where *N. loriana* likely occurs (Borsch *et al.* 2014) (Figure 2). These areas were visited several times over 13 years to obtain genetic samples and document the population size and habitat (Table 1).

Extent of occurrence (EO) and area of occupancy (AO) are two parameters commonly used to help assess the rarity of a species (COSEWIC 2012; IUCN Standards and Petitions Subcommittee 2014). To determine EO, i.e., the area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species (COSEWIC 2012) in Canada, all known populations of *N. loriana* in Manitoba and Saskatchewan were included in a polygon. Google Maps was then used to calculate the EO.

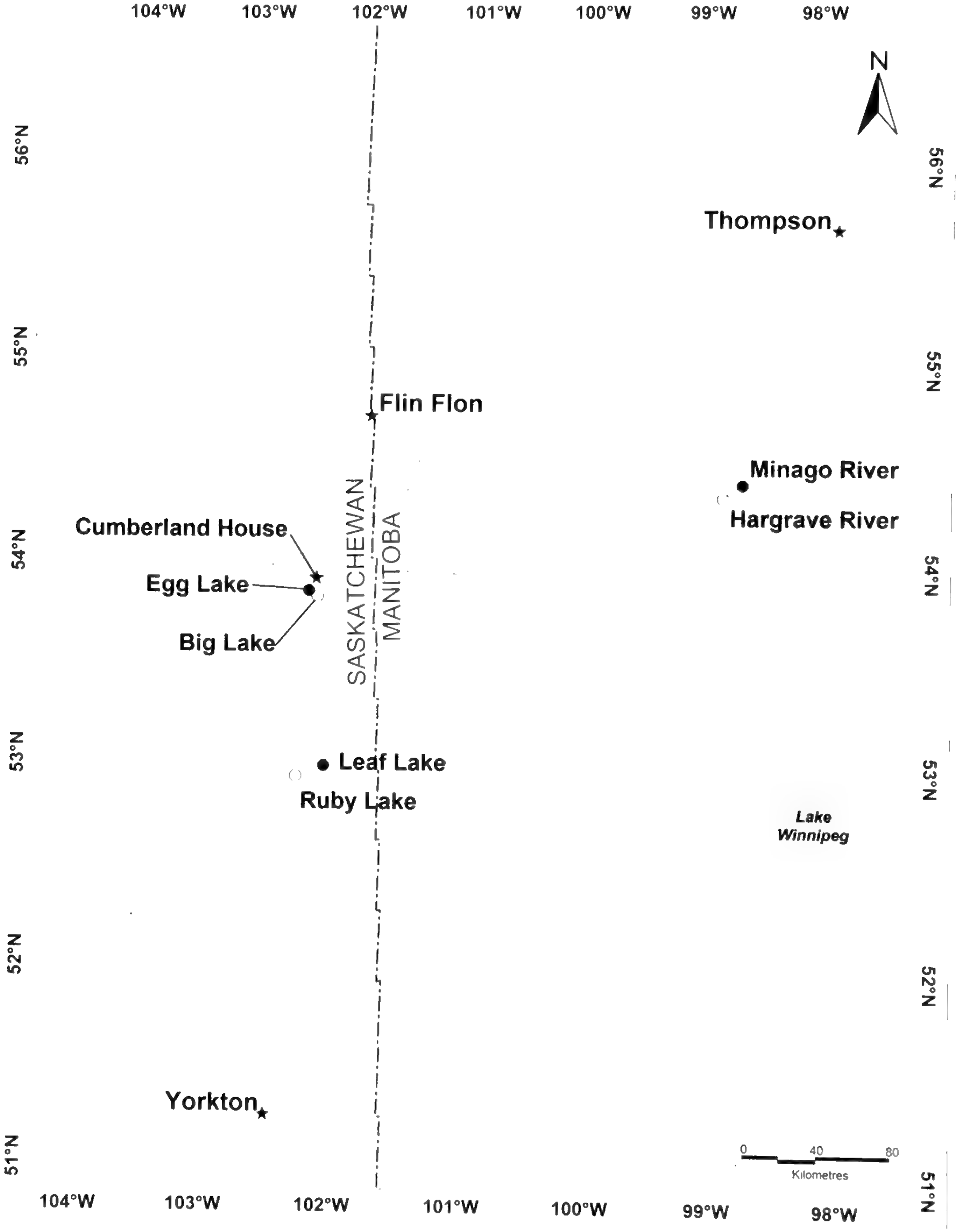

FIGURE 2. Known locations (solid circles) and areas searched (hollow circles) for *Nymphaea loriana* (Lori's Water-lily) in Manitoba and Saskatchewan, Canada.

TABLE 1. Summary of field excursions to obtain genetic samples and document the population size and habitat of *Nymphaea loriana* (Lori's Water-lily) in Manitoba and Saskatchewan.

Location	Searcher	Survey method*	Year	Total time (h)	Observation success†
Big Lake	J. Wiersema, D. Clayton, R. A. Wright	Targeted	2007	1	
Egg Lake	D. L. Dabbs and D.C. Surrendi	General	1962	?	+
	G. H. Townsend	General	1965	?	+
	J. Wiersema, B. Hellquist	Targeted	1996	~ 4	+
	J. Wiersema, B. Hellquist, T. Borsch	Targeted	2000	~ 7	+
	J. Wiersema, D. Clayton, R. A. Wright	Targeted	2007	~ 3	+
	D. Clayton, S. Greer	Targeted	2009	?	+
Hargrave River	J. Wiersema, D. B. Robson	Targeted	2008	1	
Leaf Lake	E. Kuyt	General	1959	?	+
	J. Wiersema, B. Hellquist	Targeted	1996	~ 6	+
Minago River	H. Scoggan	General	1948	?	+
	J. Wiersema, B. Hellquist	Targeted	1996	1	
	J. Wiersema, B. Hellquist, T. Borsch	Targeted	2000	6	–
	J. Wiersema, D. B. Robson	Targeted	2007	3	
	J. Wiersema, D. B. Robson	Targeted	2008	11	+
Ruby Lake	J. Wiersema, B. Hellquist	Targeted	1996	~ 1	–

* General surveys involved collecting many species, whereas targeted ones involved searching specifically for *N. loriana*.
† + indicates that *N. loriana* was found during the excursion; – indicates that it was not found.

AO is the area within the EO that is occupied by a taxon, excluding cases of vagrancy (COSEWIC 2012). The AO for each population was determined by collecting GPS points around the perimeter of the population and calculating the area or, if the population was small, by visually estimating the area covered by the plants.

The population size was estimated by traveling the entire perimeter of the population by boat and keeping a running tally of plants observed. However, it is impossible to determine the exact number of plants, as the rooting zone cannot be seen from the surface; for this reason, population sizes are only approximate. Plant species that were intermingled with or growing within 25 m or so of the perimeter of the *N. loriana* populations were collected and considered to be associated species. Plant specimens collected during these excursions were identified and deposited in various herbaria (Botanischer Garten und Botanisches Museum Berlin-Dahlem, Harvard University, and the Manitoba Museum) (Borsch *et al.* 2014).

Results and Discussion

Distribution

There are three known populations of *N. loriana* in Canada (Figure 2): one in Manitoba and two in Saskatchewan (Table 2). The populations in Saskatchewan and Manitoba appear to be disjunct with a gap of about 240–260 km in between. The two Saskatchewan populations are about 90 km away from each other. The EO was calculated to be approximately 15 100 km^2.

The Manitoba population is along the Minago River, north of Lake Winnipeg. In total, an 80-km stretch of the river, from Highway 6 east to Highway 373, was examined during various field trips. A portion of the Hargrave River was also navigated, but the low water clarity was considered to be unsuitable for water-lilies. The Minago population consists of three locations along an 8-km stretch of the river giving it an AO of approximately 12 km^2. *Nymphaea loriana* seeds appear to have been spreading downstream to the easternmost portions. This is the largest known population in Canada, estimated at around 500 plants.

The second population, found in Leaf Lake, north of Hudson Bay, Saskatchewan, has an AO of about 4 km^2. Nearby Ruby Lake was also visited but no *N. loriana* was detected. The third population was found in Egg Lake, which forms part of the Cumberland Marshes south of Cumberland House, Saskatchewan; its AO is approximately 4 km^2. Big Lake to the southeast of Egg Lake was also visited, but no *N. loriana* sightings were made. Thus, the total AO in Canada is about 20 km^2. Although only a few plants were found during initial reconnaissance of the Saskatchewan sites, and additional plants were found during a subsequent visit to the

TABLE 2. Populations of *Nymphaea loriana* (Lori's Water-lily) in Canada.

Location	Latitude, longitude	First observation	Last observation	Population size
Egg Lake, Saskatchewan	52°53'N, 102°19'W	1962	2009	< 200
Leaf Lake, Saskatchewan	52°58'N, 102°9'W	1959	1996	< 50
Minago River, Manitoba	54°28'N, 98°38'W	1948	2008	< 500
Total for Canada				< 750

Egg Lake population, a thorough survey of these areas has not been conducted; thus, there may be more individuals present.

The distribution of water-lilies, and many other aquatic species of plants in northern Saskatchewan and Manitoba, is poorly known. There are only 49 documented populations of water-lilies from Manitoba and 27 from Saskatchewan (Table 3). This is a result of several factors: poor accessibility because of the low density of roads in this area, the presence of water-lilies in deep water rather than along the shore, logistical problems involved in bringing watercraft into remote lakes and rivers, and the high cost of botanical collecting expeditions.

Targeted searches along streams, rivers, and shallow lakes within the EO are needed to determine exactly how widespread *N. loriana* and other more common species of water-lilies are. In particular, maps of the Saskatchewan River Delta area indicate several water-lily–bulrush mixtures similar to that found in Egg Lake at Deep Lake, Cow Lake, Highbank Lake, and Bewley Lake and these should be examined (R. A. Wright, personal communication, 2008). The Overflowing and Pasquia Rivers in Saskatchewan and Manitoba should also be searched. Areas in north-central Manitoba that should be searched for water-lilies include Clearwater Lake Provincial Park, Saskeram and Tom Lamb Wildlife Management Areas, and Moose and Cedar Lakes. Areas outside the EO, including the Nelson River and associated tributaries, and areas in northern Ontario where *N. leibergii* and *N. odorata* are known to coexist (north of Thunder Bay) should be searched. The discovery of just three more occurrences of this species would likely alter its status. Alerting the public about the need for more information about this species may result in additional sightings.

Habitat

Nymphaea loriana occurs in lake and river systems that are part of the Hudson Bay–Nelson Drainage Basin (Atlas of Canada 2006). Plants occur mainly several metres from shore in slow-moving rivers or shallow lakes. *Nymphaea loriana* was growing in water 1–2 m deep. Water-lilies are less tolerant of fast currents and water fluctuations than *Nuphar* spp. (pond-lilies) and, as their habitat is rarer, water-lilies are less common.

The Minago River begins northeast of Moose Lake and flows in a northeasterly direction. The river widens to form Hill Lake then receives water draining from Hargrave Lake via the Hargrave River and from Black Duck Lake via Black Duck Creek and Drunken Lake. The Minago eventually drains into Cross Lake, then the Nelson River and finally Hudson Bay. The surficial geology in this area consists of glacio-lacustrine deposits with periodic rock outcrops (Manitoba Mineral Resources Division 1981). West of Highway 6, the Minago flows through some exposed Ordovician dolomitic limestone, but east of the highway any exposed rock is Precambrian granite and gneiss. The area where *N. loriana* was found is part of the Hayes River Upland Ecoregion of the Boreal Shield Ecozone (Marshall and Schut 1999).

Water-lily populations along the Minago typically occur in small tributary streams that are dammed by beavers or along portions of the river margins with slow-moving, shallow water. Both *N. leibergii* and *N. tetragona*, as well as *N. leibergii* × *N. tetragona* hybrids were observed along the Minago River system. *Nymphaea leibergii* was associated with all three subpopulations of *N. loriana* but *N. tetragona* was found in the relatively still water in the mouths of tributaries. *Nymphaea loriana* was only found along a several-kilometre stretch of shallow water in the river channel proper. The vegetation in this area consisted of a broad, wet meadow of grasses and *Salix* spp. (willows), which likely flood in the spring but dry up later in the year. Near the shore, marginal and emergent plants including *Acorus americanus* (American Sweetflag), *Carex lacustris* (Lake Sedge), *Equisetum fluviatile* (Water Horsetail), *Schoenoplectus tabernaemontani*, *Sparganium angustifolium* (Narrow-leaved Burreed), *Eleocharis palustris* (Common Spikerush), and *Typha latifolia* (Broad-leaved Cattail) were common. Submerged and

TABLE 3. Number of water-lily (*Nymphaea*) populations in Manitoba and Saskatchewan based on herbarium specimens* and their rarity rank according to NatureServe (2015b).

	Manitoba		Saskatchewan		
Species	Number of populations	Status†	Number of populations	Status†	Canadian status
Nymphaea leibergii	18	S4	22	S2	N4N5
Nymphaea loriana	1	SNR	3	S1	N1
Nymphaea odorata	12	S2	0	n/a	N5
Nymphaea tetragona	17	S2	2	— §	N5
Nymphaea tetragona × *N. leibergii*	1	— §	0	n/a	— §

Note: n/a = not applicable as the taxon does not occur in this jurisdiction.

*Herbaria consulted include the Manitoba Museum (MMMN), the University of Manitoba (WIN), W. P. Fraser Herbarium (SASK), and the National Vascular Plant Herbarium (DAO).

† 1 = critically imperiled, 2 = imperiled, 4 = apparently secure, 5 = secure, NR = not ranked/under review.

§ Although there are herbarium specimens of this taxon from this jurisdiction, it was not ranked by NatureServe (2015b) for unknown reasons.

floating-leaved plants associated with *N. loriana* included *Myriophyllum sibiricum* (Siberian Water Milfoil), *Nuphar variegata*, *Potamogeton pusillus* (Small Pondweed), *P. natans*, *Ranunculus aquatilis* (White Water Buttercup), and *Utricularia vulgaris* ssp. *macrorhiza* (Greater Bladderwort). The presence of these plants may affect the habitat of *N. loriana* by contributing organic matter to the river bottom, as well as helping to decrease the water velocity.

The Cumberland Marshes receive water from both the North and South Saskatchewan rivers to the southwest, which have their headwaters in the Rocky Mountains of Alberta. Water from the Cumberland Marshes eventually drains into Cedar Lake, Lake Winnipeg, and the Nelson River ending up in Hudson Bay. The surficial geology in this area consists of clayey, calcareous alluvial materials underlain by glacial till (Acton *et al.* 1990). It is part of the Saskatchewan Delta landscape area in the Mid-Boreal Lowland Ecoregion of the Boreal Plain Ecozone (Acton *et al.* 1998). The species was found at least 500 m from the shore of Egg Lake. Associated floating and emergent plant species included *N. leibergii*, *Nuphar variegata*, and *Schoenoplectus tabernaemontani* (R. A. Wright, personal communication). Most of the *N. loriana* individuals were not in open water, unlike the other two floating-leaved species, but were dispersed within the *S. tabernaemontani* beds (R. A. Wright, personal communication). Other submerged plants in Egg Lake included *Potamogeton zosteriformis* (Flat-stemmed Pondweed), *P. natans*, *M. sibiricum*, and *Utricularia minor* (Lesser Bladderwort) (R. A. Wright, personal communication). The water depth where *N. loriana* was growing was about 100–120 cm. The water was clear but somewhat tannin stained.

Leaf Lake receives water from several small streams originating in the Pasquia Hills. Water from Leaf Lake drains into the Overflowing River and then eventually into Lake Winnipegosis, Manitoba. The surficial geology of the area consists of glacial till plain and glaciofluvial materials that are highly calcareous (Broughton and Macdonald 1980). It is part of the Overflowing River Lowland landscape area in the Mid-Boreal Lowland Ecoregion of the Boreal Plain Ecozone (Acton *et al.* 1998). Only a few plants have been observed, again together with *N. leibergii*, in the clearer waters of one of Leaf Lakes' influent streams.

Conservation Issues

In Manitoba, the Minago River is on provincial crown land and is not part of any national or provincial park or wildlife reserve. In Saskatchewan, both the Cumberland Marshes and Leaf Lake are also on provincial crown land. The Cumberland Marshes, a 364 000-ha wetland that is part of the Saskatchewan River Delta, is internationally recognized as a Canadian Important Bird Area (IBA Canada 2009). Ducks Unlimited Canada has approximately 130 000 ha of the Cumberland Marshes under conservation easements with the Saskatchewan government to ensure the protection of wildlife in this area (Patterson 2005).

Three factors might negatively affect *N. loriana* populations: changes in water quality and water levels and collecting by the horticulture industry. *Nymphaea loriana* appears to require high water clarity, which may be negatively affected by the release of sediments resulting from natural resource development in the boreal forest: forestry, toxic chemicals and sediments from mining operations, and agricultural nutrients and pollutants (Chow-Fraser *et al.* 1998; Kreutzweiser *et al.* 2013).

The Minago River area in Manitoba is considered too remote to be commercially logged, at least at the present time. The forests immediately surrounding the Cumberland Marshes are also not part of any current forest management agreement (FMA). However, those around Leaf Lake are part of the Pasquia/Porcupine FMA. Industrial logging has been occurring in this area since the 1940s, and will continue in the near future. Some forestry practices may cause soil erosion, increasing sediment flow into the lake and negatively affecting *N. loriana*. Leaving unlogged buffer zones between riparian and logged areas would help decrease soil erosion.

Mining activities may increase turbidity and release toxic compounds into aquatic systems, as well as increasing acidity (Beamish *et al.* 1975; Kreutzweiser *et al.* 2013). A nickel mine is planned for an area north of Grand Rapids; the environmental impact statement prepared for the project states that a "site water management plan" and an "erosion and sediment control plan" will be implemented to mitigate the effects of polishing-pond discharges into the Minago River (Victory Nickel 2010).

The population of *N. loriana* in the Cumberland Marshes area may be affected by lower water quality as the Saskatchewan River runs through agricultural areas and several urban centres that contribute fertilizers, pesticides, sewage, and household chemicals to the water. The anticipated spread of agriculture further north into the Boreal Transition ecoregion as climate change occurs may alter nutrient concentrations and result in increased pollution from agricultural operations (Bayley *et al.* 1992). The Minago River, with its headwaters originating in north-central Manitoba, and Leaf Lake, with headwaters originating in the undeveloped Wildcat Hills, are less likely to become contaminated, as agricultural land does not occur adjacent to them or their tributaries at present. However, Leaf Lake receives a considerable nutrient load from migrating waterfowl.

Nymphaea loriana is restricted to habitats with relatively shallow water and is vulnerable to drastic changes in water levels, which may occur as a result of both climate change and dam construction. The Saskatchewan River has several dams already: Gardiner, Francois-Finlay, and E. B. Campbell. The E. B. Campbell dam results in less water flowing downstream at certain times of the year (Patterson 2005). A dam at Grand Rapids in Manitoba has impacted the Cumberland Marshes by causing higher water levels and flooding west of The Pas (Patterson 2005). No new hydroelectric projects are planned for the immediate future along either the Minago or Saskatchewan River or the streams providing water to, and draining, Leaf Lake. However, higher oil prices could result in a greater demand for hydroelectricity and may spur the creation of another dam on the Saskatchewan River. Changes in the water level in these river systems because of the loss of glaciers in the Rocky Mountains may also decrease *N. loriana* habitat (Schindler 2001). Thus global climate change may eventually have a negative impact on this species (Nelson *et al.* 2014).

Since the 1940s, a series of small dams have been created in the Cumberland Marshes to increase habitat for muskrat, which were trapped for fur. Nowadays, management of this area focuses on restoring some of the hydrologic variability that no longer occurs because of the presence of dams on the river. Any drastic changes in the water level in the Cumberland Marshes as a result of a dam may impact the *N. loriana* population located there (Kreutzweiser *et al.* 2013).

Water-lilies are important horticulturally, as they are attractive additions to water gardens, and many species are being used in breeding experiments to create new hybrids (Slocum 2005). The popularity of *N. odorata* in water gardening has resulted in this species spreading to areas where it was not found naturally, and, in fact, it is becoming invasive in parts of the United States (Else and Riemer 1984). The popularity of water-lily gardening may make *N. loriana* the target of overzealous collectors, who could endanger the population. The remote locations of *N. loriana* in deep wetlands will help protect the species, as these populations are not easily accessible. The NatureServe threat assessment calculator shows the overall threat impact for *N. loriana* to be "Low" (NatureServe 2015a).

Conclusions

Nymphaea loriana is a newly identified species that appears to be limited to clear, non-turbid rivers, streams, and lakes in the Boreal Plains and Boreal Shield of Manitoba and Saskatchewan. Monitoring known populations would help to determine whether *N. loriana* is spreading or declining. Additional surveys of potentially appropriate habitats in northern Saskatchewan, Manitoba, and possibly even Ontario may reveal additional populations.

Although *N. loriana* does not appear to be in any immediate danger of extinction, circumstances may change in the near future to alter that. Measures to decrease the release of toxic contaminants from mining operations and prevent soil erosion and increased nutrient flow into nearby rivers from forestry and agriculture would help decrease any negative impact on this, and many other species, in boreal wetlands. Additional surveys and monitoring work would provide the information needed to help scientists determine whether *N. loriana* is in need of legal protection.

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Note

Swimming Long-tailed Vole (*Microtus longicaudus*) Killed by an Osprey (*Pandion haliaetus*)

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Jung, Thomas S. 2016. Swimming Long-tailed Vole (*Microtus longicaudus*) killed by an Osprey (*Pandion haliaetus*). Canadian Field-Naturalist 130(1): 32–33.

Osprey (*Pandion haliaetus*) are piscivores, and observations of them preying on non-fish species are rare. I observed an Osprey preying on a Long-tailed Vole (*Microtus longicaudus*) that was swimming in the Sikanni Chief River in northeastern British Columbia. This is one of few reports of an Osprey preying on a small mammal, and it provides further evidence that Osprey may prey on such species as the opportunity arises. This observation also points to the apparent vulnerability of small rodents to novel predators while they are swimming.

Key Words: Long-tailed Vole; *Microtus longicaudus*; Osprey; *Pandion haliaetus*; predation

Ospreys (*Pandion haliaetus*) are piscivores, with more than 99% of their diet composed of fish (reviewed by Poole *et al.* 2002). They tend not to be selective in terms of the species of fish they consume, but they are selective when it comes to size of prey, with individual fish usually measuring 25–35 cm (Poole *et al.* 2002). Most prey are taken alive; Ospreys rarely scavenge.

Observations of Osprey preying on non-fish species are rare; however, several instances of Osprey preying on small mammals have been documented. Specifically, Proctor (1977) and Campbell and Hillary (2009) reported three observations of Ospreys preying on Meadow Voles (*Microtus pennsylvanicus*), while Wiley and Lohrer (1973) described a pair of Ospreys regularly preying on Hispid Cotton Rats (*Sigmodon hispidus*). Larger rodents have also been documented as prey of Osprey, including an Eastern Gray Squirrel (*Sciurus carolinensis*; Taylor 1986), a Muskrat (*Ondatra zibethicus*; Kern 1976), and an unidentified species of ground squirrel (*Urocitellus* sp.; Werren and Peterson 1988). Most of these observations have been of Osprey killing these mammals while they were on land, usually near a waterbody or en route from an inland nesting site, exceptions were a Meadow Vole (Campbell and Hillary 2009) and a Muskrat (Kern 1976) that were captured while swimming. Nevertheless, small mammals are apparently rare prey of Osprey (Wiley and Lohrer 1973). Here, I report an additional observation of an Osprey preying on a small mammal.

On 23 August 2014, I was angling on the south side of the Sikanni Chief River (57.24069°N, 122.68529°W), approximately 155 km northwest of Fort St. John, British Columbia. At approximately 07:50 Mountain Standard Time, I observed a small mammal, which I initially identified as a juvenile Muskrat, swimming across the river about 25 m upstream of my position. Earlier that morning, I had observed an Osprey perched on a large, live White Spruce (*Picea glauca*) tree on the north shore of the river. Within ≤ 1 minute of my observing the swimming small mammal, the Osprey left its perch and plunged toward the water, emerging with an animal taken from the middle of the river. The Osprey flew about 15 m above the water, dropped the mammal, circled back over the north side of the river, and flew out of sight.

Fortunately, the Osprey dropped the mammal on a rocky shore on the south side of the river, where, after several minutes of searching for it among the rocks, I found it dead. I identified it as a Long-tailed Vole (*Microtus longicaudus*), based on its general size, head shape, and, specifically, its long, bi-coloured tail (Smolen and Keller 1987; Nagorsen 2005). It is not known why the Osprey dropped the vole, but perhaps it had lost interest in the vole as prey.

This observation is of scientific value from two perspectives. First, Osprey are not usually regarded as predators of small mammals (Wiley and Lohrer 1973; Poole *et al.* 2002). Others have reported similar incidents of Osprey apparently preying on voles (Proctor 1977; Campbell and Hillary 2009); however, both reports assumed that the species was a Meadow Vole and identification was unconfirmed. Here, I was able to positively identify the species of vole taken. Regardless, taken together, these observations suggest that Osprey may occasionally prey on small mammals, such as voles, when the opportunity arises.

Second, it is interesting that the vole drew the Osprey's attention and was attacked while it was swimming. One of the apparent Meadow Voles observed to be killed by an Osprey by Campbell and Hillary (2009)

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was also captured when it was in the water. Thus, although some species of small mammals may only occasionally enter the water, they may be susceptible to novel predators while swimming (*sensu* Jung *et al.* 2011).

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Note

The Timing of Egg-laying in Macrobiotid Species (Tardigrada) on the Island of Newfoundland

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Previous sampling of lichens and mosses on the island of Newfoundland has not located any macrobiotid (family Macrobiotidae) eggs, which are often crucial to the positive identification of adults of this family, particularly *Macrobiotus* and *Minibiotus* species. Because recent studies have established that egg-laying in macrobiotid species in the more northerly Labrador part of the province occurs in late summer and early fall, it was hypothesized that egg-laying on the more southerly island of Newfoundland would take place later in the year. In this study, conducted on the Burin Peninsula from September to December 2005, moss samples were taken every 2 weeks and macrobiotid adults and eggs were extracted. The eggs of 3 species of *Macrobiotus* and 1 species of *Minibiotus* were recovered later in the fall after the first frost.

Key Words: Tardigrada; *Macrobiotus*; *Minibiotus*; egg-laying; Newfoundland

Introduction

Freshwater and semi-terrestrial tardigrades produce several eggs at a time, which are either smooth and are shed in the old exuvium during a moult or are intricately ornamented and are laid freely in the environment, singly, in pairs, or in groups. Smooth eggs are produced by species of both heterotardigrades and eutardigrades, whereas ornamented eggs are produced only by the latter (Kinchin 1994). Egg shell ornamentation varies and allows one to distinguish between species, particularly within the genera *Macrobiotus* C.A.S. Schultze, 1834 and *Minibiotus* Schuster, 1980 where the adults quite often closely resemble one another. Although the evolutionary benefit of ornamented eggs is unclear, Ramazzotti and Maucci (1983) have proposed that the processes keep eggs from being swept away by external agents, such as wind and water.

Little is known about the timing of egg-laying in tardigrades. Ramazzotti and Maucci (1983) state that eggs can be found at any time of year in mosses, lichens, and soil, and Pennak (1953) generalizes the peak of reproductive activity between November and May. Nelson (1982) has found that eggs appear to be more numerous during the winter in soil-inhabiting species. Kristensen (1980) has reported finding the largest number of eggs in Greenland samples during mid-winter months. In Tennessee, Kendall-Fite (1993) found the eggs of *Minibiotus intermedius* Plate, 1888 most often during December, whereas Nichols (1999), working further south in Alabama, found few eggs and mostly in January and April. In the United Kingdom, Morgan and King (1976) state that eggs, whether associated with an exuvium or deposited freely, can be found there in small numbers throughout the year. However, they also suggest that, depending on climatic conditions, egg-laying may occur in small peaks throughout the year, including one in January.

In a preliminary survey of the tardigrades of the island of Newfoundland, very few eggs were found in moss and lichen samples, and no macrobiotid eggs were found (Bateman and Collins 2001). However, a more recent investigation of tardigrades in Labrador, the mainland portion of the province of Newfoundland and Labrador, yielded interesting results (Boeckner *et al.* 2006). During a preliminary survey in October 2001, no eggs were found. However, in 2002, 1 egg was located in the June samples, and 35 eggs were found 2 months later in August. Because the climate of the northeast coast of Labrador is cooler than that of the island it was surmised that egg-laying on Newfoundland occurred later in the year than in Labrador. The temperatures during August in Labrador correspond more closely with those found in early October on the island (Environment Canada 2011). The most probable explanation, then, for the lack of eggs in the previous Newfoundland study (Bateman and Collins 2001) might be the time of sampling (between June and August), which was too early to collect eggs laid later, in the fall.

Species of the genera *Macrobiotus* and *Minibiotus* can be positively identified only through the concurrent collection of eggs and adult specimens at the same location (Kinchin 1994). A number of *Macrobiotus* species, including *M. harmsworthi* J. Murray, 1907, and *M.* cf. *hufelandi* C.A.S. Schultze, 1833, as well as *Minibiotus intermedius*, were tentatively identified earlier on Newfoundland (Bateman and Collins 2001), but as no eggs were collected together with the adults, no definite identifications could be made.

The primary purpose of this study was to determine when macrobiotid reproduction and egg-laying occurs on the island of Newfoundland. This will enable positive identification of *Macrobiotus* and *Minibiotus* species based on availability of both adults and eggs.

Methods

Preliminary sampling of potential study areas in the vicinity of Marystown (47°10'N, 55°10'W) on the Burin Peninsula, Newfoundland, was conducted in early September 2005 to determine which sites contained tardigrades. Of the 11 sites selected, 10 contained tardigrades. These sites were then sampled at 2-week intervals for 4 months (September to December). Because the main purpose of the study was to find out if and when egg-laying was taking place, no attempts were made to take multiple samples at each site, but rather to take a single sample from as many sites as possible to enhance the chance of locating eggs.

Each sample, consisting of approximately 200 g of moss, was stored in a labeled brown paper lunch-style bag and allowed to dry out naturally. A volume of 14 cm^3 of each dried moss sample was soaked in separate plastic Petri dishes in tap water for 18–24 h to activate the cryptobiosing tardigrades and then attempt to induce anoxybiosis, causing the tardigrades to release their hold on the moss and collect in the water from which they can be easily removed (Romano 2003). After stirring and squeezing the moss sample to remove any tardigrades not already suspended in the water, the samples were soaked in tap water again and squeezed thoroughly a second time to ensure maximum recovery of tardigrade adults and eggs. Both active and inactive tardigrades, as well as eggs and exuvia, were removed from the dish by hand using a glass pipette. Each adult tardigrade and each egg was mounted in Hoyer's medium (Kinchin 1994) on a microscope slide, covered with a coverslip, and dried on a slide dryer for a week.

Identification of the specimens was based primarily on the work of Ramazzotti and Maucci (1983) with additional information on individual species from Bertolani and Rebecchi (1993), Kathman (1989, 1990), and Kathman and Cross (1991). The microscope slides containing the adults and eggs (K2005: numbers 001-415) are held in the Biology Department, Memorial University.

Results

Based on descriptions and diagrams in Argue (1971, 1972, 1974), Morgan and King (1976), Ramazzotti and Maucci (1983), Kathman (1989, 1990), Bertolani and Rebecchi (1993), and Kinchin (1994), 4 types of eggs were recovered and identified as belonging to *Macrobiotus crenulatus*, *M. harmsworthi*, *M.* cf. *hufelandi*, and *Minibiotus* cf. *intermedius*. Only 4 of the 10 sample sites yielded eggs during this period; thus, only collections from these 4 sites are reported (Table 1).

Single eggs of *Macrobiotus* cf. *hufelandi*, *M. harmsworthi*, and *M. crenulatus* were obtained in September and October, but most eggs were found from mid-October onward. The specific periods during which eggs were located for each of the 4 macrobiotid species in this study were: *M. crenulatus*, mid-September to early December; *M.* cf. *hufelandi*, early September to early December; *M. harmsworthi*, October to late December; *Minibiotus* cf. *intermedius*, late November to December (sampling ended in late December).

Discussion

The results of this limited study suggest that egg-laying by *Macrobiotus* cf. *hufelandi*, *M. harmsworthi*, *M. crenulatus*, and *Minibiotus* cf. *intermedius* on the Burin Peninsula, Newfoundland, takes place in the fall. It appears then, that concurrent collection of eggs and adults of these 4 species in areas with a climate similar to that of Newfoundland could be achieved by sampling in late fall. This is not to say that egg-laying might not also take place at other times of the year, perhaps dur-

TABLE 1. Number of eggs of 4 macrobiotid species found from September to December 2005 on the Burin Peninsula, Newfoundland.

Date	Species				
	Macrobiotus crenulatus	*Macrobiotus harmsworthi*	*Macrobiotus* cf. *hufelandi*	*Minibiotus* cf. *intermedius*	All species
2 Sept.	0	0	1	0	1
17 Sept.	1	0	0	0	1
1 Oct.	1	1	1	0	3
15 Oct.	11	0	3	0	14
29 Oct.	11	0	0	0	11
13 Nov.	19	0	0	0	19
26 Nov.	19	0	11	2	32
11 Dec.	4	0	2	2	8
24 Dec.	0	9	0	1	10
Total	66	10	18	5	99

ing winter or spring; however, no sampling was attempted at these times. It is unlikely that egg-laying takes place during the summer months, as previous collecting during many summers has yielded no eggs. Morgan and King (1976) have found that (in the United Kingdom) fertilized eggs hatch in 1–10 days, depending on climatic conditions. It seems likely, therefore, that tardigrade eggs do not persist in the environment for long periods; thus, even if eggs were laid early in the year, they would not be found during the summer.

The number of sampling sites was relatively small in this limited study ($n = 11$). Authors such as Degma *et al.* (2011: 71) state that

> Because of the patchiness of Tardigrada populations (e.g., Meyer 2006; Jönsson 2007), a large number of replicate samples is necessary for obtaining valid data for ecological studies (e.g., Nelson 2002). The required number of samples per treatment (value of environmental variable) can be very high (from a few hundred to more than 1000) to reduce the standard error of the population estimates. This fact makes ecological studies of tardigrade populations and communities very difficult, and few, if any, studies have had sufficient sample sizes.

Our study, then, in common with most studies of tardigrades in natural settings, also suffers from limited sampling. Future such studies should, therefore, involve many more sampling sites and individual samples, although Degma (2010) has stated that it is possible to take qualitative samples if the researcher is interested only in species richness.

The current study was limited to samples of moss and cannot necessarily be generalized to egg-laying in other substrates, such as lichens, liverworts, leaf litter, and soil. As Meyer (2013) has pointed out, most terrestrial sampling in the Americas has focused on cryptogams, with 90% collected from such substrates compared with 14% from leaf litter, 20% from soil, and 24% in aquatic samples. Future studies of egg-laying should, therefore, include samples from other cryptogams (lichens and liverworts), leaf litter, and soil to see if the timing of egg-laying on these substrates is similar to that for mosses.

It would also be instructive to conduct a year-round sampling study to see if egg-laying takes place at other times of year, particularly January through May, as has been found in other locations (e.g., Pennak 1953; Morgan and King 1976; Kristensen 1980; Nichols 1999).

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Note

Northern Goshawk (*Accipiter gentilis*) Attacks Waterbirds at Sea

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Gaston, Anthony J. 2016. Northern Goshawk (*Accipiter gentilis*) attacks waterbirds at sea. Canadian Field-Naturalist 130(1): 38–39.

A Northern Goshawk (*Accipiter gentilis*) was twice observed hunting over the sea, close to shore, for small grebes (*Podiceps* spp.). Neither predation attempt was successful. Attacks on marine birds on the sea by goshawks are very rarely reported.

Key Words: Northern Goshawk; *Accipiter gentilis*; grebe; *Podiceps*; predation

The Northern Goshawk (*Accipiter gentilis*) is primarily a forest-living raptor, feeding on birds and mammals up to the size of grouse and rabbits (Cramp and Simmons 1980; Widen 1989; Squires and Reynolds 1997; Drennan 2006). It is not often seen in open country and rarely in waterside habitats (Cramp and Simmons 1980; Squires and Reynolds 1997). Although goshawks sometimes prey on waterbirds on land (Schnurre 1956; Veldkamp 2008; Verdal and Selås 2010), published observations of predation by Northern Goshawks on birds on water are unusual (Sulkava *et al.* 2006; Magyar 2011), and predation attempts on the sea have not been described previously. This note reports two predation attempts on waterbirds on the sea.

On 3 February 2015 at 1000, an immature, probably female based on size (Figure 1), Northern Goshawk was seen swooping low over an Eared Grebe (*Podiceps nigricollis*) on the sea about 20 m from shore off the north coast of Gabriola Island, British Columbia. The grebe dived to avoid capture, but the goshawk circled over the spot and made a second attempt as the bird resurfaced, plunging into the water with its talons spread and "spread-eagling" on the surface briefly before rising from the water. The grebe again avoided capture by diving and the goshawk, now with wet belly, primary, and tail feathers, flapped to shore and sat on a rock with wings spread. After 4 minutes of intermittent preening it flew off into the nearby forest.

Flocks of about 50 Barrow's Goldeneye (*Bucephala islandica*) and about 500 Surf Scoters (*Melanitta perspicillata*), which were feeding about 100 m away from the goshawk attack, responded to the event by vocalizing, huddling together, and swimming quickly toward the attack location, approaching to within 30 m of the spot where they remained for 3 minutes before they resumed feeding.

FIGURE 1. Immature Northern Goshawk (*Accipiter gentilis*) on the shore at Gabriola Island, British Columbia, February 2015, after failing in a predation attempt on an Eared Grebe (*Podiceps nigricollis*). Photo: A. J. Gaston.

On 7 February 2015, about 400 m west of the first observation site, an immature Northern Goshawk was seen flying about 1 m above the sea toward a Horned Grebe (*Podiceps auritus*) sitting on the water surface about 50 m offshore. The goshawk extended its feet forward as it came level with the grebe, but the grebe dived and the goshawk pulled out of its swoop before making contact with the sea surface. It then continued flying at the same altitude and landed on a rock close to the shore, where it sat for another 5 minutes before observations ceased. The distance from the goshawk's take-off point to the intended prey was about 100 m. Scattered American Wigeon (*Anas americana*) and Common Mergansers (*Mergus merganser*) on the water within 100 m of the grebe showed no reaction to the hawk, but a female Bufflehead (*Bucephala albeola*) within 15 m of the hawk's course dived underwater although the goshawk made no attempt to approach it.

The behaviour of the goshawk on both occasions clearly indicated intended predation, especially in the first instance, where the bird plunged into the sea up to

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its belly. However, neither attempt was successful. In both instances, the target birds were the smallest among many waterbirds present and, in both cases, the sea was only slightly rippled. The two observations involved a bird in identical plumage and, given the proximity of the two sites, could easily have been the same individual.

Although ducks, gulls, and other waterbirds have been noted among the prey of Northern Goshawks in northwestern North America (Drennan 2006), no predation at sea has been reported. A record of a Pigeon Guillemot (*Cepphus columba*) among goshawk prey in southeast Alaska (Lewis *et al.* 2006) was probably taken on the sea, as these birds breed very close to shore and are not found on fresh water (Squires and Reynolds 1997). However, the possibility that it was taken on land near the nest cannot be excluded.

In the current observations, the goshawk hunted close to shore in sheltered waters with little wave action. Forest extended to within 50 m of the shoreline in both cases. It seems likely that the attacks were initiated from the shelter of trees, but, in both instances, the action was not seen until the goshawk was over the sea. The distance from take-off to prey noted during the second predation attempt was considerably farther than is typically attended by success in the species (Kenward 1978). As the bird involved was an immature, it is likely that these predation attempts were part of a learning process that would eventually result in concentration on more typical prey (Frank Doyle, personal communication, March 2015).

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A Checklist of Ants (Hymenoptera: Formicidae) of Saskatchewan

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Based on field surveys, museum specimens, and published literature, we document 73 ant species in three subfamilies and 12 genera for the province of Saskatchewan, Canada. An additional 16 species are known from surrounding regions and are likely to occur in Saskatchewan.

Key Words: Ants; Saskatchewan; checklist; Hymenoptera; Formicidae

Introduction

The ant fauna of Saskatchewan, Canada, has been relatively poorly studied, and, thus, we present a list of ant species from the province based on our own field surveys, examination of museum specimens, and a search of the literature. Additional species that are anticipated in Saskatchewan based on their presence in surrounding regions are also noted.

Few published papers provide species-level information on ants from Saskatchewan. Kidd and Longair (1997) examined boreal ants, identifying five species. Both Radtke *et al.* (2014) and Glasier and Acorn (2014) examined grassland ants and listed 13 and 33 species, respectively. Several ecological studies (Ferguson 2000, 2001, 2004; Chikoski *et al.* 2006) have dealt with ants in Saskatchewan, but they did not identify them to species. Hansen and Klotz (2005) reviewed *Camponotus* species from North America and listed five species for the province, but did not provide specimen localities. Likewise, Wheeler and Wheeler (1986) mention *Formica planipilis* from Saskatchewan, but do not provide a locality. In their taxonomic reviews of *Lasius*, Wilson (1955) and Wing (1968), report seven *Lasius* species from southern Saskatchewan locations. In addition, Francoeur's (1973) review of *fusca*-group *Formica* reported three species in the province. With this patchwork of studies, it is difficult to assess the diversity of ants found in the province.

Ant fauna from the regions bordering Saskatchewan, however, are relatively well reported. A preliminary checklist (Wheeler *et al.* 1989) of ants in Manitoba (to the east) identifies 52 species, while a key for Alberta (to the west) lists 93 species (Glasier *et al.* 2013). Ant lists from the southern bordering states of Montana (Wheeler and Wheeler 1988) and North Dakota (Wheeler and Wheeler 1977) identified 76 and 87 species, respectively. It may be expected that Saskatchewan would share similar ant species diversity as that reported in the surrounding regions. However, little is known about the ant fauna of the Northwest Territories and Nunavut to the north.

Study Area

Saskatchewan's surface area is 651 900 km^2, and the province includes four main ecozones: prairie, boreal plains, boreal shield, and taiga shield (Figure 1). The ecozones differ as follows.

The prairie ecozone is characterized by mixed grasslands to the south and aspen parkland in the north. The southern grasslands are dominated by wheatgrasses and speargrasses, with wetter areas hosting small shrubs, such as Wolf-willow (*Elaeagnus commutata* Bernhardi ex Rydberg) or Snowberry (*Symphoricarpos* spp. Duhamel). The northerly aspen parkland is dominated by fescue grasslands and aspen woodlands. The Cypress Hills, along the southwestern edge of the province, are also found in this ecozone. This is the only area of the province that remained unglaciated during the last ice age, and because of its elevation, it is covered in Lodgepole Pine (*Pinus contorta* Douglas ex Loudon), aspen (*Populus* spp. L), and White Spruce (*Picea glauca* (Moench) Voss) forests (Saskatchewan Conservation Data Centre 2014).

The boreal plain ecozone is a mix of boreal forest, farmland, and peatlands. In the southern areas, aspen forests dominate, with some White Spruce (*Picea glauca* (Moench) Voss) or Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh). Northward in this zone, peatlands with Tamarack (*Larix laricina* (Du

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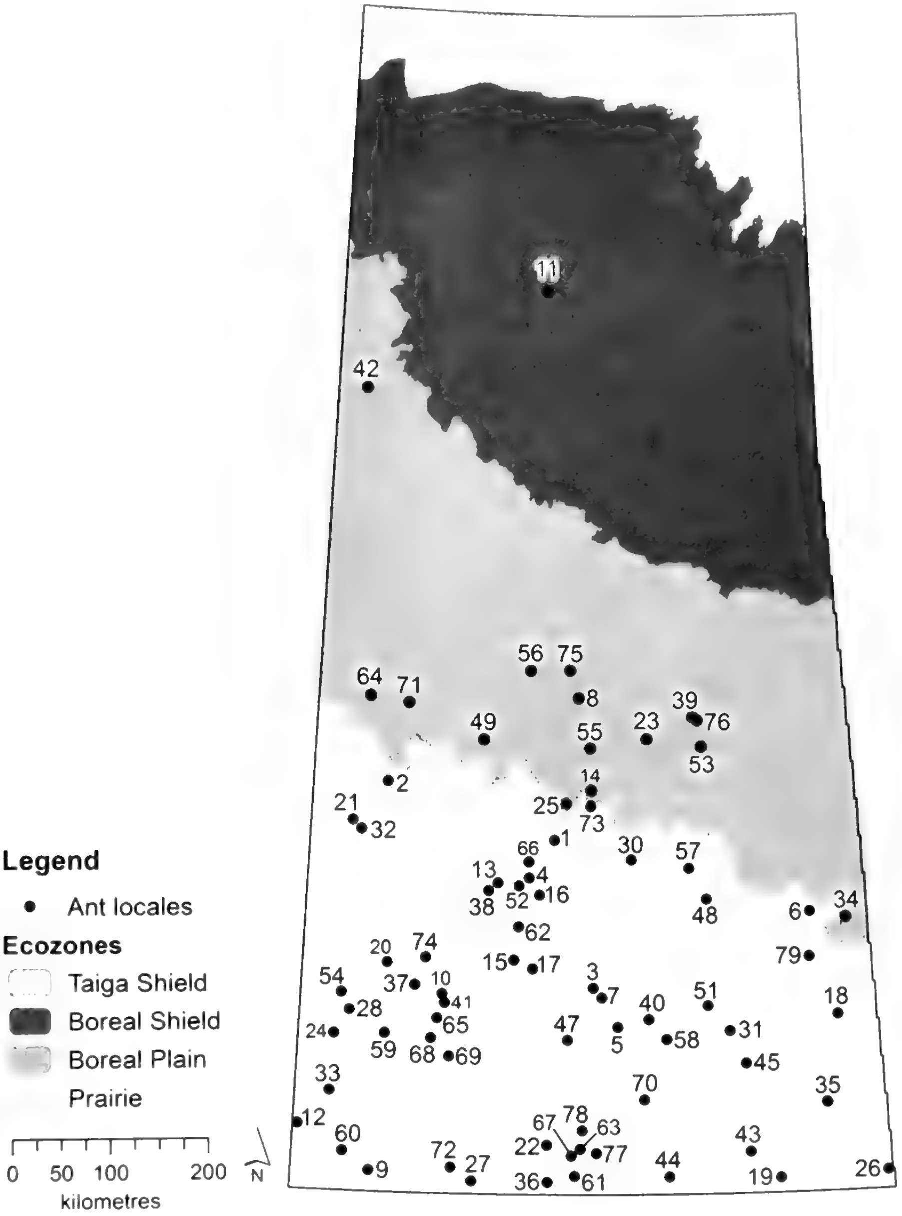

FIGURE 1: Sampled localities in Saskatchewan. Locality numbers are matched with species records in the checklist of ants.

Roi) K. Koch) and Black Spruce are common in low-lying areas, whereas elevated areas are dominated by mixed aspen and White Spruce forests. Jack Pine (*Pinus banksiana* Lambert) and spruce woodlands are sporadic, and found in areas with sandy soils (Saskatchewan Conservation Data Centre 2014).

The boreal shield ecozone is covered in numerous freshwater lakes. It is vegetated by a mix of Jack Pine and Black Spruce in sandy soil areas. In wet, low-lying areas, Tamarack and Black Spruce peatlands are common, while White Birch (*Betula papyrifera* Marshall) and Black Spruce forests are found in drier areas (Saskatchewan Conservation Data Centre 2014).

The taiga shield ecozone encompasses the northern part of Saskatchewan. It is an area of thin soils over Precambrian bedrock and is considered transitional between boreal and tundra zones. Lowland woodlands are composed of Jack Pine, Black Spruce, and sporadic White Spruce stands. At higher elevations and further north, boreal forest transitions to tundra of mostly short Black Spruce woodlands with lichen understory (Saskatchewan Conservation Data Centre 2014).

Methods

There are few collections of ants in Saskatchewan, and we were able to examine only the holdings at the University of Saskatchewan (UofSASK; specimens collected in the 1950s). A set of specimens in vials, awaiting pinning and identification at the Agriculture and Agri-Food Canada Research Station, Saskatoon, was not examined. Neither the University of Regina nor the Royal Saskatchewan Museum insect collections contained any known ant collections.

Collections of Saskatchewan ants housed outside Saskatchewan included those at the University of Alberta, the University of Calgary, the Royal Alberta Museum, and the Canadian National Collection of Insects, Arachnids and Nematodes. The University of Alberta's E. H. Strickland Entomological Museum (UASM) has close to 100 ants from three main localities. The University of Calgary Entomology Collection (BDCU) comprises about 70 specimens from four localities. The Royal Alberta Museum Entomology Collection (PMAE) contains ants primarily from Grasslands National Park and includes several hundred specimens. The Canadian National Collection of Insects, Arachnids and Nematodes (CNC) has 2740 ant specimens from 60 Saskatchewan localities.

In addition, we undertook two ant surveys: one at Cree Lake (Glasier and Nielsen) in 2010 and one at the Great Sand Hills (Glasier and Acorn) in 2012. Voucher specimens from these surveys have been deposited in the E. H. Strickland Museum at the University of Alberta. In total, ant species are reported from 79 localities across the province (Figure 1).

Results and Discussion

Overview of the Ant Fauna

Based on sampling, examination of the literature, and museum collections, there are 73 species of ants, from 12 genera, and three subfamilies known from Saskatchewan. An additional 16 species and five genera are expected to be found in the province, as they are present in surrounding regions. The richest genus is *Formica*, with 33 recorded species. Other species-rich genera include *Camponotus*, *Lasius*, and *Myrmica*. Of the reported 73 ant species, all are believed to be indigenous.

Comparison with surrounding regions, especially Alberta (Glasier *et al.* 2013), implies that 90 or more species are most likely found in the province. Additional sampling in the northern and eastern regions of Saskatchewan should be considered to better clarify ant species distributions. Focused sampling in areas of central and southern Saskatchewan, especially grasslands and forests, will probably reveal additional species not yet reported from the province. With climate change and increasing numbers of introduced ant species in Canada, it is perhaps interesting to document which species are currently known from each region so that future studies are able to use this material as a baseline for comparisons.

Checklist of Ants (Hymenoptera: Formicidae) from Saskatchewan

Species are organized alphabetically by subfamily, genera, and species. Comments on each genus, its diversity, and ecology are provided. For each species, all known localities from Saskatchewan are listed alphabetically, along with the source of the record. If a locality is not given, we provide a short explanation of why the species is included in the list. Locality number is given before the locality name ("#. locality") and matches the numbers in Figure 1.

SUBFAMILY DOLICHODERINAE

Genus *Dolichoderus*

Both *Dolichoderus* species listed are expected in Saskatchewan because of their presence in Eastern Canada as well as Alberta (Glasier *et al.* 2013; LHB, unpublished observation). Members of this genus are rather easy to identify, because of the "shelf" on their propodeum (MacKay 1993; Fisher and Cover 2007). Found most often in conifer forests, they often form long foraging lines and often farm homopterans on plants (Fisher and Cover 2007).

Dolichoderus plagiatus (Mayr) 1870 — Expected but not confirmed: found in Alberta (LHB, unpublished observation) and Manitoba (Wheeler *et al.* 1989).

Dolichoderus taschenbergi (Mayr) 1866 — Expected but not confirmed: found in Alberta (Glasier *et al.* 2013) and Manitoba (Wheeler *et al.* 1989).

Genus *Tapinoma*

Tapinoma sessile is one of the most widespread species in North America (Fisher and Cover 2007). It can sometimes be a minor pest in houses and is commonly called the Odorous House Ant because of the strong "blue cheese" or "coconut" odour they produce when crushed (Ellison *et al.* 2012).

Tapinoma sessile (Say) 1836 — 3. Aylesbury (CNC), 5. Buffalo Pound Provincial Park (CNC), 10. Clearwater Lake (BDCU), 11. Cree Lake (UASM), 12. Cypress Hills Interprovincial Park (CNC), 13. Delisle (BDCU), 19. Estevan (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (UASM), 31. Indian Head (CNC), 38. Laura (CNC), 50. Ogema (CNC), 54. Prelate (BDCU), 59. Roadene (CNC), 63. Saint Victor (CNC), 65. Saskatchewan Landing Provincial Park (CNC), 66. Saskatoon (CNC), 67. Scout Lake (CNC), 78. Willows (CNC).

SUBFAMILY FORMICINAE

Genus *Brachymyrmex*

Brachymyrmex depilis was found at the Sandy Point Campground, Alberta (50.73°N, 110.07°W), 5.5 km west of the Saskatchewan border, and there is little doubt that this species will be found in Saskatchewan as well. These small, yellowish ants often farm subterranean homopterans on grass roots. Taxonomically, *B. depilis* could contain multiple different species, and more work is needed on this complex to determine whether regional differences warrant dividing it into multiple species (Fisher and Cover 2007).

Brachymyrmex depilis Emery 1893 — Expected but not confirmed; it has been found at Sandy Point Park, Alberta, along the South Saskatchewan River, 5.5 km west of the Saskatchewan border (Glasier *et al.* 2013; Glasier and Acorn 2014).

Genus *Camponotus*

Camponotus is one of the most speciose genera in North America; they are commonly referred to as carpenter ants, as most species live in dead wood (Mackay and Mackay 2002; Hansen and Klotz 2005; Fisher and Cover 2007). In Saskatchewan there are six species in three subgenera: *Camponotus*, *Tanaemyrmex*, and *Myrmentoma*. Saskatchewan's *C. pennsylvanicus* look like intermediates between *C. pennsylvanicus* and *C. modoc*, and some myrmecologists consider these two taxa conspecific; more work and examination of these species is needed (MacKay and MacKay 2002).

Camponotus herculeanus (Linnaeus) 1758 — 8. Clarine Lake (Kidd and Longair 1997), 11. Cree Lake (UASM), 49. Norbury (UofSASK), 55. Prince Albert (CNC; UofSASK), 58. Regina (UofSASK), 64. Saint Walburg (CNC), 66. Saskatoon (CNC, UofSASK), 75. Waskesiu Lake (CNC), 76. White Fox (CNC), no exact locality given (Hansen and Klotz 2005).

Camponotus modoc Wheeler W. M. 1910 — 32. Jay Lake (CNC), 71. Turtle Lake (CNC), no exact locality given (Hansen and Klotz 2005).

Camponotus nearcticus Emery 1893 — No exact locality given (Hansen and Klotz 2005).

Camponotus novaeboracensis (Fitch) 1855 — 6. Canora (CNC), 48. Mozart (CNC), 52. Pike Lake (CNC), 62. Rudy (CNC), 66. Saskatoon (UofSASK), 72. Val Marie (CNC), 79. Yorkton (CNC), no exact locality given (Hansen and Klotz 2005).

Camponotus pennsylvanicus (DeGeer) 1773 — 58. Regina (CNC), no exact locality given (Hansen and Klotz 2005).

Camponotus vicinus Mayr 1870 — 27. Grasslands National Park (UASM), 28. Great Sand Hills (UASM), 72. Val Marie (CNC), no exact locality given (Hansen and Klotz 2005).

Genus *Formica*

The genus *Formica* is widely distributed in the northern hemisphere and is the most speciose genus in Saskatchewan, with 33 confirmed species. *Formica* are ecologically important in temperate ecosystems, and they are major predators of other insects as well as important food sources for a wide range of organisms, including woodpeckers and bears (Fisher and Cover 2007; Ellison *et al.* 2012). Within the province, there are six species complexes (the *exsecta*, *fusca*, *microgyna*, *neogagates*, *rufa*, and *sanguinea* groups). Social parasitism is exhibited by *sanguinea* group species, which are facultative slave-making ants of *fusca* and *neogagates* group species (Wheeler and Wheeler 1963, 1986; Fisher and Cover 2007). *Microgyna* group queens are temporary social parasites of other *Formica* species (Wheeler and Wheeler 1963, 1986). The record of *F. accreta* at Cree Lake Saskatchewan is a significant northern extension of its known range and is likely an example that more sampling in northern regions is needed to better understand the distributions of ant species. Taxonomically, this genus still needs much work, and there may be several undescribed species in Canada. In Saskatchewan, *F.* cf. *rubicunda* is particularly difficult to assess, as some individuals may be easily confused with closely related species, such as *F. subintegra*.

Formica accreta Francoeur 1973 — 11. Cree Lake (UASM).

Formica adamsi Wheeler 1909 — 66. Saskatoon (UofSASK), 72. Val Marie (CNC).

Formica altipetens Wheeler 1913 — Expected but not confirmed: found in Alberta (Glasier *et al.* 2013) and Manitoba (Wheeler *et al.* 1989).

Formica argentea Wheeler 1902 — 5. Buffalo Pound Provincial Park (CNC), 10. Clearwater Lake (BDCU), 28. Great Sand Hills (BDCU), 29. Highgate (CNC), 37. Lacadena (Francoeur 1973; CNC), 66. Saskatoon (UofSASK; Francoeur 1973; CNC).

Formica aserva Forel 1901 — 8. Clarine Lake (Kidd and Longair 1997), 11. Cree Lake (UASM), 31. Indian Head (UofSASK), 34. Kamsack (CNC), 39. Love (UofSASK), 42. Methy Lake (Wheeler 1913), 46. Moose Mountain Provincial Park (CNC), 56. Prince Albert National Park (CNC), 66. Saskatoon (UofSASK; CNC), 71. Turtle Lake (CNC), 78. Willows (CNC).

Formica bradleyi Wheeler 1913 — 17. Elbow (CNC), 24. Fox Valley (CNC), 28. Great Sand Hills (UASM), 47. Mortlach (CNC).

Formica canadensis Santschi 1914 — 17. Elbow (Francoeur 1973; CNC), 18. Esterhazy (Francoeur 1973; CNC), 27. Grasslands National Park (PMAE), 28. Great Sand Hills (UASM), 31. Indian Head (Francoeur 1973), 40. Lumsden (Francoeur 1973; CNC), 43. Midale (UofSASK), 66. Saskatoon (Francoeur 1973; CNC).

Formica dakotensis Emery 1893 — 11. Cree Lake (UASM).

Formica densiventris Viereck 1903 — Expected but not confirmed: found in Alberta (Glasier *et al.* 2013) and Quebec (Francoeur 1977, 2010).

Formica fossaceps Buren 1942 — 61. Rockglen (CNC).

Formica fusca Linnaeus 1758 — 8. Clarine Lake (Kidd and Longair 1997).

Formica glacialis Wheeler 1908 — 1. Aberdeen (CNC), 11. Cree Lake (UASM), 53. Pontrilas (Francoeur 1973; CNC), 73. Wakaw (CNC), 75. Waskesiu Lake (CNC), 77. Willow Bunch (CNC).

Formica hewitti Wheeler 1917 — 11. Cree Lake (UASM), 12. Cypress Hills Interprovincial Park (CNC).

Formica lasioides Emery 1893 — 9. Claydon (CNC), 12. Cypress Hills Interprovincial Park (CNC), 13.

Delisle (BDCU), 16. Dundurn (CNC), 27. Grasslands National Park (PMAE; UASM), 66. Saskatoon (CNC), 69. Swift Current (CNC).

Formica limata Wheeler 1913 — 10. Clearwater Lake (BDCU), 27. Grasslands National Park (PMAE; UASM), 47. Mortlach (CNC).

Formica microgyna Wheeler 1903 — 27. Grasslands National Park (PMAE; UASM).

Formica montana Wheeler 1910 — 3. Aylesbury (CNC), 10. Clearwater Lake (BDCU), 12. Cypress Hills Interprovincial Park (CNC), 27. Grasslands National Park (PMAE; UASM), 41. Matador (CNC), 66. Saskatoon (CNC).

Formica neoclara Emery 1893 — 10. Clearwater Lake (BDCU), 12. Cypress Hills Interprovincial Park (CNC), 17. Elbow (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (UASM), 54. Prelate (BDCU), 58. Regina (UofSASK), 66. Saskatoon (UofSASK).

Formica neogagates Viereck 1903 — 9. Claydon (CNC), 10. Clearwater Lake (BDCU), 16. Dundurn (CNC), 17. Elbow (CNC), 19. Estevan (CNC), 24. Fox Valley (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (BDCU; UASM), 46. Moose Mountain Provincial Park (CNC), 66. Saskatoon (CNC).

Formica neorufibarbis Emery 1893 — 11. Cree Lake (UASM), 14. Doremy (CNC), 23. Fort à la Corne (CNC).

Formica obscuripes Forel 1886 — 5. Buffalo Pound Provincial Park (CNC), 9. Claydon (CNC), 10. Clearwater Lake (BDCU), 12. Cypress Hills Interprovincial Park (CNC), 13. Delisle (BDCU), 17. Elbow (CNC), 19. Estevan (CNC), 26. Gainsborough (Weber 1935), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (BDCU; CNC), 31. Indian Head (CNC), 36. Killdeer (CNC), 44. Minton (CNC), 56. Prince Albert National Park (CNC), 64. Saint Walburg (CNC), 66. Saskatoon (CNC), 69. Swift Current (CNC), 74. Wartime (CNC).

Formica obscuriventris Mayr 1870 — 66. Saskatoon (UofSASK).

Formica obtusopilosa Emery 1893 — 7. Chamberlain (UofSASK), 27. Grasslands National Park (PMAE; UASM), 60. Robsart (CNC).

Formica oreas Wheeler 1903 — 10. Clearwater Lake (BDCU), 17. Elbow (CNC), 56. Prince Albert National Park (UofSASK), 66. Saskatoon (UofSASK; CNC), 69. Swift Current (CNC).

Formica pergandei Emery 1893 — 47. Mortlach (CNC).

Formica perpilosa Wheeler 1913 — 27. Grasslands National Park (UASM), 77. Willow Bunch (CNC).

Formica planipilis Creighton 1940 — 52. Pike Lake (UofSASK), no exact locality given but is listed by Wheeler and Wheeler (1986).

Formica podzolica Francoeur 1973 — 5. Buffalo Pound Provincial Park (CNC), 6. Canora (CNC), 12. Cypress Hills Interprovincial Park (CNC), 13. Delisle (BDCU), 32. Jay Lake (CNC), 33. Junction Reservoir (PMAE), 38. Laura (CNC), 45. Montmartre (CNC), 46. Moose Mountain Provincial Park (CNC), 51. Pasqua (CNC), 56. Prince Albert National Park (CNC), 66. Saskatoon (UofSASK; CNC), 71. Turtle Lake (CNC), 77. Willow Bunch (CNC).

Formica puberula Emery 1893 — 66. Saskatoon (CNC).

Formica ravida Creighton 1940 — 11. Cree Lake (UASM).

Formica cf. *rubicunda* Emery 1893 — 27. Grasslands National Park (PMAE).

Formica spatulata Buren, 1944 — 51. Pasqua (CNC).

Formica subaenescens Emery 1893 — 56. Prince Albert National Park (CNC).

Formica subintegra Wheeler 1908 — Expected but not confirmed: found in Alberta (Glasier *et al.* 2013) and Manitoba (Wheeler *et al.* 1989).

Formica ulkei Emery 1893 — 19. Estevan (CNC), 35. Kenosee Lake (CNC).

Genus *Lasius*

Lasius is the second most speciose genus in Saskatchewan, with 14 confirmed species. Most species are omnivorous and many have close associations with above and/or below ground homopterans (Newton *et al.* 2011). There are four main species complexes: *claviger*, *flavus*, *niger*, and *umbratus* groups. All *claviger* and *umbratus* group queens exhibit temporary social parasitism on other *Lasius* species (Wilson 1955; Wing 1968; Fisher and Cover 2007). Because of the subterranean nature of many *Lasius* ants, they can be rather difficult to find; however, other species, such as *L. neoniger* are common and can often be found making "volcanoes" or cone-shaped mounds along sidewalks or in sandy areas. There is a debate about whether some *Lasius* species have a true holarctic distribution or if they might have been introduced in North America; more work is needed to resolve this discussion.

Lasius alienus (Förster) 1850 — 16. Dundurn (CNC), 66. Saskatoon (CNC).

Lasius coloradensis Wheeler 1917 — 27. Grasslands National Park (PMAE), 60. Robsart (CNC), 66. Saskatoon (CNC; UofSASK), no exact locality given, on map only (Wing 1968).

Lasius crypticus Wilson 1955 — 3. Aylesbury (CNC), 5. Buffalo Pound Provincial Park (CNC), 9. Claydon (CNC), 11. Cree Lake (UASM), 19. Estevan (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (BDCU; UASM), 61. Rockglen (CNC), 77. Willow Bunch (CNC), no exact locality given, on map only (Wilson 1955).

Lasius fallax Wilson 1955 — 66. Saskatoon (Uof SASK).

Lasius flavus (Fabricius) 1781 — 5. Buffalo Pound Provincial Park (CNC), 21. Farewell Lake (Wilson, 1955), 66. Saskatoon (CNC).

Lasius interjectus Mayr 1866 — 66. Saskatoon (CNC).

Lasius latipes (Walsh) 1863 — 28. Great Sand Hills (UASM).

Lasius murphyi Forel 1901 — No exact locality given, on map only (Wing 1968).

Lasius neoniger Emery 1893 — 4. Beaver Creek (CNC), 19. Estevan (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (UASM), 31. Indian Head (UofSASK; CNC), 33. Junction Reservoir (PMAE). 66. Saskatoon (CNC), 70. Truax (UofSASK), no exact locality given, on map only (Wilson 1955).

Lasius niger (Linnaeus) 1758 — 77. Willow Bunch (CNC).

Lasius occidentalis Wheeler W. M. 1909 — Expected but not confirmed: found in British Columbia and Manitoba (Wing 1968).

Lasius pallitarsis (Provancher) 1881 — 4. Beaver Creek (CNC), 5. Buffalo Pound Provincial Park (CNC), 10. Clearwater Lake (BDCU), 13. Delisle (BDCU), 27. Grasslands National Park (PMAE; UASM), 38. Laura (CNC), 45. Montmartre (CNC), 65. Saskatchewan Landing Provincial Park (CNC), 66. Saskatoon (UofSASK; CNC), 69. Swift Current (CNC), no exact locality given, on map only (Wilson 1955).

Lasius subglaber Emery 1893 — 66. Saskatoon (CNC), no exact locality given, on map only (Wing 1968).

Lasius subumbratus Viereck 1903 — 27. Grasslands National Park (PMAE; UASM), 40. Lumsden (CNC), 58. Regina (CNC; Wilson 1955).

Lasius umbratus (Nylander) 1846 — 3. Aylesbury (CNC), 5. Buffalo Pound Provincial Park (CNC), 19. Estevan (CNC), 22. Flintoft (CNC), 27. Grasslands National Park (PMAE), 66. Saskatoon (CNC), 77. Willow Bunch (CNC).

Genus *Polyergus*

Polyergus mexicanus is the only species of its genus reported in Saskatchewan. This species is an obligate slave-making ant, parasitizing *fusca* group *Formica* species (Trager 2013). *Polyergus* are easily recognized by their toothless, sickle-shaped mandibles, which are highly adapted for fighting other ants.

Polyergus mexicanus Forel 1899 — 11. Cree Lake (UASM).

SUBFAMILY MYRMICINAE

Genus *Formicoxenus*

Formicoxenus are small and live within the nests of *Formica* or *Myrmica* (Francoeur *et al.* 1985). They rely on their hosts for food and protection, but often construct side chambers where they keep their own larvae (Francoeur *et al.* 1985). As they live in the nests of other ants, *Formicoxenus* can often be difficult to detect using regular sampling methods. To find these small reddish-brown ants, it is often best to sift the soil of a potential host colony, using a strainer or sieve. They look similar to *Leptothorax* and *Temnothorax*, but have erect setae on their eyes, a characteristic that can be detected only by using a microscope.

Formicoxenus hirticornis (Emery) 1895 — Expected but not found: found in Alberta (Glasier *et al.* 2013) and Manitoba (Wheeler *et al.* 1989).

Formicoxenus quebecensis Francoeur 1985 — 11. Cree Lake (UASM).

Formicoxenus provancheri (Emery) 1895 — Expected but not confirmed: found in Alberta (Francoeur *et al.* 1985; Glasier *et al.* 2013; Glasier and Acorn 2014), Ontario, and Quebec (Francoeur *et al.* 1985).

Genus *Harpagoxenus*

Harpagoxenus is an obligate slave-making ant of *Leptothorax* species (Stuart and Alloway 1983). The only species in Canada, *H. canadensis* Smith primarily enslaves *Leptothorax* species. These ants are similar in size to *Leptothorax* and *Temnothorax*, but have toothless mandibles and large block-like heads.

Harpagoxenus canadensis Smith 1939 — Expected but not confirmed: found in Alberta (Glasier *et al.* 2013), Ontario (Stuart and Alloway 1983), and Quebec (Francoeur 1977).

Genus *Leptothorax*

Species in the genus *Leptothorax* are difficult to identify confidently without comparative material and much familiarization (Fisher and Cover 2007; Glasier *et al.* 2013). They are common in a wide range of habitats and often nest in rotten wood or under stones.

Leptothorax acervorum (Fabricius) 1793 — Expected but not confirmed: found in Yukon (Francoeur 1997), Manitoba, and Quebec (Francoeur 1983).

Leptothorax muscorum (Nylander) 1846 — 4. Beaver Creek (CNC), 8. Clarine Lake (Kidd and Longair 1997), 11. Cree Lake (UASM), 15. Dunblane (CNC), 17. Elbow (CNC), 27. Grasslands National Park (PMAE), 31. Indian Head (CNC), 47. Mortlach (CNC), 66. Saskatoon (CNC).

Leptothorax retractus Francoeur 1986 — 66. Saskatoon (CNC).

Leptothorax wilsoni Heinze 1989 — Expected but not confirmed: found in Alberta (Buschinger and Schumann 1994), Quebec, and New Brunswick (Heinze 1989).

Genus *Monomorium*

Monomorium minimum is a wide-ranging species complex found across most of North America (Fisher and Cover 2007). It is often found under rocks or in rotting wood. *Monomorium pharaonis* is an introduced ant that is primarily found in heated buildings (Klotz *et al.* 2008). Both species are small, have colonies of a few thousand workers, often move nest sites, and have multiple queens per colony (Wheeler and Wheeler 1963, 1986).

Monomorium minimum (Buckley) 1867 — 10. Clearwater Lake (BDCU), 27. Grasslands National Park (PMAE; UASM).

Monomorium pharaonis (Linnaeus) 1758 — Expected but not confirmed: an introduced species found across North America and expected in human dwellings (Klotz *et al.* 2008). Found in Alberta (Glasier *et al.* 2013), Manitoba (Ayre 1977), Quebec (Francoeur 1977), British Columbia, Nunavut, Ontario, and Nova Scotia (LHB, unpublished observation).

Genus *Myrmica*

Identification of *Myrmica* species can be difficult, as many species are distinguished by few or obscure characteristics (Fisher and Cover 2007; Ellison *et al.* 2012; Glasier *et al.* 2013). They are common throughout Saskatchewan and are found in most ecoregions. *Myrmica* are generalist omnivores that hunt insects, harvest plant materials, and farm homopterans (Fisher and Cover 2007; Newton *et al.* 2011). Taxonomically, this genus is still in need of more work in North America (Fisher and Cover 2007; Jansen *et al.* 2010), and the two undescribed species (*Myrmica* AF-eva and *Myrmica* cf. AF-sub) highlight this lack of understanding.

Myrmica alaskensis Wheeler 1917 — 1. Aberdeen (CNC), 11. Cree Lake (UASM), 57. Quill Lake (UofSASK), 66. Saskatoon (CNC).

Myrmica americana Weber 1939 — 17. Elbow (CNC), 27. Grasslands National Park (PMAE; UASM), 47. Mortlach (CNC).

Myrmica brevispinosa Wheeler 1917 — 16. Dundurn (CNC), 31. Indian Head (CNC), 25. Gabriel's Bridge (South Saskatchewan River) (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (UASM), 66. Saskatoon (UofSASK), 69. Swift Current (CNC).

Myrmica crassirugis Francoeur 2007 — 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (UASM).

Myrmica detritinodis Emery 1921 — 2. Atton's Lake (CNC), 11. Cree Lake (UASM), 66. Saskatoon (CNC).

Myrmica fracticornis Forel 1901 — 2. Atton's Lake (CNC), 3. Aylesbury (CNC), 5. Buffalo Pound Provincial Park (CNC), 6. Canora (CNC), 8. Clarine Lake (Kidd and Longair 1997), 11. Cree Lake (UASM), 17. Elbow (CNC), 31. Indian Head (CNC), 47. Mortlach (CNC), 56. Prince Albert National Park (UofSASK), 66. Saskatoon (CNC).

Myrmica incompleta Provancher 1881 — 12. Cypress Hills Interprovincial Park (CNC), 30. Humbolt Lake (CNC), 31. Indian Head (CNC), 38. Laura (CNC), 41. Matador (CNC), 56. Prince Albert National Park (CNC), 66. Saskatoon (CNC; UofSASK), 71. Turtle Lake (CNC), 75. Waskesiu Lake (CNC).

Myrmica latifrons Stärcke 1927 — 2. Atton's Lake (CNC), 4. Beaver Creek (CNC), 27. Grasslands National Park (PMAE; UASM), 32. Jay Lake (CNC), 38. Laura (CNC), 45. Montmartre (CNC), 47. Mortlach (CNC), 66. Saskatoon (UofSASK).

Myrmica lobifrons Pergande 1900 — Expected but not confirmed: found in British Columbia (Higgins and Lindgren 2008), Yukon (Francoeur 1977), Alberta (Glasier *et al.* 2013), Manitoba, Ontario, New Brunswick, and Newfoundland and Labrador (LHB, unpublished observation).

Myrmica nearctica Weber 1939 — 68. Success (UofSASK).

Myrmica undescribed code AF-eva by André Francoeur — 19. Estevan (CNC), 27. Grasslands National Park (PMAE; UASM), 28. Great Sand Hills (UASM), 38. Laura (CNC), 60. Robsart (CNC).

Myrmica cf. undescribed code AF-sub by André Francoeur — 11. Cree Lake (UASM).

Genus *Pogonomyrmex*

Pogonomyrmex species are commonly called harvester ants, as they harvest and eat seeds of grasses and other plants (Fisher and Cover 2007). *P. occidentalis* colonies also construct obvious cone-shaped nests, often covered with small stones, which makes them easily visible from many metres away.

Pogonomyrmex occidentalis (Cresson) 1865 — 28. Great Sand Hills (CNC; UASM).

Genus *Solenopsis*

Solenopsis molesta is the only species in the genus *Solenopsis* in the province, and it is part of a species complex that is found throughout North America (Fisher and Cover 2007). These ants are often called thief ants, for their tendency to nest near larger ants from which they "steal" stored food (Fisher and Cover 2007).

Solenopsis molesta (Say) 1836 — 20. Eston (CNC), 27. Grasslands National Park (PMAE; UASM).

Genus *Stenamma*

Stenamma diecki is found in southern forests of other Canadian provinces and may be found in southern woodlands, such as the Cypress Hills, in Saskatchewan. This species forages individually, prefers moist soils, and will feign death for a short time when disturbed, making it difficult to detect (Talbot 1976).

Stenamma diecki Emery 1895 — Expected but not confirmed: found in British Columbia (Higgins and Lindgren 2008), Ontario (Smith 1957), Quebec (Francoeur 1977), and New Brunswick (LHB, unpublished observation).

Genus *Temnothorax*

The two species of *Temnothorax* in Saskatchewan are often found in grassland habitats. These ants forage alone, are cautious of other ants, and are opportunistic feeders, eating anything from plant sap to invertebrates (Fisher and Cover 2007; Newton *et al.* 2011).

Temnothorax ambiguus (Emery) 1895 — 27. Grasslands National Park (PMAE; UASM), 66. Saskatoon (CNC).

Temnothorax rugatulus (Emery) 1895 — 27. Grasslands National Park (PMAE;UASM), 72. Val Marie (UofSASK).

SUBFAMILY PONERINAE

Genus *Hypoponera*

Hypoponera punctatissima is an introduced ant species found worldwide (Bolton and Fisher 2011), in Canada primarily in heated buildings. It has been found across Canada (LHB, unpublished observation) and is likely found in Saskatchewan (Klotz *et al.* 2008).

Hypoponera punctatissima (Roger) 1859 — Expected but not confirmed: in Canada, found in Quebec (Francoeur 1977), Alberta (JHA, unpublished observation), Ontario, and British Columbia (LHB, unpublished observation).

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Note

Larval Sea Lampreys (*Petromyzon marinus*) Do Not Emigrate from a Risky Habitat Under Semi-natural Conditions

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Ayotte, Jacqueline L., and István Imre. 2016. Larval Sea Lampreys (*Petromyzon marinus*) do not emigrate from a risky habitat under semi-natural conditions. Canadian Field-Naturalist 130(1): 49–52.

Sea Lamprey (*Petromyzon marinus*), invaded the upper Great Lakes in the early 20th century, precipitating abrupt declines in a number of native fish species. A recently proposed alternative method for the behavioural manipulation of Sea Lamprey populations is the use of conspecific damage-released alarm and predator cues as potential repellents. We examined whether larval Sea Lamprey (*Petromyzon marinus*) ammocoetes can be manipulated to emigrate from an area by labeling their habitat "risky" with the regular release of chemosensory alarm cues over several days. In a semi-natural laboratory environment, we exposed eight replicate groups of eight ammocoetes twice a day, for 7 days, to deionized water (control), ammocoete whole-body extract (damage-released alarm cue), and 2-phenylethylamine HCl (predator cue). None of the experimental stimuli induced emigration from the experimental arena. This approach does not hold any promise for ammocoete behavioural manipulation in the context of a Sea Lamprey integrated management program.

Key Words: Sea Lamprey; *Petromyzon marinus*; ammocoete; repellent; chemosensory cues; risk avoidance

Introduction

Methods to control Sea Lamprey (*Petromyzon marinus*) populations include the use of the larval lampricide, 3-trifluoromethyl-4-nitrophenol, low-head barrier dams, and trapping (McLaughlin *et al.* 2007). To reduce the reliance on lampricides as a management tool, the Great Lakes Fishery Commission encouraged the development of alternative methods for Sea Lamprey population control (GLFC 2011). A recently proposed alternative method is the use of conspecific damage-released alarm and predator cues as potential repellents (Imre *et al.* 2010).

As many aquatic organisms use chemosensory cues (Kats and Dill 1998) to assess relevant threats, a natural repellent-based approach could contribute effectively to the integrated Sea Lamprey population control program. A push–pull strategy for Sea Lamprey control has been recently suggested by Imre *et al.* (2010), in which sex pheromones combined with chemosensory alarm cues would function to manipulate the behaviour of migratory Sea Lampreys by pushing them away from spawning habitats and luring them into areas where traps or other forms of control are deployed. Recent studies have demonstrated that migratory Sea Lampreys strongly avoid conspecific damage-released alarm and predator cues (Di Rocco *et al.* 2014; Imre *et al.* 2014).

There is little information available about the response of ammocoetes to chemosensory alarm cues. Ammocoetes create U-shaped burrows in sandy substrates in which they may spend over a decade as filter feeders (Potter 1980). Recently, Perrault *et al.* (2014) found that free-swimming ammocoetes exposed to conspecific damage-released alarm cues increased their number of escape attempts and directional changes. However, the findings of Perrault *et al.* (2014) are difficult to extrapolate to natural systems, because the study did not provide burrowing substrate for the ammocoetes.

The objective of this study was to determine whether ammocoetes can be manipulated to leave established burrows if their habitat becomes "risky." Consistent with the findings of Kim *et al.* (2011), we expected that the ammocoetes would emigrate from experimental arenas that were regularly exposed to chemosensory alarm cues. Further, we predicted that emigration would occur at night. These predictions were tested in stream channels supplied with natural substrate and water from the St. Marys River in Sault Ste. Marie, Ontario, Canada.

Methods

Experimental subjects

Ammocoetes were collected by Fisheries and Oceans Canada in September 2014 by electrofishing in Crystal Creek (Sault Ste. Marie). They were kept under a natural photoperiod (11 h light, 13 h dark) in stream channels at Fisheries and Oceans Canada Sea Lamprey Control Centre, Sault Ste. Marie, with a 5-cm sand substrate to allow for burrowing. The stream channels were supplied with unfiltered water at ambient water temperature (mean ± standard deviation = 9 ± 0.5°C) pumped directly from the St. Marys River at a constant rate of 0.15 L/s.

Stimulus preparation

An ammocoete whole-body extract was prepared using five ammocoetes of unknown sex (mean weight = 4.1 ± 1.4 g). Ammocoetes were euthanized with a swift blow to the head (use of tissue donor and experimental subjects were approved by the Algoma University Animal Care Committee; AUP no. 2014-II-02). We harvested 20.5 g of body tissue from donors and homogenized it in 50 mL of distilled water. We filtered the extract through cheesecloth and diluted it to a final volume of 500 mL. We further diluted the solution to one part alarm cue to 10 parts water and froze it in 10-mL aliquots at −20°C. We also prepared 10 mL of 0.32 M 2-phenylethylamine HCl (PEA HCl) solution just before distribution into experimental arenas. PEA HCl is a compound present in mammalian urine that induces an avoidance response in migratory Sea Lampreys (Imre *et al.* 2014).

Assuming full and uniform distribution of these stimuli in the experimental arena from top to bottom, the minimum concentration experienced by the ammocoetes was about 71 ppm for the alarm cue and 2.3×10^{-4} M for the PEA HCl. The concentration of these stimuli was considerably higher than that needed to induce significant avoidance responses by migratory Sea Lampreys (3.3 ppm for the Sea Lamprey extract and 2.1×10^{-5} M for PEA HCl; Imre *et al.* 2014).

Experimental set-up

Six stream channels at the Fisheries and Oceans Canada Sea Lamprey Control Centre were used to create 12 experimental arenas (two parallel experimental arenas per stream channel). The two experimental arenas (20 cm wide by 90 cm long) and associated emigration areas (20 cm wide by 30 cm long) in each stream channel were separated by pine boards (2.5 cm wide by 15 cm high by 120 cm long) positioned in the middle of each channel and delimited by perforated metal barriers at the upstream end and metal mosquito nets inserted at 90 cm and 120 cm, respectively, from the upstream end (Figure 1). Experimental animals could enter the emigration area through a slit (1 cm above the substrate) cut in the mosquito net separating the emigration area from the experimental arena.

The upstream end of the experimental arenas was located 60 cm downstream from the inflow. We added fine sand (to a depth of approximately 5 cm) to each experimental arena so that ammocoetes could establish burrows. The discharge in each stream channel was adjusted to 0.15 L/s to create a water velocity of about 0.01 m/s in the experimental arenas. Dye tests were performed to determine the water velocity and the optimal location for administering the stimuli. In these tests, the dye spread quickly to cover the whole surface of the experimental arenas and blanketed the substrate uniformly.

Experimental design

The experiment was performed between 12 and 25 October 2014 at the Fisheries and Oceans Canada Sea Lamprey Control Centre. Eight randomly chosen ammocoetes were transferred to each of the experimental arenas. After a 24-h acclimation period, each of the replicate arenas was injected with one of three treatments twice a day, for 7 days: distilled water (control), ammocoete whole-body extract, or PEA HCl. For each treatment, we performed eight replicates.

Each morning at 0900 and in the evening at sundown, 10 mL of one of the three stimuli were injected 10 cm upstream from the upper end of each experimental arena. The stimulus injection areas of the two parallel experimental arenas in the same stream channel were separated by a 40 cm long wooden barrier to prevent mixing of the administered stimuli. Stimuli of the same type were injected upstream of both experimental arenas in the same stream channel. Stimuli were administered in a single dose to mimic a single predation event (ammocoete whole-body extract) or the presence of a mammalian predator (PEA HCl). Treatments were rotated among the six stream channels to eliminate any potential biases created by their position.

We recorded the number of ammocoetes in the emigration areas in the morning (result of emigration at night) and at sundown (result of emigration during the day). The ammocoetes were in the experimental arenas for 7 days or, if any individuals left the experimental arena earlier, they were removed, quickly euthanized using tricaine methanesulfonate (0.015 mL/L), weighed

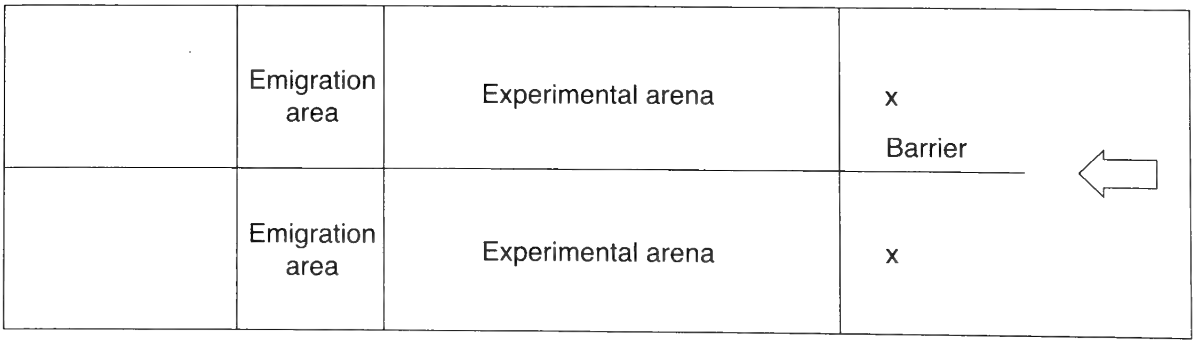

FIGURE 1. Overhead view of a stream channel containing two parallel experimental arenas with their associated emigration areas used to test the response of Sea Lamprey (*Petromyzon marinus*) ammocoetes to conspecific damage-released alarm cues and a predator cue under semi-natural conditions. The arrow indicates the direction of water flow. The experimental stimuli were released in the locations indicated with an x in the diagram. The barrier separated the stimulus release areas to avoid mixing of the stimuli destined for the individual experimental arenas.

(to the nearest 0.1 g), and measured for total length (to the nearest mm).

A total of 192 ammocoetes were used in the experiment (mean total length = 8.0 ± 1.9 cm, mean wet mass = 1.1 ± 0.6 g). Water temperature (mean = 9 ± 0.5°C), discharge (mean = 0.14 ± 0.01 L/s), water velocity (mean = 0.01 ± 0.003 m/s), and water depth (mean = 7.6 ± 0.2 cm) were recorded throughout the experiment.

Statistical analysis

One-way analyses of variance (ANOVA) were used to compare the number of emigrants, wet mass, total length, water velocity, discharge, and water depth among treatments. All statistical analyses were performed using Statistica 12 (StatSoft Inc., Tulsa, Oklahoma, USA) with a significance level of $\alpha = 0.05$.

Results

Overall, no ammocoetes emigrated from the experimental arenas. There were no statistical differences in wet mass or total length between the treatment groups ($F_{2,\,189} = 1.65$, $P = 0.19$; $F_{2,\,189} = 1.85$, $P = 0.16$, respectively). Similarly, water discharge and velocity were not significantly different between treatments ($F_{3,\,12} = 1.56$, $P = 0.25$; $F_{3,\,12} = 2.05$, $P = 0.16$, respectively), but water depth was ($F_{3,\,4} = 18.87$, $P < 0.01$).

Discussion

This is the first study to investigate the willingness of ammocoetes to emigrate from a risky habitat in a semi-natural environment. We predicted that ammocoetes periodically exposed to conspecific whole-body extract and predator cues over several days would emigrate at night in search of a more suitable habitat. Contrary to our predictions, no ammocoetes left the risky experimental arenas over 7 days of repeated exposure. In contrast, juvenile Atlantic Salmon (*Salmo salar*) density significantly decreased in stream areas labeled daily with damage-released alarm cues (Kim *et al.* 2011), compared with control sections.

We noted only one variance in ammocoete behavior during the experiment; during the evening application of the stimuli, one ammocoete was noted slowly swimming upstream while PEA HCl was administered. When the ammocoete arrived at the front end of the experimental arena and was exposed to PEA HCl, it rapidly changed direction, swimming quickly to the opposite end of the arena and vigorously burrowing into the substrate. This behaviour suggests that ammocoetes do respond to PEA HCl, not unlike migratory Sea Lampreys (Imre *et al.* 2014; Di Rocco *et al.* 2014), but the alarm cues in our experiment did not seem sufficient to initiate relocation once ammocoetes were established in burrows. Vulnerability to predation at this stage in life apparently prevented the ammocoetes from leaving the safety of an established burrow.

Habitat choice is crucial for survival and maximizing individual fitness. Typically, animals will choose a habitat that is plentiful in food and low in predators, but trade-offs often create more risky situations (Lima and Dill 1990). Although it would seem evolutionarily unfavourable to occupy a habitat where there is a high risk of predation, it is apparently beneficial for the ammocoetes to remain in the safety of their burrows if danger is detected nearby, rather than risk being eaten while trying to emigrate.

Quintella *et al.* (2005) found that ammocoetes occupying favourable environments may remain in their burrows for several months without moving. The favourable habitat provided by our experimental set-up – low ammocoete density, optimal substrate composition, and consistent environmental conditions – could partly explain why we did not observe any emigrating ammocoetes. Thus, our findings might not reflect an accurate representation of ammocoete behavioural responses at other times of the year, as most ammocoete movement occurs during spring flooding (Manion and McLain 1971). Future research should examine the effect of repellents on ammocoetes in the spring. Alternatively, it is possible that a higher concentration or more frequent addition of the stimuli is needed to induce ammocoete emigration from the experimental arenas.

In conclusion, no ammocoetes left the experimental area in the repeated presence of damage-released alarm or predator cues throughout the experiment. This approach appears to be ineffective as a natural deterrent for ammocoetes established in burrows.

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Note

Cougars (*Puma concolor*) Killed by North American Porcupines (*Erethizon dorsatum*)

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Elbroch, L. Mark, Rafael Hoogesteijn, and Howard Quigley. 2016. Cougars (*Puma concolor*) killed by North American Porcupines (*Erethizon dorsatum*). Canadian Field-Naturalist 130(1): 53–55.

Predation is inherently risky, and Cougars (*Puma concolor*) are occasionally injured while hunting prey. Between 2001 and 2015, we documented the cause of death of 59 Cougars (22 subadults and 37 adults) in the Southern Yellowstone Ecosystem, Wyoming. Here we report on 2 animals (9% of subadult mortalities) killed as a result of complications after hunting North American Porcupines (*Erethizon dorsatum*). We also report an observation of a Cougar killed in Venezuela by quills of a Prehensile-tailed Porcupine (*Coendou prehensilis*). Porcupines may kill and wound more Cougars than previously suspected and may be an important cause of mortality, at least for subadult animals.

Key Words: Cougar; Puma; *Puma concolor*; North American Porcupine; *Erethizon dorsatum*; fitness consequences; mortality; predation

Introduction

Predation is inherently risky and, thus, it is no surprise that Cougars (*Puma concolor*) are injured from time to time while hunting prey many times their size (e.g., Ross *et al.* 1995). Cougars have been tossed from the backs of large ungulates, slammed into trees, and punctured by tree limbs or antlers while hunting deer (*Odocoileus* spp.), Elk (*Cervus elaphus*), and Bighorn Sheep (*Ovis canadensis*) (Ross *et al.* 1995; Murphy and Ruth 2010). Cougars have also died from injuries sustained in falls associated with hunting Bighorn Sheep in steep terrain (Ross *et al.* 1995; Murphy and Ruth 2010).

The much smaller North American Porcupine (*Erethizon dorsatum*) also presents a danger to Cougars and other carnivores (Mukherjee and Heithaus 2013; Katzner *et al.* 2015). The porcupine is unique among North American mammals in that it has weapons to deter potential predators. Each porcupine is covered by approximately 30 000 quills — sharp, rigid, hollow hairs, 2–10 cm long, each tipped with 700–800 barbs (Cho *et al.* 2012). Barbs increase the ease with which quills penetrate skin, as well as the difficulty of removing them. In fact, researchers have found that quills penetrate skin with only 56% of the force required to pierce the same tissue with a hypodermic needle (Cho *et al.* 2012).

Cougars hunt porcupines wherever the 2 species are sympatric, and North American Porcupines (e.g., Anderson 1983; Ackerman *et al.* 1984; Knopff *et al.* 2010) and southern porcupine species, such as *Sphiggurus mexicanus* (López-González and González-Romero 1998) and *Coendou mexicanus* (Chinchilla 1997; Foster *et al.* 2010), in Central and South America are a common prey listed in studies of Cougar diet. Although porcupines generally constitute only a small percentage of Cougar diet, occasionally they make up a larger proportion. For example, Robinette *et al.* (1959) reported that porcupines accounted for 19% of items found in 277 Cougar intestinal tracts and scats and 275 stomachs collected in Utah and Nevada. Knopff *et al.* (2010) reported that porcupines made up a larger percentage of subadult than adult Cougar diets (13.52% versus 0.76%), suggesting that not all Cougars hunt porcupines equally.

Speculation on the dangers associated with hunting porcupines varies. Robinette *et al.* (1959) reported 3 Cougar kittens killed by quills as a result of complications after hunting porcupines and suggested the dangers were real. In contrast, Maser and Rohweder (1983) reported that Cougars do not appear to be in any danger from porcupines, because they found numerous Cougars with partly digested quills in their stomachs. In fact, there is some evidence that Cougars have defensive mechanisms to protect their digestive tracts from porcupine quills. Ferguson *et al.* (2011) investigated internal nodules in the gastrointestinal tracts of Cougars: 83% of 160 Cougars exhibited nodules; 14% of all small nodules (< 2 cm diameter) encapsulated quills, and 4 Cougars exhibited larger nodules with quills.

The danger of porcupine quills is that those that enter a predator's internal cavities may migrate unpredictably and, over extended periods, may pierce vital organs. For example, Johnson *et al.* (2006) conducted a review of 296 Domestic Dogs (*Canis familiaris*) treated for porcupine quills. Veterinarians removed all exterior quills immediately, but some dogs returned for additional treatment because of complications that were interior and overlooked during initial visits. These complications became apparent as long as 192 days after the incident with the porcupine. Six dogs developed lameness, 4 developed peri-ocular complications, and 28 developed large abscesses requiring surgery. Johnson *et al.* (2006)

also noted that quill migration was not correlated with the original entry point of the quills, nor did the number of quills that migrated correlate with complications.

Methods

Between 2001 and 2015, we fit 114 Cougars of all ages with VHF and GPS collars (Vectronics, Berlin, Germany; Lotek Wireless, Richmond Hill, Ontario) to study demographics and spatial and foraging ecology. The study took place in the Southern Yellowstone Ecosystem (see Elbroch *et al.* 2013 for a description of the study area). All collars were equipped with mortality sensors, which alerted us when collars had not moved for more than 8 h. We investigated sites where Cougars died to determine the cause of death. A veterinarian conducted necropsies to assess interior and exterior clues, and we sent blood and tissue samples to the Wyoming State Veterinary Laboratory for disease analyses.

Results

Over the study period, we documented the cause of death for 22 subadult and 37 adult Cougars (Elbroch and Quigley, unpublished data), and here we report the details of 2 animals killed as a result of complications after hunting porcupines. These represent 9.0% of subadult mortalities and 3.4% of total mortalities. Subadults died primarily from starvation or were killed by predators (each accounted for 18% of mortalities), and adults were primarily killed by people (49% of mortalities). We also report an opportunistic observation of a Cougar killed by quills of a Prehensile-tailed Porcupine (*Coendou prehensilis*) in the Llanos of Venezuela.

M34, a 15-month-old male Cougar from northwest Wyoming, was found dead on 14 September 2005. His underside, chest, neck, and one side of his face (including the ocular cavity) were completely covered by hundreds of deeply, embedded quills. No further details were recorded, and the cause of death was considered complications from porcupine quills.

F99, a 16-month-old female Cougar from northwest Wyoming, successfully killed a porcupine on 16 November 2014 but later died on 13 December 2014. A necropsy revealed porcupine quills in her chest and abdominal cavities. Her entire chest cavity was dotted with wounds from migrating quills that had entered through her chest, and the quills themselves were evident in her lungs, chest cavity walls, and fibrin clots. One lung had completely failed and consolidated because of damage from migrating quills, and the other was significantly wounded. The veterinarian concluded that she died from lung failure, resulting from complications from porcupine quills.

In February 1996, RH found the carcass of a subadult Cougar estimated to be 3 years old, at the edge of a dry watercourse on a private cattle ranch called Hato Piñero in the Llanos of Venezuela (8°56'N, 68°04'W). The carcass held scattered quills of a Prehensile-tailed Porcupine. Some of the larger quills had perforated the bones of the braincase and were embedded in the brain. This was determined to be the cause of death.

Discussion

Numerous carnivores prey on porcupines, and likely many incur increased risk of injury or death from quills acquired while killing the animal or after eating it (Mukherjee and Heithaus 2013; Katzner *et al.* 2015). Quick (1953) reported that some American Marten (*Martes americana*), Fisher (*Pekania pennanti*), Canadian Lynx (*Lynx canadensis*), Ermine (*Mustela erminea*), Red Fox (*Vulpes vulpes*), and American Mink (*Neovison vison*) trapped in British Columbia between 1947 and 1949 had quills embedded in them, emphasizing the diversity of carnivores potentially impacted by hunting porcupines.

In some areas, Cougars are the primary predator of porcupines (Sweitzer 1996), and, thus, they may suffer more from such complications than other predators. For example in a study of Cougar stomach contents in agricultural and prairie environments of North and South Dakotas, Thompson *et al.* (2009) reported that 12 of 14 Cougars examined exhibited porcupine quills (the Cougars were primarily killed by vehicles and legal hunters).

Determining the full extent to which Cougars suffer injury or mortality from hunting porcupines requires vigilance by researchers during necropsies. Only with greater awareness among wildlife researchers studying Cougars can we ascertain the frequency with which they suffer injury or death following the hunting of porcupines. With more accurate numbers of injuries and mortalities, we may be able to determine how this may influence Cougar population dynamics. More Cougars may die following encounters with porcupines than previously suspected, and this may be an important cause of mortality for young Cougars.

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Arctic Plants Produce Vastly Different Numbers of Flowers in Three Contrasting Years at Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada

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Panchen, Zoe A. 2016. Arctic plants produce vastly different numbers of flowers in three contrasting years at Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada. Canadian Field-Naturalist 130(1): 56–63.

To maximise reproductive success in the short Arctic growing season, plants pre-form flower buds the year prior to flowering. Flower bud production depends on warm ambient temperatures. Thus, although currently Arctic plants have low rates of sexual reproductive success, the warming climate may increase reproductive success. Following the long, warm growing season in 2012, plants at Lake Hazen, Ellesmere Island, produced many flowers in the short, cold growing season of 2013. Conversely, few flowers were produced in 2014, a long, warm growing season, but many flowers were produced in 2015, another long, warm growing season. Potentially higher rates of reproductive success in a warming climate could be compromised if consecutive years do not have long, warm growing seasons.

Key Words: *Arnica angustifolia*; Narrow-leaved Arnica; *Cassiope tetragona*; Arctic White Heather; *Pedicularis capitata*; Capitate Lousewort; climate change; flowering; flower abundance; reproductive success

Introduction

To maximise sexual reproductive success in the short Arctic growing season and to minimise time spent developing flower buds at the beginning of the growing season, many Arctic plants pre-form their flower buds in the year or years prior to flowering (Sørensen 1941). Of the complete flora of 184 species and varieties found in northeastern Greenland, for example, 80% pre-form their flower buds (Sørensen 1941). Given the circumpolar nature of Arctic flora, a similar proportion of the 125 species known to grow in the vicinity of Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada, likely also pre-form their flower buds (Sørensen 1941; Porsild and Cody 1980; Soper and Powell 1985; Elven 2003).

The extent to which the pre-formed flower bud primordia differentiate before the onset of winter varies among species but by August, differentiation has reached the extent to which it will differentiate in that year (Sørensen 1941). By winter, the flower buds of *Cassiope tetragona* (L.) D. Don (Arctic White Heather; Itsutit [Aiken *et al.* 2007]; Ericaceae) are fully formed with developed pollen visible, whereas those of *Arnica angustifolia* Vahl (Narrow-leaved Arnica; Qursuqtainnarmik nunaralik [Mallory and Aiken 2012]; Asteraceae) and some *Pedicularis* spp. L. (Orobanchaceae) are only partially formed, with anthers and petals visible and the ovary partially formed but no ovules visible (Sørensen 1941).

Flower abundance of some Arctic and alpine species is influenced by temperatures in the summer or autumn of the preceding year or by snow depth in the winter just prior to flowering. Flower abundance of *Dryas integrifolia* Vahl (Mountain Avens; Malikkaat [Aiken *et al.* 2007]; Rosaceae) and *Saxifraga oppositifolia* L. (Purple Saxifrage; Aupilattunnguat [Aiken *et al.* 2007]; Saxifragaceae) at Tanquary Fiord, Quttinirpaaq National Park, Ellesmere Island, Nunavut, is influenced by August and October mean minimum temperature, respectively, in the year preceding flowering (Panchen and Gorelick 2015). In Zackenbergdale, Greenland, the flower abundance of *C. tetragona*, *Salix arctica* Pall. (Arctic Willow; Supitit [Aiken *et al.* 2007]; Salicaceae) and *Papaver radicatum* Rottb. (Arctic Poppy; Igutsat niqingit [Mallory and Aiken 2012]; Papaveraceae) are influenced by the sum of temperatures above 0°C (heat sum) in the preceding year's growing season, while flower abundance of *Dryas* species is influenced by snow depth in the preceding winter and heat sum in the preceding and current growing seasons (Høye *et al.* 2007; Ellebjerg *et al.* 2008). In Svalbard, Norway, *C. tetragona* flower abundance is influenced by snow depth in the context of extreme weather events, where shallow snow depth and an extremely warm spell mid-winter resulted in reduced flower numbers the following summer (Semenchuk *et al.* 2013). In the alpine setting of the Rocky Mountains in Colorado, flower abundance of *Delphinium nelsonii* Greene (Twolobe Larkspur; Ranunculaceae) was influenced by snow depth in the preceding winter, where it is thought that shallower snow depths in more recent years may have exposed the flower buds to frost damage (Inouye and McGuire 1991). In the same area, flower abundance of *Androsace septentrionalis* L. (Pygmyflower Rock Jasmine; Primulaceae), an annual or short-lived perennial, was influenced by the preceding year's summer precipitation and May temperature in the year of flowering but not the preceding year's growing season temperatures (Inouye *et al.* 2003).

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The Canadian Arctic Archipelago experienced dramatically different weather during each of the growing seasons from 2012 to 2015, leading to growing season lengths and temperatures that differed substantially over the four years. At Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut (81.82°N, 71.35°W), 2012 and 2015 were warm years with long growing seasons, while 2013 was a cold, snowy year with a short growing season and 2014 was a dry year with very little snow and a growing season length and temperatures intermediate between 2013 and 2015. Vastly more flowers were observed on plant species at Lake Hazen in 2013 and 2015 compared with 2014. This article presents critical baseline natural history data on Canadian high Arctic flowering phenology in a part of Canada that is rarely surveyed. Moreover, it documents the effects of variable weather conditions on Arctic plant flower production.

Methods

The flowering progression of three species, *A. angustifolia*, *C. tetragona* and *Pedicularis capitata* Adams (Capitate Lousewort; Kukiujait [Aiken *et al.* 2007]; Orobanchaceae), was monitored at Lake Hazen, Quttinirpaaq National Park, from 13th June to 31st July in 2013, 2014 and 2015 (Figure 1). A population of

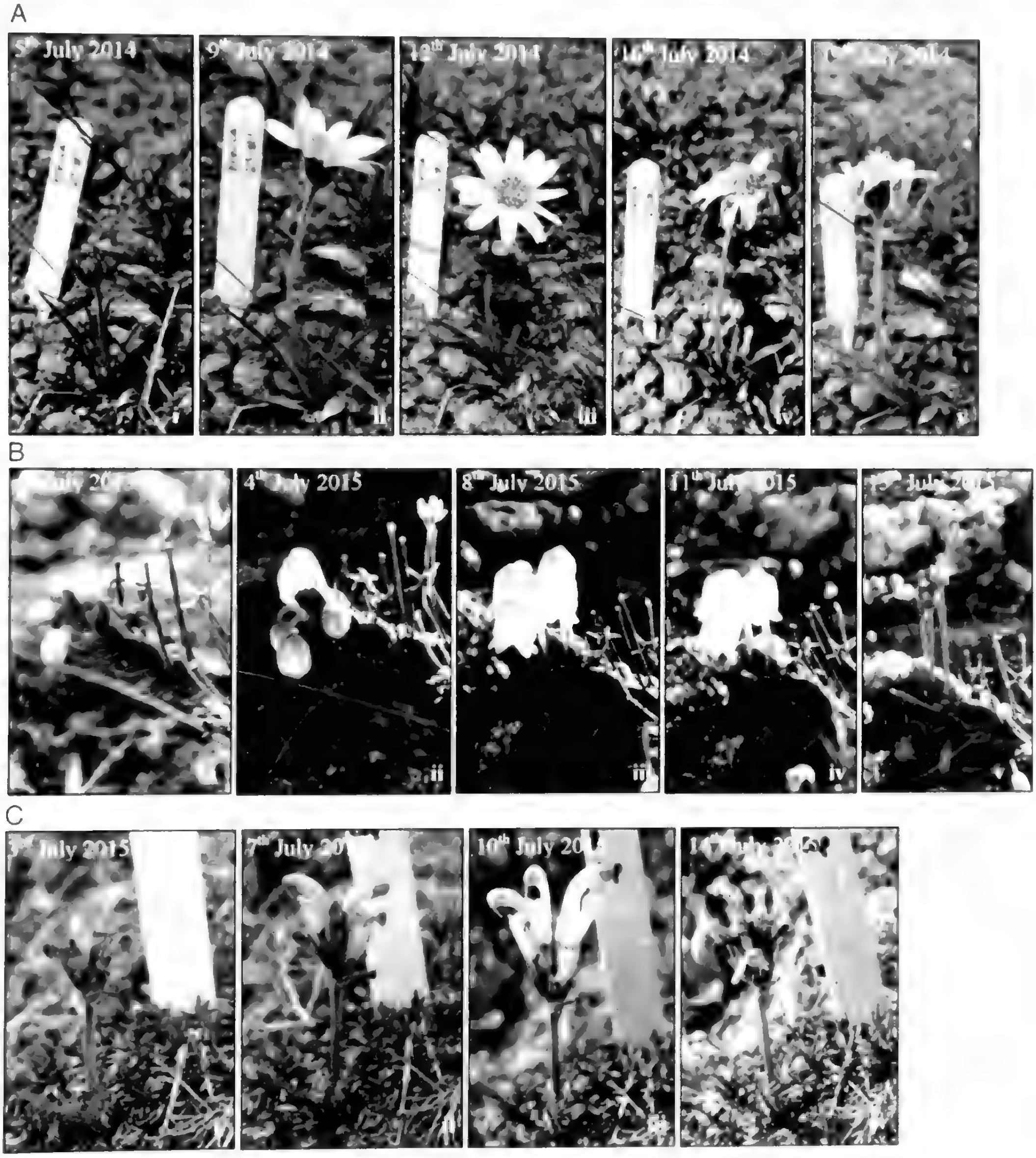

FIGURE 1. Flower progression of (A) *Arnica angustifolia* (Narrow-leaved Arnica) (B) *Cassiope tetragona* (Arctic White Heather) and (C) *Pedicularis capitata* (Capitate Lousewort) at Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada, showing flower(s) in bud (Ai, Bi and ii, and Ci), open flowers (Aii and iii, Biii and iv, and Cii and iii) and finish of flowering (Aiv and v, Bv and Civ). Photos: Zoe A. Panchen (panels A and C), Carly Cassey (B).

the perennial *A. angustifolia* was monitored on a southwest facing stream bank southeast of McGill Mountain (81.85°N, 71.35°W), a population of the woody species *C. tetragona* was monitored in a northeast facing gully on McGill Mountain (81.95°N, 71.49°W) and a population of the perennial *P. capitata* was monitored on the shores of Skeleton Lake (81.83°N, 71.48°W). Areas with established populations of each species were selected as monitoring sites before flowering began in 2013, except in the case of *A. angustifolia*, which only grows in a few locations at Lake Hazen and was not found until it was already in flower in 2013.

The sites were visited every 3–4 days in all 3 years. In 2013, monitoring was qualitative and subjective, following an approach successfully used by Panchen *et al.* (2012), wherein the date of first flower, peak flowering and finish of flowering of each population was recorded. After reviewing the 2013 results, the approach for subsequent years was changed to counting flowers to provide a more definitive date for start, peak and finish of flowering. Thus, in 2014 and 2015, monitoring was quantitative wherein 30 plants in each population were randomly tagged before flowering started and the number of flowers on each tagged plant was counted every 3–4 days. The inflorescence (capitulum holding many small flowers) of *A. angustifolia* was counted as a single flower.

The start, peak and finish of flowering for each species were determined from the flower count of the tagged plants. Start of flowering was defined as the date on which open flowers (Figure 1) were first observed on the 30 tagged plants, peak flowering as the date on which the greatest number of open flowers was counted and finish of flowering as the first date at the end of flowering on which no open flowers were observed. For each species, the peak number of flowers produced on the 30 tagged plants and the number of tagged plants that flowered in 2013–2015 were compared. For 2013, the peak number of flowers produced on 30 plants and the number of plants flowering out of 30 plants were estimated from observational field notes and photographs of the population or individual plants when they were in peak flower.

May to September mean monthly temperatures for the individual years 2012-2015 and the 10-year (2001–2010) and 30-year (1981–2010) means at Eureka Weather Station, Ellesmere Island, Nunavut, Canada, were obtained or calculated from Environment Canada (2015) data. The Eureka Weather Station (79.59°N, 85.56°W) is the closest weather station to Lake Hazen and experiences a similar climate, with temperatures between the two locations well correlated (Soper and Powell 1985; Edlund and Alt 1989; Thompson 1994).

Results

Flower abundance of *A. angustifolia*, *C. tetragona* and *P. capitata* populations was much greater in 2013 and 2015 than in 2014 (Table 1, Figures 2 and 3). Compared with 2014, in 2013 and 2015 there were 1.5 times more flowers on tagged *A. angustifolia* plants and 1.5 times more *A. angustifolia* tagged plants flowering; 273 times more *C. tetragona* flowers and 2.5 times more *C. tetragona* plants flowering; and 6.3 times more *P. capitata* flowers and 2.3 times more *P. capitata* plants flowering (Table 1).

Of the 4 years 2012–2015, 2012 was the warmest growing season with the May–September mean temperature at Eureka 1.81°C and 2.32°C warmer than the 10- and 30-year means, respectively (Table 2). The coldest growing season occurred in 2013, with the May–September mean temperature 3.05°C and 2.54°C colder than the 10- and 30-year means, respectively. Mean monthly temperatures were above 0°C for a month longer in 2012, 2014 and 2015 than in 2013 suggesting that 2013 had a shorter growing season than the other 3 years.

Arnica angustifolia and *P. capitata* started, peaked and finished flowering earlier in 2014 and 2015 than in 2013 (Table 3), corroborating temperature data, which indicated that the growing season was likely longer in 2014 and 2015 than in 2013. *Cassiope tetragona* started flowering earlier in 2014 and 2015 than in 2013 and peaked and finished flowering earlier in 2015 than in

TABLE 1. Comparison of number of flowers per population on the date of peak flowering (Table 3) and number of tagged plants that produced flowers (30 tagged plants in each population) of *Arnica angustifolia* (Narrow-leaved Arnica), *Cassiope tetragona* (Arctic White Heather), and *Pedicularis capitata* (Capitate Lousewort) over 3 years at Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada.

	No. flowers on date of peak flowering			No. tagged plants that flowered		
Species	2013*	2014	2015	2013*	2014	2015
Arnica angustifolia	30	20	31	30	20	30
Cassiope tetragona	9000	33	9316	30	12	30
Pedicularis capitata	75	12	76	30	13	30

*2013 numbers are estimates.

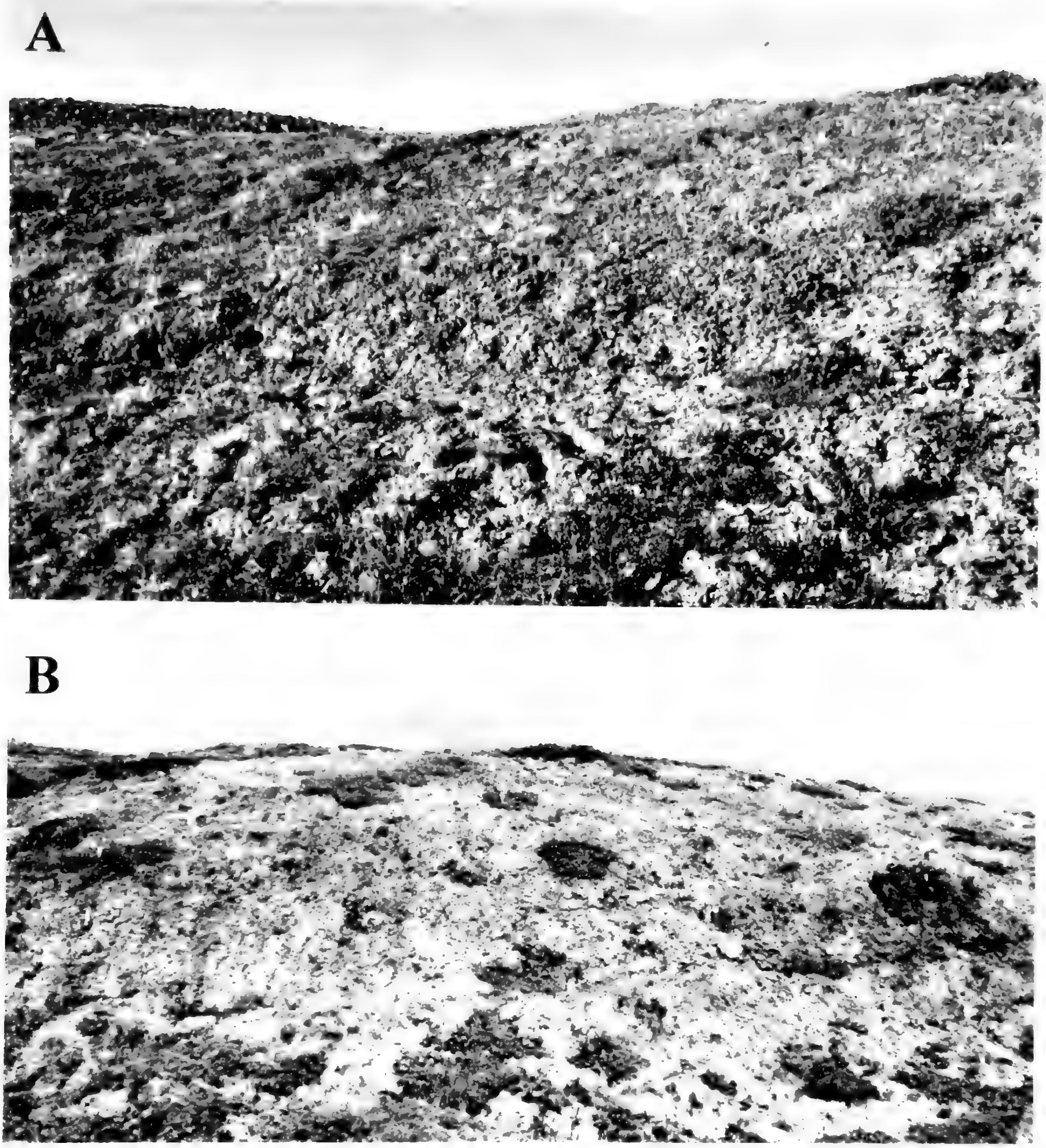

FIGURE 2. *Arnica angustifolia* (Narrow-leaved Arnica) population on a southwest facing stream bank, southeast of McGill Mountain, Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada. Over 100 flowers are visible in the 2013 photograph (A) and just 20 flowers (marked with white plastic plant tags) in 2014 (B). Both photos are of the same site taken from approximately the same position and angle but B is at a lower magnification than A. The patch of vegetation at the top right of A is on the centre skyline in B and the dip in the centre skyline in A is on the left in B. Photos: Zoe A. Panchen.

2013 and 2014. The *A. angustifolia* population was found on the last day at Lake Hazen in 2013 and was deemed to be at or close to peak flowering on that day because no flower buds remained and the majority of the plants had fresh-looking flowers, i.e., few of the ray flowers around the edge of the capitulum were wilting. Given the time from start to peak flowering at Lake Hazen in 2014 and 2015 of 7 and 4 days, respectively (Table 3), *A. angustifolia* likely started flowering later in 2013 than in 2014 and 2015.

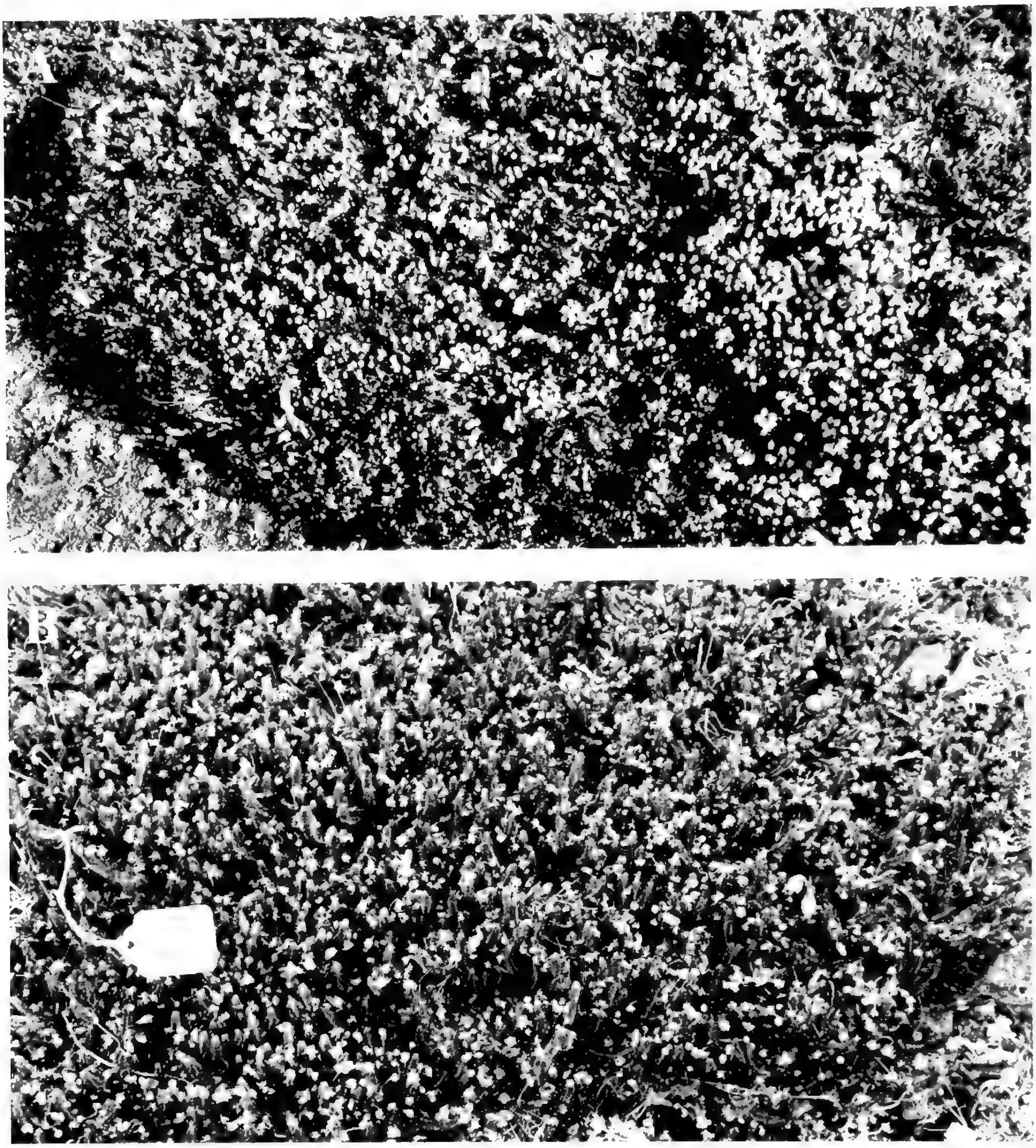

FIGURE 3. *Cassiope tetragona* (Arctic White Heather) in a northeast facing gully on McGill Mountain, Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada with over 300 flowers in 2013 (A) and with just three flowers in 2014 but over 100 flowers/fruits from 2013 still visible (B).

TABLE 2. Mean monthly temperature (°C) from May to September, 2012–2015, compared with 10-year (2001–2010) and 30-year (1981–2010) means at Eureka Weather Station, Ellesmere Island, Nunavut, Canada. Source: Environment Canada (2015).

Month	2012	2013	2014	2015	10-year mean	30-year mean
May	−9.40	−12.31	−8.50	−12.60	−9.45	−10.20
June	5.40	0.50	1.00	4.30	3.49	3.00
July	8.60	4.45	5.85	9.60	5.50	6.10
August	5.10	−1.14	4.27	4.10	4.19	3.20
September	−2.40	−8.50	−4.62	−5.10	−5.47	−6.40
Average, May–Sept.	1.46	3.40	−0.40	0.06	−0.35	−0.86
Average, June–Aug.	6.37	1.27	3.71	6.00	4.39	4.10

TABLE 3. Dates for start, peak, and finish of flowering of *Arnica angustifolia* (Narrow-leaved Arnica), *Cassiope tetragona* (Arctic White Heather) and *Pedicularis capitata* (Capitate Lousewort) over 3 years at Lake Hazen, Quttinirpaaq National Park, Ellesmere Island, Nunavut, Canada.

Species	Year	Start of flowering	Peak flowering (days since start of flowering)	Finish of flowering (days since start of flowering)
Arnica angustifolia	2013	*	31 July	> 31 July†
	2014	5 July	12 July (7)	22 July (17)
	2015	9 July	13 July (4)	23 July (14)
Cassiope tetragona	2013	12 July	19 July (7)	> 31 July†
	2014	2 July	22 July (10)	> 31 July†
	2015	27 June	8 July (11)	23 July (26)
Pedicularis capitata	2013	18 July	21 July (3)	> 31 July†
	2014	7 July	10 July (3)	13 July (6)
	2015	7 July	10 July (3)	20 July (13)

*Not found until after start of flowering.
†Not finished flowering when the Lake Hazen site was vacated on 31st July.

Discussion

The number of flowers in populations of three Arctic plant species at Lake Hazen was dramatically different in 2014 than in 2013 and 2015. There were many flowers in a year with a cold, short growing season (2013) following a year with a warm, long growing season (2012). There were few flowers in a year with a warm, long growing season (2014) following a year with a cold, short growing season (2013). There were many flowers in a year with a warm, long growing season (2015) following a year with a warm, long growing season (2014). Possible reasons for the low flower abundance in 2014 could be that the 2013 growing season might have been too short or temperatures may not have been warm enough for the species to pre-form flower buds (Sørensen 1941; Høye *et al.* 2007; Ellebjerg *et al.* 2008; Panchen and Gorelick 2015). In 2013, the mean temperature in August, the month in which flower bud differentiation is suspended (Sørensen 1941), was already below freezing but was above freezing in 2012, 2014 and 2015. Another possible reason is that the three species may have exhausted their available nutrient and carbohydrate resources in the sexual reproductive cycle in 2013 and, hence, did not have enough resources available to pre-form buds in 2013 for the 2014 flowering season. Arctic plants are generally resource limited and may not flower every year as they must build up enough nutrients and carbohydrates over 1 or more years for the resource-intensive sexual reproductive cycle (Mooney and Billings 1960; Fox and Stevens 1991; Wookey *et al.* 1993; Pielou 1994).

Of the three species studied, *C. tetragona* is the only one considered a snow bed species, it relies on the insulation of snow cover to protect the aboveground pre-formed flower buds from the harsh Arctic winters (Soper and Powell 1985). At Lake Hazen, it grows in gullies, depressions and on the lee side of hills where snow drifts form. In 2013, the gully on McGill Mountain was filled with approximately 30 cm of snow on 20th June and was not free of snow until 2nd July. In 2015 there was approximately 10 cm of snow in the gully on 13th June and it was snow free by 24th June. In 2014, however, the gully was snow free before 14th June. *Cassiope tetragona* may have had fewer flowers in 2014 than in 2013 and 2015 due to the absence of a protective snow layer and the resulting exposure may have killed the pre-formed flower buds (Inouye 2008; Semenchuk *et al.* 2013). *Arnica angustifolia* and *P. capitata* are perennials and their pre-formed buds are protected below ground from the cold air temperatures that are typically -40°C during the winter (Soper and Powell 1985; Thompson 1994).

The strategy to maximise sexual reproductive success by pre-forming flower buds in the prior year or years can only be effective if consecutive years have a long, warm growing season; the first year must be long enough and warm enough to pre-form sufficient flower buds (Høye *et al.* 2007; Ellebjerg *et al.* 2008; Panchen and Gorelick 2015), the second year must be long enough and warm enough to produce viable seed and a subsequent year must be long enough and warm enough to produce surviving seedlings (Muller *et al.* 2011).

Arctic plants have low rates of sexual reproductive success and, in theory, warmer temperatures and longer growing seasons resulting from recent climate change should increase sexual reproductive success (Bliss 1971; Wookey *et al.* 1993; Muller *et al.* 2011; Alsos *et al.* 2013). However, the extreme events and more varied climate, also associated with recent climate change (Easterling *et al.* 2000a, 2000b; Semenchuk *et al.* 2013), might be problematic for sexual reproductive success of Arctic plants given the 2+ year cycle to produce flowers (Inouye and McGuire 1991; Inouye 2008; Semenchuk *et al.* 2013). The observations did not test sexual reproductive success per se, however, flower abundance can be used as a proxy for reproductive success. If there are few flowers, then the possibility of sexual reproduction is lower.

The difference in methods between 2013 and 2014–2015 and the lack of quantitative measurements in 2013 introduces some uncertainty into the findings. However, the difference between the years is so dramatic that even if the flowers had been counted rather than estimated in 2013, the same results and conclusions would likely have been drawn.

The 2012–2015 observations at Lake Hazen may be indicative of larger-scale processes that could affect Arctic plant populations. Decreased rates of sexual reproduction resulting from increasingly greater year-to-year variation in growing conditions are likely to have important and long-lasting consequences in Arctic ecosystems (Soper and Powell 1985; Pielou 1994; Svoboda and Freedman 1994).

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Road Mortality of Reptiles and Other Wildlife at the Ojibway Prairie Complex and Greater Park Ecosystem in Southern Ontario

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The Ojibway Prairie Complex in Windsor contains the largest protected tallgrass prairie ecosystem in Ontario and supports numerous species at risk. Despite its ecological significance, it is crossed by multiple high-traffic roads. Road mortality is a major threat to endangered species in Canada, particularly reptiles. The main goal of this study was to describe the nature and extent of vertebrate road mortality, with a focus on reptiles, on roads bisecting the Ojibway Prairie Complex, and the Greater Park Ecosystem, in Windsor and LaSalle, Ontario. A systematic road mortality survey was conducted by bicycle along seven roads (12.5 km) in 2010, 2012, and 2013. Also, opportunistic observations (n = 103) spanning over 30 years were assembled from a variety of sources. In total, 2083 vertebrates (49 species), including 446 reptiles (11 species), were recorded "dead on road" during systematic surveys. The highest diversity of reptiles was recorded on Matchette Road, whereas the highest rate of reptile mortality was recorded on Malden Road. Reptile species at risk were killed on all roads surveyed. Combining systematic and opportunistic data, we found seven reptile species at risk: Butler's Gartersnake (*Thamnophis butleri*), Eastern Foxsnake (*Pantherophis vulpinus*), Eastern Massasauga (*Sistrurus catenatus catenatus*), Blanding's Turtle (*Emydoidea blandingii*), Eastern Musk Turtle (*Sternotherus odoratus*), Northern Map Turtle (*Graptemys geographica*), and Snapping Turtle (*Chelydra serpentina*). Reptile road mortality "hotspots" occurred where each road is intersected by a naturalized utility right-of-way. Our results can be used to focus mitigation efforts in space and time to reduce mortality rates and enhance connectivity in the Ojibway Prairie Complex and Greater Park Ecosystem.

Key Words: Reptiles; vertebrates; species at risk; road mortality; Ojibway Prairie Complex; Windsor; LaSalle; utility right-of-way

Introduction

Our understanding of the negative impacts of roads on wildlife is increasing. In Canada, road mortality is now considered a major threat to the persistence of endangered species, particularly reptiles (e.g., Row *et al.* 2007). Road mortality surveys have been used in areas of ecological importance to identify the nature and extent of wildlife road mortality (Ashley and Robinson 1996; Vijayakumar *et al.* 2001; Smith and Dodd 2003; Langen *et al.* 2007; Coelho *et al.* 2008; Shepard *et al.* 2008), and to measure the effectiveness of mitigation measures (Dodd *et al.* 2004; Aresco 2005; Baxter-Gilbert *et al.* 2015).

The Ojibway Prairie Complex (OPC), in extreme southwestern Ontario, is recognized as a Carolinian Canada Signature Site (Johnson 2005); it contains the largest protected tallgrass prairie remnant in Ontario, (Rodger 1998). This "complex" of tallgrass prairies, savannahs, forests, and provincially significant wetlands supports a multitude of regionally, provincially, and globally significant species of flora and fauna, some of which are found nowhere else in Canada (City of Windsor 2013). Furthermore, as many as 10 reptile species listed federally as at risk have been recently documented in the OPC and the surrounding greater park ecosystem (City of Windsor 2013; COSEWIC 2015).

Situated within an urban landscape, the OPC and Greater Park Ecosytem is surrounded and fragmented by residential, industrial, commercial, and agricultural lands as well as an extensive network of local, collector and arterial roads, in addition to a newly built provincial highway. Many species of wildlife, including at-risk reptiles, have been observed killed on these roads over the previous three decades (P. Pratt, unpublished data). These data were collected opportunistically, and no attempt has been made to document road mortality in this region systematically.

The main goal of this study was to describe the nature and extent of vertebrate road mortality, with a focus on reptiles and species at risk, on roads bisecting the OPC and Greater Park Ecosystem in the city of Windsor and the town of LaSalle. Our objectives were to identify which vertebrate species are killed on roads, estimate road mortality rates for each group, and identify spatial and temporal patterns of vertebrate road mortality.

Methods

Systematic Road Mortality Surveys

Seven collector and arterial roads in the study landscape were surveyed (Figure 1; Table 1). They were divided into two groups, reflecting different survey effort: in section B, all amphibians, birds, mammals, snakes, and turtles found dead on a road were recorded systematically, whereas, in section A, only dead snakes and turtles were recorded systematically. Also, more surveys were conducted in section B (n = 157) than in

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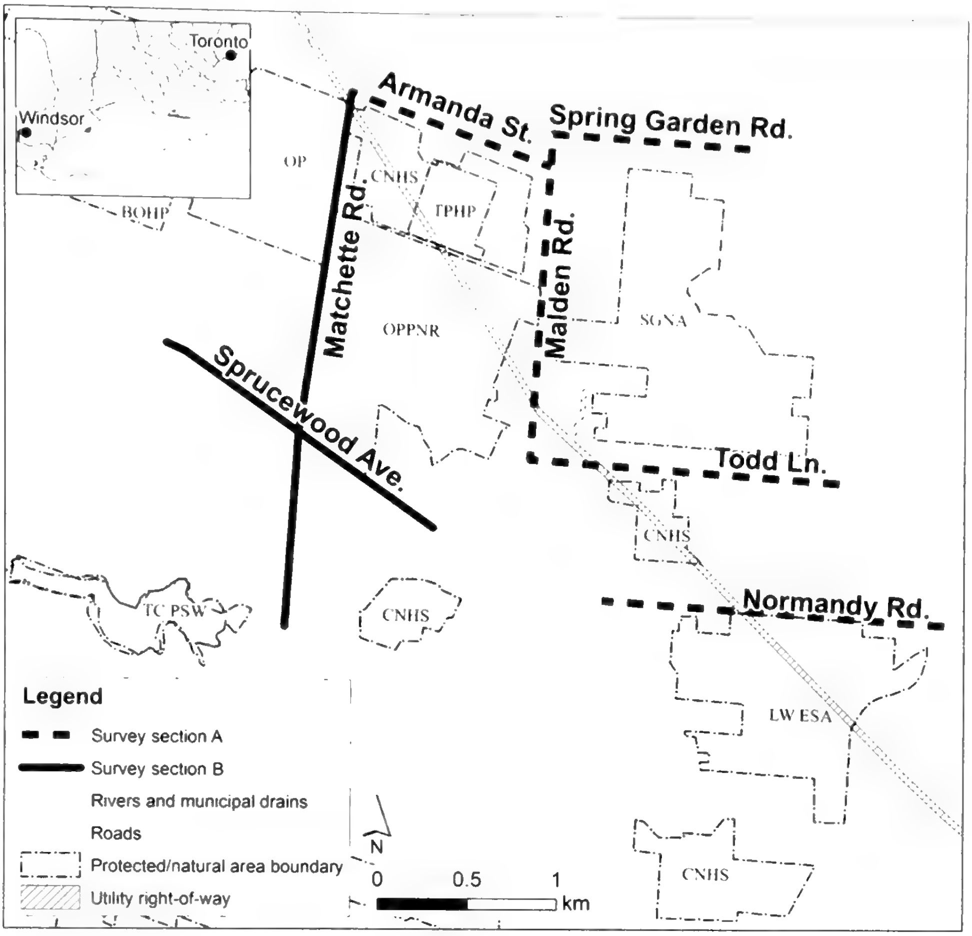

FIGURE 1. Map of the Ojibway Prairie Complex and Greater Park Ecosystem study area showing approximate boundaries of protected areas and roads surveyed for dead vertebrates during 2010–2013. BOHP = Black Oak Heritage Park, CNHS = Candidate Natural Heritage Site, LW ESA = LaSalle Woods Environmentally Significant Area, OP = Ojibway Park, OPPNR = Ojibway Prairie Provincial Nature Reserve, SGNA= Spring Garden Natural Area, TC PSW = Turkey Creek Provincially Significant Wetland, and TPHP = Tallgrass Prairie Heritage Park.

TABLE 1. Length, traffic intensity, and adjacent land use for roads surveyed during a systematic road mortality study in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario, from 2010 to 2013.

Length of survey route (km)	Road (length surveyed, km)	Estimated average annual daily traffic*	Adjacent land use†
Section A (7.85)	Armanda Street (1.17)	2200 (2006 data)	91% res, 9% row
	Spring Garden Road (1.09)	2500 (2005 data)	81% res, 8% ins, 8% row, 3% com
	Malden Road (1.82)	8654 (2006 data) 8000 (2013 data)	67% res, 19% row, 6% com, 6% nat, 2% ins
	Todd Lane (1.74)	9580–12 027 (2006 data) 15 236 (2008 data)	85% res, 11% row, 4% rec
	Normandy Road (2.03)	6619–8744 (2006 data)	70% res, 18% nat, 6% rec, 4% row, 2% ins
Section B (4.75)	Matchette Road (3.00)	6836–9300 (2006 data)	54% res, 38% nat, 6% row, 2% rec
	Sprucewood Avenue (1.75)	4619–6235 (2006 data) 5700–9402 (2008 data)	58% res, 25% rec, 12% nat, 5% row

*Sources: Dillon Consulting (2007, 2009); P. Bouliane, personal communication, 2014; County of Essex (2014).

†Sources: City of Windsor (2007); Town of LaSalle (2014). "Adjacent land use" is estimated using a GIS by dividing the length of road frontage for a given land use or zoning designation (both sides of the road) by the total length of road frontage (i.e., double the road length). Note: com = commercial, ins = institutional, nat = natural heritage/environment, rec = recreational, res = residential, row = opened and unopened road right-of-way.

section A ($n = 135$). Results for snakes and turtles from both sections were pooled.

Roads were surveyed by bicycle at speeds of 12–17 km/h on 3 days a week (on average every other day, except section A was surveyed on average every 4 days in 2010) for 52 non-consecutive weeks. Three technicians conducted road surveys: surveyor 1 in 2010–2013, surveyor 2 in 2012, and surveyor 3 in 2013. Surveys took place from May to mid-August in 2010 and 2013 and from late-August to October in 2012 and 2013. (Data from a single late-April survey are combined with May data.) The posted speed limit on all roads surveyed was 50 km/h. The survey route was traveled in a loop such that both lanes of each road were surveyed and it took about 3 h to complete a full survey. Surveys were always conducted with the flow of traffic; however, for each survey we alternated between completing section A or section B first. Most surveys (> 70%) were completed between 1100 and 1700. When all effort is combined, we surveyed the equivalent of almost 1800 km of roads, an average of 300 km/month (range 244–382 km/month).

For each specimen found dead on a road, the following data were recorded: UTM coordinates (accuracy of 5–10 m), road name, and location on road (yellow line, centre of lane, white line, or shoulder). During periods of high amphibian mortality, UTM coordinates were not recorded for these species; rather, these were tabulated by pre-defined road segment. Species, age class, and sex were also recorded when possible; however, many amphibians (54%), birds (46%), and mammals (31%) could not be identified to species. Photographs were taken of all species listed as at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2015).

To avoid duplication of records, all dead specimens were removed from the road and discarded in adjacent vegetation or roadside swale. When physical removal was not possible (because of carcass condition or safety concerns), specimens were left in situ and the white line adjacent to the carcass was marked with a water-resistant cattle marker or lumber crayon. These marks continued to be visible for at least a week after marking, which was generally sufficient to allow for the specimen to be removed from the road by other means. Carcass persistence rates were not estimated. All animals encountered alive on roads were noted and either left in situ (if on the road shoulder) or helped across the road in the direction in which they appeared to be traveling.

Opportunistic Data Collection

Observations of snakes and turtles on roads, dead or alive, were also solicited from various local naturalists (including the authors) and organizations to assemble a dataset of opportunistic records. Opportunistic data were kept separate from those collected during our surveys. Observations in this dataset spanned over 30 years (1984–2014) and included records of snakes and turtles found dead ($n = 106$) and alive ($n = 17$) on roads in the study landscape. Many observations were provided by staff at the Ojibway Nature Centre. In most cases, records were verified by qualified personnel. All results reported here are based on our systematic data, unless otherwise specified.

Data Analysis and Mapping

Mortality rates are reported either as number of dead on road (DOR) individuals per 100 km surveyed (e.g., [446 DOR /1798 km surveyed] × 100 = 24.8 DOR/100 km surveyed) or as number of DOR individuals per km per survey (e.g., [446 DOR] / [11.5 km per survey, on average] / [157 surveys] = 0.25 DOR/km/survey). Rates per month or per survey road were calculated in the same way, but using only the relevant subset of the data. Frequency estimates (DOR/km/survey) are assumed to be representative of daily mortality rates (i.e., DOR/ km/day) for birds, mammals, snakes, and amphibians, as other research has shown that most carcasses of these animals remain on the road for only one day (Enge and Wood 2002; DeGregorio *et al.* 2011; Santos *et al.* 2011). For turtles, however, per survey rates may not be synonymous with daily rates as some investigators have found most specimens remain on the road for two or more days (Langen *et al.* 2007; Santos *et al.* 2011).

To determine whether there were significant differences in the numbers of dead animals recorded per taxon across calendar months (data pooled by month, regardless of year), we made comparisons using a χ^2 goodness-of-fit test using SPSS 22.0 (IBM, Armonk, New York, USA). Departures from expected equal frequencies across all months were determined by residuals that were greater or less than the critical value of ± 1.96. When a significant difference from an expected frequency was found, pairwise goodness-of-fit tests were performed to determine which months were significantly different from the others. Sample sizes were too low to compare monthly mortality rates for at-risk turtles.

Scientific names of all reptiles and amphibians follow Crother (2012). Maps were produced in ArcGIS version 9.1 (ESRI, Redlands, California, USA). All distances were determined using the "Measure" tool in ArcGIS.

Spatial Analysis

The distribution of reptile road mortality events was analyzed using Siriema version 1.1 (Coelho *et al.* 2006). Roadkill data were weighted for species at risk (SAR) using the following scheme based on the COSEWIC (2015) list: non-SAR/not at risk = 1, special concern = 2, threatened = 3, endangered = 4 (Table 2); thus, "hotspots" (and any future mitigation efforts) would be biased toward such species. (A sensitivity analysis on Malden Road demonstrated that the location

TABLE 2. Vertebrates found during a systematic road mortality survey in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario, from 2010–2013.

Species (COSEWIC status)*		Opportunistic data†	Systematic data				
			2010 (May–mid-Aug.)	2012 (Late Aug.–Oct.)	2013 May–(mid-Aug.)	2013 (Late Aug.–Oct.)	Total
REPTILES							
Eastern Foxsnake (END; Carolinian pop.)	*Pantherophis vulpinus*	DOR + AOR	6	29	8	7	50
Eastern Massasauga (END; Carolinian pop.)	*Sistrurus catenatus catenatus*	DOR	0	0	0	0	0
Northern Brownsnake (NAR)	*Storeria dekayi dekayi*	DOR	61	64‡	4	11	140
Northern Red-bellied Snake	*Storeria occipitomaculata occipitomaculata*	—	12	4	1	3	20
Butler's Gartersnake (END)	*Thamnophis butleri*	DOR	8	10	0	1	19
Eastern Gartersnake	*Thamnophis sirtalis sirtalis*	DOR + AOR	42	45‡	29	11	127
Unidentified snake	*Thamnophis* sp.	—	0	9	0	0	9
Unidentified snake	—	—	7	8	2	2	19
Snapping Turtle (SC)	*Chelydra serpentina*	DOR + AOR	4‡	11	2	1	18
Midland Painted Turtle	*Chrysemys picta marginata*	DOR + AOR	17‡	6	10	0	33
Blanding's Turtle (THR; Great Lakes /St. Lawrence pop.)	*Emydoidea blandingii*	DOR + AOR	1‡	1	0	0	2
Northern Map Turtle (SC)	*Graptemys geographica*	DOR + AOR	2	0	3	0	5
Eastern Musk Turtle (SC)	*Sternotherus odoratus*	—	1	0	0	0	1
Red-eared Slider	*Trachemys scripta elegans*	DOR + AOR	1	0	2	0	3
All reptiles (11 species in surveys)			**162**	**187**	**61**	**36**	**446**
AMPHIBIANS							
American Toad	*Anaxyrus americanus*	—	166	4	101	22	293
Green Frog/Bull Frog	*Lithobates clamitans, L. catesbeiana*	—	133	1	3	1	138
Northern Leopard Frog (NAR: eastern populations)	*Lithobates pipiens*	—	60	9	40	61	170
Unidentified amphibians	—	—	674	16	12	0	702
Total amphibians (4 species)			**1033**	**30**	**156**	**84**	**1303**
BIRDS							
Red-winged Blackbird	*Agelaius phoeniceus*	—	5	0	9	0	14
Mallard Duck	*Anas fulvigula*	—	1	0	0	0	1
Ruby-throated Hummingbird	*Archilochus colubris*	—	0§	0	0	0	0
Northern Cardinal	*Cardinalis cardinalis*	—	0	0	4	1	5
American Goldfinch	*Carduelis tristis*	—	1	0	0	0	1
Rock Dove	*Columba livia*	—	0§	0	0	0	0
Gray Catbird	*Dumetella carolinensis*	—	0	0§	0	0	0
Baltimore Oriole (including one unidentified *Icterus* sp.)	*Icterus galbula*	—	3	0	0	0	3
Tree Swallow	*Iridoprocene bicolor*		1	0	0	0	1
House Sparrow	*Passer domesticus*	—	3	0	7	7	17
Black-capped Chickadee	*Poecile atricapillus*	—	0	0	1	0	1
Rose-breasted Grosbeak	*Pheucticus ludovicianus*		3	0	0	0	3

TABLE 2 *(continued)*. Vertebrates found during a systematic road mortality survey in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario, from 2010–2013.

Species (COSEWIC status)*		Opportunistic data†	Systematic data				
			2010 (May–mid-Aug.)	2012 (Late Aug.–Oct.)	2013 May (mid-Aug.)	2013 (Late Aug.–Oct.)	Total
Ring-necked Pheasant	*Phasianus colchicus*	—	0	1	0	0	1
Common Grackle	*Quiscalus quiscula*	—	0§	0	0	0	0
Eastern Bluebird (NAR)	*Sialia sialis*	—	0	0	1	0	1
Chipping Sparrow	*Spizella passerina*	—	0§	0	0	0	0
European Starling	*Sturnus vulgaris*	—	3	0	12	2	17
Carolina Wren	*Thryothorus ludovicianus*	—	0	0§	0	0	0
House Wren	*Troglodytes aedon*	—	2	0	0	0	2
American Robin	*Turdus migratorius*	—	2	0	24	1	27
Mourning Dove	*Zenaida asiatica*	—	1	0	0	0	1
Unidentified birds	—	—			70	89	289
All birds (21 species)			**95**	**9**	**67**	**13**	**184**
MAMMALS							
Short tailed Shrew	*Blarina brevicauda*	—	3	1	0	0	4
Virginia Opossum	*Didelphis virginiana*	—	1	2	1	1	5
Domestic Cat	*Felis catus*	—	0	0	0	2	2
Woodchuck	*Marmota monax*	—	0	2	0	0	2
Striped Skunk	*Mephitis mephitis*	—	4	5	0	0	9
Meadow Vole	*Microtus pennsylvanicus*	—	3	0	0	0	3
Muskrat	*Ondatra zibethicus*	—	1	0	0	0	1
White-footed Mouse	*Peromyscus leucopus*	—	0	1	0	0	1
Raccoon	*Procyon lotor*	—	4	2	1	1	8
Eastern Gray Squirrel	*Sciurus carolinensis*	—	3	1	9	11	24
Eastern Cottontail Rabbit (most probable species)	*Sylvilagus floridanus*	—	2	5	7	3	17
Eastern Chipmunk	*Tamias striatus*	—	14	0§	5	4	23
Unidentified Bat	—	—	1	3	0	0	4
Unidentified small mammals (Shrews, voles, mice, etc.)		—	20	6	2	3	31
Unidentified mammals		—	5	11	0	0	16
All mammals (13 species)			**61**	**39**	**25**	**25**	**150**
Total vertebrates (49 species)			**1351**	**265**	**309**	**158**	**2083**

*Source: COSEWIC (2015). END = endangered, THR = threatened, SC = special concern, NAR = not at risk.

†Incidental observations of snakes and turtles on roads: DOR = species found at least once dead on road; AOR = species observed at least once alive on road.

‡Snake or turtle species observed AOR at least once during a survey in that time period.

§Bird or mammal observed DOR in Section A during systematic surveys, but whose numbers were not tallied.

of mortality hotspots was sensitive to the SAR weighting.)

The Siriema analysis consisted of two steps (Coelho *et al.* 2008). First, Ripley's K function is used to test for significant spatial aggregations of road mortality events ($L(r)$ values) on each study road, and, if found, to determine at which spatial scales (i.e., radius length) such aggregations occur. Second, using a relevant radius length from step one as an input, hotspot analysis is used to identify the relative locations along each road where significant spatial aggregations occur (N_{events}-$N_{\text{simulated}}$). We used a linear, as opposed to a two-dimensional, K-function and hotspot analysis (Coelho *et al.* 2006) because all roads are linear (except for a minor curve on two of the roads), and no major differences were detected during an initial analysis of a sample of roads using both methods.

For the Ripley's K-function analysis, we used a 95% confidence interval (CI), an initial radius of 0.025 km, a radius step of 0.025 km, and 100 simulations. For the hotspot identification, we used a 95% CI, 100 simulations, 500 road divisions, and two radii for each road: a radius for which the greatest intensity of spatial clustering was reported (from Ripley's K) and a radius of 0.050 km. Two radii identified as having significant aggregations were used (one relatively longer than the other), so that results could better inform placement of both fine-scale (e.g., ecopassages) and broad-scale (e.g., barrier fencing or traffic calming) mitigation strategies (Coelho *et al.* 2006). Only roads with significant spatial aggregations of road mortality (based on Ripley's K analysis) were subjected to hotspot identification. For north–south roads, kilometre 0.00 was set at the southern end and for east–west roads, kilometre 0.00 was set at the western end.

Results

Species Composition of Road Mortality

Overall, 2083 vertebrates of 49 species were found dead during systematic surveys. This includes four species of amphibians, 21 species of birds, 13 species of mammals, five species of snakes, and six species of turtles (Table 2). Eastern Gartersnakes (*Thamnophis sirtalis sirtalis*) and Northern Brownsnakes (*Storeria dekayi dekayi*) made up the majority (70%) of snakes recorded, while Midland Painted Turtles (*Chrysemys picta marginata*) and Snapping Turtles (*Chelydra serpentina*) accounted for the majority (82%) of turtles. On average, dead snakes were observed seven times more frequently than dead turtles (Table 3).

Just over a fifth (21%) of all dead snakes and turtles were SAR. Six such species were found in this study: Blanding's Turtle (*Emydoidea blandingii*), Eastern Musk Turtle (*Sternotherus odoratus*), Northern Map Turtle (*Graptemys geographica*), Snapping Turtle, Butler's Gartersnake (*Thamnophis butleri*), and Eastern Foxsnake (*Pantherophis vulpinus*). Butler's Gartersnakes, Eastern Foxsnakes, and Snapping Turtles made up the vast majority (92%) of SAR records. On average, dead SAR snakes were observed twice as often as SAR turtles (Table 3). An additional SAR, the Eastern Massasauga (*Sistrurus catenatus catenatus*) was found dead opportunistically during the study period (Table 2). Seven provincially listed snakes and turtles were observed dead at the OPC and Greater Park Ecosystem, and, of these, three species appeared to be disproportionately represented.

Temporal and Spatial Patterns of Road Mortality

Mortality rates differed significantly between months for amphibians ($\chi^2 = 1483.12$, df = 5, $P < 0.001$; peak in July–August), birds ($\chi^2 = 73.87$, df = 5, $P < 0.001$; peak

TABLE 3. Vertebrate mortality rates recorded during a systematic road mortality survey in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario, from 2010 to 2013. Rates for amphibians, birds, and mammals are based on data from Section B only; rates for all other groups are based on combined data from both sections.

Vertebrate group	Average mortality rate, no./100 km	Above average mortality rates by month, no./100 km						Above average mortality rates by road, no. 100 km*†				
		May	Jun	Jul	Aug	Sep	Oct	Nor	Mal	Mat	Spr	Tod
Amphibians	176.2	—	—	607.2	192.3							
Birds	24.7	32.3	48.0	40.4						n a		
Mammals	20.1	—	26.9	24.4	23.0							
Snakes	21.4	—	—		36.2	26.3	28.7		52.3			
Turtles	3.4	6.0	5.9	—		4.1				7.2	4.7	
Species at risk												
All†	5.3	—	6.3	—	—	9.1	7.1		9.4	7.4		
Snakes	3.8	—	—	—	—	6.6	6.3	4.0	7.0	5.3		3.9
Turtles†	1.4	—	3.2	—	—	2.5			2.5	2.1	1.8	

*Nor = Normandy Road, Mal = Malden Road, Mat = Matchette Road, Spr = Sprucewood Avenue, Tod = Todd Lane. Above average mortality rates for snakes, turtles, and species at risk were not observed on Spring Garden or Armanda roads.
†χ^2 tests were not conducted.

in May–July), snakes ($\chi^2 = 98.5$, df = 5, $P < 0.001$; peak in August–October), SAR snakes ($\chi^2 = 32.8$, df = 5, $P < 0.001$; peak in September–October), and turtles ($\chi^2 = 24.71$, df = 5, $P < 0.001$; peaks in May–June and September), but not for mammals ($\chi^2 = 6.08$, df = 5, $P = 0.299$). Temporal patterns remained after controlling for the number of kilometres surveyed per month (Figure 2, Table 3).

Turtle mortality was hatchling-biased in May and September (67% and 62%, respectively), but not in June (13%). Over half (62%) of all dead SAR turtles were found in June and September, whereas most dead non-hatchlings (70%) were found in June. Snake mortality was adult-biased (88%) in August, whereas, in September and October, mortality was more evenly represented by younger age classes (55% and 67%, respectively). Over half (65%) of SAR snake mortality was observed in September and October. Above average mortality rates for SAR turtles and SAR snakes, combined, were observed on Malden and Matchette roads (Table 3). The highest diversity of dead snakes and turtles (11 species) and SAR (six species) were observed on Matchette Road. Three SAR (Butler's Gartersnake, Eastern Foxsnake, and Snapping Turtle) were each observed at least once during all months and on most roads.

Road Mortality Hotspots

Significant aggregations of snake and turtle road mortality events were detected at multiple scales on five of seven roads: Matchette, Malden, Spring Garden, Todd, and Normandy roads (Table 4, Figure 3). Aggregation intensity was highest at the scale of 0.300 km to 1.050 km for each of these five roads (Table 4). Significant aggregations were also detected at the scale of 0.050 km for all five roads except Spring Garden Road. Significant dispersion was detected only on Matchette Road (Table 4, Figure 3).

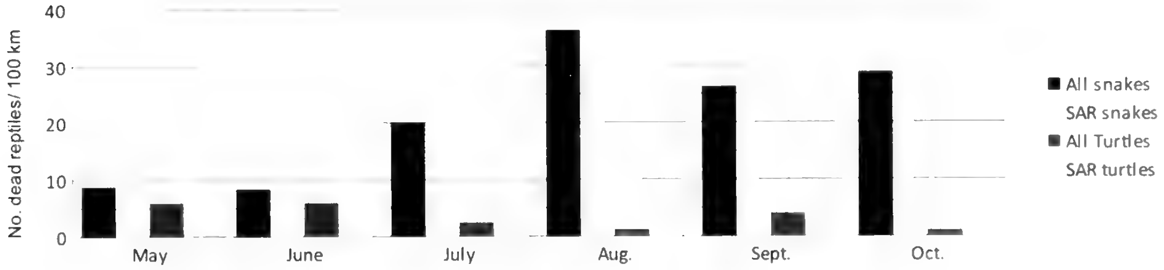

FIGURE 2. Mortality rates recorded during 52 non-consecutive weeks from 2010 to 2013 on seven collector and arterial roads in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario.

TABLE 4. Radii with significant aggregations and dispersions (to the nearest 0.025 km) and locations of hotspots (to the nearest 0.050 km) determined during a reptile road mortality study in the Ojibway Prairie Complex and Greater Park Ecosystem, Windsor and LaSalle, Ontario, from 2010 to 2013.

				Length (and relative location) of road mortality hotspots* with greatest intensity, km	
Road	Radii with significant* aggregations, km	Radii with highest aggregation intensity, km	Radii with significant* dispersions, km	Finer scale (0.050 km radii)	Broader scale (radii varies)
Malden Road	0.025–1.375 1.475–1.550	1.050 1.125	n/a	0.150 (km 0.200 – km 0.350)	0.400 (km 0.000 – km 0.400); 0.250 km radius
Matchette Road	0.025–1.400	0.825	1.675–2.725	0.200 (km 2.750 – km 2.950)	1.000 (km 2.000 – km 3.000); 0.825 km radius
Normandy Road	0.025–1.225	0.850	n/a	0.300 (km 0.550 – km 0.850)	0.600 (km 0.650 – km 1.250); 0.450 km radius
Todd Lane	0.025–0.600	0.300	n/a	0.200 (km 0.250 – km 0.450)	0.650 (km 0.000 – km 0.650); 0.300 km radius
Spring Garden Road	0.225–0.325 0.375–0.400 0.450–0.500	0.475	n/a	n/a	n/a

*Based on a 95% confidence interval.

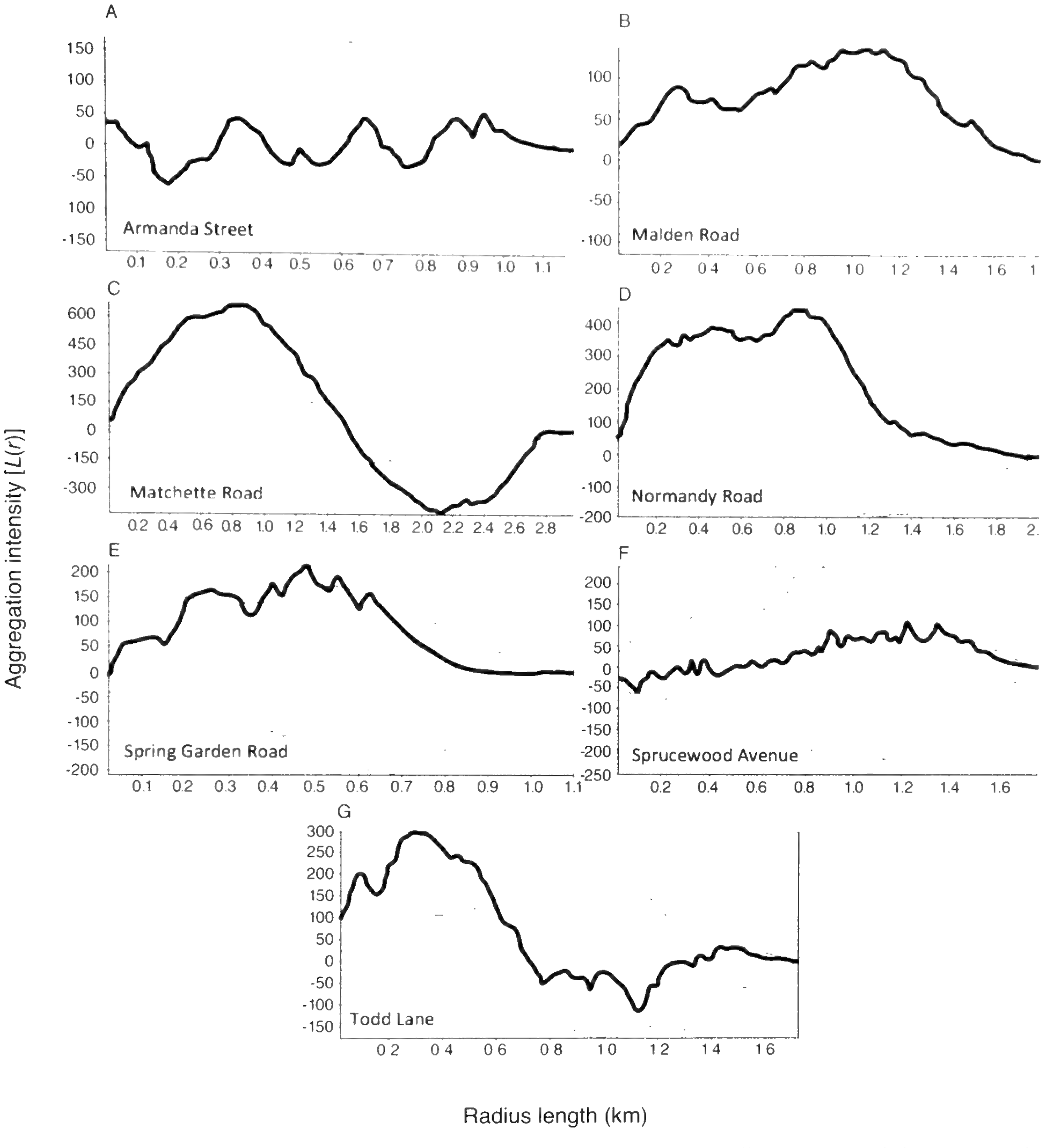

FIGURE 3. Ripley's K analysis for significant spatial aggregations of reptile road mortality events recorded on seven roads during a systematic road mortality study in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario. In each graph, aggregation intensity [$L(r)$] is a function of radius length [r (km)], and 95% confidence limits are represented by the two light black lines. Significant aggregations of road mortality events occur where the bold black line exceeds the upper confidence limit.

Results of hotspot analysis were aberrant for Malden, Normandy, and Spring Garden roads when using the radii with the highest aggregation intensity for each of these roads (1.050 km, 0.850 km, and 0.475 km, respectively). Subsequent analyses were conducted for Malden and Normandy roads using the radii of the next smallest "peaks" in $L(r)$ from the Ripley's K analyses (0.250 km and 0.450 km, respectively; Figure 3). Spring Garden Road was dropped from further analysis after trials with four radii continued to produce aberrant results.

Snake and turtle road mortality hotspots appeared to be associated with the presence of a utility right-of-way that bisects the study landscape (parallel natural gas and high-voltage hydro transmission lines) and crosses four study roads (Matchette, Malden, Todd, and Normandy; Figures 1, 4). For each of these four roads, and at two scales of analysis, the highest intensity road mortality hotspot occurred in close proximity to where each road intersects the right-of-way (Figure 4). Depending on the scale of analysis used, approximately a third (33/82 or 40%) to half (45/82 or 55%) of all SAR records from the four roads were observed within hotspots (a combined length of 0.850–2.650 km; Table 4, Figure 3).

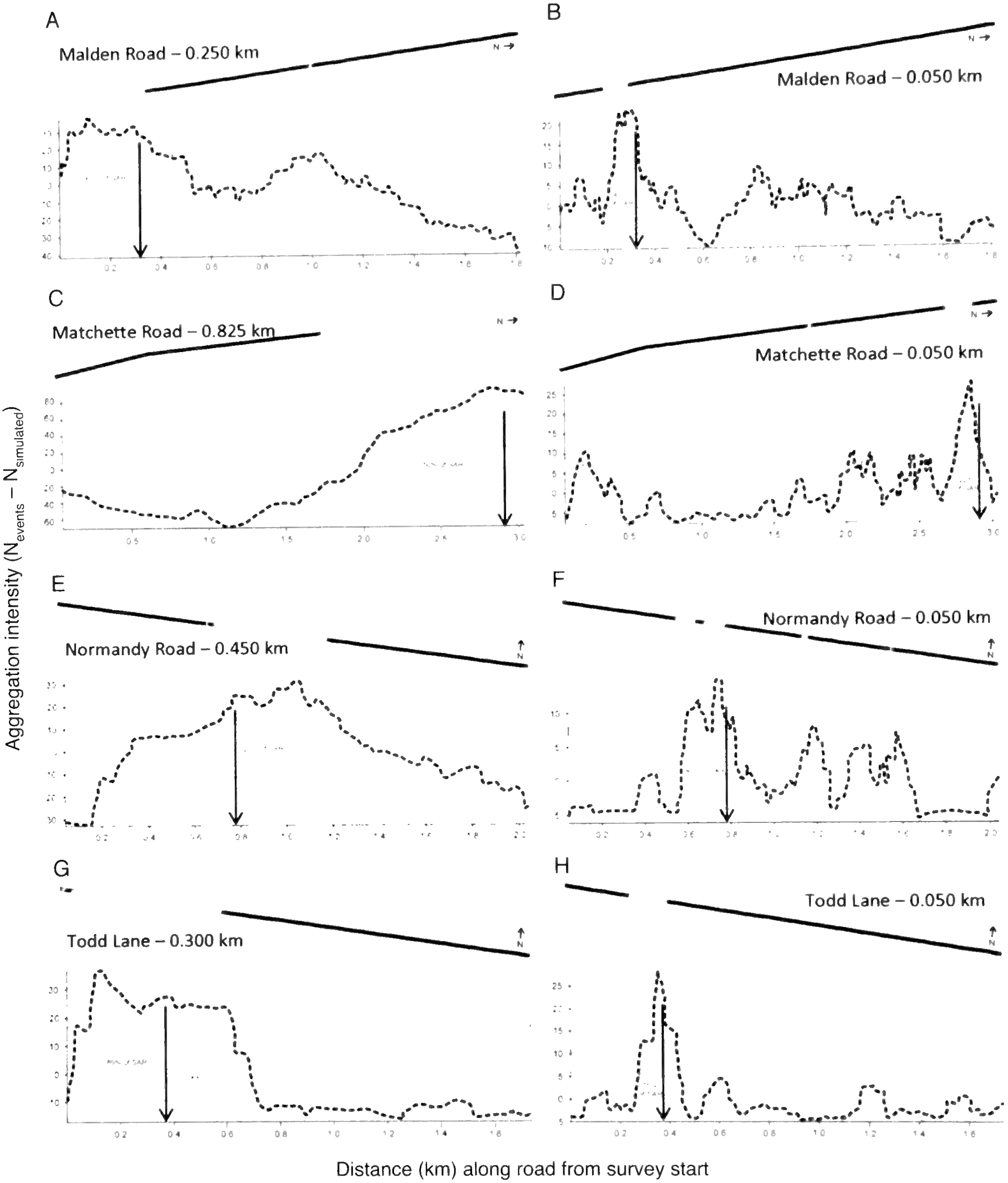

FIGURE 4. Hotspot analysis for significant spatial aggregations of reptile road mortality events recorded on four roads in the Ojibway Prairie Complex and Greater Park Ecosystem in Windsor and LaSalle, Ontario. In each graph, aggregation intensity (N_{events} $N_{simulated}$) is a function of distance (km) along road from survey start (i.e., km 0.0), and 95% confidence limits are represented by light gray horizontal lines. Significant aggregations of road mortality events (i.e., hotspots) occur where the bold dashed line exceeds the upper confidence limit. Aggregations of greatest intensity are highlighted in light gray, and their approximate extent (to the nearest 0.05 km) is indicated by the light gray vertical bars. The proportion of species at risk (SAR) observations that occur within the hotspots (i.e., within the gray bars) is indicated. Above each graph, roads are depicted as a solid black line and segments with significant aggregations of road mortality events are represented in light grey. The scale of analysis (i.e., radii) is indicated next to each road name. Black arrows indicate the approximate location of the utility right-of-way intersection with each road. (Note: for Normandy Road, 50% of SAR records occured between km 0.550 and km 1.250)

Discussion

Limitations of this Study

We recognize three major limitations to our study: underestimation of the number of species found dead as well as mortality rates; overgeneralization of temporal patterns; and under-representation of spatial aggregations of roadkill.

Ours is not a comprehensive list of all vertebrates killed on roads in and surrounding the OPC. Considering the short time frame of our study, the fact that a large proportion (41%) of specimens we collected were not identified to species, and that we only recorded 17% of the approximately 301 vertebrate species known locally (City of Windsor 2013), it is likely that additional species are being killed on roads in the study landscape.

There is no doubt that the rates of road mortality that we observed are underestimates of the true mortality rates in the study landscape during our study. There are a number of reasons for this. First, most animals killed on roads are removed or obliterated within a day by scavengers, high traffic volumes, or other forces (Kline and Swann 1998; Clevenger *et al.* 2001; Hels and Buchwald 2001; Enge and Wood 2002; Smith and Dodd 2003; DeGregorio *et al.* 2011; Santos *et al.* 2011; Farmer and Brooks 2012), which could result in road mortality being underestimated by a factor of 12–16 (scavenging: Slater 2002, as cited by DeGregorio *et al.* 2011). Second, surveying by bicycle led to slight underestimates of mortality rates of small snakes compared with surveying on foot (S. Boyle, personal communication, 2013). Third, we did not survey for carcasses in roadside swales, where some animals killed on roads likely ended up (e.g., Dodd *et al.* 2004). Fourth, we did not estimate or correct for differences in detection rates between observers (i.e., observer bias). Finally, we surveyed only the arterial and collector roads in the study area, not the multiple "local" roads, on which Eastern Foxsnakes have been confirmed killed in 2010, 2012, and 2013 (P. Pratt, unpublished data).

The temporal patterns in road mortality that we observed after pooling data from all three survey years may not be representative of within-year patterns. However, more in-depth analyses of the data are hindered by unequal survey effort within years and, in 2013, a series of temporary road closures on our study roads. Regardless, the patterns we observed for snakes and turtles are consistent with the biology of these two faunal groups. For example, high mortality of turtles in May and June can be explained by adult dispersal during nesting and emergence of hatchlings that overwintered. Also, high mortality of turtles and snakes from August to October can be explained by emergence of neonates as well as snake dispersal to hibernation sites.

Additional aggregations of road mortality may remain undetected in the study landscape because of scavenging pressure, low sample size, or short length of study. Some hotspots could be "masked" if scavenging pressure is relatively high in those areas. After placing fresh snake carcasses, DeGregorio *et al.* (2011) found they were removed more often in certain habitat types (forested versus dune habitats). Also, Santos *et al.* (2011) found that lower traffic rates facilitate scavenger access to carcasses. Although scavengers are present in the study landscape (see Table 2), we did not conduct tests to determine how scavenging pressure is distributed along our study roads. Hotspots were not identified on three roads — Sprucewood, Armanda, and Spring Garden roads — likely because of low sample sizes. Furthermore, our analysis was conducted using data from only two full May–October periods, which might not be sufficient to identify all hotspots. Additional spatial aggregations may become apparent with a larger dataset that spans a longer time.

Impacts of Roads on Ojibway Prairie Vertebrates

Roads are a conspicuous cause of anthropogenic mortality of vertebrates, especially snakes and species at risk, in the OPC and Greater Park Ecosystem. The average snake road mortality rate of 0.21/km/day (assuming [384 DOR snakes] / [11.5 km per survey, on average] / [157 surveys]) is higher than those reported at other Ontario sites: 0.06/km/day at the Long Point Causeway, Port Rowan (Ashley and Robinson 1996), 0.15/km/day at Rondeau Provincial Park and Point Pelee National Park combined (Farmer and Brooks 2012), and 0.19/km/day at Dyer's Bay, Northern Bruce Peninsula (Reed and Mackenzie 2010).

We confirmed that seven reptile SAR are being subjected to road mortality at the OPC and Greater Park Ecosystem, and that mortality occurs on all major, and some local, roads in the focal area. During our study, we estimate that SAR were being killed on roads across the OPC at a minimum average rate of 19 individuals a month (assuming: [5.3 DOR/100 km surveyed] × [11.5 km surveyed/survey day, on average] = [0.61 DOR/day] × [30.7 days/month]). The population-level impacts of the rates of road mortality experienced by SAR in general, and each species in particular, remain unknown. Regardless, road mortality undoubtedly places additional pressure on small populations of reptiles already experiencing a wide range of threats and stressors as a result of inhabiting an urban landscape (Mitchell *et al.* 2008). Furthermore, management documents for at least two of these species highlight the need to address road mortality and habitat fragmentation across their range (Parks Canada Agency 2013; OMNR 2011).

A precedent has already been set for mitigating road mortality at protected areas across Ontario. For example, using today's SAR designations for reptiles (COSEWIC 2015), the diversity of SAR affected by roads at the OPC (seven) is equal to or greater than that observed at Long Point Provincial Park (seven SAR: Ashley and Robinson 1996), Rondeau Provincial Park (seven SAR: Farmer and Brooks 2012), Point Pelee National Park (four SAR: McKay and Brown 2007;

Farmer and Brooks 2012), and Bruce Peninsula National Park (four SAR: Eco-Kare International 2010; Reed and McKenzie 2010). Efforts to mitigate road mortality are complete or underway in all four of these parks. Our results provide insight into where and when similar mitigation efforts would have the greatest impact in terms of reducing road morality at the OPC and Greater Park Ecosystem.

Management Considerations

Mitigation measures would produce the greatest benefit for SAR and other reptiles if they are prioritized at locations where SAR road mortality is highest or during periods of peak mortality rates, or both. Our results suggest that the following four roads should be targeted: Malden, Matchette, Normandy, and Todd. At a minimum, the installation of physical mitigation structures (e.g., barrier walls or fencing), 150–300 m in length, at the intersection of each of these roads and the utility right-of-way, for a total of 850 m, would target road sections where, collectively, over a third of SAR mortality was recorded. If these structures were extended to 400–1000 m, depending on the road, for a total of 2650 m, mitigation measures would target road sections where just over half of all SAR mortality was recorded on these roads. Furthermore, there is an opportunity for mitigation measures along the four roads mentioned above to contribute not only to reducing road mortality, but also to increasing landscape connectivity for snakes and turtles.

The utility right-of-way that bisects the study landscape is managed to prevent development of a forest canopy, thus providing a continuous corridor of suitable open habitat for snakes, particularly in areas dominated by residential development or dense forest. Results from this road mortality study, in combination with previous habitat suitability modeling for Eastern Massasauga (Choquette 2011) and radiotelemetry data on Eastern Foxsnakes (S. Marks, personal communication, 2013), suggest that the right-of-way is either used as a movement corridor or has potential to function as a corridor for SAR snakes in the study area. Considering the importance of protecting and restoring connectivity in this fragmented landscape, mitigation work done on roads in the vicinity of the utility right-of-way should combine efforts to reduce road mortality and increase connectivity (e.g., diverting animals to newly installed, or existing culverts, with the use of barrier fencing).

In addition to permanent solutions, and to address the widespread nature of SAR road mortality, temporary mitigation measures (e.g., seasonal road closures, seasonal speed limit reductions, etc.) could be used during peak mortality periods for certain taxa and age classes, at a minimum, in June, September, and October, when relatively high mortality rates of snake and turtle SAR were observed. Efforts could be further extended to include May and August to cover additional periods of high turtle and snake mortality. Finally, the potential benefits to all vertebrate groups of permanent road closures or traffic speed reductions should not be overlooked (see Martinson 2009; Farmer and Brooks 2012).

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Remnant Freshwater Mussel Diversity in Rondeau Bay, Lake Erie

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Reid, Scott M., Victoria Kopf, Anita LeBaron, and Todd J. Morris. 2016. Remnant freshwater mussel diversity in Rondeau Bay, Lake Erie. Canadian Field-Naturalist 130(1): 76–81.

In 2014 and 2015, 27 sites in Rondeau Bay, Ontario, Canada, were surveyed for freshwater mussels. Rondeau Bay is a large coastal wetland on the north shore of Lake Erie. Twenty-three species were identified from 120 live mussels, 15 fresh whole shells, 329 weathered whole shells, and 1121 weathered valves. Live individuals of the following species were collected: Eastern Pondmussel (*Ligumia nasuta*; endangered in Canada), Giant Floater (*Pyganodon grandis*), Round Pigtoe (*Pleurobema sintoxia*; endangered in Canada), and Three-ridge (*Amblema plicata*). Fresh whole shells of the Mapleleaf (*Quadrula quadrula*; threatened in Canada) were also found. Most species (78%), including 7 species at risk, were collected only as weathered shells. These results indicate a substantial decline in freshwater mussel diversity since the Zebra Mussel (*Dreissena polymorpha*) invasion of Lake Erie. Evidence shows that a viable population of only Giant Floater remains.

Key Words: Freshwater mussels; Unionidae; unionids; species at risk; Zebra Mussel; *Dreissena polymorpha;* Rondeau Bay; Lake Erie; wetland; refuge; Giant Floater; *Pyganodon grandis*

Introduction

The invasion of the Laurentian Great Lakes basin by dreissenid mussels — Zebra Mussel (*Dreissena polymorpha* Pallas, 1771) and Quagga Mussel (*D. bugensis* Andrusov, 1897) — has resulted in substantial and widespread declines in native mussel abundance and diversity (Schloesser and Nalepa 1994). By the early 1990s, native mussels were nearly extirpated from offshore waters in lakes Erie and St. Clair (Metcalfe-Smith *et al.* 2005). Over the past 15 years, an increasing number of studies have demonstrated the importance of Great Lakes coastal wetlands to freshwater mussel conservation. Compared with adjacent open water habitat, wetlands are less suitable for dreissenid colonization and survival (Bowers and Szalay 2003; Sherman *et al.* 2013) and, thus, provide a refuge for native mussels. Remnant mussel assemblages have been identified in coastal areas of lakes Erie, Huron, Ontario, and St. Clair (Zanatta *et al.* 2002; Bowers and Szalay 2003; Sherman *et al.* 2013; Reid *et al.* 2014; Zanatta *et al.* 2015).

Although intensive, semi-quantitative inventories of unionid mussels have recently been carried out in coastal wetlands along the western and southern shores of Lake Erie (Zanatta *et al.* 2015), similar efforts have not been undertaken in Canadian waters. In 2014 and 2015, targeted surveys for 2 Canadian species at risk, Rainbow Mussel (*Villosa iris* (Lea, 1829)) and Eastern Pondmussel (*Ligumia nasuta* (Say, 1817)), were conducted in Rondeau Bay to inform species status assessments and delineation of protected habitats. Rondeau Bay (42°17'35"N, 81°53'24"W) is a large (37 km^2), shallow (maximum depth 3 m) coastal embayment and wetland complex with abundant submerged macrophyte growth, on the north shore of Lake Erie. The bay is bounded by Rondeau Provincial Park on the east and connected to the central basin of Lake Erie through a navigation channel. Occasional mussel surveys have occurred in Rondeau Bay over the past 120 years, with the last effort described as, "largely fruitless" (Zanatta *et al.* 2002).

Methods

In 2014, 12 sites were sampled from 24 to 26 June (Figure 1). Site selection was based on historical Rainbow Mussel collection records (Lower Great Lakes Unionid Database, Fisheries and Oceans Canada) and the occurrence of sand and gravel habitat, which is suitable for Rainbow Mussel (Metcalfe-Smith *et al.* 2005). At these sites, the lake bed substrate was visually assessed as 71% sand and gravel and 29% clay, silt, and organics (mean values). In 2015, 15 sites were sampled from 22 to 25 June (Figure 1). Habitat selection in 2015 was informed by past experience collecting Eastern Pondmussel (Reid *et al.* 2014). Compared with the 2014 sites, the lake bed of sites surveyed in 2015 had less sand and gravel (20% of substrate composition) and more clay, silt, and organics (80%). Depths of soft sediment were also greater (up to 0.5 m versus up to 0.2 m). Combined, sites were widely distributed along the entire shoreline of the bay and represented a variety of habitats.

Each site was searched for 4.5 person-hours (Metcalfe-Smith *et al.* 2000) using a visual-tactile sampling method (Reid *et al.* 2014). Visual-tactile searching involved either floating on an air mattress and hand searching the sediment for mussels (both on the surface and probing through sediment for burrowed mussels)

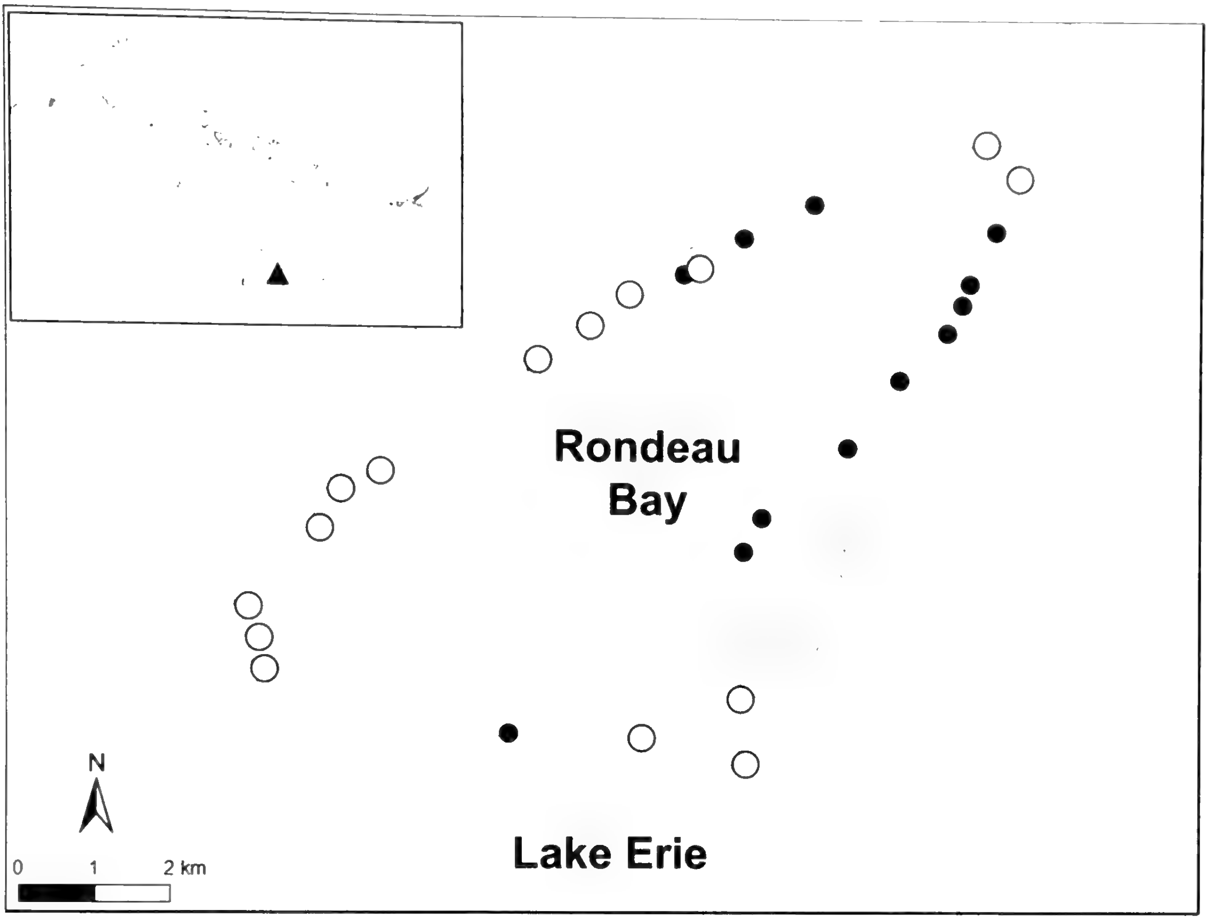

FIGURE 1. Location of 2014 (●) and 2015 (○) freshwater mussel sampling sites in Rondeau Bay, Lake Erie, Ontario.

or searching for mussels with a 0.33-m diameter underwater viewer (Plastimo Round Underwater Viewer Nuova Rade, Busalla, Italy) or polarized lenses. Water depths at searched habitats were between 0.15 and 1.50 m. Live mussels and shells were identified to species (Metcalfe-Smith *et al.* 2005). Shell length (mm) of live mussels was measured with a dial caliper (± 0.1 mm). Live mussels and attached dreissenids were weighed separately (± 0.1 g). After processing, live mussels were returned to the sediment.

Results

Twenty-three species were identified among 120 live mussels, 15 fresh whole shells, 329 weathered whole shells, and 1123 weathered valves (Table 1). Excessive shell degradation made 912 weathered shells and shell fragments impossible to identify. Most species (78%), including 7 species at risk, were identified from weathered shells and valves only. Weathered shell material was dominated numerically at the tribe level by Lampsilini (82% of collection) and at the species level by Fatmucket (*Lampsilis siliquoidea* (Barnes, 1823); 60% of collection), Wabash Pigtoe (*Fusconaia flava* (Rafinesque, 1820); 10%), Deertoe (*Truncilla truncata* (Rafinesque, 1820); 9%), Pink Heelsplitter (*Potamilus alatus* (Say, 1817); 5%), and Mapleleaf (*Quadrula quadrula* (Rafinesque, 1820); 3.5%). A single, weathered Rainbow Mussel valve was found. Only species from the tribes Alasmidontini, Pleurobemini, and Quadrulini were identified from fresh whole shells, including the threatened Mapleleaf and endangered Round Pigtoe (*Pleurobema sintoxia* (Rafinesque, 1820)). Substantially more shell material was collected in 2014 than in 2015. Correspondingly, 4 times as many species were identified from shell material in 2014 (median = 8, range = 1–12) than in 2015 (median = 2, range = 0–6).

Despite the intensive search effort (> 120 h), live mussels from only 4 species — Eastern Pondmussel, Giant Floater (*Pyganodon grandis* (Say, 1829)), Round Pigtoe, and Three-ridge (*Amblema plicata* (Say, 1817)) — were collected. Based on abundance, the current mussel assemblage is almost exclusively Giant Floater (97.5%, Table 1). Almost all live Giant Floaters were collected in 2015; of these, 84% were collected from 4 sites along the western shoreline. A wide range of Giant Floater shell lengths indicates ongoing population recruitment (Figure 2). Dreissenids were attached to 88% of live mussels (all 4 species) and found at most

TABLE 1. Number of weathered whole shells (WW), weathered valves (WV), fresh whole shells (FW), and live mussels in timed searches of Rondeau Bay, Lake Erie, Ontario, in 2014 and 2015. The number of collection sites is given in parentheses.

Scientific name	Common name	2014				2015			
		WW	WV	FW	Live	WW	WV	FW	Live
Amblema plicata (Say, 1817)	Three-ridge	0	1	0	1	0	0	0	0
Amphinaias pustulosa (Lea, 1831)	Pimpleback	2 (2)	8 (2)	0	0	0	11 (1)	0	0
Elliptio dilatata (Rafinesque, 1820)	Spike	1	9 (2)	0	0	0	0	0	0
Epioblasma triquetra (Rafinesque, 1820)	Snuffbox*	0	8 (2)	0	0	0	0	0	0
Fusconaia flava (Rafinesque, 1820)	Wabash Pigtoe	31 (7)	103 (10)	0	0	0	1	0	0
Lampsilis cardium Rafinesque, 1820	Plain Pocketbook	2 (2)	19 (4)	0	0	0	0	0	0
Lampsilis siliquoidea (Barnes, 1823)	Fatmucket	241 (7)	573 (10)	0	0	1	22 (2)	0	0
Lasmigona costata (Rafinesque, 1820)	Flutedshell	0	2 (1)	0	0	0	0	0	0
Leptodea fragilis (Rafinesque, 1820)	Fragile Papershell	3 (2)	25 (4)	0	0	0	0	0	0
Ligumia nasuta (Say, 1817)	Eastern Pondmussel*	6 (4)	22 (6)	0	0	0	2 (2)	0	1
Ligumia recta (Lamarck, 1819)	Black Sandshell	1	5 (2)	0	0	1	0	0	0
Obliquaria reflexa Rafinesque, 1820	Threehorn Wartyback	0	4 (3)	0	0	0	0	0	0
Obovaria subrotunda (Rafinesque, 1820)	Round Hickorynut*	0	2 (2)	0	0	0	0	0	0
Pleurobema sintoxia (Rafinesque, 1820)	Round Pigtoe*	2 (2)	7 (3)	1	1	0	0	0	0
Potamilus alatus (Say, 1817)	Pink Heelsplitter	13 (5)	47 (8)	0	0	0	3 (2)	0	0
Ptychobranchus fasciolaris (Rafinesque, 1820)	Kidneyshell*	1	11 (1)	0	0	0	0	0	0
Pyganodon grandis (Say, 1829)	Giant Floater	2 (1)	14 (5)	1	1	1	2 (2)	11 (7)	116 (10)
Quadrula quadrula (Rafinesque, 1820)	Mapleleaf*	2 (2)	20 (3)	0	0	0	26 (2)	2 (2)	0
Strophitus undulatus (Say, 1817)	Creeper	1	0	0	0	0	0	0	0
Toxolasma parvum (Barnes, 1823)	Lilliput*	0	5 (4)	0	0	0	0	0	0
Truncilla donaciformis (Lea, 1828)	Fawnsfoot*	4 (1)	4 (3)	0	0	0	0	0	0
Truncilla truncata Rafinesque, 1820	Deertoe	14 (5)	115 (7)	0	0	0	0	0	0
Villosa iris (Lea, 1829)	Rainbow Mussel*	0	1	0	0	0	0	0	0
Total		**326**	**1004**	**2**	**3**	**3**	**67**	**13**	**117**

*Species-at-risk (COSEWIC 2015).

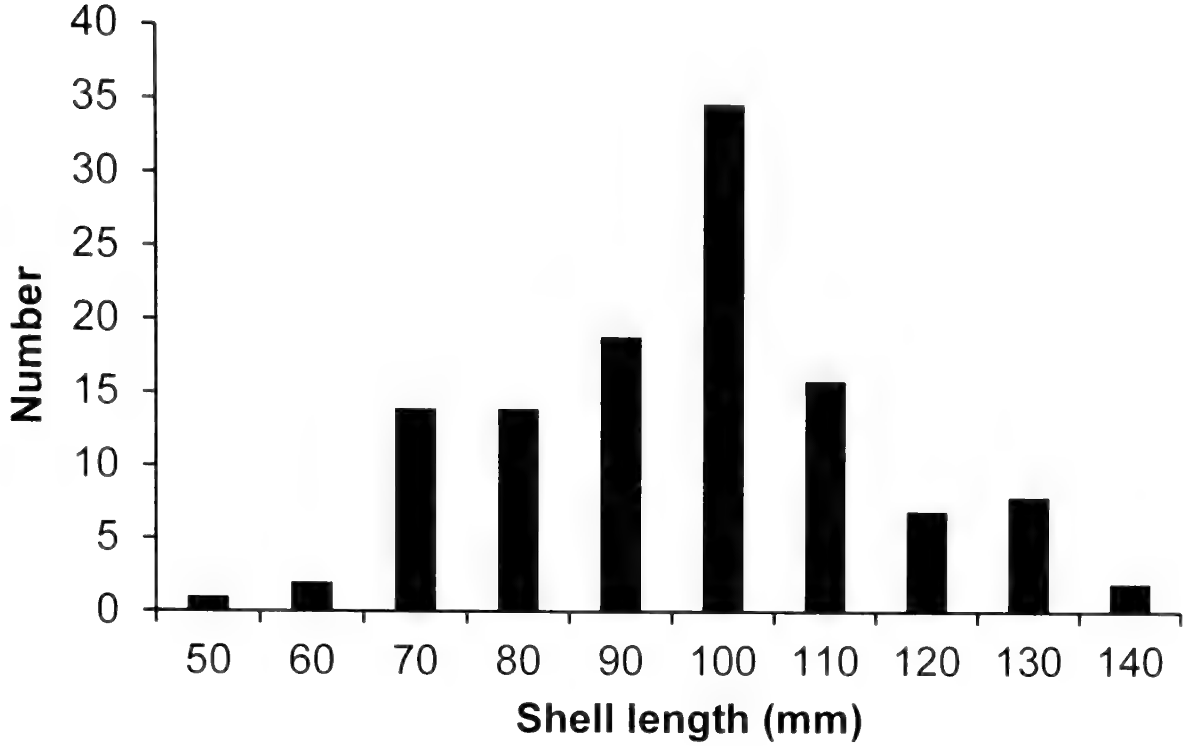

FIGURE 2. Frequency distribution of shell length of the 117 live Giant Floaters (*Pyganodon grandis*) collected from Rondeau Bay, Lake Erie, Ontario, in 2014 and 2015.

sites (89%). Up to 79 g of dreissenids were removed from individual live mussels. The mass ratio of attached dreissenids to live mussel ranged from 0.0009 to 1.393 (median = 0.0422).

Discussion

In this study, shell material from 70% of the species known from the Canadian waters of Lake Erie (Metcalfe-Smith *et al.* 1998) was found, more species than found in previous surveys in Rondeau Bay (Table 2). Except for Cylindrical Papershell (*Anodontoides ferussacianus* (Lea, 1834)), all species previously reported from Rondeau Bay were detected. Before the Zebra Mussel invasion of Lake Erie (about 1989), 15 species had been collected from Rondeau Bay, of which 9 belonged to the tribe Lampsilini. Subsequent sampling identified 9 additional species and suggested that a more balanced representation of species from all 5 tribes was historically present (Table 2). Most (89%) of these new records, however, were associated with weathered shells. The large amount of shell material encountered during this study is likely the result of high mortality of native mussels following the Zebra Mussel colonization of Rondeau Bay (Schloesser *et al.* 1996) and likely offset the poor detectability typical of many freshwater mussel species (Strayer and Smith 2003).

The remaining, depauperate mussel fauna in Rondeau Bay includes small numbers of 3 species-at-risk and 1 abundant species. Mussel diversity and densities are much lower than in important refuges identified in the western basin of Lake Erie and the Lake St. Clair delta (McGoldrick *et al.* 2009; Zanatta *et al.* 2015). The abundance and richness of Rondeau Bay mussels is comparable to assemblages in the large, shallow region of Sandusky Bay and the south shore, central basin Lake Erie wetlands (Zanatta *et al.* 2015).

As reported for other Lake Erie and Ontario coastal wetlands, an abundant Giant Floater population is present in Rondeau Bay. The species' persistence after the Zebra Mussel invasion can be attributed to its opportunistic life history strategy (high fecundity, early age of reproduction, and short life-span; Haag 2012) and its association with habitats, i.e., soft substrates, that are not well suited for Zebra Mussel and allow for native mussels to burrow (Bowers and Szalay 2003; Zanatta *et al.* 2015). Low density populations of mussels at risk have also been detected in north shore Lake Ontario coastal wetlands (Reid *et al.* 2014). However, the viability of such small populations is uncertain. Our study highlights the need for further, intensive sampling of north shore Lake Erie wetlands to document the viability of other remnant populations of mussel species at risk.

TABLE 2. Comparison of Rondeau Bay mussel species collected in 6 surveys between 1894 and 2015. Historical records are from the Canadian Museum of Nature, the University of Michigan Museum of Zoology, the Royal Ontario Museum, and Environment Canada collections.

Common name	1894	1934	1961–65	1988	2001	2014–15
SUBFAMILY AMBLEMINAE						
TRIBE AMBLEMINI						
Three-ridge					L	L
TRIBE LAMPSILINI						
Black Sandshell					W	W
Fawnsfoot				L	W	W
Deertoe			*	L	W	W
Eastern Pondmussel	L	L	*	L	W	L
Fatmucket	L	L	L	L	W	W
Fragile Papershell		L	L	L	W	W
Kidneyshell					W	W
Lilliput						W
Pink Heelsplitter	L	*			W	W
Plain Pocketbook		L	*		W	W
Rainbow		L	*			W
Round Hickorynut						W
Snuffbox	L	*	*		W	W
Threehorn Wartyback					L	W
TRIBE PLEUROBEMINI						
Round Pigtoe			*		W	L
Spike						W
Wabash Pigtoe			L	L	W	W
TRIBE QUADRULINI						
Mapleleaf	L		*		W	L
Pimpleback		*				W
SUBFAMILY UNIONINAE						
TRIBE ALASMIDONTINI						
Creeper						W
Cylindrical Papershell		L				
Flutedshell					W	W
Giant Floater	L	L	L	L	W	L
Total number of species	**6**	**10**	**11**	**7**	**17**	**23**

Note: L = live mussel or fresh whole shell, W = weathered shell or valve, * = no description of material provided with record.

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This research was supported by funding from Environment Canada, Fisheries and Oceans Canada, and the Ontario Ministry of Natural Resources and Forestry. Christine Head, Fielding Montgomery, Mike Parna, Hailey Smith, and Jenna Snelgrove assisted with sampling. The manuscript was improved with comments from 3 anonymous reviewers.

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Book Reviews

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

ZOOLOGY

A Chorus of Cranes

By Paul A. Johnsgard. 2015. University of Colorado Press, Boulder, CO, USA, 80303. 226 pages, 29.95 USD, Paper.

With many high quality color photos by photographer Thomas Mangelsen, this book is far from a coffee table edition. Author Johnsgard, who has written several books on cranes, has updated his 1983 *The Cranes of the World* (Johnsgard 1983) as well as an earlier similarly-titled book by Walkinshaw (1973).

This book focuses primarily on the two North American crane species, the Sandhill Crane (*Grus canadensis*) and Whooping Crane (*G. americana*), but also covers the other 13 species of cranes found in the world. All aspects of the biology and ecology of cranes are covered in this high quality volume.

For readers who are knowledgeable of Johnsgard's work on waterfowl behaviour (Johnsgard 1965), the descriptions and illustrations of crane behavior will be well appreciated. Readers will also appreciate current information on the distribution and conservation status of each species of crane.

Professional readers will find a trove of useful information. One of the best features that sets this book apart from others on cranes and other bird species is the complete bibliography of North American and International Crane Workshops. Other bibliographic listings are provided under the categories of World Surveys and Crane Bibliographies, General Topics and Taxonomic Works, Platte River Valley References, Sandhill Crane References, Whooping Crane References, and References on the Old World Species of Cranes. The bibliographies are relatively complete and up-to-date, as of the time of publication. There is also a listing of internet sites relevant to cranes.

I highly recommend this book for anyone with an interest in cranes. Professionals and students will find this book a good starting point for research on cranes, especially the Sandhill and Whooping Cranes. The bibliographies alone are exceptional sources of literature. Birders and others with a broad interest in birds and nature will find this an enjoyable and informative book about a fascinating group of birds. I have to note as well that *A Chorus of Cranes* can be an attractive book for the coffee table. My copy is there right now beckoning me to pick it up and browse.

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Voices in the Ocean: A Journey into the Wild and Haunting World of Dolphins

By Susan Casey. 2015. Doubleday Canada, 320 Front Street West, Suite 1400, Toronto, ON, Canada, M5V 3B6. 304 pages, 34.00 CAD, Cloth.

Susan Casey has a few titles to her credit, all dealing with ocean ecology and the wildlife of the world's oceans. In this latest work, she is following the research and current status of dolphins, including orcas and other cetaceans. She begins with the good things which we have learned about dolphins: their communication, their disposition towards humans, their fidelity to place and pod or family. Within the general framework of our good interactions with them are numerous stories of dolphins rescuing humans, showing the way to struggling or drowning swimmers unknown to any humans nearby, and their way of detecting human physiological anomalies like pregnant women, handicapped swimmers or situations where the person was cramping or having a heart attack while swimming in the dolphin's vicinity. These stories collected from around the world are legend among those who interact with dolphins, making the emotional connection between marine mammals and the more familiar four-footed land animals. They show that dolphins have at least the same intelligence, self-recognition, ability to problem-solve, and the ability to be individually sensitive to different stresses in their environment.

The second part of the book is all about those different environmental stresses which human intervention imposes on the marine mammal populations. Harvesting of dolphins for food, for pets and for the entertainment industry are documented with specific sites and methods of harvest which have been used in recent decades. Casey is not afraid to name names, whether they be the location of the dolphin slaughter, the theme parks which misuse the animals or the players involved. Canada gets a particularly bad report with regard to Marineland and Gamefarm at Niagara Falls. The treatment of the dolphins, orcas and seals in the waterpark, and the crowding and care of bears and deer in the game paddock, are both harshly criticized. The Canadian and Ontario Government's historical lack of regulation is also explained, as this is a reason for the overcrowding and care limitations that have taken place. Thankfully, she is able to tell us that some regulations for the animals' living conditions have been proposed for legislation.

Different conservation issues for dolphins, whales, orcas and many other marine mammals are documented as the book unfolds. The reader is taken to villages in Japan and the Solomon Islands where dolphin hunting is common, enculturated and quite profitable. It is also shown to be wasteful, cruel to the animals and continued despite many protests. With increased understanding of dolphin and cetacean sensitivities more is understood of how their environment is degraded, invaded and made hostile to the animals living there. Underwater research involving sonar blasts which map the ocean floor are one assault on the sensitive hearing of the animal, so is sonar testing by the US Navy. The effects are ignored by industry, contested by the navy and simply misunderstood by most.

There is much bad news in the book and some good news, as in most environmental reviews. This book is more than an environmental review however, as it also includes stories on the cultural importance of whales and dolphins, including a village in California that has an indigenous connection to the animals, a group in Hawai'i that regularly swims and prays with dolphins and a host of protectors, former dolphin and orca trainers, and island residents who fight the harvest and exploitation of dolphin. Worshippers, protectors and effective managers of the world's cetacean herds are documented for their care and connection to the animals.

I found myself drawn in by the arguments in favour of dolphin and whale protection, horrified by the graphic descriptions of how dolphins are harvested and taken aback by the mistreatment of the animals I have observed with pleasure in aquariums in many parts of the world. The book is an eye-opener and one which is difficult to read due to its graphic content. It ends on a historical and peaceful note of a civilization long forgotten who lived with, prayed with and respected dolphins, as depicted in the art of their towns and buildings. Who is to know what their real relationship was? Our relationship is more tenuous, more consumer-based and still developing. Susan Casey has opened a door in this book, one which shows us fascinating animals and challenges us to look seriously at dolphins, whales, orcas, belugas and any of the other marine mammals in their environment, and their relationships to us.

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Herpetology [Fourth edition]

By F. Harvey Pough, Robin M. Andrews, Martha L. Crump, Alan H. Savitzky, Kentwood D.Wells, and Matthew C. Brandley. 2015. Sinauer Associates Inc., 23 Plumtree Road, PO Box 407, Sunderland, MA, USA, 01375-0407. 591 pages, 99.95 USD, Cloth.

Linnaeus, in the definitive 10th edition of his *Systema Naturae* in 1758, dumped those vertebrates for which he had little regard into his Class Amphibia (which initially included reptiles and several miscellaneous forms), dismissing them all as "foul and loathsome" and concluding that the creator had not bothered to make many of them. This soon proved to be a northern bias. Subsequent attention to the tropics and the recent use of DNA analysis revealed a multitude of species. Current totals are 7,300 amphibians (salamanders and newts, frogs and toads, and caecilians) and 10,000 reptiles (crocodilians, tuataras, lizards and snakes). By contrast, mammals have only about 5,500 species whereas birds total 10,500.

Since Darwin replaced the concept of divine creation of each species with gradual evolution, many group relationships have been revised to reflect changing concepts. Based on recent advances in palaeontology and DNA analysis, birds have been reassigned to "reptiles" by most systematists and, together with crocodilians, are regarded as one distinct evolutionary line. Some now regard turtles as another distinct line, and leave only lizards, snakes, and the tuataras as reptiles. However, Pough and his coauthors argue that the traditional living reptiles share with amphibians dependence on external heat sources, in contrast to birds and mammals which generate heat internally from consumed food. Dependence on external heat sources results in many common patterns in activity and distribution of reptiles and amphibians that justify the traditional combined study of the two groups together (i.e., omitting birds) as herpetology, despite each group's long, separate evolution.

This comprehensive 591-page, 2-column, thought-provoking coffee table book is divided into 17 chapters, addressing four deceptively simple questions: I. What are amphibians and reptiles? (Chapters 1-5), II. How do they work? (6-11), III. What do they do? (12-16), and IV. What are their prospects for survival? (17). Changing perspectives are discussed in Chapter 1 "Why study herpetology?" which emphasizes the diversity of amphibians and reptiles, their shared characteristics, place in terrestrial ecosystems, and their future. Chapter 2 delves into phylogenetic systematics and origins of amphibians and reptiles. Chapters 3 and 4 summarize the systematics and diversity of extant amphibians and reptiles respectively. Chapter 5 outlines the biogeography of both groups. Chapter 6 discusses water and temperature relations, emphasizing thermoregulation, and Chapter 7 energetics and performance, ending with hibernation, aestivation, freeze resistance and tolerance. Chapters 8 and 9 cover reproduction and life histories of amphibians and reptiles, respectively. Chapter 10 focuses on body support and locomotion, Chapter 11 on feeding, Chapter 12 on spatial ecology, 13 on communication, 14 on mating systems and sexual selection, 15 on diets, foraging, and interactions with parasites and predators, and 16 on populations and species assemblages. The wrap–up chapter (17) discusses conservation and the future of amphibians and reptiles, touching on a mix of their declining populations, biodiversity conservation, human perceptions and impact (exotic species introductions, pollution, commerce, hallucinogens, hunting, magic, medicine, pets, use in research and teaching, global climate change and interactions among these). Then patterns of species extinction and extirpation are outlined, leading to discussion of conservation options and declining amphibians as a model issue, and finally the rediscovery of species and de-extinction attempts to revive extinct species from surviving relatives.

A Preface draws attention to the prominent use of colour throughout the 549 illustrations of both animals and concepts in this edition. The range maps use splashes of colour to convey approximations of distributions of groups of species but lacks precision, particularly for those which penetrate into northern Canada.

The text is intended for use in an undergraduate or graduate university course, and also as an information source for hobbyists and naturalists. It presents not just comprehensive coverage with citations to original research and overview papers, but also alternative views in controversial areas and the authors' perspectives and speculations on the future for these animals. It even has flashes of humour, such as the description of a tadpole as "a sieve with a gut attached", and human interest items, like that the origin of the name Tuatara is from the native Maori word for the unique New Zealand lizard-like reptile.

Acknowledgments to the multitude of colleagues for encouragement and their published and unpublished data are given after the listing of contents. Contributors of photographs follow as well as thanks to librarians and publisher's staff and others. Separate sections at the end of the book present (in 3 to 4 columns) an 8-page Glossary of Terms (from acrodont to zygokrotaphy), a 92-page Literature Cited, a 12-page Taxonomic Index, and a 16-page Subject Index.

Each Chapter concludes with a Summary which outlines its main points and gives directions to the *Herpetology* companion website at: sites.sinauer.com/herpetology4e for links to other relevant material. Various options aimed at making the book affordable for a student are available, including the option to purchase the text for limited time periods online at reduced cost.

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Mark Carwardine's Guide to Whale Watching: Britain and Europe

By Mark Carwardine. 2016. Bloomsbury Publishing PLC., 31 Bedford Avenue, London, UK, WC1B 3AT. 272 pages,16.99 GBP, Paper.

Earlier this year I joined the author, Mark Carwardine, on one of his well-organised whale watching trips. Three hundred sightings of seven species of whale, plus thousands of dolphins and seals later, we decided the trip was a great success. With much interest I picked up Carwardine's latest book, a guide to whale watching in an area from Greenland to Novaya Zemlya, and south to the northern coast of Africa.

One third of the book is devoted the 29 species of whales found in this large area. There is a succinct section on the whale's biology. A text box provides the key characteristics used for identifying the mammal to species. A second box covers notable statistics, such as length. A strip called the "surface profile" shows the typical appearance of the whale at the surface. Martin Camm's artwork depicts the classic side view of each species. As Carwardine is an ardent photographer (I vividly remember the "frrrrrp" of the author's professional, high-speed camera at 10 frames/second in my ear as I clicked away one photo at a time) there are plenty of photos.

The bulk of the book is devoted to a detailed guide of what whales you can find along the coastline of the area covered. Altogether 24 countries and special places (Svalbard, the Faeroes) are covered. Each area has an introduction that includes the most common cetaceans and the best places to find them. Seasonality and likelihood are estimated so the reader can plan where and when to go, or what to look for, at key points along the coast.

After the introduction the author discusses each country in the area covered. Because of their position in the open ocean, Madeira, the Canaries, the Azores, the Faeroes, Greenland and Svalbard are treated separately. Generally the best places are headlands that poke out into the sea or offshore islands. Carwardine also includes the ferries that cross the Bay of Biscay, but not the numerous other European ferries. Any location that has whale watching trips is identified, but there are no details (operator's names, costs, etc.) given. (This information can be found on the internet.)

I was a little taken aback by the frequency of the author's detailed coverage of Harbour Porpoise. That was until I remembered a trip a few years ago. I went out for a few hours from Lunenburg, Nova Scotia. We did not see any whales, but the other people on this trip were thrilled by the antics of the Harbour Porpoises (and Grey Seals). Even though I live in the middle of the world's second largest country, I have spent a cumulative five months or more at sea and much more time shore watching, so I have seen these species very often. I do remember my first sighting, as a small child, of the dark shapes of Harbour Porpoise mystically emerging from a cold, grey English Channel – my first cetacean. Harbour Porpoises are often peoples first (and only) encounter with these little "whales".

So I read through the comprehensive accounts, taking special note of places I had been or hoped to go to. Each place has the most likely species to be encountered, with a sense of your chance of actually seeing them. Taking a place like Flamborough Head, UK, I see that it is good for Harbour Porpoises, but there are other species like Minke Whale and White-beaked Dolphins possible. If I had known this I would have lifted my eyes from the sea cliffs and their abundant birds to scan farther offshore.

The species accounts are really good. I particularly like the surface profiles as these silhouettes of backs, fins, spouts and heads are what you typically see first. Identifying whales is a process of adding all the clues together and the surface profile is the first step. Then you can use the identification box to refine your thoughts. Finally, there is a distribution map to show if you are in range. The artwork is very nice, although it is rare to see so much detail. Occasionally, in clear water with the animal close, it will roll on its side and you can glimpse the artist's perspective. The photographs are remarkable. They are taken from the observer's viewpoint so they typically show the best view you can get at the surface – the Sperm Whale's wrinkly skin, the Fin Whale's white chin, Bryde's Whale's nose tracks and so on. I do wonder how many thousand shots of disturbed ocean he threw away to get these gems.

The "Where to Go" section is very detailed. Anyone visiting the European coast should be able to estimate their chances of seeing cetaceans and what species to look for. The accompanying maps are clear and highlight the marine as well as land features. You can also use this section in reverse. If you want to see a specific species – say Risso's Dolphin – the book leads you to the southern Adriatic. I tried to work out the best chance I had to see Narwhal and realised Savissivik, Greenland in summer was the place. I am not sure how I could access this remote village of 70 people, but August sees 3000 Narwhal enjoying the bay.

In the Introduction Carwardine discusses the current plight of whales. For a long time I have had mixed emotions over professionally-run zoos, aquaria and botanical gardens. In my youth it was the only way I could afford to see the wildlife I was reading about. I learned much and, even today, I still read of information obtained in zoos – typically " in captivity … the longevity was … , the gestation period was …", etc. For many years now I have spent more time and money seeing animals and plants in the wild. Yet, I can see how difficult it would be for a typical family to spend the thousands of dollars and time needed to visit whale hotspots like Svalbard and Baja. So is seeing a captive animal a worthwhile experience? I do not know. Carwardine, however, is clearly against keeping cetaceans in captivity and says this is "ethically indefensible". It was much easier for me to agree with his comments on whale hunting, by-catch, overfishing and pollution.

This is a great book for the avid whale watcher and naturalist. It will be a good reference for future trips, both in deciding where to go and when passing through an area, what to see. The photographs are a bonus too.

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Wild Wolves We Have Known: Stories of Wolf Biologists' Favorite Wolves

Edited by Richard P. Thiel, Allison C. Thiel, and Marianne Strozewski. 2013. Second printing 2015. International Wolf Center, Ely, MN, USA. 280 pages, 18.95 CAD, Paper.

I was teeming with excitement at the opportunity to review *Wild Wolves We Have Known: Stories of Wolf Biologists' Favorite Wolves*, given both the topic and the well-known wolf biologists who contributed to this volume (see p. 242-245). The book is a fascinating account of the lives of 23 of the authors' favourite wolves and the packs they were associated with. While every wolf who has ever lived has a story to tell (p. xiv), each chapter focuses on a 'famous' wolf, or at least one well known to the research team and the people following their project.

These stories take place all over the world, but most occur in the United States (Yellowstone National Park in Wyoming, Montana, and Idaho; northern Montana in and around Glacier National Park; Isle Royale National Park in Michigan; Upper Peninsula of Michigan; northern Minnesota; Wisconsin; Red Wolf country in North Carolina; Mexican Wolf habitat in New Mexico, bordering Arizona; and Alaska) and Canada (Waterton Lakes National Park, British Columbia; Algonquin Provincial Park in Ontario; Wood Buffalo Provincial Park in Alberta; Northwest Territories; Yukon Territory; and Ellesmere Island in the High Arctic), with three chapters occurring in Europe (Scandinavia [mostly Sweden]; Spain; and Romania). There is a simple but very informative map on pages iv-v showing these locations. Most of the wolf stories are about Gray Wolves (*Canis lupus*) but one chapter describes a Red Wolf (*Canis rufus*), one an Eastern Wolf (*Canis lycaon*) in Algonquin Provincial Park, Ontario, and one an Eastern Coyote × Eastern Wolf hybrid just outside of Algonquin Park.

Included in the book was a trio of biologists' narratives about 3 different wild wolves from Yellowstone National Park. Rick McIntyre's story of the '06 female' (pronounced oh-six; Chapter 13) especially reverberated with me as I had watched her many times in Yellowstone and include pictures of her and her pack (Lamar Canyon) in my book, *My Yellowstone Experience*.

It takes endless hours of dedication and perseverance in making the observations and putting the pieces of the puzzle together to be able to describe the stories of these popular wolves. The editors of *Wild Wolves We Have Known* – led by Dick Thiel – do an admiral job of organizing these stories into one highly engaging and easy-to-read chronicle. And the book description provides an accurate and concise summary of its contents:

> "Most wolf biologists have encountered hundreds of wild wolves in their careers, and in that process, many have become witness to the intimate lives and fates of a select handful of individuals. Over the years, these biologists have occasionally shared stories of their 'favourite' wolves with one another, often over drinks at the local pub during wolf conferences. Few outsiders have been privy to these stories—until now! This is a remarkable collection of tales spanning the globe, from the earliest studies to the present day. Wild Wolves We Have Known tells the stories of individual wolves through the lenses of those who know them best—the biologists who have studied them. Immerse yourself in the fieldwork; observe the challenges facing the species, and bear witness to the extraordinary resilience of these remarkable wolves."

Also, a 2 min 40 sec video, produced by the International Wolf Center (http://www.wolf.org/learn/basic-wolf-info/in-depth-resources/books-and-videos-about-wolves/wild-wolves-we-have-known/), provides an excellent visual summary to this volume.

One can glean from reading this book that it is about the best of the best wolves these researchers have studied. Of course that is a relative and subjective description, but usually these creatures did have a disproportionate impact in the data that they provided to the researchers studying them, let alone the rewarding, intimate experiences they were able to gain from these animals. This book, by its very nature, is highly personalized as it is about individual wolves. I have been criticized for being too subjective and emotional when I wrote my first book, *Suburban Howls* (www.EasternCoyoteResearch.com), on Eastern Coyotes or Coywolves as they are now also called (Canadian Field-Naturalist, 2013, 127(1): 1–16). Appendix 1 (p. 245-255) of *Suburban Howls*, titled "Coyotes We Have Known", provides a summary to all of the study subjects who contributed to my observations. Additionally, in Appendix 10 (p. 267-270), "Ode to Casper, the Survivor", I provided a four-page tribute to an amazing, wolf-sized (55 pounds; also see Canadian Field-Naturalist, 2005, 119(1): 139-140) female Eastern Coyote/Coywolf that I studied for a decade on Cape Cod, Massachusetts. The stereotypical response from state wildlife managers to these sections was "biologists aren't supposed to write like that" when ascribing names and even feelings to some of my study subjects, even though I also scientifically documented the importance of some of those animals (e.g., Canadian Field-Naturalist, 2008, 122(4): 316-322 and Canadian Field-Naturalist, 2007, 121(4): 397-401). Given this backdrop, it probably isn't all too surprising that the title of *Wild Wolves We Have Known* immediately resonated with me given the similar focus, not on populations, but individual animals. While often frowned upon by wildlife agencies that are seemingly stuck in the old-school thought of focusing on populations, the heart of a growing new field, called Compassionate Conservation (Biological Conservation, 2013, 158: 422-423), emphasizes the importance of individuals. After all, it is a collection of individuals that comprise a population! While I don't think the intention of the authors of *Wild Wolves We Have Known* was to promote this new discipline, I get the definite sense that the general public really responds to these individual stories (I know I did!), which will ultimately help push wildlife managers to consider the lives of individuals, especially predators, in their management. I kept casual note of the word individual as I read *Wild Wolves* and found it mentioned on pages vii, ix, x, xii, xiv, 14, 15, 21, 131, 141, 147, 157, and 193, not to mention the fact that every chapter focused on specific wolves.

Within the book's 280 pages are 16 delightful color plates (totaling 36 pictures) that literally bring these wolves to life. Here we see what many of these wolves look like including 'Old Two Toes' (his tracks) of Wisconsin; wolf 192 of the Bechler Pack in Yellowstone; Superior National Forest, Minnesota female wolf 2407; Montana wolf 'Sage'; Alaska's Step Mountain Pack's white female 175; Tundra Wolves in the Northwest Territories; 'Ole Gimpy' of Wood Buffalo National Park, Alberta; Mexican Wolf 'Bob' in Gila National Forest, New Mexico; pups of wolf 797 in New Mexico; Mexican Wolf male 973; wolf 475 of Wisconsin's dog-killing Shanagolden Pack; Scandinavian wolf 'Ulrik'; huge Delta Pack male 760 in Yellowstone; Eastern Wolf × Coyote hybrid canid 49-09; Red Wolf 344; 'Big Al, The Little Gal' of Wisconsin's Bootjack Pack; 'Old Gray Guy' of Isle Royale National Park; and the Spanish wolf 'Ernesto'. A picture of my favorite wolf, the '06 female', was not shown in this section. In the color plate section, we also get to see some of the wolf biologists themselves in a few of these pictures. As the above section illustrates, certain biologists were comfortable naming their study wolves while others stuck to strict scientific protocols of assigning numbers. I appreciated the authors who were bold enough to name their research subjects.

Certain book chapters focused solely on the wolves themselves while others included the animals as well as the people living in the wolves ranges. Some of the authors were very forthcoming about how irrational some of the anti-wolf people they encountered were (such as p. 97 &103 in New Mexico), while others chose to stay out of politics. Simply put, I loved this book. I can't recommend it enough and believe that readers interested in nature, carnivores, and individual animals will be fascinated by these wolves as well. It is a very unique perspective, not just on wolves, but on animals in general, because of its focus on individuals. The paperback contained only minor grammatical errors and is really easy to read as each chapter stands alone. I hope that the editors consider publishing a 2nd volume of wolf stories in the future as I enjoyed this edition so much!

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OTHER

"The Real Thing". The Natural History of Ian McTaggart Cowan

By Briony Penn. 2015. RMB/Rocky Mountain Books Ltd., 1075 Pendergast Street, Victoria, BC, Canada, V8V 0A1. 640 pages, 30.00 CAD, Paper.

Ian McTaggart Cowan was a big man, both physically and professionally. He lived almost one hundred years, prominent as a naturalist, teacher and conservationist, so a book about him and his doings could not be a 'slim volume'. *"The Real Thing"* is a big book, and it will not be the last on one of Canada's major figures in his field. As explained in the Preface, the author originally planned a short biography, but Cowan had prepared his voluminous notes and reports of fauna and flora for 'educational' use. The combined result is massive, 460 pages of text, data-rich and small-print, buttressed by over 1700 'notes' (citations and sources) and other appended listings.

The 'main' title – short and 'catchy', as urged by publishers – may need 'up-front' explanation. That name was quoted (pp. 114 & 457) as if referring to Cowan as a person – who knew everything related to his subject and who was expert at everything. That's reasonable, but after reading the book, I wondered if that title had been intended for the whole field of 'nature and conservation', that absorbed Cowan's life? Most of the content (to p. 437) seemed better described by the sub-title *The Natural History of Ian McTaggart Cowan*. Only the final chapter dealt mainly with his 'working for wildlife' as expert and administrator, though various 'flash-aheads' scattered throughout the text treated later activities on topics discussed mainly in time-sequence.

The text reads well, and anyone who reads it all will learn a lot about Cowan and the fauna and flora of British Columbia and nearby regions. Assembling the many photographs was a triumph of archiving that will be appreciated. A few more illustrations of major habitats might help readers who haven't already toured widely in British Columbia. The sheer volume and 'density' of the text may deter some interested readers from cover-to-cover reading. That would be a pity, as the 'big picture' that emerges – of data collection, interpretation, teaching, conservation – is extremely instructive. The many interactions with people – family, teachers, country-folk, professionals – are punctuated by many (perhaps too many?) quotes from letters, publications, and interviews. One would have to write another book to review the content in detail!

One quote (p. 451) stating that Cowan's family was 'always number one' may have described the situation at that date (1954?). It seemed questionably applicable during the preceding 25 years of travel for data collection and analysis. His having a family devoted to the works that made up his career was indisputably a great – and appreciated – support to him. As noted by the author (p. xiv), "Writing about Ian McTaggart Cowan can border on hagiography at times".

I had few and minor criticisms:

(1) Some dates in the Chapters do not follow the dates indicated in the sections of the book. For

example, Part 1 covers the period 1910 – 1920, but Chapter 3 within this section covers the period 1923–1925.

(2) On p. 141, field work on Mandarte Island (referring to all or perhaps only the Song Sparrow studies) was credited to Tompa and Smith, starting in 1959; however, seabird work begun by Van Tets and Drent in 1957-58 also continued during this time.

(3) Cowan's field party reached Chezacut 23 July 1931, when "Buffleheads are back in their tree nests" (p.157); all Bufflehead nests should have fledged weeks earlier.

Most of Cowan's work was in British Columbia, with shorter but important periods in other western coastal and mountain habitats. His students later ranged much more widely, and his teaching carried weight in conservation across Canada – but much of the fauna and flora of BC are uniquely distinct from those of most of Canada. That geographic distinction might have deserved some recognition.

Existence and influence of the "B" (see p.xiv, and later) was completely new to this reviewer, though easily believable. My impression – from this book – was that the "B" focussed on (relatively undisturbed) 'wilderness', that by Cowan's time was already limited to far western, boreal, or arctic regions. Had the "B" really written off most of Canada – and USA – as 'beyond saving' by then?

My most serious criticism is of the 'side-bars'. In the copy I received, those were unsatisfactory. Many side-bar images were too faint to be informative – some unidentifiable – and often with too little text to help people who didn't know a species already. Side-bars, common in popular magazines, were perhaps thought 'to enhance the educational value' of the book; if so, they were unsuccessful (in my judgment). Their space (many pages in all) could have been better used.

In summary, *"The Real Thing"* is a very thorough compilation and interpretation of the work of a notable and very long-lived individual. Its completeness may make it difficult to read from start to finish, but dipping into particular chapters should be helpful for those not up to a complete "read". My personal acquaintance with "Dr. Cowan" (as I always thought of him) was limited to 1957-60, but I have no hesitation in recommending this book to those who want to know more of him and his work.

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned
Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, GBP British Pound

ZOOLOGY

The Arctic Guide: Wildlife of the Far North. By Sharon Chester. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 544 pages, 27.95 USD, Paper.

Handbook of Bird Biology, 3rd Edition. By Cornell Laboratory. 2016. Wiley-Blackwell, 90 Eglinton Avenue East, Suite 300, Toronto, ON, Canada, M4P 2Y3. 705 pages, 142.95 CAD, Cloth.

Britain's Treasure Islands – UK Overseas Territories. By Stewart McPherson. 2016. Redfern Natural History Productions, 61 Lake Drive, Hamworthy, Poole, Dorset, UK, BH15 4LR. 704 pages, 29.99 GBP, Cloth.

Rainbow Dust: Three Centuries of Delight in British Butterflies. By Peter Marren. 2015. Penguin Random House, Canada Office, 320 Front Street West, Suite 1400, Toronto, ON, Canada, M5V 3B6. 320 pages, 35.00 CAD, Cloth.

Wildlife of the Galápagos: Second Edition. By Julian Fitter, Daniel Fitter, and David Hosking. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 272 pages, 19.95 USD, Cloth.

Wildlife of Madagascar. By Ken Behrens, and Keith Barnes. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 272 pages, 27.95 USD, Paper.

Handbook of the Mammals of the World – Volume 6 – Lagomorphs and Rodents I. Edited by Don E. Wilson, Thomas E. Lacher Jr., and Russell A. Mittermeier. 2016. Lynx Edicions, Montseny, 8, E-08193 Bellaterra, Barcelona, Spain. 160.00 EUR, Cloth.

A Natural History of the Sonoran Desert. By Steven John Phillips, and Patricia Wentworth Comus. 2015. University of California Press, 155 Grand Avenue, Suite 400, Oakland, CA, USA, 94612–3758. 590 pages, 39.95 USD, Paper.

The Birder's Guide to Vancouver and the Lower Mainland – Revised and Expanded Edition. By Nature Vancouver (Vancouver Natural History Society). 2016. Harbour Publishing, PO Box 219, Madeira Park, BC, Canada, V0N 2H0. 272 pages, 26.95 CAD, Paper.

Waterfowl of North America, Europe, and Asia: An Identification Guide. By Sébastien Reeber. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 656 pages, 45.00 USD, Cloth.

* **Mark Carwardine's Guide to Whale Watching: Britain and Europe.** By Mark Carwardine. 2003. Bloomsbury Publishing PLC., 31 Bedford Avenue, London, UK, WC1B 3AT. 272 pages, 16.99 GBP, Paper.

Wild Mammals of Wyoming and Yellowstone National Park. By Steven W. Buskirk. 2016. University of California Press, 155 Grand Avenue, Suite 400, Oakland, CA, USA, 94612–3758. 456 pages, 85.00 USD, Cloth.

BOTANY

Advances in Plant Breeding Strategies: Breeding, Biotechnology and Molecular Tools. Edited by J.M. Al-Khayri, S.M. Jain, and D.V. Johnson. 2015. Agritech Publications, PO Box 255, Shrub Oak, NY, USA, 10588. 656 pages, 179.00 USD, Cloth.

* **Flora of Florida – Volume II: Dicotyledons, Cabombaceae Through Geraniaceae.** By Richard P. Wunderlin, and Bruce F. Hansen. 2016. University Press of Florida, 15 NW 15th Street, Gainesville, FL, USA, 32611. 400 pages (not illustrated), 69.95 USD, Cloth.

* **Flora of Florida – Volume III: Dicotyledons, Vitaceae Through Urticaceae.** By Richard P. Wunderlin, and Bruce F. Hansen. 2016. University Press of Florida, 15 NW 15th Street, Gainesville, FL, USA, 32611. 344 pages (not illustrated), 69.95 USD, Cloth.

* **Keys to Lichens of North America - Revised and Expanded.** By Irwin M. Brodo. 2016. Yale University Press, 302 Temple Street, New Haven, CT, USA, 06511-8909. 424 pages, 30.00 USD, Paper.

Medicinal and Aromatic Plants of the World, Scientific, Production, Commercial and Utilization Aspects. Edited by A. Máthé. 2015. Agritech Publications, PO Box 255, Shrub Oak, NY, USA, 10588. 460 pages, 179.00 USD, Cloth.

Biotechnology of Plant Secondary Metabolism – Methods and Protocols. Edited by A.G. Fett-Neto. 2016. Agritech Publications, PO Box 255, Shrub Oak, NY, USA, 10588. 180 pages, 119.00 USD, Cloth.

Pacific Seaweeds – Updated and Expanded Edition. By Bridgette Clarkston, and Louis Druehl. 2016. Harbour Publishing, PO Box 219, Madeira Park, BC, Canada, V0N 2H0. 320 pages, 24.95 CAD, Paper.

Somatic Embryogenesis in Ornamentals and Its Applications. Edited by A. Mujib. 2016. Agritech Publications, PO Box 255, Shrub Oak, NY, USA, 10588. 267 pages, 159.00 USD, Cloth.

OTHER

Field Guide to Economics for Conservationists. By Brendan Fisher, Robin Naidoo, and Taylor Ricketts. 2015. Macmillan Learning, 211 E 7th Street, Suite 400, Austin, TX, USA, 78701. 208 pages, 47.99 USD, Paper.

The Serengeti Rules: The Quest to Discover How Life Works and Why It Matters. By Sean B. Carroll. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 280 pages, 24.95 USD, Cloth.

News and Comment

The Canadian Herpetologist (TCH) 5(2), Fall 2015

The Canadian Herpetologist (TCH) is a publication produced twice each year by the Canadian Association of Herpetologists and the Canadian Amphibian and Reptile Conservation Network.

CONTENTS: Executive Members of Societies — Instructions for Authors — Editorial Notes —Meetings — Feature Articles: Tales of Blue Tails: Over 25 Years of Five-lined Skink Research in Southwestern Ontario *by S. Hecnar, D. Brazeau, and D. Hecnar* — Field Notes — 2015 Spiny Softshell Turtle Recovery along the Thames River *by S. Gillingwater*; Recovering Massasaugas in Canada's Carolinian Zone *by J. Choquette*; Scales Nature Park and Georgian Bay Turtle Hospital Field Projects Update *by J. Hathaway*; Shaping the Future of Queensnake Conservation in Canada: A Collaborative Approach *by A. Edelsparre and J. McCarter* — Thesis Abstracts in Canadian Herpetology: **Basaraba, N.R.C.** M.Sc. 2014. Thompson Rivers University, Kamloops, BC. (Supervisor: K.W. Larsen) — **Bennett, A.M.** Ph.D. 2014. Trent University, Peterborough, ON. (Supervisor: D. Murray) — **Colley, M.** M.Sc. 2015. Laurentian University, Sudbury, ON. (Supervisors: J. Litzgus and S. Lougheed) — **Garner, J.L.** M.Sc. 2013. Thompson Rivers University, Kamloops, BC. (Supervisor: K.W. Larsen) — **Gosline, J.A.** M.Sc. 2015. Thompson Rivers University, Kamloops, BC. (Supervisor: K.W. Larsen) — **Lomas, E.** M.Sc. 2013. Thompson Rivers University, Kamloops, BC. (Supervisor: K.W. Larsen) — Recent Publications in Canadian Herpetology — News and Announcements — Membership Form.

Upcoming Meetings and Workshops

Society of Wetland Scientists Meeting

The Society of Wetland Scientists meeting to be held 31 May–4 June 2016 at the American Bank Center, Corpus Christi, Texas. Registration is currently open. More information is available at http://swsannualmeeting.org/.

Entomological Society of America – North Central Branch Meeting

The 71st annual meeting of the North Central Branch of the Entomological Society of America to be held 5–8 June 2016 in Cleveland, Ohio. Registration is currently open. More information is available at http://www.entsoc.org/northcentral/2016-north-central-branch-annual-meeting.

Conference on Great Lakes Research

The 59th annual Conference on Great Lakes Research to be held 6–10 June 2016 at the University of Guelph, Guelph, Ontario. The theme of the conference is: 'Great lakes solutions: integrating across disciplines and scales'. More information is available at http://iaglr.org/iaglr2016/.

American Society of Mammalogists Annual Meeting

The 96th annual meeting of the American Society of Mammalogists to be held 24–28 June 2016 at Twin Cities campus of the University of Minnesota, Minnesota, Minneapolis. Registration is currently open. More information is available at http://conferences.k-state.edu/mammalogists/.

Canadian Society of Ecology and Evolution Annual Meeting

The 11th annual meeting of the Canadian Society of Ecology and Evolution to be held 7–11 July 2016 at Memorial University, St. John's, Newfoundland. The theme of the conference is: 'From windswept land to spindrift swirl'. More information is available at http://www.csee2016.com/.

North American Congress for Conservation Biology

The 3rd biennial North American Congress for Conservation Biology to be held 17–20 July 2016 at the Monona Terrace Community and Convention Center, Madison, Wisconsin. The theme of the conference is: 'Communicating science for conservation action'. Registration is currently open. More information is available at http://www.scbnacongress.org/.

Phycological Society of America Annual Meeting

The 70th annual meeting of the Phycological Society of America to be held 24–30 July 2016 at John Carroll University, Cleveland, Ohio. More information is available at http://www.psaalgae.org/meetings/2016/7/31/psa-annual-meeting-cleveland-oh.

Botany 2016

Botany 2016 to be held 30 July–3 August 2016 at the International Trade and Convention Center, Savannah, Georgia. Registration is currently open. More information is available at http://2016.botanyconference.org/.

International Marine Conservation Congress

The International Marine Conservation Congress to be held 30 July–3 August, 2016 in St. John's, Newfoundland. Registration is currently open. More information is available at http://conbio.org/mini-sites/imcc-2016.

Annual Conference of the Animal Behavior Society

The 53rd annual conference of the Animal Behavior Society to be held 30 July–3 August 2016 at the University of Missouri, Columbia, Missouri. Registration is currently open. More information is available at http://www.animalbehaviorsociety.org/2016/index.php.

Book Reviews

The Canadian Herpetologist (TCH) 5(2), Fall 2015

Upcoming Meetings and Workshops
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THE CANADIAN FIELD-NATURALIST **Volume 130, Number 1** **2016**

(continued on inside back cover)

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Volume 130, Number 2

April–June 2016

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

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

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The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: Harlequin Duck (*Histrionicus histrionicus*) scavenging Red Sea Urchin (*Mesocentrotus franciscanus*) fragments from a foraging Sea Otter (*Enhydra lutris*) 5 February 2014, Calvert Island, BC. See article in this issue pages 91–98 by Erin Rechsteiner and Angeleen Olson. Photo: Erin Rechsteiner.

The Canadian Field-Naturalist

Volume 130, Number 2 April–June 2016

Harlequin Ducks (*Histrionicus histrionicus*) Scavenge Sea Urchin Fragments from Foraging Sea Otters (*Enhydra lutris*)

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Rechsteiner, Erin, and Angeleen Olson. 2016. Harlequin Ducks (*Histrionicus histrionicus*) scavenge sea urchin fragments from foraging Sea Otters (*Enhydra lutris*). Canadian Field-Naturalist 130(2): 91–98.

Foraging animals may risk association with potential predators to obtain otherwise inaccessible prey. We observed this strategy in wintering Harlequin Ducks (*Histrionicus histrionicus*) scavenging fragments of Red Sea Urchins (*Mesocentrotus franciscanus*) from foraging Sea Otters (*Enhydra lutris*) that were re-occupying an area from which they had been ecologically absent since about 1850. Harlequin Ducks, like other sea ducks, have not previously been reported scavenging from other birds or mammals. In British Columbia, Red Sea Urchins have reached large sizes and densities since the removal of Sea Otter predators by the marine fur trade in the 18th and 19th centuries. Observations of Sea Otters and Harlequin Ducks were made in 4 areas, spanning a time gradient of Sea Otter occupation from 1 to 5 years. During 3 months of observations (December 2013 – February 2014), Harlequin Ducks were associated with foraging Sea Otters only at sites that were recently occupied by Sea Otters (≤ 2 months), where the proportion of urchins in Sea Otter diets was highest and where the ducks acquired urchin fragments from foraging Sea Otters. We suggest that Sea Otters re-occupying their historic range and consuming predominantly large Red Sea Urchins provide a temporarily available prey subsidy for Harlequin Ducks. Our observations document a novel effect of Sea Otters providing important prey supplementation to a marine bird when foraging in urchin-rich habitats, contributing to the overall role of Sea Otters as a keystone species.

Key Words: Sea Otters; *Enhydra lutris*; sea ducks; Harlequin Ducks; *Histrionicus histrionicus*; Red Sea Urchins; *Mesocentrotus franciscanus*; prey subsidies; prey availability; wintering habitat; nearshore ecology; British Columbia

Introduction

Foraging theory predicts that efficiency declines with length of time spent searching for and capturing prey (Stephens and Krebs 1986). Predators can influence the foraging success and strategies of other species by providing access to food items they would otherwise be unable to obtain (Brockman and Barnard 1979). Food stealing and scavenging behaviours are widespread among all taxa, but are particularly prevalent in species with high cognitive ability, such as birds (Morrand-Ferron *et al.* 2007). Low food availability (Oro 1996) or poor foraging technique, for example among juveniles (Skórka and Wójcik 2008), can increase the tendency for an animal to scavenge or steal food from a predator. For example, ravens scavenge at wolf kills in winter when food availability is otherwise low and the birds' energetic demands are greatest (Stahler *et al.* 2002). Diving birds or mammals can attract non-diving or shallow-diving species when they bring deep-dwelling prey items to the surface (Brockman and Barnard 1979); for example, Slender-billed Shearwaters (*Ardenna tenuirostris*) scavenge fish scraps from Steller Sea Lions (*Eumetopias jubatus*) at the surface (Ryder 1957). Such scavenging and food stealing behaviour can increase foraging efficiency (Brockman and Barnard 1979), especially when predators make inaccessible prey items available.

Sea Otters (*Enhydra lutris)* are marine carnivores that regularly dive to depths of 40 m to forage on benthic invertebrates (Riedman and Estes 1990; Bodkin *et al.* 2004; Tinker *et al.* 2008). Sea Otters eat and handle prey at the surface, typically while floating on their back, a behaviour that could make subtidal prey more visible and accessible to shallow or non-diving scavengers. Birds including Bald Eagles (*Haliaeetus leucocephalus*; Watt *et al.* 1995) and gulls (Family Laridae; Fisher 1939) are known to scavenge or steal prey items from Sea Otters. The diets of gulls and eagles differ between areas with and without Sea Otters due to changes induced by Sea Otters in the community structure of kelp forest ecosystems (Irons *et al.* 1986; Anthony *et al.* 2008). In Alaska, Sea Otters may directly compete

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with sea duck populations, including eider ducks and scoters by consuming the same benthic invertebrate prey (Terborgh and Estes 2010). Associating with Sea Otters may be high-risk behaviour for some bird species because Sea Otters have occasionally been observed catching and killing waterfowl (Riedman and Estes 1990).

Sea Otters were extirpated from British Columbia in a commercial fur trade that started in the late 1700s (Kenyon 1969). The last known Sea Otter in the province was killed in 1929 (Cowan and Guiguet 1960). From 1969 to 1972, Sea Otters were reintroduced to the west coast of Vancouver Island (Bigg and MacAskie 1978), and since then, have expanded their range along much of the British Columbia coast (Nichol *et al.* 2015). Range expansion in Sea Otters occurs when groups of male otters relocate to the periphery of the range where, in the absence of Sea Otter predation, invertebrate prey have grown large and abundant (Lafferty and Tinker 2014). At newly occupied sites, Sea Otters consume primarily sea urchins, which in British Columbia are the large, Red Sea Urchin (*Mesocentrotus franciscanus*; Breen *et al.* 1982; Ostfeld 1982; Watson and Estes 2011; Honka 2014). Red Sea Urchins are brightly coloured and may be conspicuous to a suite of visual predators, including seabirds and ducks, when brought to the surface by Sea Otters.

Sea ducks are known to be responsive to novel or episodic food sources (Wormington and Leach 1992; Rodway *et al.* 2003; Lacroix *et al.* 2005). However, there are no observations of sea ducks obtaining food by scavenging, although this has been observed in other waterfowl groups (Walter and Becker 1997; Garthe and Hüppop 1998). In British Columbia, Harlequin Ducks (*Histrionicus histrionicus*) winter in nearshore, coastal areas (Iverson *et al.* 2004; Iverson and Esler 2006) and migrate in spring to freshwater streams to breed and nest. During winter, Harlequin Ducks feed intensely to meet the costs associated with maintenance and thermoregulation (Goudie and Ankney 1988) and to attain optimal body mass needed for successful reproduction (Bond and Esler 2006; Esler and Bond 2010). In wintering habitats, Harlequin Ducks eat small intertidal invertebrates, such as snails, crabs, amphipods, and limpets, which they obtain by head-dipping and shallow diving (Vermeer 1983; Gaines and Fitzner 1987; Rodway and Cooke 2002; Bond and Esler 2006; Esler and Bond 2010).

In this paper, we describe our observations of Harlequin Ducks scavenging from Sea Otters. This is the first observation that we know of to document scavenging behaviour in Harlequin Ducks and a commensal association between Harlequin Ducks and a carnivore. We suggest that the opportunity to scavenge food was made possible by Sea Otters re-occupying subtidal rocky habitat in the same area as wintering Harlequin Ducks, and the sudden availability of fragmented Red Sea Urchin prey at the sea surface. We further suggest that, when Sea Otters occupy areas of high sea urchin density, they can provide a temporarily available prey subsidy to Harlequin Ducks.

Study Area

We conducted foraging observations of Sea Otters from December 2013 to February 2014 on the west coast of British Columbia, Canada. We established 4 sites (Figure 1) varying in terms of time since Sea Otter re-occupation from 1 newly established site (as of January 2014) to sites of longer occupation times, ranging from 6 months to 5 years. All sites were located in the nearshore environment. Because of weather conditions and accessibility, most of our observations were conducted at sites occupied for 6 months or less.

Methods

Foraging observations

We used a 50–80× magnification Questar telescope to determine the number, size, and species of prey a Sea Otter collected on each foraging dive (see also Watt *et al.* 2000; Bodkin *et al.* 2001; Dean and Jewett 2001; Tinker *et al.* 2008 for description of the methods). Sea Otters typically forage by diving successively for prey items. Focal animals were observed over a sequence of foraging dives, which is referred to as a foraging bout. We drew or photographed nose scar patterns of focal Sea Otters (Gilkenson *et al.* 2007) to avoid repeated observations of the same individual throughout our study period.

Foraging bouts ranged from 1 to 36 dives. Observations stopped if the Sea Otter stopped foraging, the observer lost sight of the Sea Otter, or after 1 hour of observation of an individual Sea Otter. The proportion of each prey type brought to the surface in each foraging bout was calculated by dividing the number of a specific prey (e.g., Red Sea Urchin) brought to the surface during a foraging bout by the total number of prey items of all types brought to the surface during the bout. For each foraging bout observed, we recorded whether Harlequin Ducks were present (within 1 Sea Otter body length) or absent and, when present, whether they consumed Sea Otter prey scraps (Figure 2). The maximum number of Sea Otters observed at the study site was recorded each day.

Data analysis

Sea Otter occupation time is known to have a negative relation with sea urchin abundance, as Sea Otters remove urchins from the habitat (Estes *et al.* 1982; Ostfeld 1982; Tinker *et al.* 2008; Honka 2014). To explore the effect of Sea Otter occupation time on the number of urchins consumed in Sea Otter diets, we used a non-parametric Kruskal–Wallis test to determine significant differences in the mean proportion of urchin consumed in foraging bouts among sites. We explored occupation time to establish whether the proportion of urchins declined as occupation time increased — as in other studies — and if so, whether we could assume

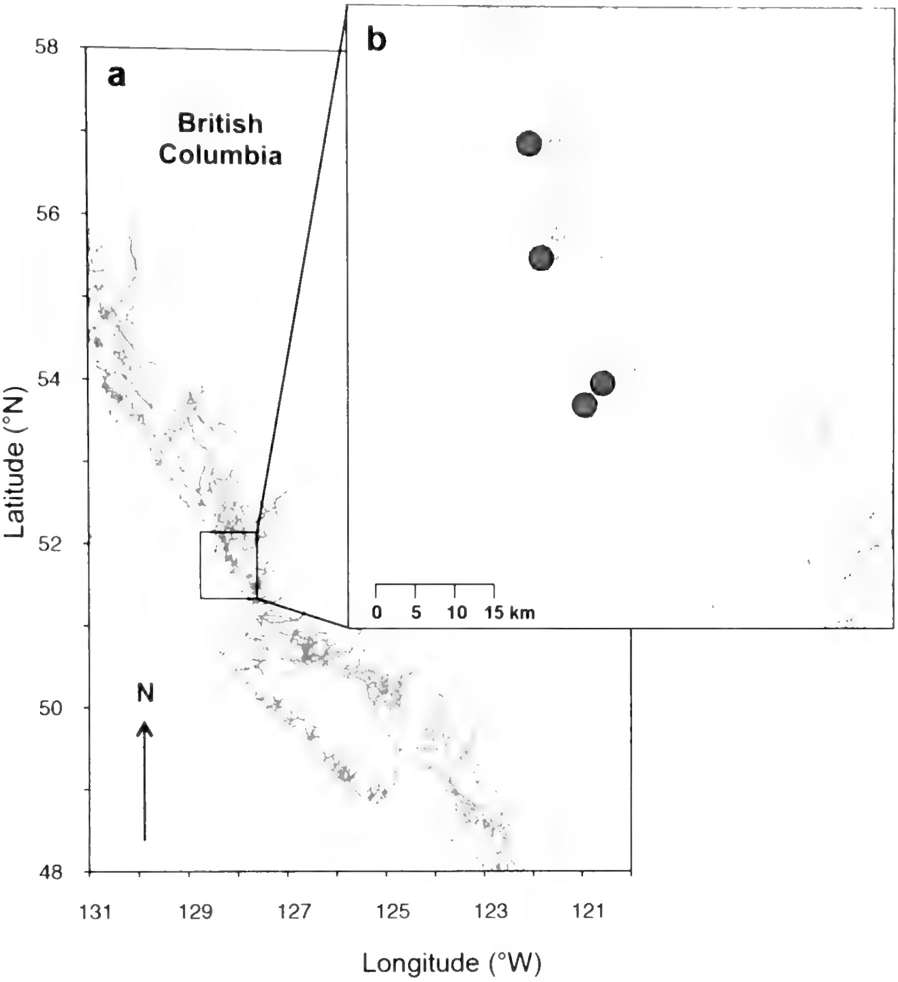

FIGURE 1. The coast of British Columbia (a), and study sites (grey circles in b). From north to south, Sea Otters (*Enhydra lutris*) arrived at these sites in 2009, 2011, January 2014, and July 2013.

FIGURE 2. Sea Otter (*Enhydra lutris*) off the west coast of British Columbia, with Harlequin Duck (*Histrionicus histrionicus*) nearby consuming Red Sea Urchin (*Mesocentrotus franciscanus*) fragments made accessible by the Sea Otter. Photo: Erin Rechsteiner.

that the availability of sea urchin scraps to Harlequin Ducks occurs where urchins are large and abundant, but not when Sea Otters are foraging in locations where urchins are small and few. In this regard, time since Sea Otter occupation was used as a surrogate for the condition of urchin beds rather than an effect in and of itself.

We investigated the importance of both the proportion of sea urchins in the diet and the abundance of Sea Otters in the study area on the scavenging behaviour of Harlequin Ducks. We explored these 2 variables because Harlequin Ducks were only observed interacting with Sea Otters when the otters brought sea urchin prey to the surface (i.e., the ducks ignored the otters when other prey types were brought to the surface) and, where we saw more Sea Otters foraging in an area, there was a concurrent increase in large, brightly coloured sea urchin tests floating at the sea surface, that resulted in an obvious visual cue which may have, in part, attracted the ducks.

Results

We observed 1207 dives in 122 Sea Otter foraging bouts (Table 1). Prey types brought to the surface by foraging Sea Otters were predominantly sea urchins, turban snails, clams, and crabs, and Sea Otter diets differed among sites (Figure 3). The mean proportion of sea urchins in Sea Otter diets differed significantly among sites ($\chi^2 = 52.72$, $P < 0.001$) and was highest at sites recently colonized by Sea Otters, where urchins were presumably abundant (Figure 3).

Although Harlequin Ducks were present at all four sites, they were only observed scavenging Sea Otter prey fragments at Choked Pass, where the proportion of Red Sea Urchin in the diet was highest (0.68). When Harlequin Ducks were present at other Sea Otter sites, they did not interact with the otters. At Choked Pass, Harlequin Ducks scavenged from Sea Otters in 16% of foraging bouts. The number of ducks present during a foraging bout ranged from 1 to 10 (mean 1.9, standard error 0.32, $n = 12$). Harlequin Ducks were only observed to interact with Sea Otters when they brought sea urchins to the surface and the ducks did not scavenge any other prey types.

We found evidence that both the proportion of Red Sea Urchins brought to the surface and the number of Sea Otters counted at the foraging sites may be important in predicting the scavenging behaviour of the Harlequin Ducks (Figure 4). Harlequin Ducks were more often present when the proportion of sea urchin in an individual Sea Otter's foraging bout was high (median 0.88; Figure 4) and were more often present when the number of Sea Otters in the study area was high (median 63; Figure 4).

Discussion

In this study, we observed overwintering Harlequin Ducks scavenging on scraps of Red Sea Urchin generated by foraging Sea Otters. Our observations suggest that a high abundance of Sea Otters with a high proportion of Red Sea Urchin in their diets provide an opportunity for opportunistic scavenging by Harlequin Ducks. Harlequin Ducks only scavenged urchin scraps and did not interact with Sea Otters consuming other prey types. From our observations, Red Sea Urchins, being large and brightly coloured, provided obvious visual cues. We could typically spot a Red Sea Urchin at the sea surface immediately before our focal Sea Otter resurfaced, whereas other prey items of Sea Otters were rarely as large or as brightly coloured. Because Harlequin Ducks are visual predators, we suspect the ease of observing sea urchin prey would have attracted the ducks to high densities of foraging otters that were focused on urchins. Harlequin Ducks were most often present on foraging bouts where otters brought up a majority of Red Sea Urchins on successive dives (median 0.88 proportion urchin in a foraging bout) and ducks were typically absent on dives where the proportion of urchin was lower (median 0.23 proportion urchin in a foraging bout). Our observations suggest that Sea Otters re-occupying historic habitat where Red Sea Urchins are large and plentiful provide an important, but temporary, prey subsidy to Harlequin Ducks.

As Sea Otters expand into new habitat they forage on large and abundant prey, usually sea urchins (Estes and Palmisano 1974; Breen *et al.* 1982; Ostfeld 1982; Laidre and Jameson 2006; Tinker *et al.* 2008; Watson and Estes 2011; Honka 2014). Range expansion often

TABLE 1. Level of foraging activity by Sea Otters (*Enhydra lutris*) observed at each study site on the west coast of British Columbia from December 2013 to February 2014.

Site	Occupation time, years	No. dives	No. bouts	Dives/bout, mean ± SE	No. otters, mean ± SE
Choked Pass	0.17	727	77	9.4 ± 0.9	64 ± 4.7
West Beach	0.5	226	21	10.8 ± 1.8	49 ± 8.6
Breadner Group	3	136	13	10.5 ± 2.0	17 ± 0*
Simonds Group	5	118	11	10.7 ± 3.1	40 ± 0†

*Two days of observation were conducted at this site; the Sea Otter count was the same on both days.
†One day of observation was conducted at this site.
Note: SE = standard error.

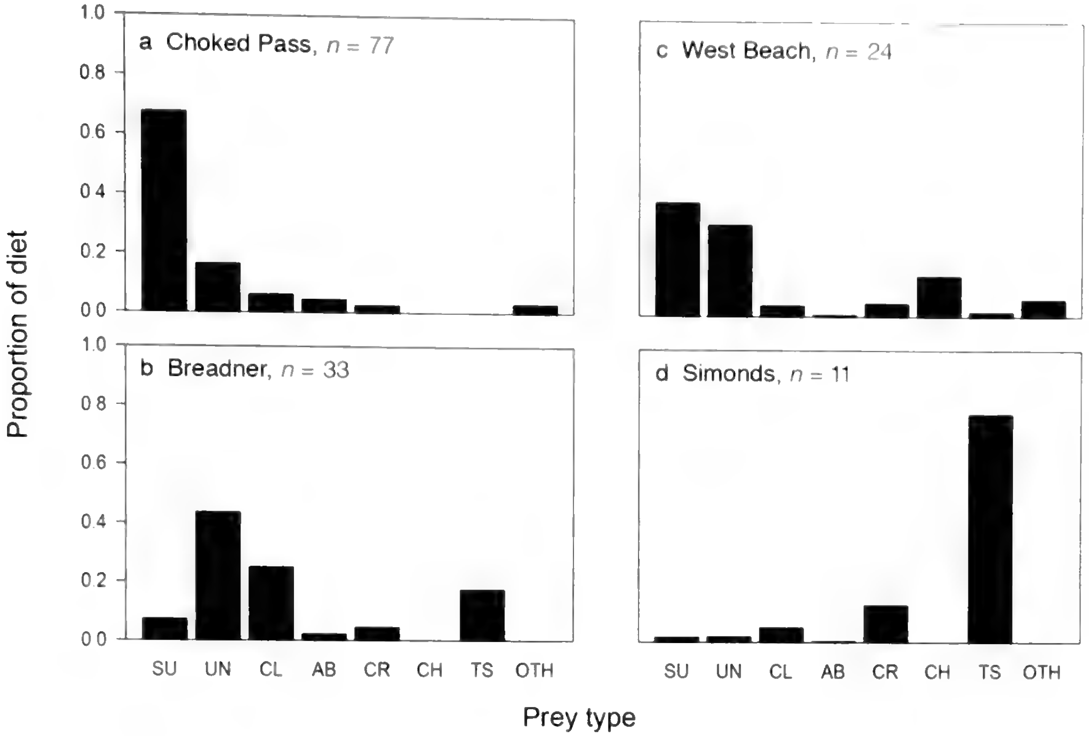

FIGURE 3. The proportion of prey types brought to the surface during Sea Otter (*Enhydra lutris*) foraging bouts (*n*) observed at our 4 study sites. Note: SU = sea urchin, UN = unidentified, CL = clam, AB = abalone, CR = crab, CH = chiton, TS = turban snail, OTH = other prey type.

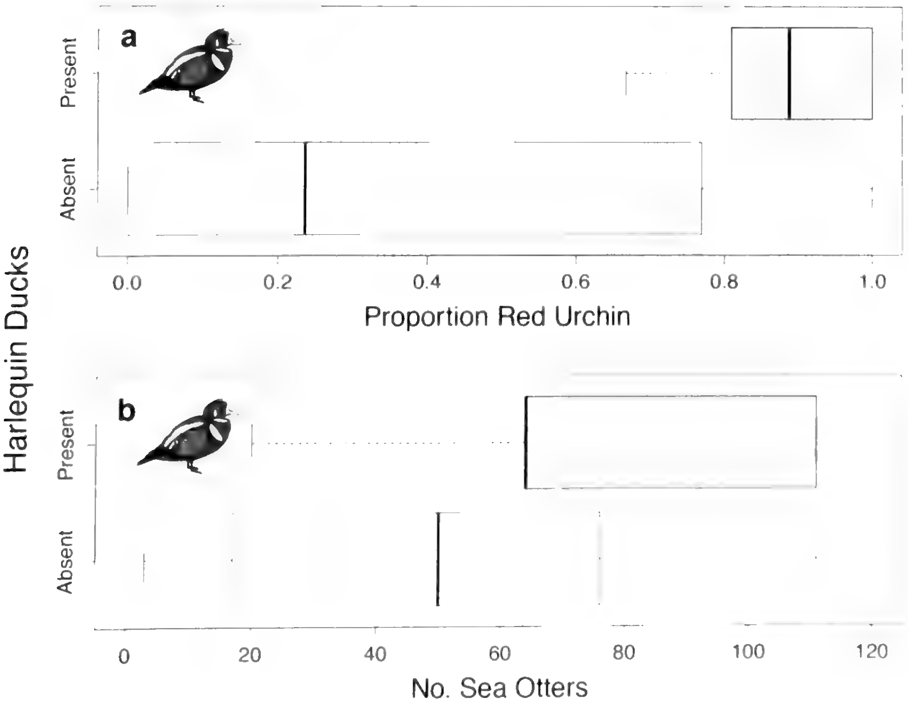

FIGURE 4. Presence and absence of Harlequin Ducks (*Histrionicus histrionicus*) related to (a) the proportion of Red Sea Urchin (*Mesocentrotus franciscanus*) in the foraging bout and (b) the number of Sea Otters (*Enhydra lutris*) in the foraging area. Dark vertical lines indicate the median, box edges indicate the 1st and 3rd quartiles, and dashed lines indicate the range. Illustration: Angeleen Olson.

occurs during the winter when rafts of non-territorial male Sea Otters leave food-limited areas to exploit large and abundant prey at the periphery of the range (Jameson 1989; Lafferty and Tinker 2014). This can result in peripheral groups of male Sea Otters eating and fragmenting large red urchins where Harlequin Ducks are also wintering.

Although Sea Otters and Harlequin Ducks both forage in exposed, nearshore habitats for at least several months of the year, to the best of our knowledge, they have not previously been observed interacting (J. A. Estes, personal communication, 2014; D. Esler, personal communication, 2015). The interaction between Sea Otters and Harlequin Ducks may have been previously overlooked because observations require recent recolonization by otters and winter feeding observations of both Sea Otters and Harlequin Ducks. The effect of returning Sea Otters on Harlequin Ducks illuminates another way that Sea Otters make for more robust species assemblages via both direct and indirect effects.

Harlequin Ducks typically forage on intertidal snails, crabs, amphipods, and limpets (Vermeer 1983; Gaines and Fitzner 1987; Rodway and Cooke 2002; Bond and Esler 2006; Esler and Bond 2010) in waters less than 5 m deep (Holm and Burger 2002), whereas Red Sea Urchins occur in the shallow subtidal area to depths up to 125 m (McCauley and Carey 1967), and are rare in Harlequin Duck diets. Urchin size can affect their quality as prey, with large reproductive urchins being higher in lipids and key nutrients than the smaller immature individuals that might be available to Harlequin Ducks unassisted by Sea Otters (Oftedal *et al.* 2007). Of the sea urchins consumed by Sea Otters at Choked Pass, 87% had a test diameter equal to or larger than about 7.5 cm, and Harlequin Ducks not scavenging on otter prey typically consume invertebrates that are less than 2 cm in diameter (Vermeer 1983). The Red Sea Urchins brought to the surface by Sea Otters would have been too large and collected at depths too deep for Harlequin Ducks to either handle or dive for. The role of Sea Otters in fragmenting the urchin prey to sizes that could be handled by ducks likely drove the commensal interaction that we observed.

Wintering male and female Harlequin Ducks store nutrients and lipids in preparation for spring migration and breeding, aiming for an optimal premigration weight (Bond and Esler 2006; Esler and Bond 2010). Bond and Esler (2006) found that Harlequin Ducks that fed on herring roe at wintering sites spent less time foraging but gained weight more rapidly than ducks that did not eat herring roe. The ability to acquire energy rapidly at wintering sites by adapting foraging strategies to exploit new prey items may benefit Harlequin Ducks when they return to their nesting sites in spring.

Although the effects of Sea Otters on kelp forest ecosystems are well known, our observations reveal another pathway by which otters induce direct effects on the nearshore environment, contributing to their overall role as keystone predators. Sea Otters provided a useful dietary supplement to a sea bird that may be energetically constrained during winter (Goudie and Ankney 1986; Esler *et al.* 2002) and for which winter survival has the potential to be a demographically limiting stage in the annual cycle (Esler *et al.* 2000). This is also the first observation that we know of, of Harlequin Ducks scavenging from a carnivore, illuminating the plasticity in foraging strategies that these ducks can employ. Our observations suggest that Sea Otter range expansion and the associated sea urchin consumption in recently colonized areas provides a temporarily available prey resource for Harlequin Ducks that may increase their fitness in the short term during a period of Sea Otter population recovery.

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Nesting Behaviour and Reproductive Success of Sprague's Pipit (*Anthus spragueii*) and Vesper Sparrow (*Pooecetes gramineus*) during Pipeline Construction

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Industrial activity occurs in the breeding habitat of several species at risk, including the federally threatened Sprague's Pipit (*Anthus spragueii*). To evaluate whether oil pipeline construction reduces the productivity of this species, we examined (a) noise levels in relation to distance from the pipeline right-of-way (ROW), (b) the extent to which noise and song frequencies overlapped, (c) the distribution of Sprague's Pipit nests relative to the ROW, and (d) Sprague's Pipit reproductive success during exposure to pipeline construction and clean-up activity. We also examined the songs, nest locations, and reproductive success of the Vesper Sparrow (*Pooecetes gramineus*) for comparison. Study plots (400 × 400 m, $n = 30$) were established in grassland adjacent to the pipeline ROW or 600 m away from the ROW in similar habitat. Mean maximum noise levels during pipeline activity included frequencies that overlapped the song range of both species and were louder than the recommended 49 dB threshold up to 250 m from the ROW. Sprague's Pipit nests were evenly distributed across close and distant plots, whereas Vesper Sparrow nests were more abundant within 50 m of the ROW. Sprague's Pipit daily nest survival rate and the number of young surviving to day 8 both increased with increasing distance from the ROW; and Vesper Sparrow daily nest survival decreased slightly with exposure to pipeline activities. Our findings validate the restricted activity period and indicate that the recommended setback distance of 350 m is a reasonable guideline for pipeline projects.

Key Words: Sprague's Pipit; *Anthus spragueii*; breeding success; industrial activity; pipeline; Vesper Sparrow; *Pooecetes gramineus*; noise; setback distance

Introduction

Industrial activity is a major source of disturbance that can affect the abundance, reproductive success, and survival of breeding birds (Bayne *et al.* 2008; Ludlow 2013). Direct impacts involve visual or acoustic disturbances that alter breeding behaviour (Lyon and Anderson 2003), spatial distributions (McClure *et al.* 2013), or rates of predation (Francis *et al.* 2009). Indirect effects range from large-scale habitat fragmentation (Herkert *et al.* 2003) to local changes in habitat structure (Forman and Alexander 1998; Ingelfinger and Anderson 2004). Regulators must anticipate both types of impacts when they develop guidelines for industrial activities, even in situations where information is lacking or incomplete.

In this study, we evaluate whether pipeline construction reduces the productivity of Sprague's Pipit (*Anthus spragueii*; hereafter "pipit") and the Vesper Sparrow (*Pooecetes gramineus*). The pipit is a federally threatened grassland songbird (COSEWIC 2010; Government of Canada 2016) that is typically associated with native mixed-grass prairie at both the patch and landscape scales (Davis 2004; Davis *et al.* 2013). The Vesper Sparrow is a habitat generalist (Best and Rodenhouse 1984) that is considered "secure" in Canada (NatureServe 2015).

Federal guidelines recommend that high-disturbance activity should not occur within 350 m of pipit nests from 1 May to 31 August, to avoid disturbing breeding birds and to reduce potential effects on nest survivorship (Environment Canada 2011). Unusual sights and noises may distract or scare away breeding birds. Similarly, noises that interfere with calls and songs may make it difficult for displaying males to hear or communicate with their prospective mates and competitors (Habib *et al.* 2007) and may affect communication between parents and their young (Leonard and Horn 2012; McIntyre 2013). Compared with continuous industrial noise, pipeline construction and clean-up noises are more sporadic, intermittent, and occur over a wider range of amplitudes.

The opportunity to investigate the effects of this activity arose with the construction of the Alberta Clipper, a 1080-km long, 914-mm diameter oil pipeline that extends from eastern Alberta to southwestern Manitoba. For the purposes of this study, the Canadian Wildlife Service granted special permits that relaxed the restricted activity period and allowed the pipeline company (Enbridge Inc., Calgary, Alberta, Canada) to construct within the setback distance for pipit nests during the breeding season.

To assess the potential for acoustic interference from pipeline activities, we compared the frequency ranges of construction and clean-up noise to the frequencies of pipit and Vesper Sparrow songs. To assess impacts on reproduction, we located and monitored nests up to 1000 m away from the pipeline right-of-way (ROW). We tested whether nesting success was reduced closer to the ROW and with increased exposure to activity. We predicted that pipits would avoid nesting near the ROW and that, as generalists, Vesper Sparrows would be unaffected by the ROW and, therefore, exhibit a random nesting pattern.

Methods

Study design

We collected data from 10 May to 31 August 2009 along portions of the Alberta Clipper pipeline route (Figure 1). Most (98%) of the pipeline route is adjacent to an existing pipeline corridor, which has been in use since the early 1950s. Pipeline construction and clean-up activities are generally carried out by crews that may spend a few hours to a few days in a given area, using heavy equipment. They focus on a portion of the pipeline called a "spread" and their work is part of a short-term, discontinuous process, where discrete events are separated by longer periods of inactivity. Construction activities include surveying, grading, clearing, pipe-stringing, trenching, welding, pipeline lowering, backfilling, and reclamation. Clean-up activities include grade replacement, topsoil replacement, and seeding.

Habitat generally consisted of flat or gently rolling native mixed-grass or planted pasture, with a varying number of shrubs and the occasional wetland or stand of small trees. We set up 30 400-m × 400-m study plots along portions of the pipeline that follow the existing corridor, focusing on a 165-km construction spread and a 75-km clean-up spread (Figure 1). On the construction spread, the 40-m wide ROW had been mowed in winter 2008–2009. Construction had been completed on the clean-up spread in 2008, but the ROW was not vegetated and topsoil was still stored in windrows as of May 2009.

Plots were established prior to the start of construction activity in locations where pipits were observed during point count surveys conducted from 10 to 14 May 2009. We paired plots adjacent to the ROW (close) with others that were 600 m away from the ROW (dis-

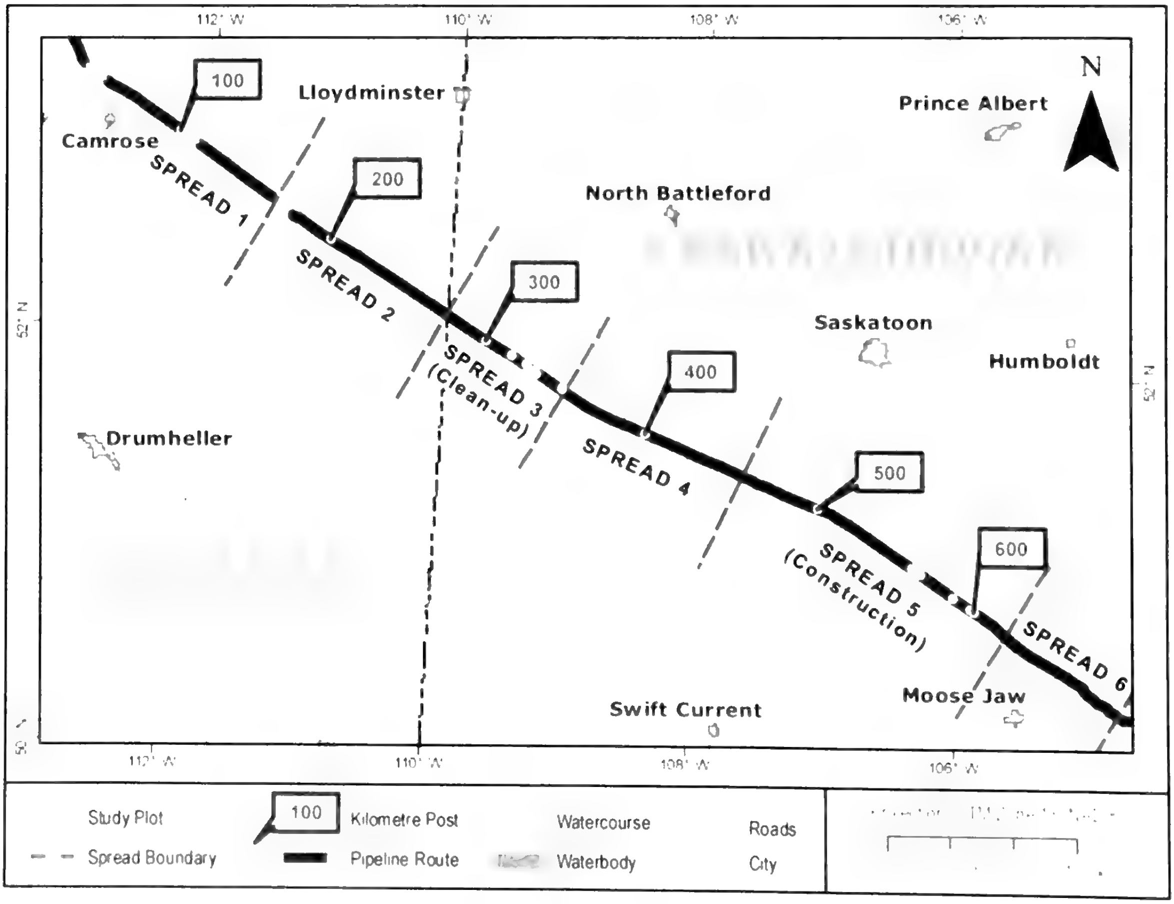

FIGURE 1. Location of the Alberta Clipper pipeline route across portions of Alberta and Saskatchewan, Canada, showing study plots ($n = 30$). The numbers in boxes refer to the length of the pipeline in kilometres at that point.

tant), where possible. We were not able to establish the same number of close and distant plots because pipits were not always present at distant locations. We separated each pair of plots by at least 1 km to ensure biological and statistical independence.

We focused our nesting studies on 23 plots that were located on grassland dominated by native vegetation to reduce confounding effects of habitat type and pipeline activity, given that pipits are less abundant in planted pasture (Davis and Duncan 1999; Davis *et al.* 1999; Fisher and Davis 2011). Of these, 7 close and 3 distant plots were on the construction spread and 7 close and 6 distant plots were on the clean-up spread. Three of the close plots included a portion of the existing reclaimed pipeline corridor, which was 7–20 m wide within these plots (mean 12.5 m). Eleven plots (4 distant and 7 close) had areas of scattered low-growing shrubs, including Pasture Sage (*Artemisia frigida* Willdenow), Western Snowberry (*Symphoricarpos occidentalis* Hooker), silverberry (*Elaeagnus* spp.), and wild rose (*Rosa* sp.). Grassland contained scattered shrubs covering from 15% (1 plot) to 60–70% (3 plots, mean 65%) on distant plots, and from 40–65% (4 plots, mean 55%) to 75–80% (3 plots, mean 78%) on close plots, with the remainder being open grassland. Of these 11 plots, 4 (2 distant and 2 close) had stands of tall brush, e.g., willow (*Salix* sp.), and in 1 case small Trembling Aspens (*Populus tremuloides*), that made up an additional 10–20% (mean 14%) of the cover. These 11 plots were included because at least 1 pipit was detected there during point counts and they contained Vesper Sparrow nests. Pipit nests were not found in 5 plots that were 55–80% grassland with scattered shrubs (3 close and 2 distant plots on the construction spread). We used all but 1 of the 30 plots for noise measurements and analyses because we would not expect a difference in noise transmission related to vegetation for these species.

Pipeline activities occurred at different times on each spread and on each plot. The earliest start date was 15 June 2009 and the last day of pipeline activity was 29 July 2009. The last day that a nest was monitored was 31 August 2009.

Noise and bird songs

We measured noise levels at 19 close and 10 distant plots using a Type 2250 Hand-Held Analyzer (Brüel and Kjaer, Naerum, Denmark) held approximately 1 m from the ground, away from the body, and facing the ROW. We took measurements at 100-m intervals along a linear 1-km transect that was perpendicular to the pipeline and ran through the centre of each plot, starting at the edge of the ROW. We calibrated the sound meter each morning before use and recorded each sample as an overall A-weighted decibel reading (frequency-weighted to approximate human hearing) based on a 1-minute average. We took at least 2 baseline noise measurements during periods without any pipeline activity and 1 clean-up or construction noise measurement. We combined construction and clean-up noise measurements into 1 activity category because we had too few samples to analyze separately. We deleted measurements with obvious noise contamination (e.g., airplane noise) or paused until the noise contamination was over. We also measured wind speed with a Kestrel 2000 hand-held wind meter (Kestrelmeters, Birmingham, Michigan, USA) and excluded noise data collected at wind speeds above 18 km/h.

To examine the potential for acoustic masking, we quantified pipit and Vesper Sparrow song frequencies, using recordings from the Macaulay Library (2009), and assessed the degree of overlap between the song frequencies and the noise frequency spectra for construction and clean-up activities.

Nests

We located nests by having 2 researchers walk slowly and methodically across a plot, each holding the end of a weighted 25-m rope. As the researchers dragged the rope over the vegetation, 1 or 2 observers followed behind to watch for flushed birds. We conducted 2–5 rope-drags (mean 3.2) in each plot between 27 May and 25 July. We started rope-drags within an hour of sunrise and ended in late morning or late afternoon, stopping if the weather turned cool or rainy. We searched for nests on the ROW before initiation of construction or clean-up activity, and we also found nests opportunistically as researchers walked within or to and from the study plots.

We marked nest locations with wooden stakes or survey flags placed 5 m directly north and south of the nest. For nests found during the incubation stage, we estimated nest age by candling the eggs (Lokemoen and Koford 1996). When nests were found during the nestling stage, we based the age of the chicks on physical characteristics (e.g., eyes open or closed, feather growth; Jongsomjit *et al.* 2007). We calculated nest initiation date by back-dating from the actual or estimated hatch date, using 13 days as the incubation period for pipit (Davis 2009) and 12 days for Vesper Sparrow (Jones and Cornely 2002).

We visited nests every 3–4 days to count the number of eggs and/or chicks, to determine nest fate, and to identify the type of pipeline activity that was occurring. Field crews were instructed to stop visiting nests after day 8 if they felt there was a risk of premature fledging, based on nestling periods of 11–14 days for pipits (Davis 2009) and 7–14 days for Vesper Sparrows (Jones and Cornely 2002). Of the nests that were monitored for at least 8 days, 86% of pipit nests and 58% of Vesper Sparrow nests continued to be monitored beyond this point. We visited each nest up to 3 days after the estimated fledging date and classified nests as fledged, survived to at least day 8 (for pipits), depredated, abandoned, failed, or unknown. Given the number of days between the penultimate check and the final check, we were conservative in our assessments of nest fate, classifying 25% of pipit nests and 26% of Vesper

Sparrow nests that were monitored on or past day 8 as unknown. Given that Vesper Sparrows can fledge at 7 days from hatching (Jones and Cornely 2002), we classified Vesper Sparrow nests as fledged if nestlings were present at least 7 days after hatching, there were no signs of nest destruction at the final post-fledging nest check, and 1 of the following was observed: fledglings near the nest, adults giving alarm calls or carrying food near the nest, or the nest bowl intact but enlarged and fecal sacs present. We used the same criteria to assess the outcome of pipit nests but classified them as survived to day 8, as opposed to fledged, because pipit chicks tend to stay in the nest longer (Davis 2009). We considered nests to be depredated when eggs or nestlings were absent before their predicted fledging dates or if there were signs of nest destruction during the final post-fledging nest check. We classified nests as abandoned when eggs were cold but still intact, adults were not present during subsequent nest checks, and the eggs did not hatch when expected based on the typical incubation period. We classified nests as failed when they were destroyed by severe weather or cattle or when only Brown-headed Cowbird (*Molothrus ater*) nestlings survived. We classified nest fate as unknown if we did not visit the nest up to at least 7 days after hatching for Vesper Sparrows or to at least 8 days for pipits, or if at the final post-fledging nest check, the nest was empty, but there were no reliable clues as to the fate of the clutch.

Data analysis

We used Sigma Plot version 11.0 (Systat Software, San José, California, USA) to analyze noise data, testing for effects of distance (1-way ANOVA followed by Holm-Sidak post-hoc test) and comparing activity levels with baseline levels (paired t-tests, $\alpha = 0.05$).

We tested for differences in nest locations with respect to the ROW by generating frequency distributions with 50-m distance classes and using χ^2 tests to compare the observed percentage of nests in each class with the percentage that would be expected if the nests were evenly distributed, i.e., 1/8 or 0.125.

We used SAS version 9.3 (SAS Institute, Inc., Cary, North Carolina, USA) for all analyses related to reproductive success. We used the logistic exposure method (Shaffer 2004) to determine the extent to which daily survival rate (DSR) varied as a function of nest age (Age), date (Date), distance from the ROW (Distance), whether or not an active nest overlapped with any days of construction or clean-up activity (Activity), and the number of days an active nest overlapped with construction or clean-up activity, determined by examining field crew activity logs (Exposure). The total number of days that the nest was exposed to pipeline activity was unique to each nest-visit interval, whereas 1 value for Activity was assigned to a nest. For nests with known fate, we used the halfway point between the last visit when the nest was active and the final visit to calculate the final interval length. For nests whose fates were unknown, we included nest-visit intervals only up to the last visit that the nest was active (Manolis *et al.* 2000).

We determined whether nest age or date influenced daily survival rates before examining the effects of pipeline activity on nest survival. However, we found no evidence of age or date effects for either species (null was the top-ranked model) and, therefore, tested for treatment effects by considering the following models: Distance, Activity, Exposure, Distance + Activity, Activity + Exposure, Distance + Exposure, and a Distance × Exposure interaction. We also compared the best models with a null (constant survival) model. We calculated Akaike information criterion scores corrected for small sample size (AIC_c) and used AIC_c weights to derive model-averaged estimates for DSR (Burnham and Anderson 1998).

We used generalized linear mixed models (PROC GLIMMIX) to assess the effects of nest initiation date (Initiation), Activity, and Distance on the number of Vesper Sparrow young that fledged and the number of pipit young that survived to at least 8 days post-hatch. We used the square root of the number of nests in each plot as a weighting factor and assigned plot as a random effect to account for multiple nests in each plot. We modeled the number of Vesper Sparrow fledglings and the number of pipit young surviving to at least day 8 as a Poisson distribution with a log link and used a Laplace approximation to derive AIC_c values. We used AIC_c to rank 10 models composed of a main and additive effect of Initiation, Activity, and Distance, along with an interactive effect of Initiation and Activity, and a null model.

Results

Noise and bird songs

Activity noise levels decreased exponentially with increasing distance from the pipeline ROW (1-way ANOVA, $F_{10, 126} = 23.35$, $P \leq 0.001$), reaching 49 dB at approximately 250 m (Figure 2). Noise readings were asymptotic after 500 m from the ROW but remained significantly higher than baseline levels (paired t-tests, P range < 0.001–0.03). The rate of decrease was frequency specific ($y = 42.4642 + 25.1351e^{(-0.005x)} - 0.0025x$, $r^2_{adj} = 0.99$), and the range of noise frequencies from both construction and clean-up activities (6.3–20 000 Hz) overlapped with pipit (3150–8000 Hz) and Vesper Sparrow (2000–18 000 Hz) song frequencies (Macaulay Library 2009).

Nests

We found 69 pipit and 53 Vesper Sparrow nests, including 20 pipit and 13 Vesper sparrow nests that were outside the study plots. We used 49 pipit and 40 Vesper Sparrow nests for nest location analyses (nests outside the study plots were excluded as they were found opportunistically), 57 pipit and 42 Vesper Sparrow nests for nest survival analyses (nests that did not overlap with pipeline activity were excluded), and 50 pipit

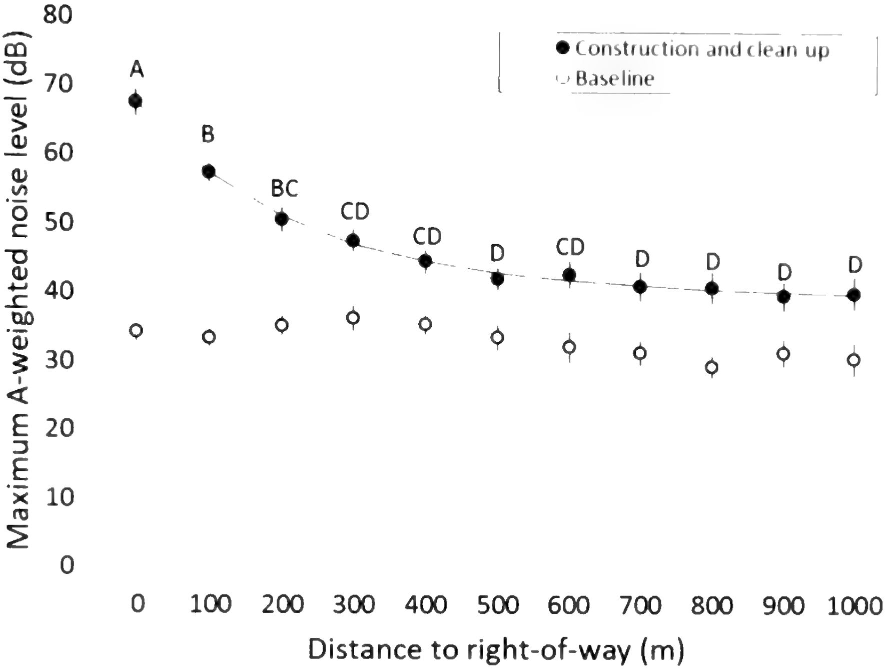

FIGURE 2. Relation between maximum A-weighted noise levels and distance from the pipeline right-of-way under pre-activity conditions (baseline) and during construction and clean-up activities. Values are means ± standard errors. Means with the same letter are not significantly different, and all differences between means for baseline and construction/clean-up conditions are significant ($P < 0.05$).

and 33 Vesper Sparrow nests for productivity analyses (14 of 64 useable pipit nests had an unknown number fledged). Nests used for productivity analyses can also be used for nest survival analyses because the data are truncated to the last day they were visited with known fate.

Pipit nests were evenly distributed with respect to distance from the ROW in close ($\chi^2 = 5.4$, df = 7, $P = 0.61$) and distant plots ($\chi^2 = 9.3$, df = 7, $P = 0.23$, Figure 3). Vesper Sparrow nests were also evenly distributed, but only in distant plots ($\chi^2 = 4.3$, df = 7, $P = 0.74$). In close plots, Vesper Sparrow nests were unevenly distributed ($\chi^2 = 23.5$, df = 7, $P = 0.001$), and the number of nests within 50 m of the ROW was higher than expected ($\chi^2 = 17.0$, df = 1, $P < 0.05$).

Median clutch initiation was 26 June for pipits ($n = 69$) and 14 June for Vesper Sparrows ($n = 53$). For both species, the range of clutch initiation dates (23 May to 30 July for pipits; 13 May to 17 July for Vesper Sparrows) fell within the restricted industrial activity period for pipits (1 May to 31 Aug).

Of the 58 pipit and 42 Vesper Sparrow nests with known fate, 41% of pipit nests and 40% of Vesper Sparrow nests survived, with predation accounting for 85% of unsuccessful pipit nest and 88% of unsuccessful Vesper Sparrow nests. Daily survival rates tended to be lower during incubation than during the nestling period for pipits and were nearly equal for Vesper Sparrows (Table 1). Assuming incubation and nestling periods of 13 and 12 days, respectively, for pipits (Davis 2009) and 12.5 and 10 days for Vesper Sparrow (Jones and Cornely 2002), overall nest success (product of incubation and nestling DSR) tended to be lower for pipits than for Vesper Sparrows (Table 1). On average however, more pipits per nest and per successful nest survived to at least day 8 compared with the number of Vesper Sparrow fledglings (Table 1), likely a result, in part, of their larger clutch sizes (4.8 ± 0.1 for pipits vs. 3.9 ± 0.1 for Vesper Sparrows). One pipit nest and 2 Vesper Sparrow nests were parasitized by Brown-headed Cowbirds. The pipit nest and 1 of the Vesper Sparrow nests contained 1 cowbird egg; the other Vesper Sparrow nest contained 2 cowbird eggs.

In total, 32 pipit and 39 Vesper Sparrow nests that were within 100 m of a plot were active during pipeline construction or clean-up. Distance and Exposure were considered the most parsimonious models for pipits and Vesper Sparrows, respectively, but no models were more than 2.6 AIC_c units away from the null (Table 2). Pipit DSR increased as a function of distance from the ROW, and Vesper Sparrow DSR declined with increasing exposure (Figure 4), but a high degree of variability was associated with proximity to the ROW and longer periods of exposure.

The number of pipit young that survived to at least day 8 was influenced mainly by distance from the ROW. In pipit nests further from the ROW, more young tended to survive to day 8 ($\beta = 0.001$, 85% CI = 0.0003–0.0017; Figure 5), although the underlying model was only 1.3 AIC_c units from the null (Table 3). The number of Vesper Sparrow fledglings was influenced mainly by an interaction between distance and activity (Table

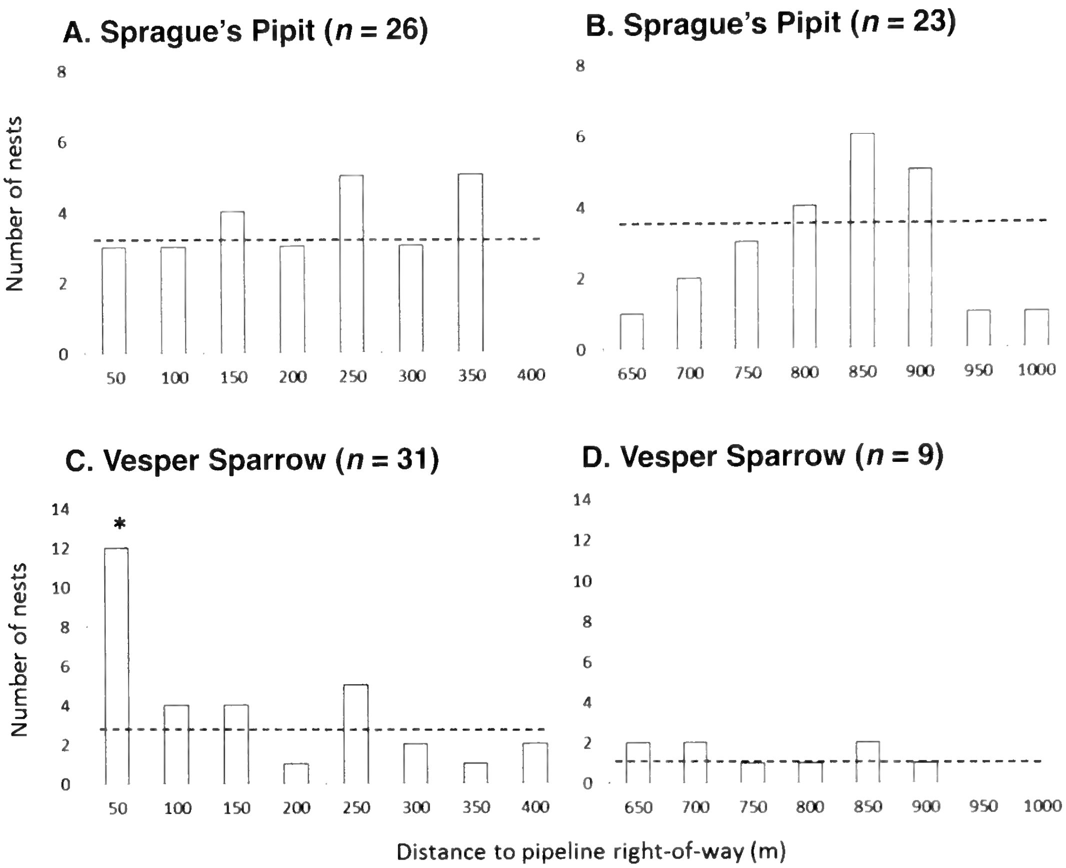

FIGURE 3. Distribution of Sprague's Pipit (*Anthus spragueii*, A–B) and Vesper Sparrow (*Pooecetes gramineus*, C–D) nests in relation to the pipeline right-of-way. Dashed line is the number of nests expected with even distribution and asterisks denote a significant ($P < 0.05$) difference between observed and expected. Numbers on the X axis refer to the tops of 50-m distance classes, and n = number of nests.

TABLE 1. Breeding success of Sprague's Pipit (*Anthus spragueii*) and Vesper Sparrow (*Pooecetes gramineus*) based on 58 pipit and 42 sparrow nests with known fate.

Parameter	Sprague's Pipit	Vesper Sparrow
Incubation DNS (95% CI)	0.930 (0.765–0.982)	0.957 (0.939–0.970)
Nestling DNS (95% CI)	0.969 (0.946–0.982)	0.959 (0.941–0.972)
Overall nest success, % (range)	27.0 (1.6–63.5)	38.0 (24.8–51.4)
Chicks surviving to day 8 ± SE	2.2 ± 0.3	1.4 ± 0.4
Chicks per successful nest ± SE	3.6 ± 0.2	2.7 ± 0.4

Note: CI = confidence interval, DNS = daily nest survival, SE = standard error.

TABLE 2. Comparison of daily nest survival model results for Sprague's Pipit (*Anthus spragueii*) and Vesper Sparrow (*Pooecetes gramineus*). Corrected Akaike information criterion (AIC_c) scores and their weights are shown for the top model, for models within 2 AIC_c units of the best model with the same or fewer number of parameters, and for the null model.

Species (effective sample size, no. nests)	Model	k	AIC_c	ΔAIC_c	AIC_c weights
Sprague's Pipit					
(765, 57)	Distance	2	205.5	0.0	0.25
	Exposure	2	207.5	2.0	0.09
	Null	1	208.1	2.6	0.07
Vesper Sparrow					
(398, 42)	Exposure	2	115.1	0.0	0.23
	Null	1	115.5	0.5	0.18

Note: k = number of parameters, ΔAIC_c = change in score compared with top model.

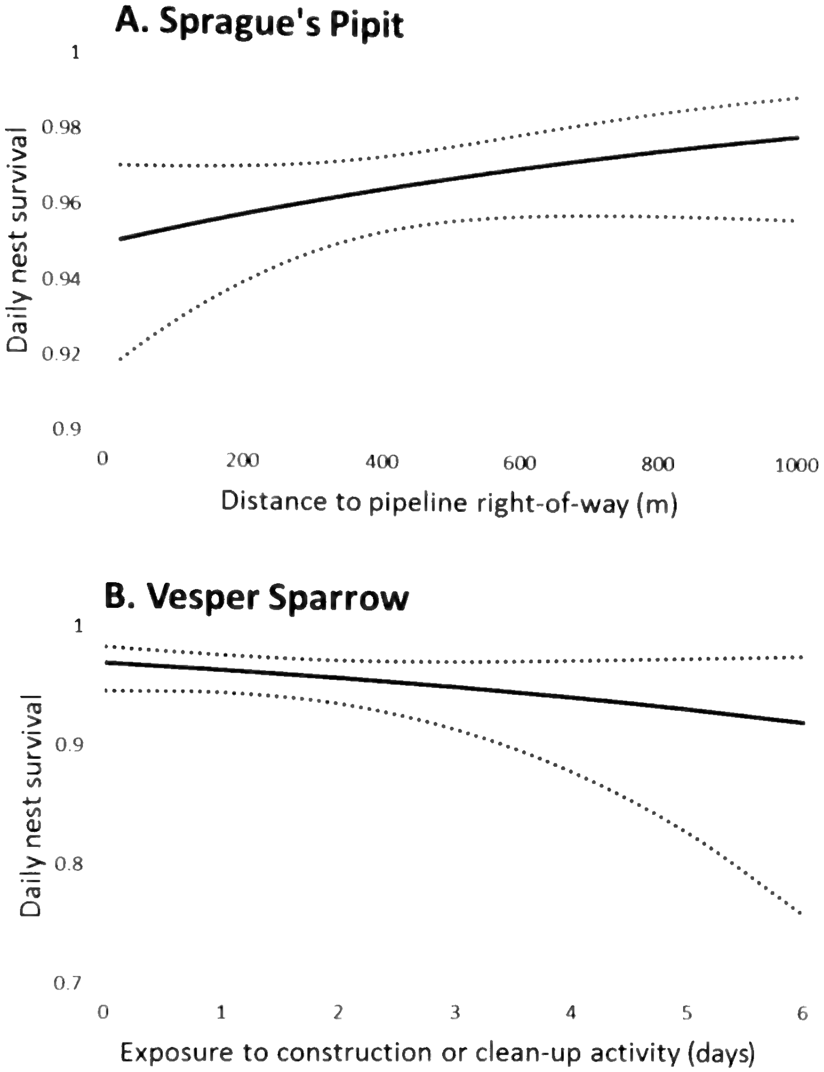

FIGURE 4. Model-generated estimates of daily survival of (A) Sprague's Pipit (*Anthus spragueii*) nests as a function of distance from the pipeline right-of-way and of (B) Vesper Sparrow (*Pooecetes gramineus*) nests as a function of exposure to pipeline construction or clean-up activity. Dotted lines denote 85% confidence limits.

3). The Distance × Activity parameter had confidence limits that did not include 0 ($\beta = 0.010$, 85% CI = 0.004–0.016) and the number of Vesper Sparrow fledglings also increased with distance from the ROW, but only in the absence of construction or clean-up activities. When activity was occurring, Vesper Sparrow nests closer to the ROW tended to fledge more young.

Discussion

Pipeline construction and clean-up had some effect on nest-site selection and reproductive success of both Sprague's Pipit and Vesper Sparrows. Although the overall distribution of pipit nests was fairly even with respect to the ROW, Vesper Sparrow nests were more abundant than expected close to the ROW. These results suggest that differences in the vegetation close to the ROW may have been an important factor in Vesper Sparrow nest-site selection. Also, as predicted, pipit nest survival increased with distance from the ROW, compared with a slight decline for Vesper Sparrows with increased exposure to pipeline activities. Pipit nests that were further from the ROW also tended to have more young survive to 8 days, whereas distant Vesper Sparrow nests tended to fledge fewer young in the presence of pipeline activity.

Noise and bird songs

Next to the ROW, maximum construction and clean-up noises were far above the 49 dB suggested as an upper limit for continuous noise within the breeding habitat of listed songbird species (Nicholoff 2003; Environment Canada 2011). Maximum noise levels were still above this threshold 250 m from the ROW and were only 3 dB below it at the 350-m setback distance. Pipeline construction and clean-up noises occurred at

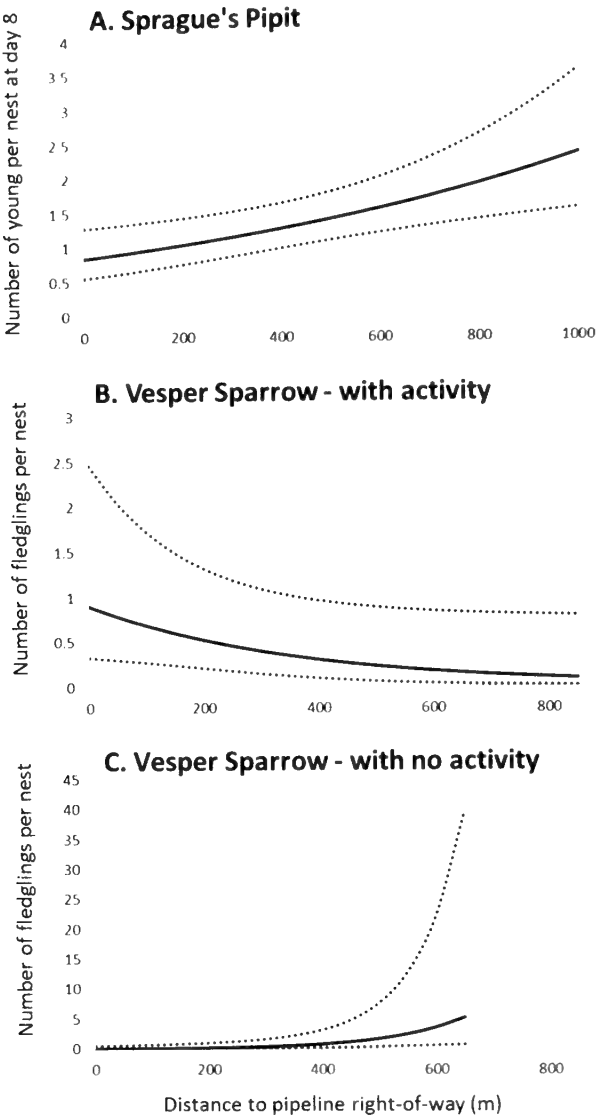

FIGURE 5. Model-generated estimates of the number of Sprague's Pipit (*Anthus spragueii*) young per nest that survived to at least day 8 (A), and the number of Vesper Sparrow (*Pooecetes gramineus*) young per nest that fledged with (B) and without (C) construction or clean-up activity, as a function of distance to the pipeline right-of-way. Dotted lines denote 85% confidence limits.

TABLE 3. Comparison of model results for the mean number of Sprague's Pipits (*Anthus spragueii*) per nest that survived to a least 8 days post-hatch and the mean number of Vesper Sparrow (*Pooecetes gramineus*) young per nest that fledged. Corrected Akaike information criterion (AIC$_c$) scores and their weights are shown for the top model, for models within 2 AIC$_c$ units of the best model with the same or fewer number of parameters, and for the null model.

Species (no. observations)	Model	*k*	AIC$_c$	Δ AIC$_c$	AIC$_c$ weights
Sprague's Pipit (50)	Distance	3	199.5	0.00	0.28
	Null	2	200.8	1.30	0.14
Vesper Sparrow (33)	Distance × Activity	5	74.4	0.00	0.42
	Activity × Initiation	5	75.1	0.71	0.29
	Null	2	77.4	3.01	0.09

Note: *k* = number of parameters, Δ AIC$_c$ = change in score compared with top model.

pipit and Vesper Sparrow song frequencies, making these activities a potential source of acoustic interference. It is not known whether pipits or Vesper Sparrows vary the pitch or intensity of their songs in response to industrial activities, but other species adjust their songs in noisy urban and forested environments to ensure their signals travel far enough to maintain territories and attract mates (Warren *et al.* 2006; Nemeth and Brumm 2009), even if this leads to increased energy and fitness costs (Brumm 2004; Patricelli and Blickley 2006). More research is needed to examine whether, or how, grassland birds adjust their songs in the presence of industrial noise and if this carries any fitness costs.

Nest-site selection

The fact that over half (52%) of our plots had 15 80% shrub cover likely affected the distribution of pipit nests, given that this species tends to avoid shrubby habitat (Davis *et al.* 1999; Grant *et al.* 2004). All close plots were also located in areas where some habitat modification had occurred (i.e., the ROW was mowed on the construction spread and not vegetated on the clean-up spread) and along an existing pipeline corridor that had been established in the 1950s. In this light, the even distribution of pipit nests with respect to the ROW is at odds with the tendency for this species to occur in lower numbers near anthropogenic edge habitats (Koper and Schmiegelow 2006; Koper *et al.* 2009; Sliwinski and Koper 2012) and to avoid compressor stations and well sites (Bogard 2011; Hamilton *et al.* 2011; Gaudet 2013).

In comparison, the high proportion of Vesper Sparrow nests within 50 m of the ROW suggests that suitable habitat for this species occurred along and in close proximity to the existing pipeline corridor during nest-site selection. This is consistent with Vesper Sparrows' high tolerance for vehicle traffic (Best and Rodenhouse 1984). Vesper Sparrows also have a much broader habitat niche than pipits and occupy many different types of anthropogenic habitats, including hayfields, cropland, abandoned fields, and roadsides (Jones and Cornley 2002).

Nest success

Nest survival and survivorship for pipits and Vesper Sparrows were similar to observations in southeastern Alberta (Ludlow *et al.* 2014), southern Saskatchewan (Davis 2003; McMaster *et al.* 2005), north-central North Dakota (Grant *et al.* 2005), and north-central Montana (Jones *et al.* 2010), and our findings suggest that pipit reproductive success is negatively affected by proximity to the ROW. However, given that we have data for only 1 year and nest success can fluctuate among years (Davis 2003; Jones *et al.* 2010), our nest success results should be interpreted with caution. The fact that we found only a weak effect of distance supports Ludlow *et al.* (2015), who found no effect of oil and gas infrastructure on pipit reproductive success. Jones and White (2012) also reported no reproductive effects associated with distance to a range of habitat edges, including an active railroad ROW. Species nesting near roads, ROWs, and trails may experience lower reproductive success because some predators hunt and scavenge along these linear disturbances, especially when there are medium to low volumes of traffic (Pescador and Salvador 2007). Barton and Holmes (2007) reported high rates of nest abandonment because of predation near trails, and Ludlow *et al.* (2014) found lower reproductive success and evidence of avoidance near trails for pipits and Baird's Sparrows (*Ammodramus bairdii*), whereas Vesper Sparrows nested closer and fledged more young closer to trails.

Given that nest failure was primarily a result of predation, the fact that the number of Vesper Sparrows that fledged during pipeline activities was relatively high close to the ROW suggests that these activities were reducing the number of predators or their foraging ability. Further research is required to identify mechanisms that might account for this, including studies that characterize the nest predator community and clarify how industrial development affects parental care and predator density and behaviour.

Management Implications

Setback distances and periods of restricted activity are designed to address a range of issues noted in Canada's Species at Risk Act, including prohibitions related to harming or harassment. Environment Canada (2011) considers the construction and clean-up of large-diameter pipelines to be high-level disturbance activities, in the same category as the construction of permanent structures, such as roads, buildings, and compressor stations. Our results suggest that the restricted activity period from 1 May to 31 August and the 350-m setback distance are reasonable guidelines.

Our noise measurements indicate that construction and clean-up noises are above the 49 dB guideline up to 250 m from the ROW and only slightly below this level at 350 m. In terms of reproductive success, distance from the ROW tended to affect pipit nest survival rates and the number of young surviving to day 8: our estimates of pipit DSR at 0 m, 350 m, and 1000 m from the ROW (0.950, 0.965, and 0.980) translate into nest success estimates of 29%, 43%, and 62%, respectively, assuming constant survival. These are similar to rates found in other pipit studies in Saskatchewan (24%; Davis 2003), Montana (27%; Jones *et al.* 2010); and southwest Manitoba (47%; Davis and Sealy 2000), but the higher rates that occurred further from the ROW suggest that 350 m should be viewed as a minimum setback distance. To protect pipit populations, we recommend that the current guideline be applied until further research determines the demographic consequences of nesting near sites that are, or have been, exposed to industrial development and whether tolerance thresholds exist that might further inform land-use policy and regulations.

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Reproductive Rates in Lesser Scaup (*Aythya affinis*) in Southwestern Manitoba: Another Look at the Data

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Hammell, Gord. 2016. Reproductive rates in Lesser Scaup (*Aythya affinis*) in southwestern Manitoba: another look at the data. Canadian Field-Naturalist 130(2): 110–121.

Surveys indicate that Lesser Scaup (*Aythya affinis*) populations declined during the early 1980s and have since remained below conservation goals. Reasons suggested for the decline include chemical contamination, climate change, and reduced food resources. According to the latter theory, reproductive success of Lesser Scaup has declined because females now arrive on the breeding grounds with fewer nutrient reserves than in the past and this diminished body condition is the result of reduced food resources available at wintering and/or migration areas. To determine whether reproductive success has declined over time, I examined selected Lesser Scaup reproductive rates from 2008 to 2014 in southwestern Manitoba and compared them with those recorded before the continental population decline. Estimated productivity (age class IIa broods/pair), hatching date, Ia and IIa brood size, duckling survival rate (first sighting to age class IIa), and proportion of age class IIa broods with females in attendance were unchanged from values recorded in 1970–1972. Thus, if females are arriving on southern breeding areas with reduced body reserves, they may be recovering these losses before nesting, enabling them to attain reproductive rates similar to those in the past. In addition, these results are consistent with the hypothesis that reduced food resources at non-breeding areas could affect recruitment of southern prairie-parkland breeders to a lesser extent than northern breeders because of the longer time between arrival and egg-laying in the south.

Key Words: Lesser Scaup; *Aythya affinis*; Manitoba; reproductive rates

Introduction

A species' population size and distribution are determined by patterns of natality and mortality that may change over space and time. Thus, wildlife managers must understand sources of variation in these vital rates to achieve management goals, especially for a population in decline. The Lesser Scaup (*Aythya affinis*) is a medium-sized diving duck that breeds in the boreal forests and prairie-parklands from Alaska to northern United States (Anteau *et al.* 2014). Combined North American breeding populations of Lesser Scaup and the similar-looking Greater Scaup (*A. marila*) have declined from highs of 5–7 million birds in the 1970s to 3–4 million in the past decade (Dooley *et al.* 2015). The decline appears to have started in the early 1980s. Lesser Scaup constitute about 90% of the combined population and most of the decline has been attributed to this species because of widespread decline in the Canadian western boreal forest, where most Lesser Scaup breed (Afton and Anderson 2001). Lesser Scaup (but not Greater Scaup) also breed in southwestern Manitoba parkland, and a decline in the local scaup population has been noted from the early 1980s to about 2000 when scaup numbers appear to have stabilized (Figure 1).

Several hypotheses have been offered to explain lowered scaup populations, including exposure to chemical contaminants (Custer *et al.* 2003; Anteau *et al.* 2007; DeVink *et al.* 2008a,b), climate changes affecting boreal forest wetlands (Drever *et al.* 2012), and changes in food resources in wintering and migration habitats (Afton and Anderson 2001), all of which could affect recruitment through reduced breeding propensity, clutch size, nest success, or female and duckling survival. The spring condition hypothesis (SCH; Afton and Anderson 2001) posits that reproductive success of scaup has declined because females now arrive on the breeding grounds with fewer nutrient reserves than they did in the past and this decline in body condition is the result of reduced food resources (quality and quantity) available at wintering, migration, or breeding areas.

Consistent with the SCH, the body condition (spring lipid reserves) of females was lower than in the past across a wide area of the upper-midwest United States at traditional migration stopover areas (Anteau and Afton 2009a). Also, wetland quality, availability of food resources, and foraging efficiency of females were low across the same broad landscape (Anteau and Afton 2008a,b, 2009b). Similarly, on the breeding grounds, lipid reserves of females recently arrived in the southern Manitoba parkland in 2000 and 2001 were much lower than 1977–1980 values (Anteau and Afton 2004). For boreal breeding scaup, historical nutrient reserve data are sparse (body mass only; Trauger 1971) but lipid reserves of boreal females measured during 2003–2004 in northern Alberta and the Northwest Territories were much lower than historical values reported for females in northwestern Minnesota in 1986–1988 and southwestern Manitoba in 1977–1980 (Anteau and Afton 2004, 2009a; but see DeVink *et al.* 2008c). Furthermore,

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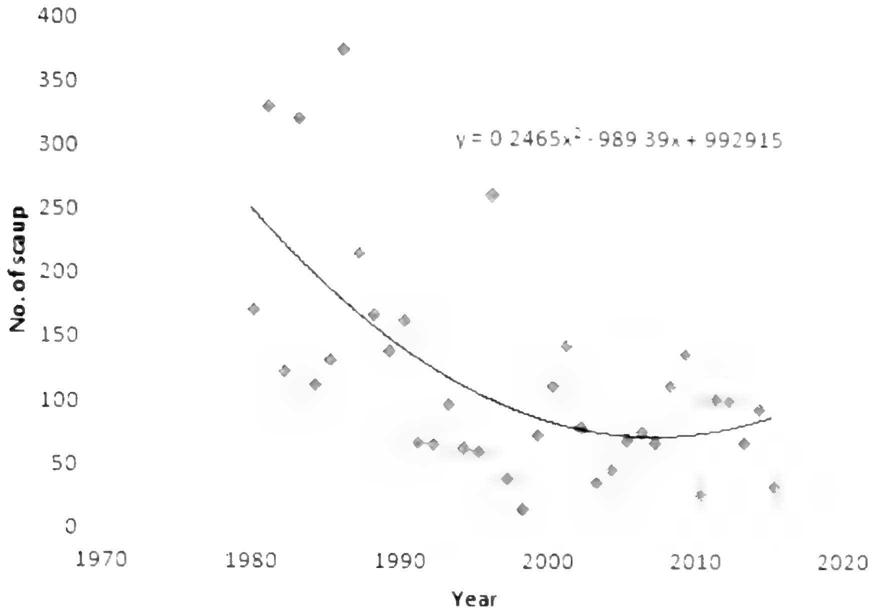

FIGURE 1. Total number of Lesser Scaup (*Aythya affinis*) and Greater Scaup (*A. marila*) from United States Fish and Wildlife Service/Canadian Wildlife Service annual waterfowl counts in the 3 segments nearest the study area near Erickson, Manitoba, 1980–2015 (stratum 40: transect 4, segment 4; transect 6, segments 3 and 4). The solid line represents a polynomial trend line. Source: Migratory Bird Data Center (n.d.).

recent studies have reported that some reproductive parameters, such as nest success, female survival, duckling and brood survival, and breeding probability, were low in boreal and parkland breeding sites, at rates that would be consistent with the SCH (Fournier and Hines 2001; Brook 2002; Koons and Rotella 2003; Walker and Lindberg 2005; Walker *et al.* 2005; Corcoran *et al.* 2007; Martin *et al.* 2009).

Afton and Anderson (2001) and Anteau and Afton (2009a) speculated that reduced food resources at non-breeding areas would affect body condition and, hence, recruitment of northern boreal breeders more than southern prairie-parkland breeders because of the shorter time between arrival and egg-laying in the north. Ice-free conditions occur about 1 month later at Yellowknife, Northwest Territories, a boreal breeding site, than at Erickson, Manitoba, a parkland site (Afton 1984; Brook 2002). As a result, female scaup arrive later in northern boreal areas than on southern breeding areas, but initiate egg-laying at about the same time at both latitudes (Brook 2002; Gurney *et al.* 2011). Resident females typically delay egg-laying by 4–6 weeks after arrival in southern Manitoba (Afton 1984), but boreal females begin nesting shortly after arrival (Trauger 1971; Brook 2002). Such a relatively lengthy pre-laying period in the south might allow females to recoup migratory nutrient losses and better prepare for egg-laying, incubation, and brood-rearing. Therefore, in southern breeding latitudes, reproductive rates might be reduced from pre-continental population decline values, but perhaps not as much as for females breeding at higher latitudes.

However, at the Erickson breeding site, Koons and Rotella (2003) reported estimates of nest success (11%) and duckling survival (20%) during 1999-2000 to be low and similar to rates recorded for recent studies in boreal forest areas (Fournier and Hines 2001; Brook 2002; Walker and Lindberg 2005; Walker *et al.* 2005; Corcoran *et al.* 2007; Martin 2007). In southern Saskatchewan, in 1999–2000, Brook (2002) reported lower nest success (3%) and duckling survival (38% Dawson and Clark 1996) than at Yellowknife (14% and 61%, respectively). As well, Koons and Rotella's (2003) nest success and duckling survival estimates at Erickson were much lower than those recorded there before the continental population decline (31% and 68%, respectively; Afton 1984), and their female breeding season survival estimate (73%) was lower than that reported for any northern-latitude breeding duck. In addition, clutch initiation date, which is often negatively associated with reproductive success (Dawson and Clark 2000; Esler *et al.* 2001; Blums *et al.* 2002; Brook 2002) was later than historical estimates: 24 June versus 15 June (Koons and Rotella 2003). Such low vital rates suggest that recruitment may be negatively affected in the southern breeding grounds more so than previously thought.

Field studies conducted in parkland habitat during the scaup population decline have been of short duration, e.g., 2 years (Brook 2002; Koons and Rotella 2003), and, thus, given annual variation in environmental conditions, are of limited value in determining how reproductive rates vary over time or in understanding factors affecting the rates. Accordingly, to provide a longer time series for reproductive success in southern parkland habitat, I collected information on Lesser Scaup from 2008 to 2014 (the recent period) and compared it with pre-decline, 1970– 1972 (the early period) data from previous research (Hammell, unpublished data, 1973). Because, at Erickson, the total number of scaup breeding pairs has declined from the early period; lower reproductive rates have been reported recently; and body condition of scaup females on arrival in spring may be lower than in the past, I predicted that recent-period reproductive rates would be lower than comparable early-period estimates.

I predicted that my current estimates of productivity and duckling survival would be lower than those recorded in the early period on the basis of Koons and Rotella's (2003) findings. I also expected mean Ia and IIa brood sizes to be smaller mainly because of lower duckling survival. I expected my recent mean hatching date (MHD) estimates to be later than those in the early period if scaup are initiating egg-laying later (Koons and Rotella 2003), but still renesting at similar rates described for the early period (Afton 1984). However, MHD might not be later (similar to the early period) or might even be earlier if scaup are initiating laying later but not renesting because of time constraints resulting from a shorter breeding season (i.e., exhibiting a truncated hatching distribution relative to that in the early period). Also, female waterfowl are usually in poor body condition at hatch, and time spent in brood care reduces time spent on self-maintenance in preparation for migration (Afton and Paulus 1992). Female scaup leave their broods for longer times as broods mature and eventually abandon them and spend more time feeding than when with broods (Afton 1993). Presumably, adult females can regain lost reserves more efficiently than females with broods. Therefore, if brood-rearing female scaup are in poorer body condition and/or are initiating nesting later than in historical times, the decision to abandon the brood might be made earlier, and I would expect my recent study to show lower proportion of age class IIa broods with an attending female.

Study Area

The study area is situated in the parkland pothole region of southwestern Manitoba near Erickson (50°30'N, 99°55'W). The topography of the area is rolling with numerous ponds and lakes. The intensively studied areas constitute a block (6.8 km^2) and a roadside transect (71 km) established in 1970–1972, and the same block study area (BSA) and a different roadside transect (21.7 km, 4.0–12.5 km to the southeast) established in 2009 (Figure 2). The 2009–2014 transect, which partly coincided with the earlier one, was established to increase pair and brood sample sizes as preliminary data collection in 2008 indicated that the scaup breeding population on the BSA (19–23 pairs, 1970–1972) had decreased significantly (2–5 pairs, 2008–2014; Hammell 2014). Given the study goals and resources available, this new, spatially proximate transect was logistically more feasible than the historical one. In 1970–1972, the BSA contained about 160 wetlands: 68 class 1, 50 class 2, 12 class 3, 7 class 4, and 23 class 5; size range ≤ 0.2–11.5 ha (Stewart and Kantrud 1971). In 2008–2014, there were about 141 (loss of 2 small dugouts and 17 class 1–3 wetlands). Relative to other agricultural areas of Manitoba, the study site has changed little in wetland area or upland use from the

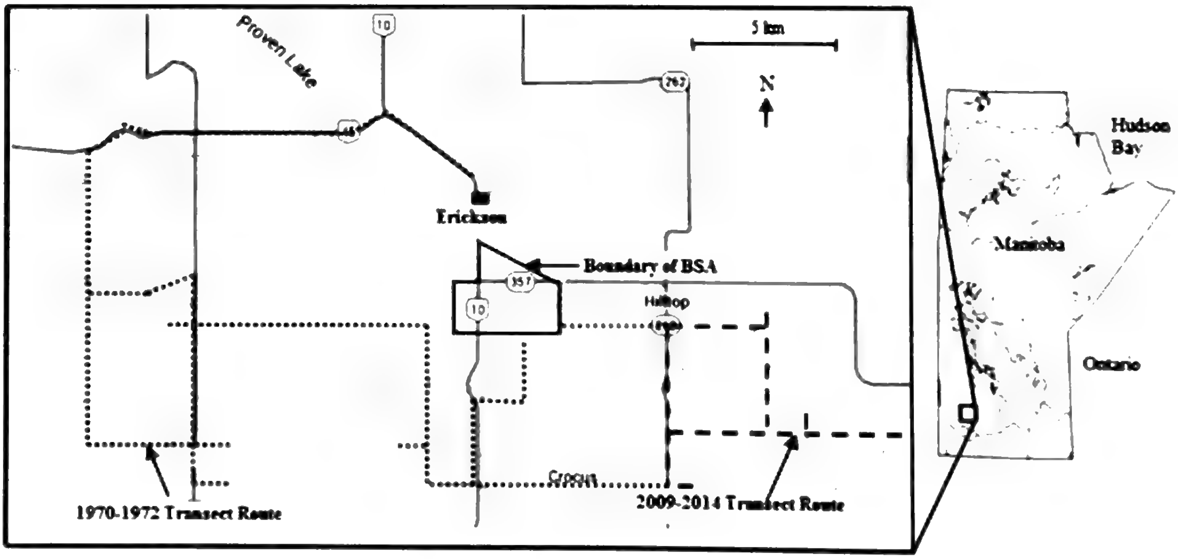

FIGURE 2. Location of block study area (BSA) and 1970–1972 and 2009–2014 transects, near Erickson, Manitoba.

early 1970s (Hammell 2014). During the record wet year, 2011, several permanent ponds (class 5) joined forming several larger wetlands (largest 21.7 ha). The 1970–1972 transect consisted of 56–59 semi-permanent (class 4) and permanent wetlands (mean = 2.1 ha, range: <0.8–8.9 ha), selected according to size criteria, whose open water area could be viewed in entirety from a roadside vehicle. The 2009–2014 transect (15.8 km^2) consisted of all class 2–5 wetlands with observable water (32 class 2 [temporary], 56 class 3 [seasonal], 41 class 4, and 32 class 5) within 400 m on either side of the road and required walking and driving to survey adequately. I chose a 400 m (rather than 200 m) width because evidence suggests that wider transects better represent wetland density and distribution and, thus, more reliably represent breeding density of scaup and more fully accommodate larger wetlands (Austin *et al.* 2000). To increase sample sizes for both study periods, additional hatch date and brood size data were collected opportunistically from other wetlands near the BSA and transects. The uplands in the Erickson area are a mixture of lands sown to cereal and oilseed crops, hay, pasture, and native woodland. During 2008–2014, BSA and transect land use patterns were, respectively, cultivated, 39% and 18%; pasture, 13% and 43%; hayland, 24% and 15%; wetland, 14% and 15%; woodland, 6% and 5%; other (yard sites, ditches, commercial, etc.), 4% and 4%. One permanent small island occurred on the BSA and none on the 2009–2014 transect. The area and changes over time are described in more detail by Rogers (1964), Sunde and Barica (1975), Afton (1984), Koons and Rotella (2003), and Hammell (2014).

Methods

Breeding pair surveys

To record breeding populations of scaup on the BSA, 1 or 2 observers walked a fixed route at approximately weekly intervals from early May to late June, 1970–1972, and from mid-May to mid-June, 2008–2014 (5–6 annual surveys). Wetlands were scanned from 1 or more elevated locations between 0600 and 1400. All class 1–5 wetlands were visited. Observed pairs and single males and females on isolated ponds were added for total pair count. I used data from surveys conducted after migration but during the pre-egg-laying and early-laying periods to avoid the bias of non-paired males being counted as representing pairs. Migration was considered over when pair numbers stabilized on the BSA. I approximated timing of egg-laying by backdating egg embryo age in nests ($n = 63$) found in 1970–1972 (Westerskov 1950) or by backdating from estimated date of earliest brood appearance (assuming egg-laying + incubation = 36 days) in 2008–2014. I averaged the results of BSA surveys within years and used these values for comparison between 1970–1972 and 2009–2014.

On the 1970–1972 roadside transect, I collected data at approximately weekly intervals (about 6 h to complete) but this information was not suitable for comparisons of productivity (broods/pair) with recent data because not all ponds in a pre-determined area were observed (only selected classes 4 and 5); therefore, in 1970–1972, breeding-pair estimates were derived from BSA data only but brood data were from the BSA and transect. For breeding pair counts on the 2009–2014 roadside transect, I used criteria similar to those for the BSA. I conducted counts between 0530 and 1800 as scaup were highly visible throughout the day and previous research has shown no differences in numbers of indicated pairs for counts conducted from 0530 to 1330 (Diem and Lu 1960). From 2009–2014, I conducted 3 annual roadside surveys during late migration to early nesting (21–25 May, 31 May–4 June, 6–11 June). I walked to distant or hidden wetlands and viewed them from several locations to ensure complete coverage. For 2009 and 2010, time constraints allowed only a partial survey of this transect (40 % of class 2 and 3 wetlands, 60% of class 4 and 5 wetlands), taking about 8 h to complete. For 2011–2014, I visited all wetlands with observable water (classes 2–5) within 400 m of the road, over 2 days (17 h). I checked class 1, tillage and class 2 wetlands with closed emergent vegetative stands while en route to other wetlands but did not visit these consistently as scaup are rarely observed on them (Hammell 1973; this study). Some wetlands were bisected by the roadside transect; thus, I recorded pairs on the entire wetland and included this total in the total transect pair count.

As the 2009 and 2010 transect pair data were incomplete, results were adjusted for biases described above to estimate the number of pairs on the entire transect for those years. Using 2011–2014 data, I developed a correction factor (CF) for each survey count using numbers of pairs observed on all wetlands and numbers observed only on wetlands that were in addition to those surveyed in 2009 and 2010:

$$CF = \frac{PR_{added}}{PR_{total}}$$

where, in 2011–2014, PR_{added} is the number of pairs counted on wetlands that were not visited in 2009 or 2010, and PR_{total} is the total number of pairs counted on all wetlands. This factor is the proportion of the count on missed wetlands and was determined within each year for those counts considered post-migration and these values were averaged. The average (CF_{average}) of the yearly count averages for 2011–2014 was applied to average counts for 2009 and 2010, e.g.,

$$\textit{Estimated total pairs all ponds (2009)} = \frac{\textit{Average pairs recorded (2009)}}{[1.00 - CF_{average}]}$$

This analysis indicated that the mean number of scaup pairs recorded in 2009 and 2010 on the partly surveyed transect represented about 70% of the total number of pairs on the entire transect and this adjustment was applied to the 2009 and 2010 raw data as above. Yearly productivity estimates for the BSA and transect correlated positively in the recent period and means did not differ significantly (unpublished data); thus, estimated pairs and broods on the BSA were added to those on the roadside transect and this total represented the pair and brood estimate on the entire 22.6 km^2 study area.

Brood surveys

Broods of scaup are relatively easily found, as they usually swim to open areas in the centre of the pond when disturbed (Hammell 1973; Anteau *et al.* 2014). I described a brood as (a) a female with up to 12 ducklings or (b) as 2–12 isolated ducklings with no female and whose age did not correspond with that of other nearby broods. Larger groups (13–24 ducklings) were considered 2 broods. Broods were observed on wetlands on the BSA, roadside transects and nearby areas. I recorded presence or absence of an adult female and number and age of ducklings, and used information about brood age, size, and location to avoid duplication in counts. Occasionally, scaup broods contained ducklings of other waterfowl species, usually Redhead (*Aythya americana*) and these ducklings were removed from the recorded scaup brood size. I estimated brood ages based on juvenile plumage characteristics (Gallop and Marshall 1954). For each brood, a hatching date was estimated by backdating from several brood observation dates. During 1970–1972, some females were marked with a coded plastic nasal saddle, so that broods were more readily identified (Sugden and Poston 1968). Brood surveys began during the first week of July and, because scaup females usually move their broods from smaller to larger (usually class 5) wetlands as they mature (Hammell 1973; Corcoran *et al.* 2007), surveys were conducted mostly on class 4 and 5 wetlands until broods reached age class IIa (21–28 days of age). Greatest duckling losses and most brood movement occur before ducklings reach age class IIa (Hammell 1973; Afton 1983; Dawson and Clark 1996; Brook 2002; Corcoran *et al.* 2007). Also, most brood-rearing females spend increasing amounts of time away from their broods after they reach age class IIa, and at that point ducklings often form groups on lakes making it difficult to distinguish individual broods (personal observations; Hines 1977; Afton 1984). Thus, class IIa broods are relatively stable in size and location, represent a good index of juveniles fledged, and have been used similarly by other authors (Afton 1984; Koons and Rotella 2003).

Brood search effort on the BSA and transects averaged about 7 visits/wetland annually (1970–1972: mean 7.0, range 5–9, no. wetlands 73–76; 2008–2014: mean 7.2, range 5.5–9, no. wetlands 35–54). I assumed that the number of broods that left the study areas was equal to the number that arrived. Because broods move freely over the entire area of a lake (unpublished data), placing a brood "in" or "out" of the transect was difficult when the transect line bisected a lake. Thus, I counted all broods on bisected lakes and assumed that these broods resulted from the total pair count for that lake. Occasionally, broods disappeared between counts and may have moved to a nearby wetland or suffered total brood loss; the extent of such possible losses was unknown. Brood surveys on the transect were incomplete in 2009 and 2010 (3 potential brood wetlands unobserved out of 47); thus, a correction factor was applied to these data similar to that for pairs. This analysis resulted in 1 brood each being added to 2009 and 2010 total estimates.

Data analysis

Recent-period estimates of breeding pairs and broods allowed for comparisons of productivity (IIa broods/pair) and Ia (1–6 day old) and IIa (21–28 day old) brood size with early-period estimates. Because I was interested in changes between periods rather than individual years, I pooled brood size and hatching date data across years within each period. Yearly productivity estimates and brood size data for each period were tested for differences using Wilcoxon rank-sum test (data analysis using Excel, Microsoft, Redmond, Washington, USA).

Changing mean clutch size could confound brood size analysis, but I assumed no change over time based on recent research findings at Erickson: mean clutch size (1999–2000) was unchanged from historical times (Koons and Rotella 2003). I determined MHD for each period (all years combined) and looked for hatching date differences using the Kruskal-Wallis test (McDonald 2014). Similar MHD can result from different hatching distributions; thus, to look for change in hatching distribution (using analytic methods of previous authors; Rogers 1962; Hines 1977), hatching dates were assigned to weekly hatching periods in each era and compared using a Kolmogorov-Smirnov test (Holliday 2012). I tested early and recent data with non-parametric Wilcoxon and Kruskal-Wallis tests because the distribution of variables was unknown, sample sizes were small, or both. Because unpublished analysis of data distributions for the early versus recent periods (hatch date, brood size) indicated that they were similarly shaped and reasonably symmetric, I interpreted results as being tests of differences in mean values.

Mean estimates and confidence intervals for duckling daily survival rate (DSR) for the exposure period between first sighting and age class IIa (21–28 days) were calculated for early and recent periods using procedures outlined by Mayfield (1975) and Johnson (1979), and 95% confidence intervals for DSRs were examined for overlap to test for significant differences.

Amalgamated broods (0 or more females with > 12 ducklings) were seen most years and were not excluded from the data set, as these broods and single broods have similar duckling survival (Afton 1993). However, I removed data for some or all of these broods on multi-brood lakes if I was unable to accurately determine age and duckling number because of brood mixing and duckling exchange. Also, to provide an alternative measure of duckling survival, I selected broods continuously observed from age class Ia to IIa, and, for both time periods, calculated the proportion of ducklings lost. I used Fisher's exact test (McDonald 2009) to test for differences between time periods in number of ducklings lost.

Similarly, I determined the proportion of age class IIa broods with an attending female (BWF; all years combined) for early and recent periods and tested for differences with a Fisher's exact test. I excluded broods first seen without a female and broods sighted only once. When a brood female or duckling disappeared, I assumed this occurred at the mid-point of the observation interval. All statistical tests were considered significant at the $P \leq 0.05$ level.

Results

Productivity

During the early period (BSA only, 6.8 km²) and the recent period (BSA+ transect, 22.6 km²) total pairs for all years were estimated at 64 and 245, respectively, and total IIa broods recorded were 15 and 75, respectively (Table 1). Brood production was higher in years with relatively stable or rising summer water-levels (1971, 2010–2011, and 2013–2014) and decreased in years with declining summer water-levels (1970, 1972, and 2009) or dry emergent conditions (2012). Yearly productivity (broods/pair) values for early and recent periods were not significantly different ($P = 0.64$; Table 1). The range of recorded broods/pair values over both dry and wet summer conditions was similar for both the early (range 0.09–0.47) and recent period (range 0.06–0.48).

Mean hatch date and hatching chronology

MHD for the early period (30 July ± 1 day [day 210.9 ± 0.96 SE, $n = 118$]) and for the recent period (28 July ± 0.7 day [day 209.2 ± 0.70 SE, $n = 216$]) were similar ($P = 0.16$; Table 2).

Likewise, the distribution of broods hatching at weekly intervals did not differ between periods ($P = 0.98$; Figure 3).

Brood size, duckling survival and proportion IIa broods with attending female

Mean sizes of Ia and IIa broods were similar for both periods (Ia [early]: mean 6.7 ± 0.3 SE, $n = 78$; Ia [recent]: mean 6.6 ± 0.3 SE, $n = 113$, $P = 0.76$; IIa [early]: mean 6.0 ± 0.3 SE, $n = 51$; IIa [recent]: mean 6.0 ± 0.3 SE, $n = 126$, $P = 0.99$). The 95% confidence interval for the early-period DSR estimate overlapped that for the recent period; thus, DSR for the 2 periods was not different (Table 3). Duckling survival expressed as the percentage of lost age class Ia ducklings to age class IIa for the early and recent periods (10.5%, $n = 200$ and 12.6%, $n = 461$, respectively) was not significantly different ($P = 0.52$). The proportion BWF (all years) for the early period (0.77, $n = 53$) was not significantly different from that of the recent period (0.86, $n = 135$, $P = 0.19$).

TABLE 1. Lesser Scaup (*Aythya affinis*) productivity in 1970–1972 and 2009–2014, near Erickson, Manitoba.

Year	Estimated pairs	IIa broods	Broods/ pair
Early period			
1970	22	4	0.18
1971	19	9	0.47
1972	23	2	0.09
Total or mean	64	15	0.23*
Recent period			
2009	45	9	0.21
2010	38	14	0.37
2011	44	17	0.40
2012	34	2	0.06
2013	44	14	0.32
2014	40	19	0.48
Total or mean	245	75	0.31*

*Weighted means, adjusted for annual variation in numbers.

TABLE 2. Mean hatching dates for Lesser Scaup (*Aythya affinis*) during 1970–1972 and 2008–2014, near Erickson, Manitoba.

Year	Mean hatch date ± SE*	No. broods	Range (days)
Early period			
1970	212.5 ± 1.3	43	193–227 (34)
1971	212.1 ± 1.6	53	191–234 (43)
1972	204.8 ± 2.0	22	189–224 (35)
Total or mean†	210.9 ± 1.0	118	189–234 (45)
Recent period			
2008	215.4 ± 1.9	18	198–231 (33)
2009	210.0 ± 2.5	22	188–229 (41)
2010	211.5 ± 1.8	32	192–228 (36)
2011	204.8 ± 1.4	46	188–231 (43)
2012	204.9 ± 1.5	13	194–215 (21)
2013	208.8 ± 1.6	37	191–232 (41)
2014	210.7 ± 1.5	48	187–231(44)
Total or mean†	209.2 ± 0.7	216	187–232 (45)

*Days from 1 January; SE = standard error.
†Weighted means, adjusted for annual variation in numbers.

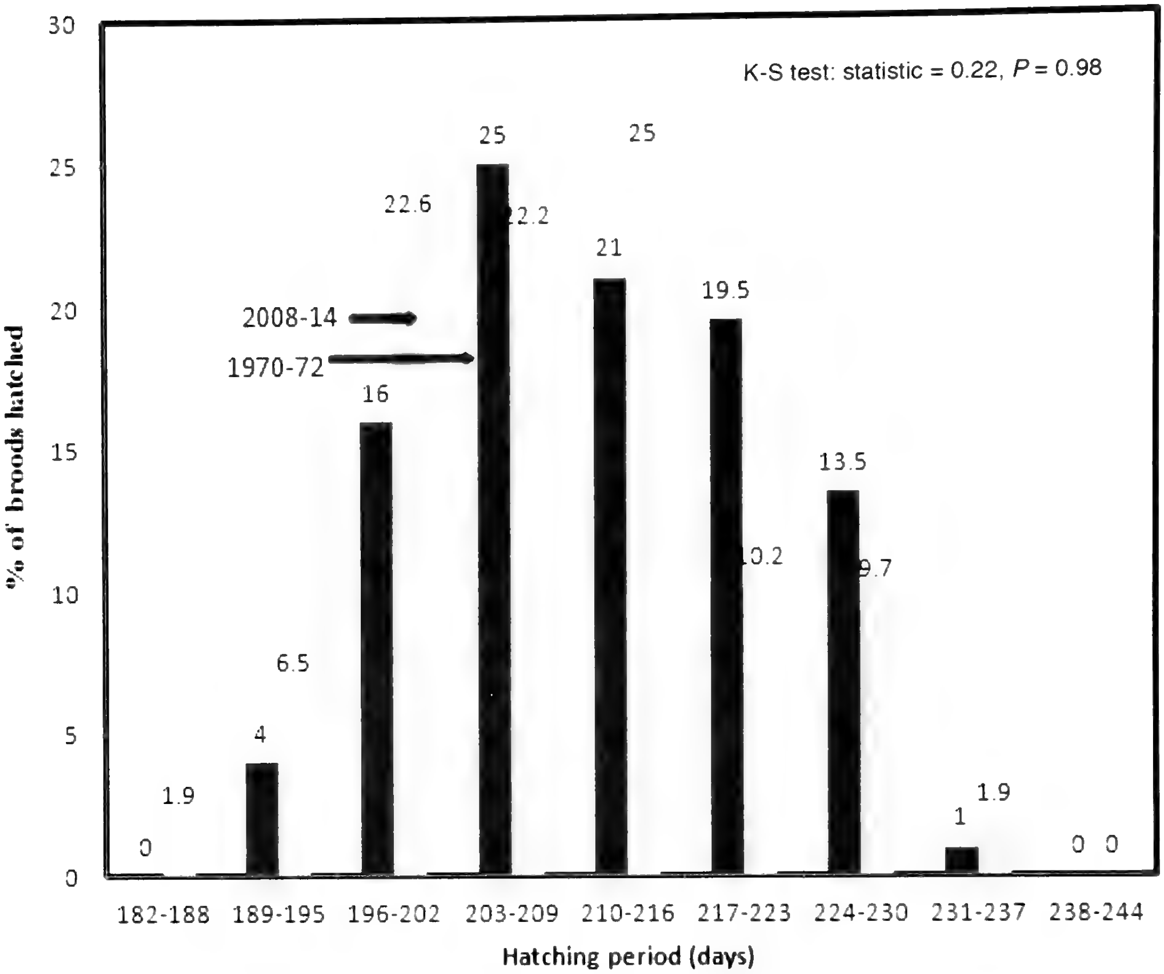

FIGURE 3. Hatching distribution for Lesser Scaup (*Aythya affinis*) near Erickson, Manitoba. Days are counted from 1 January. For 1970–1972, n = 118 (dark grey bars); for 2008–2014, n = 216 (light grey bars). K-S test = Kolmogorov-Smirnov test.

TABLE 3. Number of broods, exposure, losses, and daily survival rates for Lesser Scaup (*Aythya affinis*) ducklings from first sighting to age class IIa 1970–1972 and 2008–2014 near Erickson, Manitoba.

Year	No. broods	No. observations	No. intervals	Mean interval length (days)	Total exposure (duckling-days)	Total losses	Daily survival rate	95% CI
Early period								
1970	16	58	43	6.9 (6.0–8.0)	1705.0	5	0.99707	0.99475-0.99939
1971	31	130	104	6.5 (4.0–10.5)	3824.5	17	0.99566	0.99458-0.99674
1972	10	39	29	7.0 (3.0–15.0)	1127.0	5	0.99556	0.99160-0.99952
Total or mean	57	227	176	6.8 (3.0–15.0)	6656.5	27	0.99594	0.99438-0.99750
Recent period								
2008	10	23	18	8.5 (1.0–20.0)	1079.0	4	0.99629	0.99997-0.99261
2009	15	60	47	6.2 (1.0–15.0)	1525.5	18	0.98820	0.98268-0.99372
2010	25	98	72	7.3 (1.0–20.0)	2647.0	13	0.99509	0.99235-0.99779
2011	31	121	90	7.0 (0.5–24.0)	3751.0	20	0.99467	0.99229-0.99705
2012	12	39	24	7.8 (3.0–10.0)	1579.0	12	0.99240	0.98803-0.99677
2013	28	93	70	6.0 (1.0–19.0)	2438.0	19	0.99221	0.98865-0.99577
2014	31	91	62	6.5 (1.0–13.0)	2522.0	22	0.99128	0.98758-0.99498
Total or mean	152	525	383	6.9 (0.5–24.0)	15541.5	108	0.99305	0.99151-0.99459

Discussion

Contrary to my expectations, the reproductive parameters that I examined (i.e., IIa broods/pair, hatching dates, hatching chronology, Ia and IIa brood size, duckling DSR, and proportion BWF) have not changed between 1970–1972 and the present. If changes in natality have occurred, they are not discernible in these data. Small sample sizes may have limited my ability to find differences.

Productivity

For the early and recent periods, mean productivity was similar and yearly productivity was high (> 0.3 broods/pair) in wet years with stable water levels and much reduced (<0.1 broods/pair) in dry years when water levels were low or rapidly declining. My estimate of mean productivity (0.31 broods/pair) and productivity range for recent years was also similar to values reported at Erickson in 1977–1980 (Afton 1984). Afton's productivity estimates (nest success, assumed to be equivalent to broods/pair at hatch) ranged from 0.18 during a dry year to 0.40 during the wettest year. In contrast, using Koons' (2001; personal communication) recorded pair and brood data on his 25.8 km² Erickson study area, I calculated a broods/pair estimate of 0.09 (*n* = 43 pairs) and 0.17 (*n* = 30 pairs) in 1999 and 2000 respectively, despite the wet habitat conditions. Neither of these studies published total brood loss or IIa broods/pair values comparable to my study. Published estimates of total brood loss for scaup are few and limited to boreal scaup, but losses are high (Walker and Lindberg 2005; Corcoran *et al.* 2007).

Undoubtedly, some total brood loss is occurring at Erickson and, therefore, nest success may be higher than my IIa broods/pair values suggest.

Several potential biases may have affected my productivity estimates. In North Dakota, USA, Pagano and Arnold (2007) found that replicated single-observer counts of scaup pairs could underestimate breeding pairs by about 11% and thus, my broods/pair counts could be biased high. In addition, I cannot verify my assumption that no net brood movement occurred on and off the study areas. Nonetheless, my early and recent estimates are comparable as similar detection biases could apply to pair and brood counts. In addition, my recent transect may differ from the BSA in habitat quality for female and brood success and all recent reproductive estimates could be biased. However, I believe that habitat quality is similar across the study areas because preliminary analysis showed similar broods/pair trends over time for the BSA and recent transect and topography, soils, wetland type, predator community, and agricultural practices appear similar. Age structure of the female population can affect productivity and any change in this structure might bias results when comparing time periods. Declining age ratios in the scaup harvest suggest lower recruitment (Afton and Anderson 2001) and possibly a recent breeding population included a higher proportion of older, more experienced adults. Older females have better reproductive performance (Afton 1984) and this might account for the higher productivity I recorded in recent years. I have no data to assess this, but during 1999–2000, Koons and Rotella (2003), working with marked females, found little change (except for 3 year olds) from historical age structure in the Erickson population. Change in breeding propensity could affect my broods/pair ratios if resident breeding females fail to breed and do not settle on the study area, but this potentially important matter is beyond the scope of this study and I have assumed no change in breeding propensity over time. I suggest that future researchers address these possible biases for scaup broods/pair estimates in parkland and boreal habitat to assess the utility of estimating yearly production by this relatively inexpensive method.

Koons and Rotella (2003) reported low nesting success rates at Erickson in 1999 and 2000 (10.8% and 12.1%, respectively), both years with wet conditions. These values are much lower than Afton's (1984) predecline estimates and my productivity estimates. Koons and Rotella attached radio transmitters to females and these devices have been shown to negatively affect some reproductive parameters (Paquette *et al.* 1997; Guyn and Clark 1999; Barron *et al.* 2010; Arnold and Howeter 2012; Bloom *et al.* 2012; but see Pietz *et al.* 1995); however, Koons and Rotella found no evidence of bias in nest survival estimates (unpublished analysis). Brook (2002) reported mean nest success for 1999–2000 at St. Denis, Saskatchewan, to be very low (3% for mainland nests; 95% CI = 0.004–0.120, *n* = 18), but increasing drought conditions may have negatively influenced these results (R. Clark, personal communication). Again, my productivity estimates (IIa broods/pair) result from different methods but it is difficult to imagine how such low nest success reported by these authors could translate into the numbers of broods recorded on my study areas. These contrasting results may simply reflect a high degree of spatial-temporal variation in scaup reproductive success.

Mean hatch date and hatching chronology

I found similar MHD and hatching chronology in the early and recent periods. Neither prediction that hatching dates would be later because of later mean nest initiation date (9 days, Koons and Rotella 2003) nor that they would be earlier if scaup were no longer renesting was supported by my data. I interpret similar MHD and hatching chronology as resulting from no or little change in pattern of nest initiation from the predecline period because (1) estimated first nest initiation dates (by backdating first recorded brood dates by 36 days to account for egg-laying and incubation) during this study (mean day 156, range 151–168, *n* = 7 years) were similar to historical estimates (mean day 155, range 153–157, *n* = 3 [Hammell 1973]; mean day 155, range 152–162, *n* = 4 [Afton 1984]) and (2) the appearance of late-hatching broods in both periods (> day 224, a hatching period beyond the combined laying plus incubation span of Afton's [1984] latest recorded initial nest) could represent renesting.

Brood size and duckling survival

Also contrary to expectations, I found no difference in brood size, DSR, or percentage duckling loss estimates between pre-decline and recent periods, suggesting no change in duckling survival after first sighting to age class IIa. In contrast, Koons and Rotella (2003) found a marked decline in duckling survival from the 1970s to 2000; their estimate of duckling survival (20%) from hatch to age class IIa at Erickson was less than a third of Afton's (1984) pre-decline estimated mean (68%) for 1977–1980. Because my duckling loss analysis does not include the earliest days of the brood period (age at first sighting: early period, mean 5.7 days, $n = 78$; recent period, mean 6.9 days, $n = 173$; $P = 0.11$, no significant difference at $P \leq 0.05$ based on Mann-Whitney U test), a period when duckling loss can be high (Hammell 1973; Afton 1984; Koons 2001; Corcoran *et al.* 2007), I could be missing an increase in early total brood mortality, which would not necessarily alter my brood size or DSR estimates but that would be reflected in Afton's (1984) and Koons and Rotella's (2003) hatch to age class IIa results. Similarly, a change in total brood loss occurring later in the brood period might not be evident from my data, as DSR and brood size were calculated from broods that were present on the wetlands and I made no assumptions about the fate of broods that disappeared. However, such change in total brood loss seems unlikely because age class Ia brood sizes are unchanged between periods (no increase in small broods); no significant change was observed in the proportion of broods that disappeared (moved or suffered total loss) after having been first observed (early period: 0.29, $n = 77$; recent period: 0.19, $n = 162$; $P = 0.13$, Fisher's exact test; McDonald 2009); and a marked increase in total brood loss in recent times would imply unreasonably high nest success. I conclude that it is most likely that duckling survival is unchanged between early and recent periods.

Proportion IIa broods with attending female

The proportion of BWF is determined by both the degree of female reproductive investment and mortality during the brood season, and by timing of hatch (Gehrman 1951; personal observations). Females presumably balance investment in the brood with investment in themselves (e.g., regained body reserves). My results show that the proportion of BWF has not changed between periods, and assuming similar female mortality and hatching chronology for both periods, suggest that females are not abandoning broods earlier than in the past. This result is contrary to my prediction that females might abandon broods earlier in response to later nest initiation and/ or reduced body condition (Koons and Rotella 2003; Anteau and Afton 2004).

However, female brood season mortality may not be similar between study periods so I advise caution when interpreting these data. Nonetheless, this result is consistent with my other findings that reproductive parameters examined here have not changed over time.

Why, then, would scaup breeding pair numbers at Erickson have declined from the 1970s to the present (Koons and Rotella 2003; Hammell 2014) if, as my results suggest, reproductive success has not declined? There are 19 years of nest or female success data available for Erickson, encompassing wet and dry years (Figure 4). Although these estimates may not be exactly comparable because of different methods used, they

FIGURE 4. Estimates of productivity of Lesser Scaup (*Aythya affinis*) near Erickson, Manitoba, presented in or calculated from: 1957–1960 (Rogers 1964); 1970–1972 and 2009–2014 (this study); 1977–1980 (Afton 1984); 1999–2000 (Koons 2001). Dotted line represents productivity necessary to maintain the population.

do show a great degree of annual variation even within studies and suggest that in the past 58 years scaup experienced "good" and "bad" production years. Using published estimates of scaup vital rates in prairie-parkland habitats (annual female survival [breeding season survival × non-breeding season survival] 0.61; juvenile survival rate [fledging to following breeding season] 0.55; sex ratio of juveniles 50:50; mean IIa brood size 6; Koons *et al.* 2006; this study), I calculated a crude productivity rate (IIa broods/pair) necessary to maintain a stable population at Erickson. I assumed that all surviving adult and juvenile females returned to Erickson the following year and that immigration was minimal, a reasonable assumption as scaup are known to exhibit a high degree of philopatry (Afton 1984). I also assumed that duckling mortality from age class IIa to fledging was nil, although some mortality likely does occur. Starting with a hypothetical 100 pairs in the spring of year *y*, annual female survival + juvenile female recruitment and survival must equal 100 at year *y + 1* for a stable population. Therefore, 61 adult females + [(productivity × 100) × (6 × 0.5) × 0.55] = 100. Imposing this productivity value (calculated at about 0.24) on Figure 4, the frequencies of years above and below the putative maintenance line are similar and, consequently, scaup may have difficulty increasing populations over time. Indeed, a prolonged period of dry years occurred during the late 1980s to mid-1990s, when mean numbers of ponds counted on both segments 3 and 4, transect 6 near Erickson (1987–1995) were below the 1955–2014 segment means (unpublished analysis). Juvenile recruitment and breeding propensity is low during dry years (Rogers 1964; Hammell 1973; Afton 1984; this study), and, during these years, scaup might have suffered repeated annual breeding population loss. Given a continuation of historical fluctuating habitat conditions where gains in "good" years might be negated by losses in "bad" years, there may have existed little capacity for scaup to recuperate these losses following the dry period, and the population has remained low. In addition, change in survival or carrying capacity away from Erickson may have reduced the density of settling pairs.

Conclusion

My results do not support the hypothesis that Lesser Scaup reproductive success has decreased since the 1970s in the Erickson parklands. Although causal mechanisms responsible for reduced continental populations are, as yet, unresolved, my results are consistent with the hypothesis that recruitment of southern breeders is not much affected. If scaup females are arriving on the Erickson breeding grounds in poorer body condition than during the 1970s (Anteau and Afton 2004), they may be replenishing reserves during the 4–6 week pre-laying period (Afton 1984) and entering the laying and incubation periods with sufficient reserves to reproduce at levels similar to historical values. Captive female scaup have been shown to completely recover from a loss of 11% body mass in only 4 days, and, during migration, some wild-living scaup could increase body mass by about 60 g/day under ideal foraging conditions where abundant natural foods were supplemented by corn (Martin 2007; Anteau and Afton 2008c). In addition, at a high-elevation southern breeding site in Montana, USA, during the lengthy pre-nesting period, a female of average structural size was able to increase her body condition by 2.2 g/day (wet weight) supplementing endogenous reserves (lipids and protein) with nutrients from local dietary sources (Cutting *et al.* 2011, 2014; Warren *et al.* 2013). Together, these results suggest that mass loss can be reversed if food supplies are adequate. In contrast, boreal breeding scaup undergo a much longer migration and may arrive at northern breeding areas with reduced reserves. On arrival, they do not have a long pre-laying period in which to regain reserves (Trauger 1971; Brook 2002) and, consequently, reproductive success may be suffering (Brook 2002; Walker *et al.* 2005; Corcoran *et al.* 2007). In fact, Afton and Anderson (2001) reported that the steepest continental scaup population declines occurred in the boreal region.

This study and that of Koons and Rotella (2003) used different methods which confound direct comparisons. A repeat of Afton's (1984) pre-decline study, using his methods, would provide additional data. Also, it would be valuable to see if the results of this study hold at other southern breeding areas, by undertaking comparative studies; historical studies exist from southern Saskatchewan and Alberta (Keith 1961; Smith 1971; Hines 1977).

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Climate Warming as an Explanation for the Recent Northward Range Extension of Two Dragonflies, *Pachydiplax longipennis* and *Perithemis tenera*, into the Ottawa Valley, Eastern Ontario

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Climate warming is accepted as an explanation for the recent appearance of Blue Dasher, *Pachydiplax longipennis* (Burmeister, 1839), and Eastern Amberwing, *Perithemis tenera* (Say, 1839), in the Ottawa region, as this range expansion meets 6 criteria: (1) the climate in the newly occupied territory has warmed sufficiently to allow colonization; (2) a new range expectation based on the amount of climate warming is met; (3) other factors potentially promoting spread are excluded; (4) the possibility that range extension is a result of difficulty of observation and/or insufficient fieldwork in earlier times is excluded; (5) there is ample evidence for establishment; and (6) spread has been in the direction of the warmer territory or within it. By 2000, the mean daily temperature in the Ottawa region had increased by about 2°C since 1880 and about 1.1°C since 1960. This would allow new zonal boundaries and the prediction of expansion from a well-defined and long-occupied area into the Ottawa Valley. The two species entered this region in 2008–2012 and, subsequently, became well established.

Key Words: Climate warming; climate change; range extension criteria; dragonflies; Odonata; Blue Dasher; *Pachydiplax longipennis*; Eastern Amberwing; *Perithemis tenera*; Libellulidae; Ottawa Valley; Ontario

Introduction

The geographic limits of flora and fauna have shifted northward over the past few decades in response to recent climatic warming (Hickling *et al.* 2005; Flenner and Sahlen 2008; Mason *et al.* 2015). A sufficient number of examples now exist so that climate warming must be associated with range expansion. However, specific decisions to implicate climate warming are often not cautious and may be presented with limited understanding of other potentially contributing factors. Here, criteria are applied to such a decision with regard to dragonflies (Odonata), a group highly sensitive to climatic factors (Bush *et al.* 2013).

Although several articles have related changes in the distribution of Ontario's odonates to climate warming (Catling and Brownell 1998, 2002 [with statistics]; Bracken and Lewis 2002; Catling 2004, 2005, 2008), these alluded to warming only as a possible factor and were not rigorous in the association. The most compelling evidence for the importance of climate warming involves 2 dragonflies: Blue Dasher, *Pachydiplax longipennis* (Burmeister, 1839), and Eastern Amberwing, *Perithemis tenera* (Say, 1839), in the Ottawa Valley (Hanrahan 2011; Reddoch and Reddoch 2012; Hutchinson *et al.* 2014a,b). These species are investigated with respect to specific criteria.

Methods

The following criteria were developed to determine whether or not the range extension of *P. longipennis* and *P. tenera* is largely a result of climate warming.

Sufficient climate warming

The climate in the newly occupied territory must have warmed sufficiently to allow colonization. The warming should be of a magnitude equal to the difference between biogeographic zones. Biogeographic boundaries, such as Ontario's Carolinian Zone (which approximates the 7.8°C isotherm in Figure 1, also called the eastern deciduous forest in New York State, where it reaches its northern limit on the southeastern corner of Lake Ontario, or the middle south shore of the lake) are associated with climate boundaries, such as mean annual length of growing season, mean annual frost-free period, and mean daily temperature for the year (see Brown *et al.* 1980). The difference between biogeographic zones in southern Ontario, such as the Carolinian Zone, the Carolinian Zone with Georgian Bay and eastern Lake Ontario satellites (6.7°C isotherm in Figure 1), and the sub-Algonquin region (the northern boundary approximating the 5.5°C isotherm in Figure 1) is 1°C. Thus a rise in temperature of this magnitude may be sufficient to move to a new boundary.

Average yearly temperatures for Ottawa from 1880 to 2014 were acquired from the monthly averages data provided by Environment Canada (2015; Figure 2). These were plotted to determine whether there had been an increase of 1° or 2°, permitting zonal expansion. Statgraphics (Statpoint 2005) was used to produce a second-order polynomial regression plot. This method was employed because significance was above 95% and it explained more variation than other models.

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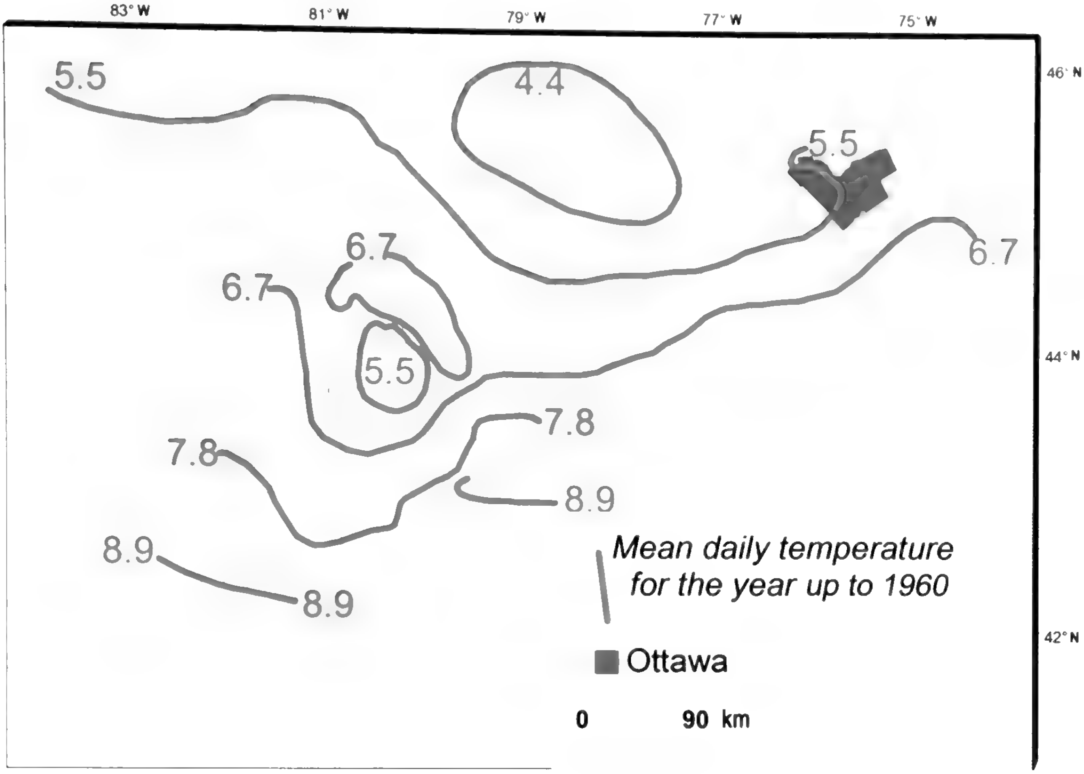

FIGURE 1. Mean daily temperature isotherms (°C) for southern Ontario. The City of Ottawa (previously Carleton County or the Regional Municipality of Ottawa-Carleton) is shaded in green. With immediately adjacent areas, this is considered to be the "Ottawa region." Source: Brown *et al.* (1980: Figure 7).

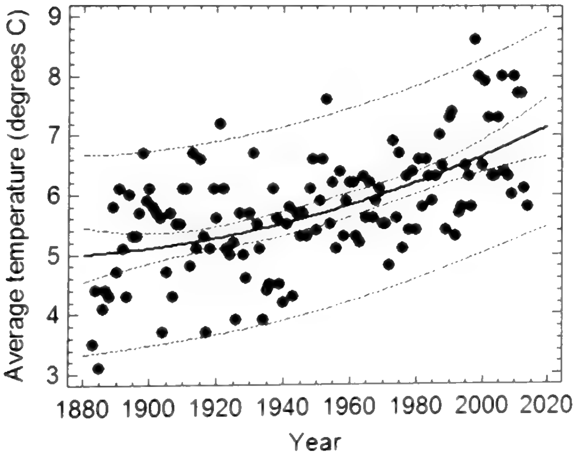

FIGURE 2. Mean daily temperature for each year, 1880–2014, at Ottawa, Ontario, Canada. The dark central line is the regression. The pair of lines closest to it are limits for confidence intervals for means (95%). The outer pair of lines are limits for predictions (95%).

New range expectation

The expansion should fulfill an expectation based on warming. If average yearly temperature has increased by 1°C during a specific period, and this is deemed sufficient, then the range may be expected to extend to the new limit, which is likely defined by an adjacent isotherm (assuming that factors governing isotherms, such as topography, have not changed). In this case, we would expect the 2 dragonflies to have extended their range to the 7.8°C isotherm, which was the former 5.5°C isotherm (Figure 1) based on extension from a 5.5–6.7°C boundary. This would include the Ottawa region defined as the City of Ottawa (previously Carleton County or the Regional Municipality of Ottawa-Carleton). The former 5.5°C isotherm is based on data from 1931–1960 (Brown *et al.* 1980), although the publication date is 1980. The latter date corresponds to a 0.8°C increase but, since the end of the record period for Brown *et al.* in 1960, the mean daily temperature for the year has increased by about 1.1°C. Plotting records contained in the Ontario Odonata Survey (Catling and Jones 2007) and the Ontario Odonata Atlas database (maintained by C. Jones at the Ontario Natural Heritage Information Centre in Peterborough) from

2007 onward enabled a consideration of the extent to which the new range expectation was fulfilled.

Exclusion of other factors

The rapid and extensive range expansion of several odonate species is thought to be related to new kinds of aquatic habitat provided by humans. Expansion of the Familiar Bluet, *Enallagma civile* (Hagen, 1861), in Ontario (Catling 1996) and the northeast generally (Catling 1998) is a good example of a species that occurs in eutrophic goldfish ponds as well as many other man-made and polluted habitats. To some extent, its expansion may be a result of these new man-made habitats. The same may be true of the Great Spreadwing, *Archilestes grandis* (Rambur, 1842), which in North America was confined to the southwestern states until the 1920s, then spread east and northeast to New England, presumably as a result of its extreme tolerance of poor water quality and degraded habitats (Kennedy 1977; Moskowitz and Bell 1998; Craves 2006). Many factors may play a role in range expansion, but for climate warming to be considered a major factor, some of these other factors must be eliminated.

Sufficient evidence for extension

An extension of range might result from occurrences that were overlooked in the past for any of a variety of reasons, particularly difficulty of observation or insufficient field study. The species must be conspicuous, and there must have been enough past fieldwork in the area under consideration to infer strongly that a particular species is a new arrival that, at one time, had a reliably more restricted occurrence. Insufficient data or limited recognition are sometimes referred to as the "recorder effect." This was evaluated in 4 ways.

Time-coded distribution: Distribution maps were produced with dates of occurrence coded for "prior to 1999" and "1999 and after," with the earlier period plotted last to emphasize differences since that time. These indicate expansion and also the number and distribution of records on which it is based. The year 1999 was chosen because it was during and after this date that significant expansion occurred based on mapping and observations (Tables 1 and 2; PMC, personal observation).

Comparison species: Comparisons were made with other species that have not changed their distribution in the region under study. This illustrates the distribution of observations of dragonflies and may suggest true absence of target species if the comparison species were present, occupied similar habitats, and were similarly conspicuous. The 2 comparison species used were Twelve-spotted Skimmer, *Libellula pulchella* Drury, 1773, which is slightly more conspicuous than our target species, and Four-spotted Skimmer, *Libellula quadrimaculata* Linnaeus, 1758, an equally conspicuous species. If these comparison species were present in the areas of the recently expanded range during the early period, then the 2 target species would have been noticed as well; if the target species were not noticed, they must have been truly absent.

Number of records: Number of records was plotted against time for each target species to indicate where and for what times the records are available. Ideally, there should be about the same number of records before and after a key date. At least there should be a relatively large number of records for each. The idea is that a much larger number of records for one period may include geographic areas not recorded for the other period of time because of unequal search effort.

Literature support: The older literature should support the idea that the expansion is recent by the absence of proposed recent immigrants and support for the earlier presence of comparison species.

Evidence for establishment

The species should be well-established, i.e., present in good numbers and over several years. Some populations, such as those of Citrine Forktail, *Ischnura hastata* (Say, 1839), appear to come and go at the northern limit of their range (Bree 2005; Catling 2008). Bree (2005) suggested that some populations of 3 odonate species with different dispersal mechanisms may establish only temporarily at their northern limit. Differences in weather from year to year have been associated with remarkable variations in abundance of mostly southern butterflies (PMC, personal observation). Thus, to accept that a species has extended its range, some evidence of permanent residency is necessary. This was considered in terms of records in consecutive years, presence of larvae or exuviae, and numbers of individuals encountered. Although this was sufficient in the present case, this criterion may be applied more rigorously (Bried *et al.* 2015a,b).

Direction and history of spread

Spread resulting from climate change should be in the direction of the warming climate. In the northern hemisphere, that direction would be north at uniform elevation. The range expansion of the damselfly, *Archilestes grandis* (see *Exclusion of other factors* above), is to some extent west to east; furthermore, the distance may have been more substantial than climate-warming effects alone can explain. Consequently, one is led to expect that factors other than, or in addition to, climate warming have played a role in the spread of this species. Criteria that support the climate warming explanation for range expansion include distance, terrain, direction, and timing.

Results

Sufficient climate warming

Since 1880, mean daily temperature for the year in Ottawa has increased by about 2°C, and since 1960 by about 1.1°C (Figure 2). The warming has been continuous. The P value for the ANOVA was < 0.001 and R^2 was 34.84%.

TABLE 1. Records of the Eastern Amberwing, *Perithemis tenera* (Say, 1839), in Ontario that are substantially outside of the pre-1999 distribution.

Year	Location*	Latitude, °N	Longitude, °W	Observer
1999	Blind Lake Bog, about 10.5 km N of Fordwich Post Office	43.9617	81.0511	M. J. Oldham, M. E. Austen
2001	Bloomfield Mill Pond	43.9863	77.2271	D. Bree
2002	Indian River mouth at Rice Lake, S of Keene	44.2388	78.1533	M. J. Oldham, V. and R. Oldham, M. Delisle-Oldham
2005	Indian River from bridge at Keene to mouth at Rice Lake	44.2517	78.1516	M. J. Oldham, M. Delisle-Oldham, R. Oldham
2010	Loughborough Lake at Perth Rd.	44.4181	76.4779	P. M. Catling
2011	Rideau River, Burritts Rapids	44.9823	75.7970	P. M. Catling
2012	N side E of Wellington opposite Conley Rd., West Lake	43.9587	77.3152	P. M. Catling
2012	Stoco Fen, Old Hungerford Rd., E of Stoco	44.4642	77.2322	J. Bartok
2012	Mud Lake pond, Britannia Conservation Area, Ottawa	45.2224	75.4743	B. Bracken, D. Moore
2012	Windsor Park, Rideau River	45.3938	75.6761	P. Hall
2012	Markham, opposite 7275 14th Avenue, about 0.5 km W of Reesor Rd.	43.8653	79.2082	B. Edwards, G. Yankech, I. Yankech, W. White
2012	Petrie Island inlet, Ottawa River	45.4995	75.4844	B. Bracken, C. Lewis
2012	Petrie Island inlet, Ottawa River	45.4995	75.4844	C. Hanrahan
2012	Haskins Rd., Burritts Rapids	44.9654	75.7934	B. Bracken, C. Lewis, M. Tate
2012	Petrie Island inlet, Ottawa River	45.4995	75.4844	L. de March
2012	Haskins Rd., Burritts Rapids	44.9654	75.7934	E. Thomson, B. McBride, D. Moore
2012	Snowdon Rd., Bolton Rd., Hanlon Marsh, Kemptville	44.5310	75.4434	M. Runtz, P. Hall
2012	Outlet River highway bridge, Sandbanks Provincial Park	43.8983	77.2212	D. Bree
2012	Outlet River above bridge, Sandbanks Provincial Park	43.9017	77.2177	D. Bree
2012	Lajoie Rd. and Trans-Canada Trail, Tweed	44.4769	77.3019	J. Bartok
2012	N of Stoco Lake, Tweed	44.4689	77.3153	J. Bartok
2012	N end of Conc. 4, N of Zephyr	44.2260	79.2504	J. Boxall, J. Hopkins, T. Lambert, D. Bishop, E. Poropat
2012	Trans-Canada Trail, Tweed	44.4667	77.3197	J. Bartok
2012	Trans-Canada Trail, Tweed	44.4826	77.2965	J. Bartok
2012	Moira River, "The Pointm", Tweed	44.4739	77.3072	J. Bartok
2012	Petrie Island, Trim Rd.	45.4995	75.4844	R. Yank
2012	Trans-Canada Trail, Tweed	44.4815	77.2978	J. Bartok
2012	Carrying Place, Rec. Field	44.0465	77.5786	D. Bree
2012	Trans-Canada Trail, Tweed	44.4592	77.3425	J. Bartok
2012	Haskins Rd., Burritts Rapids	44.9654	75.7934	B. Laporte, C. Lewis
2012	Quin-mo-lac Rd., S shore of Moira Lake	44.4750	77.4194	J. Bartok
2012	0.7 km W of Tweed	44.4689	77.3153	J. Bartok
2012	Stoco Lake, Tweed	44.4739	77.3072	J. Bartok
2012	Outlet River by County Rd. 18, Sandbanks Provincial Park	43.8983	77.2212	K. Kingdon
2012	Outlet River by County Rd. 18 Sandbanks Provincial Park	43.8983	77.2212	D. Bree
2012	Moira River and Stoco Lake, Tweed	44.4771	77.3018	J. Bartok
2012	Prince Edward Point	43.9433	76.8623	B. Ripley
2012	Outlet River, Sandbanks Provincial Park	43.8951	77.2186	J. Dewey
2012	Stoco Lake, Tweed	44.4741	77.3065	J. Bartok
2012	Outlet River, Sandbanks Provincial Park	43.8951	77.2186	J. Dewey
2012	Outlet River, Sandbanks Provincial Park	43.8951	77.2186	B. Ripley
2012	Outlet River, Sandbanks Provincial Park	43.8951	77.2186	J. Dewey
2012	Outlet River, Sandbanks Provincial Park	43.8951	77.2186	D. Bree
2012	Millpond, Bloomfield	43.9869	77.2258	D. Bree
2012	Sandbanks Provincial Park, Outlet River by County Rd. 18	43.8983	77.2211	J. Dewey
2015	W shore of Dow's Lake near marsh	45.3937	75.7031	P. M. Catling
2015	Petrie Island Causeway, E side	45.4993	75.4840	P. M. Catling

*Note: E = east, N = north, S = south, W = west.

TABLE 2. Records of the Blue Dasher, *Pachydiplax longipennis* (Burmeister, 1839), in Ontario that are substantially outside of the pre-1999 distribution.

Year	Location*	Latitude, °N	Longitude, °W	Observer
2002	Indian River mouth at Rice Lake, south of Keene	44.2388	78.1533	M. J. Oldham, V. and R. Oldham, M. Delisle-Oldham
2002	Indian River mouth at Rice Lake, south of Keene	44.2388	78.1533	M. J. Oldham, R. Oldham
2002	Lakefield Marsh	44.4271	78.2776	C. D. Jones
2009	W shore of Fishog Lake	44.7899	78.8947	D. Barry, M. Carney, E. Poropat
2009	NW end of Fishog Lake	44.7965	78.8951	D. Barry, M. Carney, E. Poropat
2009	S end in outflow of Fishog Lake	44.7727	78.8827	D. Barry, M. Carney, E. Poropat
2010	Baxter Conservation Area, Rideau River near Reevecraig	45.0977	75.6247	C. Hanrahan
2011	William A. Holland Trail, Petrie Island	45.4995	75.4844	B. Bracken, C. Lewis
2011	Mud Lake pond, Britannia Conservation Area, Ottawa	45.3731	75.7965	B. Bracken, C. Lewis
2011	Mud Lake pond, Britannia Conservation Area, Ottawa	45.3731	75.7965	M. Tate
2011	William A. Holland Trail, Petrie Island	45.4995	75.4844	B. Bracken, C. Lewis
2011	Mer Bleue Bog Trail, Ottawa	45.3920	75.5130	K. C. Hannah
2011	William A. Holland Trail, Petrie Island	45.4995	75.4844	G. Mastromatteo
2012	Mud Lake pond, Britannia Conservation Area, Ottawa	45.3731	75.7965	B. Bracken, C. Lewis
2012	Big Cedar Lake boat launch	44.6028	78.1641	D. Bree, K Holloway
2012	Mud Lake pond, Britannia Conservation Area, Ottawa	45.3731	75.7965	B. Bracken, C. Lewis, M. Tate
2012	S of Haycock Island, at Shirley's Bay, Ottawa River	45.3672	75.8907	B. Bracken, C. Lewis, M. Tate
2012	Constance Creek, Thomas A. Dolan Parkway, Dunrobin	45.4520	76.0309	B. Bracken, C. Lewis, M. Tate, G. Mastromatteo
2012	N of Rifle Rd., Shirley's Bay, Ottawa River	45.3672	75.8907	B. Bracken, C. Lewis
2012	N of Rifle Rd., Shirley's Bay, Ottawa River	45.3672	75.8907	G. Mastromatteo
2012	William A. Holland Trail, Petrie Island	45.4995	75.4844	B. Bracken, C. Lewis
2012	William A. Holland Trail, Petrie Island	45.4995	75.4844	G. Mastromatteo
2015	Dow's Lake, W side near marsh	45.3939	75.7035	P. M. Catling, B. Kostiuk
2015	Chapman Mills Conservation Area on the Rideau River	45.2780	75.7029	P. M. Catling, B. Kostiuk
2015	Petrie Island causeway	45.4991	75.4843	P. M. Catling, B. Kostiuk

*Note: E = east, N = north, S = south, W = west.

New range expectation

The specific expectation of colonization of the Ottawa region based on climate warming is fulfilled (see references above and Figures 1, 3, and 4).

Some details of the expansion are also useful in this evaluation. In 2000 Catling and Brownell (2000) noted that *P. tenera* was "restricted to the Carolinian Zone and a good example of a species that is relatively widespread and common in this region although narrowly restricted to it." Its Carolinian distribution was also noted by Catling *et al.* (1998). This Carolinian distribution, corresponding to the 7.8°C mean daily temperature for the year, is well shown by pre-1999 dots on the distribution map (Figures 1 and 3). In 2001, it was first observed in Prince Edward County, extending the range 140 km to the east (Bree 2005). In 2002, up to 25 males were counted at Bloomfield suggesting establishment, but from 2003 to 2005 they were not observed there. It was also in 2002 that *P. tenera* was found in the Indian River on Rice Lake in Peterborough (Table 1). In 2007 and afterward, it was found for the first time in the eastern townships of Quebec (Bernard 2010). In 2011 and 2012, it reached the Ottawa region about 150 km north from the Kingston region (PMC, personal observation) and 125 km north of the Thousand Islands region of New York State (White *et al.* 2010) where it had been known since 2005. From 2012 to 2015, it was seen at several localities in the Ottawa region of Ontario (Table 1). In 2012 and 2013, it was reported from 5 localities near the Ottawa River in Quebec (Hutchinson *et al.* 2014b).

Before 1999, *P. longipennis* was confined to the Carolinian Zone and its northeastern Lake Ontario satellite (Figures 1 and 4). Significant extensions in its range occurred after that (Figure 4 and Table 2). The first records in the City of Ottawa were from Burritts Rapids in 2008 (Table 2) and from Baxter Conservation Area on the Rideau in 2010 (Hanrahan 2011). In 2011 and 2012, it was reported from Petrie Island and Mud Lake on the Ottawa River by Reddoch and Reddoch (2012) and Mastromatteo (2012). Hutchinson *et al.* (2014a) and Mochon (2012) reported it to be present at many other places near the Ottawa River in 2012 and 2013, and by 2015 it was well known in the Ottawa region.

Exclusion of other factors

Many of the occurrences of *P. tenera* and *P. longipennis* north of their pre-1999 range in Ontario are in natural habitats with little or no impacts of human activ-

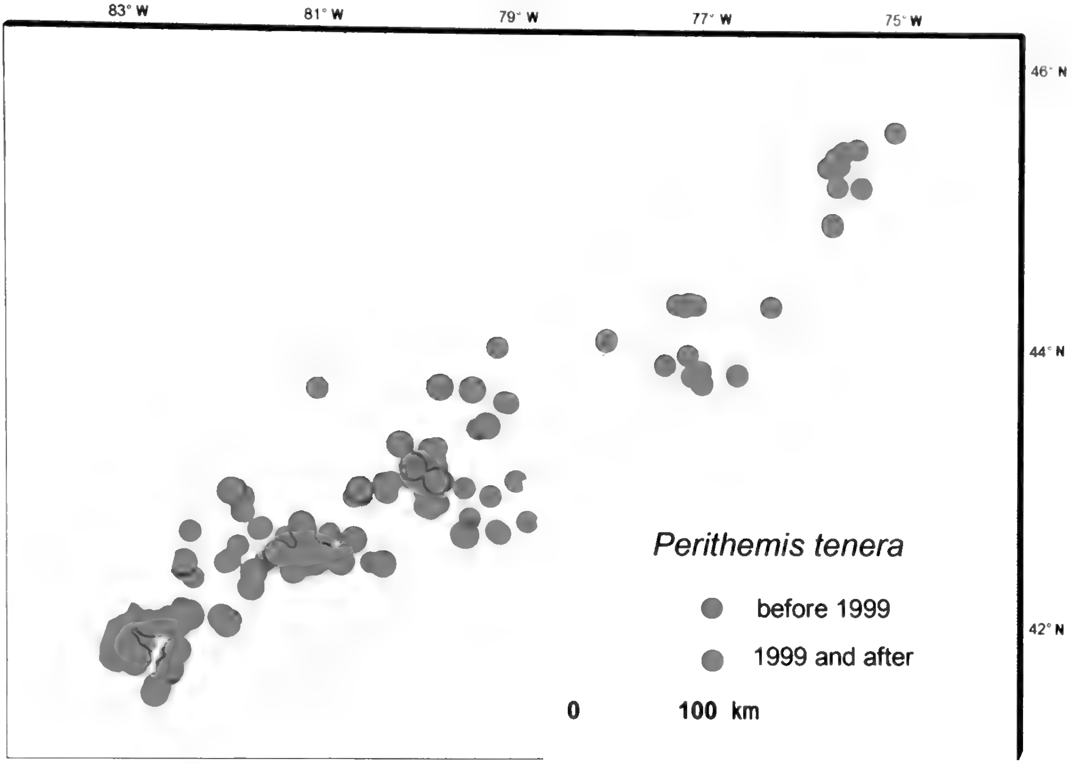

FIGURE 3. Distribution of *Perithemis tenera* in southern Ontario up to 1998 (blue dots) and 1999 and after (red dots). The blue dots were plotted over the red dots to emphasize recently expanded range.

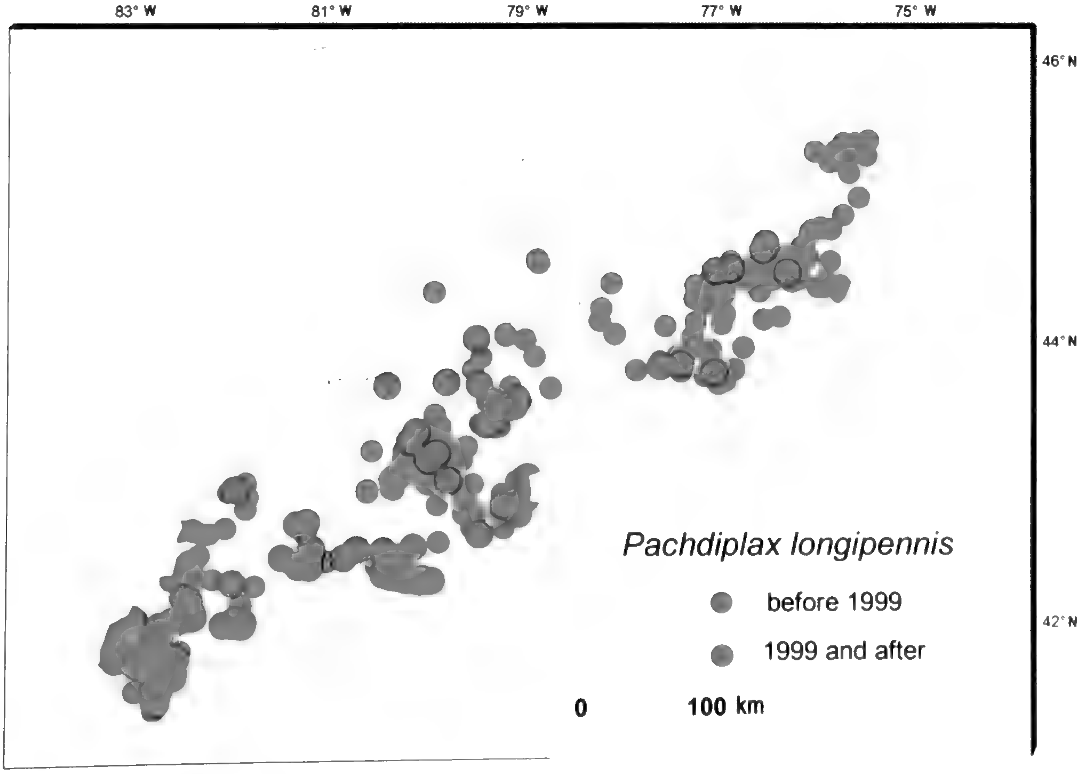

FIGURE 4. Distribution of *Pachydiplax longipennis* in southern Ontario up to 1998 (blue dots) and 1999 and after (red dots). The blue dots were plotted over the red dots to emphasize recently expanded range.

ity. *Perithemis tenera* is sometimes associated with polluted and turbid water, but only some of the new localities on and near the Ottawa River fit this description. In general, the habitats in the region that support expansion are not new.

Sufficient evidence for extension

Both *P. tenera* and *P. longipennis* are very conspicuous (Figure 5). Although females of the former may spend much time on land where they are not easily seen, the males, with amber wings, are conspicuous over water on lilypads (although often far from shore).

Time-coded distribution: The distribution mapping on Figures 3 and 4 clearly indicates expansion and suggests that it is based on ample records.

Comparison species: The presence of *L. pulchella* and *L. quadrimaculata* in the region of expansion and elsewhere (Figure 6) before 1999 suggests that recorders were present in pre-expansion times and their failure to encounter the 2 target species supports recent expansion.

Number of records: Although there are more records after the dispersal event, there are many before (Figure 7). For *P. tenera*, there are 361 records (unique date, place, and observer) beginning in 1929 (81 or 22.6% before 1998); for *P. longipennis*, there are 1135 records beginning in 1893 (201 or 17.7% before 1998; Figure 7). In the expansion area, there are 47 records (unique year, location, latitude, longitude, and observer/s) for *P. tenera* and 28 for *P. longipennis* (Tables 1 and 2). These expansion area records represent fewer than a quarter of the actual sightings in this area (PMC, personal observations), because many sightings were not accurately recorded nor submitted to the database.

Literature support: Comprehensive publications concerning dragonflies in the Ottawa region date back to 1886 (MacLaughlin 1886; Walker 1908; Ménard 1996; Sankey 1997; Bracken and Lewis 2004, 2005, 2008). No mention of *P. tenera* or *P. longipennis* was found in these. The 2 species selected for comparison were "rather plentiful" (*L. pulchella*) and "rather common" (*L. quadrimaculata*) in 1886 and noted consistently thereafter.

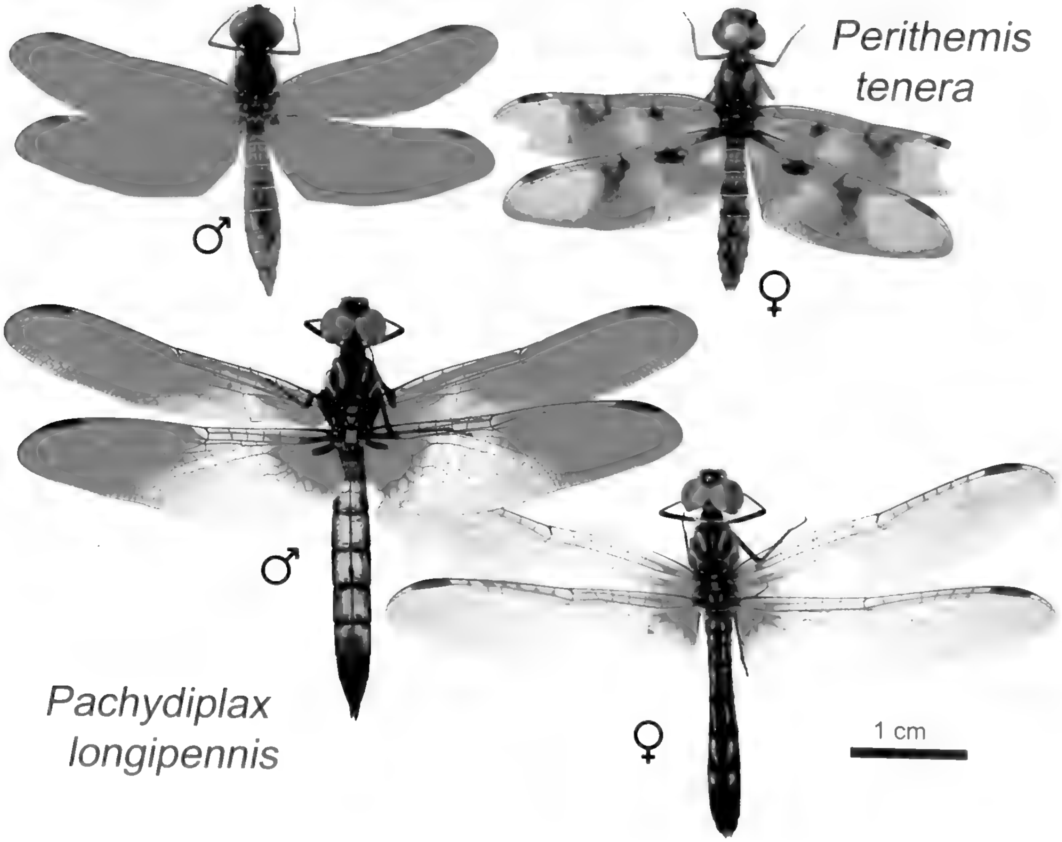

FIGURE 5. Two dragonflies that have recently expanded their ranges into the Ottawa Valley. Top: *Perithemis tenera* male, London, Ontario, 42.9444°N, 81.2197°W, P. M. Catling, 10 July 1997; female, Tilbury Conservation Area, Ontario, 42.2722°N, 82.4369°W, P. M. Catling, 5 July 1997. Bottom: *Pachydiplax longipennis* male, Crotch Lake, Ontario, 44.6583°N, 76.9708°W, P. M. Catling, 24 July 1997; female, Crotch Lake, Ontario, 44.6583°N, 76.9708°W, P. M. Catling, 9 August 1997. Photos: P. M. Catling.

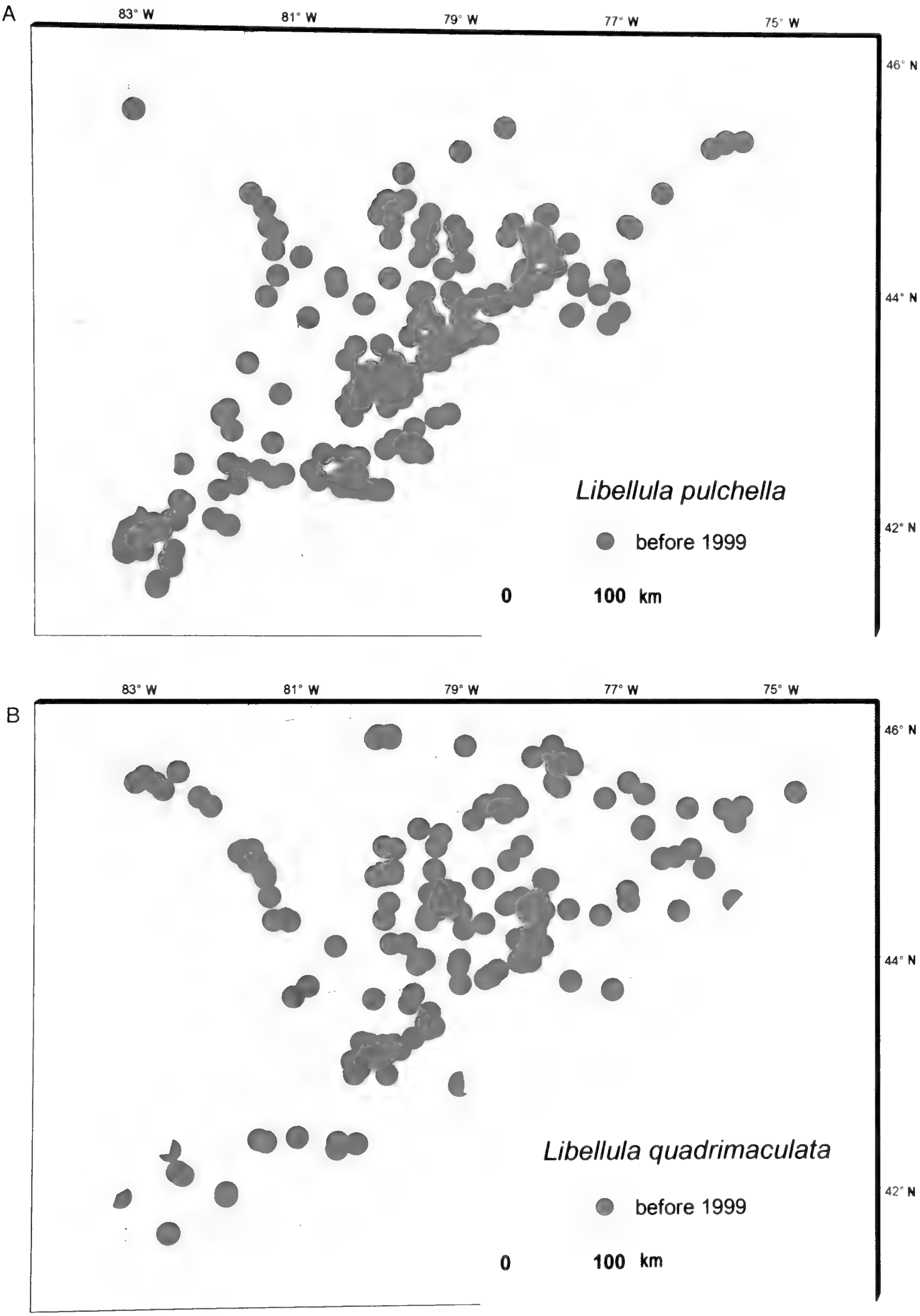

FIGURE 6. Records of (A) *Libellula pulchella* and (B) *Libellula quadrimaculata* in southern Ontario before 1999 to show distribution of dragonfly observations up to that time.

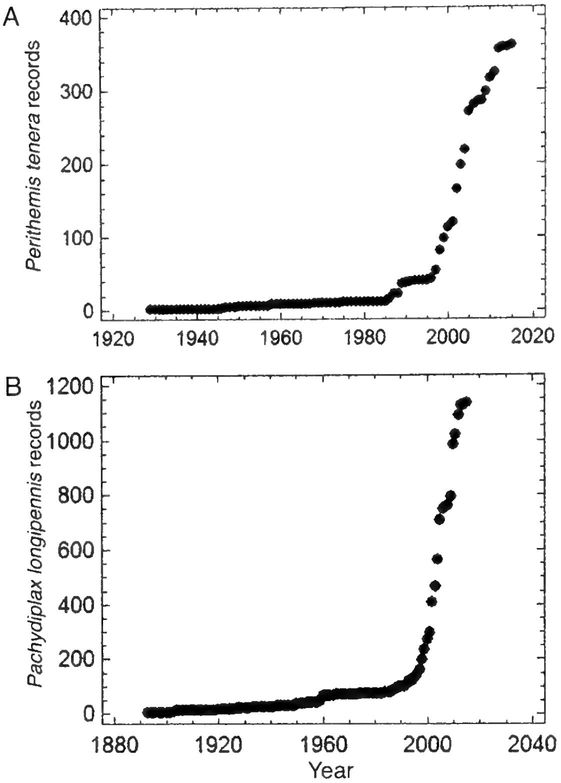

FIGURE 7. Number of records of (A) *Perithemis tenera* and (B) *Pachydiplax longipennis* that have accumulated over time.

In addition, Hutchinson *et al.* (2014a,b) noted that they had visited a large number of sites in the Ottawa region since 1987, but did not encounter the target species until 2012. Similar statements from others, with respect to over 500 recent site visits, many to areas where the target species currently occur, support their status as recent arrivals.

Evidence for establishment

Perithemis tenera was seen in 4 consecutive years in the Ottawa district (2012–2015, Table 1; PMC, personal observation), and both larvae and exuviae have been found at many sites. At one site, an estimated 300 individuals were present.

Pachydiplax longipennis has been seen in the same localities (e.g., Petrie Island and Dow's Lake) since 2011 (Table 2; PMC, personal observation). In 2012, larvae and adults were reported at 9 locations in the Ottawa region. Exuviae have been found at both Ottawa and adjacent Quebec locations.

Direction and history of spread

Both *P. tenera* and *P. longipennis* had a largely Carolinian distribution in 1999 and earlier in Ontario and probably also in New York State. *Perithemis tenera* was unrecorded in the northern counties of New York in 1992 (Donnelly 1992) and *P. longipennis* was known from only 1 northern county. The New York Dragonfly and Damselfly Survey, starting in 2005 (White *et al.* 2010), added locations for *P. tenera* on Wellesley Island and near Waterton (about 100 km south of the Ottawa region), and a number of localities near the St. Lawrence River (70–100 km south of the Ottawa region) for *P. longipennis*.

From these areas, the extension into the Ottawa region for both species is to the north, northeast, or north by northeast (or any combination). A northward movement of *P. tenera* in any westerly direction would have been unlikely due to the cooler regions of the Algonquin upland. Northeasterly movement would have involved up to 350 km. Any movement into eastern Ontario more directly from the south would have involved distances of about 250 km from the New York State equivalent of the Carolinian Zone in Oneida County. *Pachydiplax longipennis* would have had to move about 70 km from St. Lawrence County, New York, or about 90 km from Silver Lake, Ontario.

Although the origin and directions are unclear, both *P. tenera* and *P. longipennis* likely moved northward over more or less flat terrain into a warming landscape (Figures 1, 3, and 4).

Discussion

The northward spread of *P. tenera* and *P. longipennis* satisfies all noted criteria for identifying climate change as an explanation; sufficient climate warming has occurred, with a new range expectation that includes the Ottawa region. Other factors potentially associated with range expansion have been excluded. The literature and the relatively good coverage of records provide satisfactory evidence of recent arrival in 2008–2012. There is good evidence for establishment. The direction and history of spread is consistent with a climate warming explanation.

With climate warming continuously since 1880 (Figure 2; Brown *et al.* 1980: 14), both of these dragonflies have been moving north, probably at variable rates, since that time, but the most extensive and convincing evidence of a change in distribution comes from the period after 1998. Even after that time, the time of arrival in eastern Ontario may not be accurately known, but time of arrival and establishment in the Ottawa region is well established as 2008–2012.

Acknowledgements

Colin Jones provided records of *Perithemis tenera* and *Pachydiplax longipennis*, which were compiled as part of the Ontario Odonata Atlas database from 2007 onward and maintained by the Ontario Natural Heritage Information Centre in Peterborough. Raymond Hutchinson supplied references to the status of both species in Quebec.

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Note

Silver-white Variants of the Eastern Red-backed Salamander, *Plethodon cinereus*, from Eastern Canada

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The Eastern Red-backed Salamander (*Plethodon cinereus*) is well known for its colour polymorphism, which includes 8 colour phenotypes: the red-backed (striped), lead-backed (unstriped), and erythristic morphs, as well as the iridistic, albino, leucistic, amelanistic, and melanistic anomalies. Among these, the prevalence and geographic distribution of rare morphs have received little attention. In this article, we report 2 occurrences of silver-white variants of the red-backed morph of *P. cinereus* from Québec, Canada. To our knowledge, these variations in stripe colour on the red-backed phenotype represent the first 2 documented mentions for eastern Canada.

Key Words: Coloration; colour morph; dorsal stripe; silver-white variant; red-backed morph; Eastern Red-backed Salamander; *Plethodon cinereus*; Québec; Canada

Introduction

The Eastern Red-backed Salamander, *Plethodon cinereus*, has a broad geographic distribution in northeastern North America (Petranka 1998; Moore and Ouellet 2015). Like other terrestrial plethodontid salamanders, it plays an important role in forest ecosystems (Hickerson *et al.* 2012; Walton 2013; Semlitsch *et al.* 2014). This salamander's striking colour polymorphism has long attracted the attention of herpetologists and naturalists. Eight colour phenotypes are known and have been recently reviewed (Moore *et al.* 2012; Moore and Ouellet 2014). The red-backed (striped) and lead-backed (unstriped) morphs occur in most populations of *P. cinereus*, but in very different proportions (Moore and Ouellet 2015). The erythristic morph is also sporadically observed, but the iridistic, albino, leucistic, amelanistic, and melanistic anomalies are much rarer (Moore and Ouellet 2014).

In the red-backed morph of *P. cinereus*, the mid-dorsal stripe is generally red-orange, with gray-black borders that become mottled with white along the lower half of the body sides. Mid-dorsal stripe colours other than red-orange, such as shades of brown, gray, pink, white, and yellow, have also been reported (Bishop 1941; Test and Bingham 1948; Schueler 1975; Moore and Ouellet 2014). Surprisingly, little photographic evidence of these colour variations exists in the published literature. The dorsal stripe usually extends from the head to the tail; some individuals also show variations, such as disconnected stripe sections along the body or tail.

Silver-white variants of the red-backed morph of *P. cinereus* have recently been observed in the states of Ohio (Figure 18-1-C in Anthony and Pfingsten 2013; Figure 5 in Moore and Ouellet 2014), Pennsylvania (Figure 2 in Neff *et al.* 2015; C. D. Anthony, unpublished data), and Virginia (Project Noah, unpublished data; Virginia Herpetological Society, unpublished data). "White-striped morphs" of *P. cinereus* have also been reported in Massachusetts and New York (Schueler 1975; Haines-Eitzen 2015). Furthermore, one account of a "silver-backed phase" and another of a "ghost-backed phase" with a white dorsal stripe have been described for the closely related Southern Red-backed Salamander (*Plethodon serratus*) in Missouri (Drake and O'Donnell 2014). The dorsal stripes in these rare occurrences vary from gray to silver-white or white. In this article, we document 2 new occurrences of silver-white variants of the red-backed morph of *P. cinereus* in Québec, Canada.

Methods

The 2 observations presented here were made by the authors during their multiple herpetological surveys, some of which specifically targeted *P. cinereus* (Moore and Ouellet 2015). In these surveys, unusual colorations were documented using various means, including digital photography vouchers. We measured snout–vent length (snout to middle of vent on the first specimen, and snout to posterior margin of vent on the second specimen) and total length (snout to tip of the tail) in the field with electronic calipers. Both specimens were immediately released on-site following documentation.

Results

The first silver-white specimen of *P. cinereus* was a subadult observed in May 2014, under a rock in the re-

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gional county municipality of Lévis, Québec (46°44'N, 71°11'W; datum WGS84). This area is located on the south shore of the St. Lawrence River, across from Québec City. The habitat consisted of a deciduous forested outcrop at an elevation of 90 m. The salamander's mid-dorsal stripe was silver-white (Figure 1), without visible xanthophores (yellow and red pigment cells or erythrophores), but with somewhat iridescent golden flecks. Its dorsolateral body was gray-black, while its ventral body was coarsely mottled with black and white, resulting in the distinctive salt-and-pepper appearance of the species. The pigmentation of both its irises was also standard. The specimen's length was 30.7 mm snout to vent and 54.7 mm in total. On this particular site, we encountered 49 other individuals of *P. cinereus*, all of the standard red-backed morph.

The second specimen, an adult, was observed in July 2014 under woody debris in the metropolitan area of Québec City, Québec (46°45'N, 71°19'W; datum WGS84). This area is on the north shore of the St. Lawrence River, almost facing the first location (Lévis). The site was in a forested park, at an elevation of 80 m. The habitat consisted of mostly uneven-aged Sugar Maples (*Acer saccharum*). As on the first specimen, the mid-dorsal stripe was silver-white and the dorsolateral body was normally coloured (Figure 2). The col-

FIGURE 1. Silver-white variant of a red-backed morph of the Eastern Red-backed Salamander (*Plethodon cinereus*) from Québec, Canada. Natural light photo. Photo: M. Ouellet.

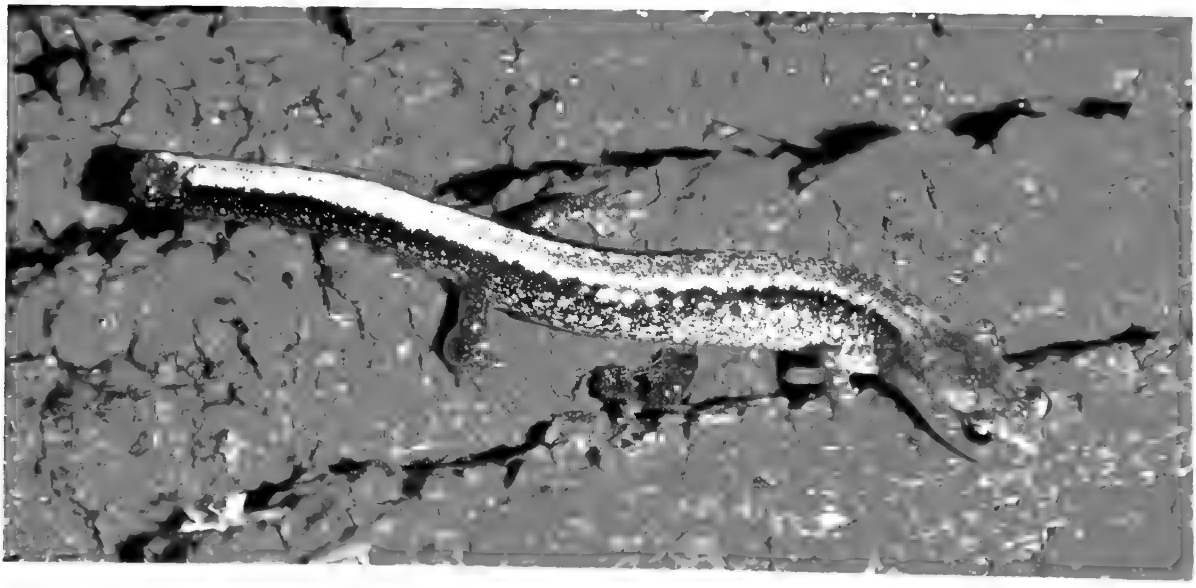

FIGURE 2. Dorsolateral view of a second silver-white variant of the Eastern Red-backed Salamander (*Plethodon cinereus*) from Québec. Artificial light photo. Photo: J.-D. Moore.

oration of the ventral body and irises was also typical of the red-backed morph. Snout to vent and total lengths were 37.8 mm and 73.5 mm, respectively. Autotomy caused tail loss just before photos were taken. A total of 24 other individuals of the red-backed morph of *P. cinereus* were also found in the site during the same survey.

Discussion

Silver-white variants of the red-backed morph of *P. cinereus* are documented here for the first time in eastern Canada. This phenotype appears to be rare, although it has already been encountered in the United States. In these occurrences, the dorsal stripes vary from gray to silver-white or white. Silver-white variants are thus characterized by the absence of visible xanthophores on the mid-dorsal stripe, compared with other variations of *P. cinereus*, which usually involve yellow and/or red pigment cells (Moore and Ouellet 2014). This phenotype of *P. cinereus* should be distinguished from the cream-backed variant (Figure 4 in Moore and Ouellet 2014) and similar colour combinations ("creamy-white stripe" in Reed 1955). Unlike the silver-white variant, xanthophores (yellow pigment cells in this case) are visible in the dorsal stripe of the cream-backed variant. Regarding terminology, the silver-white variants presented here are unrelated to the "axanthic" colour condition reported in certain amphibians, in which all the skin lacks visible xanthophores and iridophores (Lyerla and Dalton 1971; Frost *et al.* 1984; Jablonski *et al.* 2014).

Pigmentation plays significant ecological and evolutionary roles for some amphibians, and many amphibian species exhibit phenotypic variation in nature (Frost-Mason *et al.* 1994; Hoffman and Blouin 2000). Among salamanders, colour polymorphism is particularly common in *P. cinereus* throughout its range. For most of these, the environmental or genetic factors and the mechanisms involved are still unknown. Behavioural differences and the real significance of such coloration is also a matter of debate (Petranka 1998; Gibbs and Karraker 2006; Moore and Ouellet 2015). The role of the dorsal stripe itself in a rather fossorial species like *P. cinereus* is unclear. The red-backed morph may be less fossorial than the lead-backed morph, a hypothesis supported by the presence of fewer costal grooves (vertebrae) in some *P. cinereus* populations (Williams *et al.* 1968; Fisher-Reid and Wiens 2015). Given also that *P. cinereus* is mostly nocturnal (Piersol 1909; Petranka 1998), visual predation selection pressure at night is likely to be minimal. A wide variety of animals will prey on this salamander, including birds, small mammals, and snakes (Casper 2005; Anthony and Pfingsten 2013). Although colour discrimination by these predators could be limited at night, some studies have suggested that bird and snake predators can nevertheless differentiate coloration in *P. cinereus*, probably when foraging in the leaf litter during the day (Brodie and Brodie 1980; Venesky and Anthony 2007). Both silver-white variants described here appeared in good physical condition among conspecifics of the red-backed morph.

New occurrences of rare or new colour variants in *P. cinereus* are still reported, even though this species has been studied extensively since the 1900s. We hope that this article will prompt documentation of these rare morphs to better assess their prevalence and distribution in North America.

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Note

Cream Pincushions (*Scabiosa ochroleuca*; Dipsacaceae), a New Established Exotic Plant in Eastern Canada

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Layberry, Ross A., and Paul Catling. 2016. Cream Pincushions (*Scabiosa ochroleuca*; Dipsacaceae), a new established exotic plant in eastern Canada. Canadian Field-Naturalist 130(2): 137–139.

An established population of Cream Pincushions (Scabieuse jaune pâle, *Scabiosa ochroleuca* L.) in the Ottawa Valley approximately 16.5 km southeast of Arnprior is new to the flora of Ontario and eastern Canada. Other Canadian reports include a non-persisting occurrence in Victoria, British Columbia, in 1908 and a recent occurrence from Keremeos in southcentral British Columbia. Identification and ecology of this species are discussed. In the Ottawa Valley, the plant occurs with introduced Heath Snail (*Xerolenta obvia*), which also originates in eastern Europe.

Key Words: Cream Pincushions; Scabieuse jaune pâle; *Scabiosa ochroleuca*; Dipsacaceae; flora; Ontario; Canada; exotic species

Cream Pincushions (Scabieuse jaune pâle, *Scabiosa ochroleuca* L.), in the Teasel Family (Dipsacaceae), has been reported from Victoria, British Columbia, where it was collected in a vacant lot by John Macoun in 1908 (specimen at the Canadian Museum of Nature, Boivin 1966: 1026; Scoggan 1979: 1431), but was excluded from the British Columbia flora by Douglas *et al.* (2002) because "it does not persist." More recently, it has been reported from Keremeos in southcentral British Columbia where it was observed in 2015 (Curtis Bjork, personal communication, November 2015). Although the species is occasionally cultivated for its unusual flowers, there are no other records of its occurrence outside of cultivation in Canada, based on a review of the literature and specimens in various Canadian herbaria (including Acadia University, University of Alberta, Canadian Museum of Nature, Agriculture and Agri-Food Canada, Université de Montréal, the Nova Scotia Museum, Université Laval, University of Saskatchewan, and University of British Columbia). In late October 2015, it was found by RAL in the Ottawa Valley of Eastern Ontario, approximately 16 km southeast of Arnprior (Figure 1). At this site, there were at least 500 flowering plants and hundreds of non-flowering rosettes scattered over an area of scraped alvar at least 0.8 ha in extent. It appeared to be well established at this site and is, thus, new to the flora of Ontario and eastern Canada (Ontario eastward).

Voucher specimens: CANADA. ONTARIO. Ottawa, 45.3408°N, 76.1932°W, approximately 16.5 km southeast of Arnprior, west of Panmure Road, south of the Trans-Canada Highway, open scraped alvar, 22 October 2015, *P. M. Catling & R. A. Layberry s.n.*, (DAO, MICH, QFA).

Identification

A number of other similar Canadian species — including Field Scabious (*Knautia arvensis* (L.) Coulter), Marsh Devil's-bit (*Succisa pratensis* Moench), Southern Succisella (*Succisella inflexa* (Kluk) G. Beck), and Giant Yellow Scabious (*Cephalaria gigantea* (Ledebour) Bobrov) — all once included in the genus *Scabiosa*, may be separated from *S. ochroleuca* as follows (Cannon 1976; Moore 1976):

1a.	Calyx setae (6)8–16(24), receptacle hairy	*Knautia arvensis*
1b.	Calyx setae 4–5 or none, receptacle scaly	2
2a.	Marginal florets with 1 longer petal lobe so that the flowers are more or less radiate; corolla 5-lobed	*Scabiosa ochroleuca*
2b.	Marginal and central florets with lobes subequal; corolla 4-lobed	3
3a.	Involucral bracts in more than 3 rows	*Cephalaria gigantea*
3b.	Involucral bracts in 1–3 rows	4
4a.	Calyx setae 4–5	*Succisa pratensis*
4b.	Calyx setae none	*Succisella inflexa*

Seven species and 6 genera (those listed above and the familiar *Dipsacus* L.) in the Dipsacaceae are now known in the wild in Canada. No other species are known in the wild within the genus *Scabiosa* Martinov in Canada. The following characteristics are cumulatively distinctive for this genus. The plants are perennial, with leaves of non-flowering rosettes dentate or crenate and shortly white-hairy with a denser covering of hair

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FIGURE 1. Cream Pincushions (Scabieuse jaune pâle, *Scabiosa ochroleuca* L.) photographed approximately 16.5 km southeast of Arnprior, Ontario, on 23 October 2015. A. Inflorescence showing outer flowers with a longer basal petal. B. Infructescence showing young fruit with setae 2–3 times as long as the corona. C. Older inflorescence showing persistent bracts at the top of the receptacle. D. Serrate or crenate rosette leaves with a covering of short white hair. Photos: P. M. Catling.

than the stem leaves, involucel tube longitudinally sulcate, corona with 20–24 veins, setae 2–3 times as long as the corona, and corolla cream coloured. Although the stem leaves are pinnate, the basal stem leaves and rosette leaves are not (Cannon 1976; Jasiewicz 1976; Moore 1976).

Distribution and Ecology

The habitat at the Ontario site was open and included native species of open alvar (Catling and Brownell 1995) and introduced species of disturbed situations. The soil where *S. ochroleuca* was growing was mostly less than 3 cm deep over limestone rock and was alkaline and calcareous. Major plant associates included: Canada Bluegrass (*Poa compressa* L.), Spotted Knapweed (*Centaurea stoebe* L.), Tall Hawkweed (*Pilosella piloselloides* (Villars) Soják), and Wild Carrot (*Daucus carota* L.). Also present were Balsam Groundsel (*Packera paupercula* (Michaux) Á. Löve & D. Löve), Black Medick (*Medicago lupulina* L.), Butter-and-eggs (*Linaria vulgaris* Miller), Common Juniper (*Juniperus communis* L.), Common Viper's Bugloss (*Echium vulgare* L.), Gray-stemmed Goldenrod (*Solidago nemoralis* Aiton), and Umbellate Sedge (*Carex umbellata* Schkuhr ex Willdenow). The abundant rosette leaves on this site with pinnate and distinctively glandular leaves are those of Spotted Knapweed (*Centaurea stoebe* L.), which is a frequent associate.

The native distribution of *S. ochroleuca* includes southeast and east-central Europe (Jasiewicz 1976). In Europe, it occurs in native declining limestone grasslands that are rich in species, as well as in old limestone quarries (Illyés *et al.* 2007; Rahmonov *et al.* 2014). An unusual feature of the Ottawa Valley site is the abundance of the rarely encountered, introduced Heath Snail

(*Xerolenta obvia*), which shares with *S. ochroleuca* an origin in eastern Europe (Forsyth *et al.* 2015). It is not clear how these invaders reached this site.

Scabiosa ochroleuca may expand in the Ottawa Valley and/or spread elsewhere. In North America, it has also been reported in Massachusetts, where it was found in a gravel pit in 1914 (Sorrie 2011). Calcareous alvar landscapes are widespread in southern Ontario and are available to the south and from Kingston west to Manitoulin Island in Lake Huron. At the Ottawa Valley site, most of the disturbed area is dominated by Spotted Knapweed, but *S. ochroleuca* is also dominant in some smaller areas. The plants form patches up to 3 m by 3 m, where they are dominant and up to 1 m tall, but all places where they have been seen to date are more or less disturbed by bulldozing. The potential impact on native alvar vegetation requires more study as alvars are considered a high conservation priority (Catling *et al.* 2014).

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Aberrant Colouration in the Atlantic Puffin (*Fratercula arctica*), the Common Murre (*Uria aalge*), and the Thick-billed Murre (*U. lomvia*) from Atlantic Canada

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Bond, Alexander L., and Antony W. Diamond. 2016. Aberrant colouration in the Atlantic Puffin (*Fratercula arctica*), the Common Murre (*Uria aalge*), and the Thick-billed Murre (*U. lomvia*) from Atlantic Canada. Canadian Field-Naturalist 130(2): 140–145.

The colour of birds' plumage and bare parts is an important feature in choice of mate, camouflage, thermoregulation, species recognition, and flight mechanics. Abnormalities in colouration occur in a variety of species and can have important consequences for an individual's survival and fitness. We present 7 new cases of colouration abnormalities in 3 species of auk (Alcidae) and review previous reports to correctly assign the proper form of abnormality to specimens in museums or photographs. Of the 53 reported colouration abnormalities, we reclassified 42, progressive greying being the most common (18 or 19 cases out of 42, 43–45%), followed by brown (10/42 cases, 24%), in addition to 6 cases of melanism, 4 of dilution, 2 of partial leucism, and 1 likely somatic mutation. Properly describing the form of colour abnormality improves our understanding of the frequency, causes, and consequences of aberrant colouration.

Key Words: Atlantic Puffin; *Fratercula arctica*; Common Murre; *Uria aalge*; Thick-billed Murre; *Uria lomvia*; plumage; colouration; colour aberration; Atlantic Canada

Introduction

The colour of birds' plumage and bare parts (bill and legs) plays many important functional roles in flight, thermoregulation, mate choice, camouflage from predators, and species recognition (Hamilton and Heppner 1967; Barrowclough and Sibley 1980; Cairns 1986; Jones 1990; Andersson *et al.* 1998; Murphy and Pham 2012). However, a variety of colouration abnormalities of feathers and bare parts occur, albeit at very low frequencies (Sage 1962, 1963; Ross 1964; Gross 1965; Forrest and Naveen 2000; McCardle 2012). There is a long history of documenting abnormal colouration in a variety of birds (Krüper 1857; Deane 1876; Newton 1877), but only recently has the physiological basis for the varying conditions been understood (Summers 2009). Historically, many individuals with any sort of lack of plumage colouration were termed "albino," despite this term having a very specific meaning and the condition being very rare in wild populations (van Grouw 2010, 2013).

The most extreme lack of colouration, albinism, is a complete lack of eumelanin and phaeomelanin and is extremely rare (McCardle 2012). More common are cases of partial under-expression of pigments (leucism, progressive greying, brown, dilution, and ino), and these can exhibit a wide range of phenotypes from light or dark patches, to an overall dilution of pigment (van Grouw *et al.* 2011; Jakubas and Wojczulanis-Jakubas 2012; van Grouw 2013). Cases of extreme melanism, where the bird appears entirely black, are rare (Clarke 1913; Loomis 1918).

There has been a fair degree of interest and a long history of documenting plumage aberrations in seabirds (e.g., Newton 1877), including the Procellariiformes (Mancini *et al.* 2010), and Sphenisciformes (Forrest and Naveen 2000). In the auks (Charadriiformes, family Alcidae), plumage abnormalities have been described for many species (Deane 1876; Newton 1877; Arnold 1950; Lockley 1953; Tuck 1961; Sealy 1969; Reinsch 1983; Leopold *et al.* 2010; van Grouw *et al.* 2011; Jakubas and Wojczulanis-Jakubas 2012). Here, we describe five additional cases of plumage abnormalities in 3 species of Atlantic alcid: Thick-billed Murre (*Uria lomvia*), Common Murre (*U. aalge*), and Atlantic Puffin (*Fratercula arctica*), and we use current terminology to clarify the particular mutation in several museum specimens described previously.

Methods

We used the system described by van Grouw (2013) for assigning colour aberrations in 7 categories (Table 1). We made regular notes on abnormal plumages dur-

TABLE 1. The physiological and genetic basis for colour aberrations and their phenotypic effect.

Colour aberration	Physiological or genetic basis	Phenotypic effect
Albinism	Complete absence of eumelanin and phaeomelanin in all tissues, caused by inherited lack of tyrosinase	All white feathers, red eyes, pink feet and bill
Brown	Reduction in the expression of eumelanin molecules caused by incomplete oxidation	Typically black tissues become brown, and rufous/yellow/brown tissues are unaffected
Dilution – isabel	Reduced number of eumelanin molecules (but not their expression)	Typically black tissues become silver/grey, and rufous/yellow/brown tissues are unaffected
Dilution – pastel	Reduced number of eumelanin and phaeomelanin molecules (but not their expression)	Typically black tissues become silver/grey, and rufous/yellow/brown tissues become buff/cream
Ino – dark	Strong reduction in the expression of both eumelanin and phaeomelanin caused by incomplete oxidation	Typically black tissues are light brown, and rufous/yellow/brown tissues are buff/cream; bill and feet pink
Ino – light	Mild reduction in the expression of both eumelanin and phaeomelanin caused by incomplete oxidation	Typically black tissues are very pale brown/cream, and rufous/yellow/brown tones are hardly present; eyes, bill, and feet pink
Leucism	Partial or total lack of eumelanin and phaeomelanin in feathers/skin caused by inherited lack of pigment cells	Plumage all white or all-white feathers mixed with normally coloured feathers. Bill and feet can be pink or unaffected; normally coloured eyes
Melanism	Increased melanin deposits	Increase in black or darker red/brown pigments
Progressive greying	Partial or total loss of eumelanin and phaeomelanin in feathers/skin caused by gradual loss of pigment cells with age	Plumage all white or all-white feathers mixed with normally coloured feathers. Bill and feet can be pink or unaffected; normally coloured eyes

Source: Adapted from van Grouw (2013).

ing our research in eastern Canada and, where possible, documented cases of abnormal plumage with photographs. We also searched published and unpublished articles, including government reports, monographs, and journal articles for mention of plumage or colouration abnormalities in our 3 species of interest. Finally, we contacted curators at several museums known to house specimens with abnormal colouration (see Acknowledgements) and obtained photographs of the specimens in question to allow further examination and reclassification where possible.

Results

Thick-billed Murre, CMNAV 37719

This is a previously undescribed case of dilution in a bird collected by L. M. Tuck in Hants Harbour, Newfoundland and Labrador, on 12 March 1951 (Figure 1), now in the Canadian Museum of Nature (CMNAV). The normally dark brown back, neck, head, and wings are a silvery grey. Tuck (1961) also described 3 "full albinos" and 3 "partial albinos." This is almost certainly incorrect, and the latter, whose black feathers appeared grey were likely cases of dilution (van Grouw 2013) and could include CMNAV 38151 (see below); the true status of the 3 "albinos" is unknown (Table S1).

Thick-billed Murre, CMNAV 38151

This is a melanistic bird described by Tuck (1961) as being shot in Trinity Bay, Newfoundland and Labrador, on 31 January 1952 (Figure 2); its destination was listed only as the "National Museum of Canada" (now the Canadian Museum of Nature). It is uniformly dark brown/black above, and dark grey below, rather than white.

Common Murre, Cabot Island, Newfoundland and Labrador

On 2 August 2011, 1 bird among 100 adult breeding Common Murres banded on Cabot Island (49°17'N, 53°36'W) lacked pigment in parts of its bill, and in its feet (a form of progressive greying; Figure 3). On the Isle of May, Scotland, this occurs in about 1 in 1000 Common Murres (M. P. Harris, personal communication). A single Thick-billed Murre with yellow feet was seen on Coats Island in the 1980s (A. J. Gaston, personal communication).

Atlantic Puffin, Gull Island, Witless Bay, Newfoundland and Labrador

In May and June 2012, 91 adult Atlantic Puffins were banded on Gull Island (47°15'N, 52°12'W). One bird's black head feathers were grey, flecked with white (Figure 4). The bird was a breeding adult, with more than

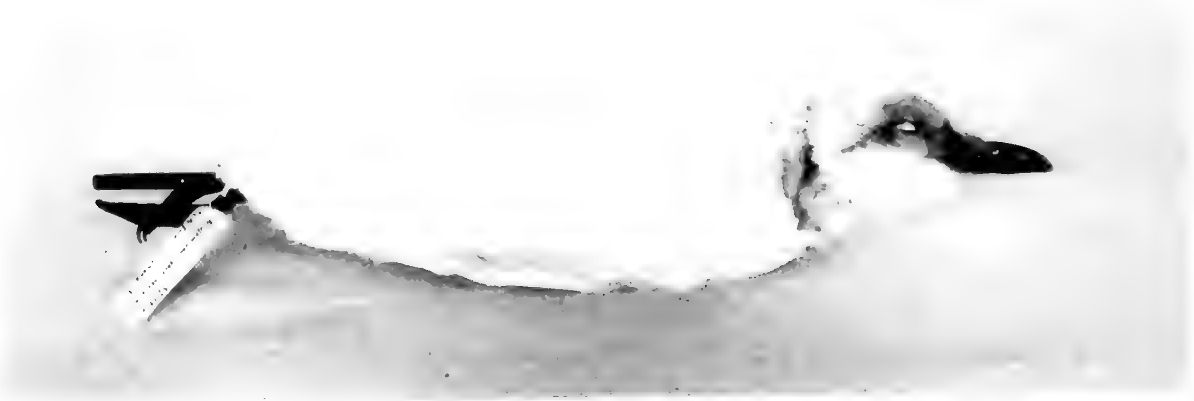

FIGURE 1. Thick-billed Murre (CMNAV 37719) showing dilution. Photo: M. Gosselin.

FIGURE 2. Melanistic Thick-billed Murre (CMNAV 38151). Photo: M. Gosselin.

FIGURE 3. Common Murre on Cabot Island, Newfoundland, showing progressive greying in the legs and bill. Photo: A. Lang.

FIGURE 4. Atlantic Puffin on Gull Island, Newfoundland, showing a likely somatic mutation, as other dark plumage appeared normal. Photo: A. Bond.

2 bill grooves (Harris 1981), and all other aspects of plumage and colouration of bare parts were typical, including the black feathers on the back and proximal region of the breast. Although this might appear to be a case of dilution, the genetic mechanism (a heritable mutation affecting the number of pigment molecules, but not their colour) would result in all black plumage appearing grey. Therefore, this is likely the result of a somatic mutation, rather than a heritable plumage abnormality.

Atlantic Puffin, Machias Seal Island, New Brunswick

In May 2013, an adult Atlantic Puffin with more than 2 bill grooves was photographed on Machias Seal Island (44°3'N, 67°06'W). It had white feathers speckled throughout the black contour feathers on its neck and back (Figure 5), showing characteristics of progressive greying. Colouration of all other aspects of plumage and bare parts appeared normal.

FIGURE 5. Atlantic Puffin on Machias Seal Island, New Brunswick, with progressive greying expressed as white feathers around the neck. Photo: T. Einfeldt.

Atlantic Puffin, Machias Seal Island, and Grand Manan basin, New Brunswick

In 2002, 2004, and 2009, a "white puffin" was observed at sea around Machias Seal Island or in the Grand Manan basin (Figure 6). The bare parts were unaffected, as were portions of the feathers (e.g., tips of primary feathers), making this an extreme case of progressive greying. Other "white puffins" have been recorded at the Isles of Scilly, United Kingdom, in May 2009 (Harris and Wanless 2011) and at the Faroe Islands in the late 1800s (Lockley 1953; see below).

FIGURE 6. A "white puffin" in the Grand Manan basin, New Brunswick, in 2009, showing an extreme case of progressive greying. Photo: New England Aquarium.

These 3 records may or may not pertain to a single individual.

Reclassification of museum specimens and previous records

We located 10 reported cases of plumage abnormalities in Atlantic Puffins, 23 in Common Murres, and 18 in Thick-billed Murres. Of these, we determined the precise form of colouration abnormality from the description, original specimen, or photographs and reclassified 10, 16, and 12 specimens of each species, respectively (Table S1). Most of these were originally described as "albino," "partial albino," or "melanistic," the most extreme forms of plumage colouration anomalies, and all were reclassified as a milder form. Among live and museum specimens combined, progressive greying was the most common abnormality (16 or 17 cases out of 41), followed by brown (10 of 41 cases), with 6 cases each of dilution and melanism (Table S1). Partial leucism was the least common abnormality and occurred in only 2 Common Murres (Table S1).

Discussion

Of the 52 cases of colour abnormalities in these 3 species, we were able to reclassify 40 (80%) and add an additional 4 cases, including rarer abnormalities affecting bare parts (Table S1). Previous classifications tended to adopt one of the extremes (albinism/melanism) rather than the underlying mechanistic explanation, which masks the root cause for the colouration abnormality and artificially groups abnormalities that have no common mechanism. This greater understanding of the mechanisms of colour aberrations has received more attention only recently (van Grouw 2010, 2013). Abnormalities of bare parts are less commonly reported than those of plumage, despite being noted in auks since the 19th century (Krüper 1857; Newton 1877). This may be because birds with abnormal plumage are easier to identify in large colonies, such as cliff-nesting murres, whereas birds with abnormally coloured bare parts would not stand out so clearly.

In the Southern Giant Petrel (*Macronectes giganteus*), there is a "white morph" with asymmetrical black feathers scattered throughout otherwise white plumage; this pattern is controlled genetically (Shaughnessy 1970). This is particularly notable, as it could be easily mistaken for a plumage abnormality (likely progressive greying). Indeed, the control of plumage colour polymorphism has a strong genetic influence across multiple species, driven by mate choice and sometimes assortative mating (but see Cooke and McNally 1975; Roulin 2004). Given that the plumage abnormalities described here are also under genetic control (van Grouw 2013), they may ultimately contribute to the formation of various colour morphs, although at the frequencies we observed in the auks, they are likely too rare to become established.

Increased participation by citizen scientists and decreased costs of digital photographic equipment will increase the chances of birds with abnormal colouration coming to light and provide us with a better sense of the frequency and consequences of such abnormalities.

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SUPPLEMENTARY MATERIAL:

TABLE S1. Summary of colouration abnormalities in Atlantic Puffins (ATPU), Common Murres (COMU), and Thick-billed Murres (TBMU). Terminology follows van Grouw (2013).

Evidence of Predation on Nestling Birds by Eastern Gartersnakes (*Thamnophis sirtalis sirtalis*)

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Halliday, William D. 2016. Evidence of predation on nestling birds by Eastern Gartersnakes (*Thamnophis sirtalis sirtalis*). Canadian Field-Naturalist 130(2): 146 151.

Diet is an important aspect of the natural history of all animals, but diet can vary through space and time because of variations in prey availability. The diet of the Common Gartersnake (*Thamnophis sirtalis*) consists mainly of earthworms and frogs, but other prey items might be important when they are locally abundant. I report an observation of a female Eastern Gartersnake (*Thamnophis sirtalis sirtalis*) regurgitating 2 nestling birds in Ottawa, Ontario, Canada. Birds are seldom present in the diet of the Common Gartersnake. This rare food choice highlights the opportunistic nature of foraging by adult Common Gartersnakes and, further, demonstrates that diet depends not only on prey preference, but also on prey availability.

Key Words: Diet; Eastern Gartersnake; *Thamnophis sirtalis sirtalis*; nestling; predation; prey preference; prey selection; Eastern Ontario

Prey preference and diet are important aspects of the natural history of all animals. Diet often depends not only on the prey preference of the species, but also on the availability of prey, which changes with space, time, and ontogeny (Carpenter 1952). If the preferred prey is less available, then diet may consist of a less preferred but more available prey item (Gregory and Nelson 1991).

The diet of the Common Gartersnake (*Thamnophis sirtalis*) consists mainly of earthworms and frogs (Rowell 2012), although it often contains many other prey items, including fish, small mammals, slugs, leeches, and occasionally birds and other snakes (Table 1). When the prevalence of prey species is averaged across studies, Common Gartersnakes show a strong preference for frogs, followed closely by earthworms, while salamanders, fish, and mammals occur in their diet less frequently, and all other prey items can be considered rare (Table 2). Studies of prey preference demonstrate that Common Gartersnakes almost exclusively eat earthworms when they are small and incorporate larger food items, such as amphibians, into their diet as they grow larger (Carpenter 1952; Gregory 1978; Halloy and Burghardt 1990; Gregory and Nelson 1991), a practice that is likely related to gape-size limitation (Halloy and Burghardt 1990; Rodriguez-Robles *et al.* 1999).

The diet of Common Gartersnakes is constrained by prey availability. Gregory and Nelson (1991) compared the diets of Common Gartersnakes living near fish hatcheries and those living at reference sites away from hatcheries. Fish were the dominant prey item in stomachs of snakes from the fish hatchery, and amphibians and earthworms were the dominant prey items in snakes from reference sites. A similar pattern has been observed on islands with nesting colonies of birds (Fetterolf 1979; Greenwell *et al.* 1984), although these researchers did not compare the diets of Common Gartersnakes, but rather observed Common Gartersnakes eating nestling birds at locations where they were abundant. One of these studies (Greenwell *et al.* 1984) examined the prey preference of Common Gartersnakes in the laboratory by presenting them with various food items, including birds. Common Gartersnakes from the island that had been observed eating nestling terns had a similar prey preference to snakes from the mainland: both populations preferred frogs, followed by earthworms and fish; birds were rarely consumed. This study suggests that prey preference in Common Gartersnakes is engrained, but increased availability of a non-preferred food item can increase its prevalence in their diet.

Here, I document an example of an Eastern Gartersnake (*Thamnophis sirtalis sirtalis*) that ate nestling birds. In July 2015, I encountered a female Eastern Gartersnake (snout–vent length: 536 mm; mass after regurgitation: 64 g; Figure 1) moving along the shore of the Ottawa River near Britannia Conservation Area, Ottawa, Ontario, Canada (45.375036°N, 75.786887°W; WGS 84). The snake was in a habitat dominated by ferns and forbs no more than 50 cm tall. I noted that it had a large food bulge. After I handled the snake, it regurgitated 2 nestling sparrows: 1 was partly decomposed and the other was mostly intact (body length: 58 mm; wing length: 23 mm; mass: 8 g; Figure 2). I was unable to identify the birds confidently to species because of decomposition and incomplete plumage, but they were likely a species that nests on the ground or in low shrubs, which would increase the chances of a gartersnake coming across the nest.

Based on the rarity of birds in the diet of Common Gartersnakes and the fact that in almost all reported

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TABLE 1. Review of studies examining the diet of the Common Gartersnake (*Thamnophis sirtalis*).

Author(s)	Location	Prey items	Sample size
Brodie and Brodie 1990	Oregon	Rough-skinned Newt	Unknown
Brown 1928	Ontario	Earthworm, Red-backed Salamander	2 snakes
Brown 1979	Michigan and New York	70% amphibians, 14.8% earthworms, 1 Meadow Vole, minor fish and bird remains. Two birds were nestling Yellowthroats, and the third was a nestling Hermit Thrush; all three were taken from their nest.	Stomach contents of 98 snakes
Carpenter 1951	Michigan	Goldfinch nestlings, 1 adult Song Sparrow	Stomach contents of 2 of the 230 snakes providing samples
Carpenter 1952	Michigan	80% earthworms, 15% amphibians, small number of mammals, fish, leeches, caterpillars. No birds.	Stomach contents of 178 snakes (28% of all captured snakes)
Catling and Freedman 1980	Ontario	6 earthworms, 2 Leopard Frogs, 3 American Toads	11 snakes
Dalrymple and Reichenback 1981	Ohio	10% of collected snakes regurgitated earthworms in spring, but only frogs in summer.	Unknown
Fetterolf 1979	Ontario	2 nestling Ring-billed Gulls in a gull colony	1 snake
Fitch 1982	Kansas	25 Plains Leopard Frogs, 10 American Toads, 8 earthworms, 7 Cope's Gray Treefrogs, 4 Woodhouse's Toads, 4 Northern Cricket Frogs, 4 American Bullfrogs, 3 White-footed Mice, 3 unknown frogs, 2 Prairie Voles, 1 Western Harvest Mouse, 1Western Chorus Frog	Stomach contents of 72 snakes
Gilhen 1984	Nova Scotia	Maritime Gartersnakes are known to eat earthworms and Red-backed Salamanders as juveniles; small fish, Yellow-spotted Salamanders, American Toads, Green Frogs, Northern Leopard Frogs, Woods Frogs, and Meadow Voles as adults.	Review
Greenwell *et al.* 1984	Michigan	Personal observations of snakes eating many nestling terns and other Larids	Unknown
Gregory 1978	British Columbia	41 amphibians, 24 earthworms, 1 bird, 1 leech, 18 unidentified	Stomach contents of 179 snakes (280 snakes sampled)
Gregory 1984	British Columbia	53 amphibians, 29 earthworms, 1 slug, 2 mammals, 4 birds, 1 leech	Stomach contents of 90 snakes (241 snakes sampled)
Gregory and Nelson 1991	British Columbia	Compared diet of snake population at hatchery versus reference sites. Hatchery: 151 fish, 0 amphibians, 12 earthworms, 2 mammals Reference: 4 fish, 146 amphibians, 31 earthworms, 1 slug, 1 mammal, 1 bird	Stomach contents of 107 snakes at the hatchery and 54 at reference sites
Gregory and Stewart 1975	Manitoba	227 frogs, 16 earthworms, 5 dragonfly nymphs, 4 nestling sparrows, 1 snail, 2 slugs	Stomach contents of 267 snakes (1059 snakes sampled)
Hamilton 1951	New York	57% earthworms, 28% amphibians, 4% insects, 3% mammals, 2% molluscs, 2% fish, 2% crayfish, 1% snakes (1 case of cannibalism by neonates, and 2 adults ate *Storeria dekayi*), 1% birds (2 nestling Song Sparrows).	Stomach contents of 241 snakes
Kephart and Arnold 1982	California	99 frogs, 2 fish, 9 leeches	Stomach contents of 18 snakes (36 snakes sampled)

incidents of such prey, the birds have been nestlings or fledglings, I hypothesize that large Common Gartersnakes are opportunistic foragers that will eat any vertebrate or invertebrate they encounter as long as they can successfully swallow it and it is within their range of food choices. The gape-size limitation has been demonstrated in captive Common Gartersnakes, where larger snakes were able to consume larger fish (Halloy and Burghardt 1990). However, this is not to negate the frequently observed preference of Common Gartersnakes for earthworms and amphibians (Table 2). Given the relatively recent introduction of earthworms to North America (Hendrix and Bohlen 2002), the preference of Common Gartersnakes for earthworms is a clear example of opportunism in diet selection.

Greenwell *et al.* (1984) conducted an interesting trial in which 12 Common Gartersnakes were presented with bird carcasses, and none consumed the birds. Yet when the researchers infused the bird carcasses with the smell of fish, 9 of the 12 Common Gartersnakes ate the birds. This novel result suggests Common Gartersnakes do not generally consider birds to be a prey item, but do so when they smell like other preferred prey items. In the case of nestling birds, if their parents are feeding them worms frequently, then perhaps the smell of worms on the birds makes them a preferred prey of gartersnakes.

The natural history of most birds likely makes them an inaccessible prey for Common Gartersnakes. Most adult birds are likely quick and agile enough to escape predation by gartersnakes. Many birds also nest in trees, making them largely inaccessible to gartersnakes. Conversely, amphibians and earthworms are often abundant in habitats occupied by Common Gartersnakes, likely because of a shared habitat preference (Halliday, unpublished data) and their terrestrial habit. Thus, amphibians and earthworms are an easily accessible prey item for Common Gartersnakes. Birds, on the other hand, spend most of their time off of the ground and are, therefore, usually inaccessible to Common Gartersnakes; however, nestling birds in ground nests and fledgling birds are exceptions to this. Nestlings and fledglings can potentially become part of the diet of Common Gartersnakes for a short time every year, just as smaller frogs become part of the Common Gartersnake diet when they metamorphose and leave the water body in which they developed (Carpenter 1952; Gregory 1984). It is possible that Common Gartersnakes evolved a general preference for earthworms and amphibians because of their accessibility throughout the active season.

In conclusion, nestling and fledgling birds are a part, however rare, of the diet of Common Gartersnakes. In areas with a high density of ground nests and fledglings, young birds could make up a substantial part of the Common Gartersnake diet during part of the summer (Fetterolf 1979; Greenwell *et al.* 1984).

TABLE 1. Review of studies examining the diet of the Common Gartersnake (*Thamnophis sirtalis*). *(continued)*

Author(s)	Location	Prey items	Sample size
Lagler and Salyer 1945	Michigan	46% earthworm, 34% frogs, 14% insects, 11% fish, 9% toads, 3% salamanders, 3% leeches, 3% snails	Stomach contents of 109 snakes (151 snakes with food in stomach out of 238 snakes sampled)
Logier 1925	Ontario	1 nestling sparrow from nest	1 snake
Rossman *et al.* 1996: 70–73	North America	Earthworms, slugs, leeches, fish (rare), amphibian larvae, amphibians, birds (rare), mammals	Review
Rowell 2012	Ontario	Primarily earthworms and frogs. Occasionally, small snakes, toads, salamanders, mice, nestling birds, bird eggs, fish, leeches, slugs, snails, millipedes, isopods, spiders, crayfish, insects, insect larvae.	Review
Walkinshaw 1943	Michigan	1 nestling Chipping Sparrow taken directly from nest, 1.2 m off the ground.	1 snake
White and Kolb 1974	California	55% treefrogs, 21.8% suckers, 11.5% dace, 5.4% meadow voles a few leeches, 1 toad	Stomach contents of 160 snakes

TABLE 2. The diet of Common Gartersnakes (*Thamnophis sirtalis*), based on 25 reviewed publications (see Table 1). Slugs and snails were combined into 1 category (Molluscs), and caterpillars and dragonfly nymphs were combined into 1 category (Insects).

Prey	No. studies*	Mean rank†	Absolute rank‡
Frogs and toads	16	2.1	1
Earthworms	14	4.1	2
Salamanders	12	6.1	3
Fish	10	6.5	4
Mammals	9	6.5	4
Leeches	8	7.9	6
Birds	13	8.5	7
Insects	5	8.5	7
Molluscs	6	8.8	9
Crayfish	2	10.8	10
Snakes	2	10.9	11

*Number of references (including review articles and books) that mention each prey item.

†Mean rank order (1 = highest preference) of prey items in the diet of Common Gartersnakes based on the 15 studies that sampled stomach contents of multiple snakes. Mean rank order was calculated by ranking prey items based on their prevalence in each study, from 1 to 11 (total number of possible prey items), then calculating the mean for each prey item across all 15 studies. Prey items not found in a study were given a rank of 11.

‡Absolute rank was calculated as the rank of the mean ranks for each prey item.

FIGURE 1. Female Eastern Gartersnake (*Thamnophis sirtalis sirtalis*) encountered in Ottawa, Ontario, Canada, that regurgitated 2 nestling birds. Snout–vent length = 536 mm, mass = 64 g. Photo: William D. Halliday.

FIGURE 2. Nestling bird regurgitated by an Eastern Gartersnake (*Thamnophis sirtalis sirtalis*) encountered in Ottawa, Ontario, Canada. Body length = 58 mm, wing length = 23 mm, mass = 8 g. Photo: William D. Halliday.

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Pre-settlement Snail Fauna on the Sandbanks Baymouth Bar, Lake Ontario, Compared with Nearby Contemporary Faunas

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The terrestrial snail fauna in a pre-settlement soil layer, radiocarbon dated at approximately 1065–1560 years old, on the baymouth bar at Sandbanks Provincial Park, Lake Ontario, was compared with 4 nearby contemporary snail faunas from forested dunes. The pre-settlement sample differed in snail diversity, with 23 species compared with 9–20 species in contemporary samples. Six species were unique to the pre-settlement sample: *Carychium exile*, *Euconulus fulvus*, *Gastrocopta armifera*, *Gastrocopta corticaria*, *Vallonia parvula*, and *Vertigo* sp. The number of individual snails was much greater at the pre-settlement site when corrected for difference in size of sample area. The reason for the higher diversity, greater number of individuals, and different fauna associated with the pre-settlement area is unclear, but may be attributed to reduction and changes in the litter layer at the contemporary comparison sites caused by European earthworms. This work suggests that major erosional and depositional events occurred on Great Lakes shoreline dunes in the past and that these can be used to study postglacial mollusc faunas and past ecological processes, with some potentially significant results.

Key Words: Sandbanks baymouth bar; Lake Ontario; land snails; diversity; European earthworms; litter layer

Introduction

When buried soil layers were found among active dunes with drifting sand and sparse vegetation cover at Sandbanks Provincial Park on the shore of Lake Ontario, it was assumed that they had been buried over the last 200 years following a period of disturbance (tree cutting, overgrazing, and fire), which created drifting sand in early settlement times (Klugh 1912; Tovell 1972; Carlisle *et al.* 1974; Neugebauer 1974). However, in 1 place the organic layer was 40 cm thick and composed of at least 3 sublayers that had eroded at different rates, forming shelves. This differential erosion appeared to be the result of differing proportions of sand and organic matter in the sublayers. The deepest sublayer contained charcoal. We speculated that the forest at this site had burned, then been covered by a thin layer of sand, and that forest had then redeveloped. As this would likely have required more than a few hundred years, the layer might substantially predate European settlement, suggesting ecological processes of fire and sand movement at much earlier times. Embedded among the vertical erosional layers were the exposed subfossil shells of terrestrial snails, which we suggest occupied a former deciduous forest, as coniferous forest and other successional vegetation on dunes in the region are associated with a very limited terrestrial snail fauna.

Here, we establish the date of these buried soil layers as pre-European and compare their terrestrial snail fauna with nearby contemporary snail faunas in woodland on dunes. Such comparison may provide information on historical changes and enable a better understanding of the impact of foreign soil and litter organisms. These include European earthworms and other introduced soil fauna that may have had profound impacts on litter and substrate in deciduous forest (Frelich *et al.* 2006; Migge-Kleian 2006). We speculate that pre-European-settlement snail faunas would have been more diverse, existed at higher densities, and differed in composition as a result of the deeper and more complex surface litter that existed at that time.

Study Area

Baymouth bar

The baymouth bar at Sandbanks Provincial Park is one of the largest freshwater baymouth bars in the world (Ainsworth *et al.* 2012). It extends from Wellington to West Point, a distance of 8 km. Much of the area is a mixture of grassland with American Beachgrass (*Ammophila breviligulata* Fernald), scrub including Bayberry Willow (*Salix myricoides* Muhl.), Riverbank Grape (*Vitis riparia* Michx.), and Sand Cherry (*Prunus pumila* L.), and shallow pools with Smooth Twig-rush (*Cladium mariscoides* (Muhl.) Torrey). The likely pre-settlement sampling area, 43.9218°N, 77.2947°W (Figure 1) is part of a series of perched dunes (dunes that sit on a plateau above the shore) that are 400 m from the front dune on the Lake Ontario shore and approximately 20 m above the Lake Ontario shoreline.

We believe that the pre-settlement site is not an assemblage resulting from deflation, i.e., erosion of ver-

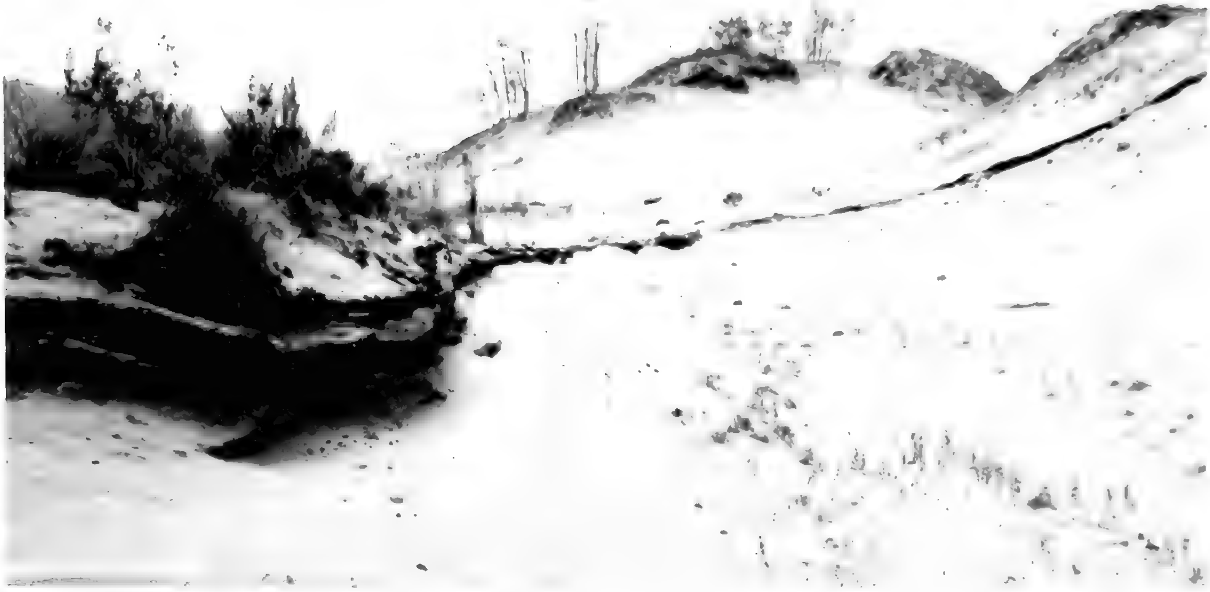

FIGURE 1. Buried soil layer sampled (the lower of 3 layers seen on the left) in dunes on the baymouth bar at Sandbanks Provincial Park, Ontario. The vertical exposure of soil forms an irregular circle remaining after the top of a hill was eroded. The sand erodes more readily than the soil, leaving a depression surrounded by a low ridge. Only part of this is seen in the photo. Photo: Brenda Kostiuk.

tical layers and transport to new horizontal layers, where shells would be concentrated and overall represent relatively long average times. An allochthonous (transported) assemblage would be less likely to include both light (organic material and small shells) and heavy material (such as adult *Neohelix* shells 30 mm across) juxtaposed but widespread. The assumption of forest burial was a key element in this investigation, so a literature search was undertaken to determine if this was likely.

Comparison sites

The current open dunes and early successional communities that include conifers are largely devoid of snails. For this reason, in the past, terrestrial molluscs must have occurred mostly in dunes vegetated with deciduous woods, as they do today. Thus, the pre-settlement snail assemblage under study here is assumed to have occurred in the only dune community hosting substantial terrestrial snail populations, that being deciduous forest.

Having decided this, the contemporary sites selected for sampling were all deciduous forest on dunes. All were within 4 km of our pre-European site: (1) approximately 43.9038°N, 77.2663°W, mature woodland dominated by Sugar Maple (*Acer saccharum* Marshall), White Ash (*Fraxinus americana* L.), Basswood (*Tilia americana* L.), and Trembling Aspen (*Populus tremuloides* Michx.); (2) 43.8981°N, 77.2187°W, mature woodland dominated by Sugar Maple, Black Maple (*Acer nigrum* Michx.), Basswood, and White Ash; (3) 43.8926°N, 77.2140°W, successional woodland of Eastern White Cedar (*Thuja occidentalis* L.), Trembling Aspen, White Pine (*Pinus strobus* L.), Paper Birch (*Betula papyrifera* Marshall), and poplars (*Populus* spp.); (4) 43.9043°N, 77.2313°W, same woodland as site 3.

Methods

Accelerator mass spectrometry

Because knowledge of the pre-settlement age is essential to the concept presented here, we support it with radiocarbon dating using accelerator mass spectrometry (AMS). This process accelerates ions to high kinetic energies before mass analysis, enabling separation of rare carbon isotopes. The age of organic material can be determined by relative abundance of isotopes (based on rate of decay), such as radioactive carbon (^{14}C). AMS analysis was done by Beta Analytic Inc. (Miami, Florida, USA) on a shell of *Neohelix albolabris* (Say, 1817), Whitelip, and a fragment of charcoal, both from 37 cm depth in the series of soil layers. The shell was pretreated with acid to reduce contamination. The charcoal was pretreated with acid alkali acid wash to remove carbonates, remove organic acids, and neutralize alkali, respectively. The measured radiocarbon ages were corrected for total isotopic fractionation effects, resulting in a conventional radiocarbon age and this was calibrated for past variance in ^{12}C to ^{14}C ratios using the

IntCal 13 database (Talma and Vogel 1993; Reimer *et al.* 2013). The results were calendar-calibrated and reported as years before present (BP, i.e., before 1950 as is standard practice).

Collection and identification of samples

At the site of the buried soil layer, snails were sampled in October 2014 and April 2015 on an exposed vertical face of buried organic layers surrounding a blowout (Figure 1). The sampling was carried out in 4 adjacent 3 m lengths, 35–40 cm below the uppermost organic layer. This represented the 37-cm depth that was dated. The total area of the face for the sampling of the organic layer was 6000 cm^2, as this was all that was available at the time. Snails were apparent in the face as a result of dark organic material being eroded around them. Only shells visible on the face were collected.

Each of the 4 contemporary comparison sites included a sampled area of 10 000 cm^2 per quadrat × 10 quadrats for a total of 100 000 cm^2. In each quadrat, 30 minutes was spent searching litter and the soil surface. Most snails were found in the first 10 minutes of search in the thin leaf litter, which was composed largely of leaves and leaf fragments from the previous year. Following this, the uppermost few millimetres of harder packed organic soil was also searched for snails of all sizes down to 1 mm diameter. Again, most snails were found in the first 10 minutes. Very few, if any, snails were found in the final 10 minutes of search, suggesting that the search was complete. Only visual search techniques were used; there was no collection or subsequent examination of litter samples. The survey was carried out in late April and early May 2015 when snails were active. Numbers of both living and dead species were recorded in each quadrat and tallied to provide a sample of species and their numbers at each site. We collected all snails in each area (quadrat or vertical face) so that samples would be quantitative and approximately comparable.

Identifications were made using Pilsbry (1939, 1940, 1946, 1948), Burch (1962), and Grimm *et al.* (2010). Specimens that were immature, broken, or too worn to identify to species, but for which identification to genus was possible, were designated "sp." Specimens of Polygyridae (*Mesodon thyroidus* or *Neohelix albolabris*), consisting of small fragments and juveniles, for which the genus and species were undeterminable, were recorded as "immature polygyrids." Subfossil and contemporary specimens were deposited in the collections of the Geology and Zoology sections, respectively, of the New Brunswick Museum.

Simple comparison and area correction

The numbers of species and individual snails at the pre-settlement site and each of the comparison sites were compared. Material not identified to species was omitted to prevent potential double-counting of a taxon. This omission made little difference because such instances were relatively few and generally involved few individuals.

The face of the pre-settlement sampling site was 1/16.7 the size of each of the sampled areas of the comparison sites; thus, it may be expected to be much poorer in diversity and smaller in population size. Beyond a certain level, there may be limits to diversity regardless of area size. However, the number of individuals may be expected to increase linearly with sample area; thus, a correction between number of individuals and size of area sampled is not unreasonable. For the horizontal surfaces of the comparison sites to be comparable to the vertical pre-settlement sample the following assumptions were necessary.

(1) Snail densities are equally distributed throughout the pre-settlement volume (as a result of an equal rate of deposition). This pre-settlement volume may represent as much as 50 years (based on 1 year of horizontal deposition per millimetre) or as little as 5 years. Regardless, if snail faunas vary in density, diversity, and composition over time, it must be assumed that the variation is minimal. This assumption is necessary because the comparison sites are snapshots of an instant in time (i.e., a few years), and the pre-settlement assemblage might appear more diverse and abundant simply by representing specimens from a longer period of time (i.e., many decades).

(2) The vertical and horizontal situations are similarly easy to sample. In fact the vertical subfossil-bearing face was easier to sample because the size of the organic material was not as variable and the shells were white and easily seen. However, the decline in new snails discovered in the first 30 minutes in the horizontal comparison plots suggested that the inventory was nearly complete.

(3) The surface areas are known. This was not entirely the case because the horizontal comparison plots had more surface area in terms of leaves and sticks and may have contained more snails as a result. Nevertheless, the excess surface area may be equivalent to less than 1 mm in the vertical sample and, if so, the comparison is reasonable.

(4) The current populations in the horizontal comparison plots are all destined for preservation as occurred in the pre-settlement sample, where calcium carbonate in the sand may have aided shell preservation. In fact a smaller number may reach the preservation stage because of predation and destruction by mammals and birds. However, predation existed in the past as well. Another associated concern is that living snails are being compared with dead snails. It is true that the horizontal comparison plots included living snails, but these amounted to less than 5% of the samples.

Although weighing these considerations does not provide any definite way of correcting for area, we suggest that a correction for area to create a range by multiplying the number of individuals at the pre-settlement site by the factor by which the comparison sites are larger (16.7) is informative as long as the limitations are understood.

Results

Likelihood of forest burial

Regardless of recent events that led to erosion, drifting sand, and forest burial, there is reason to believe that forest burial occurred in pre-settlement times. As archaeological material is scarce at Sandbanks and because of the location between historical warring Huron and Iroquois peoples (Neugebauer 1974), strong evidence that indigenous peoples played a significant role in vegetation development in the area is lacking. Thus, there is reason to believe that forest burial occurred through natural processes. Buried soils in a perched dune field serve as indicators of a late Holocene change in lake level on the Lake Superior shore (Anderton and Loope 1995). On Lake Michigan, high lake levels have been shown to destabilize coastal bluffs making sand available to leeward-perched dunes on a cycle of approximately 150 years. During high lake levels, forest is buried, but lower levels and relative sand starvation permit forestation and soil development on the dunes (Chrzastowski *et al.* 1991; Loope and McEachern 1998; Loope and Arbogast 2000).

All that is required to bury forests on perched dunes along the shore of Lake Ontario is fluctuating water levels and the factors that cause them. Overall the level of Lake Ontario has risen since 11 500 years BP when the lake was formed in postglacial times (McCarthy and McAndrews 1988). However, there is much evidence for fluctuation superimposed on this general trend. Fluctuation occurred in the early postglacial time (Jackson *et al.* 2000), and, much later (3000–2100 years BP), there were also periods of rapid rise in water level related to episodes of relatively cool, wet climate (McCarthy and McAndrews 1988). Also superimposed on the general rising trend, Flint *et al.* (1988) reported oscillations over the past 3300 years, with an amplitude in the order of 1 m over several hundred years. These oscillations have also been related to longer-term climate changes (McCarthy 1986). More recently, small-scale fluctuations in water level have occurred (Kunkel *et al.* 2013): for example, a period of high levels between 1941 and 1954 following a period of low water level from 1930 to 1940. These fluctuations are also associated with climate, with cooler, wetter periods producing the higher levels. Thus, the climatic variations responsible for fluctuations in water level in Lake Ontario over the past several thousand years and the fluctuations themselves are evident. Consequently evidence for the periodic burial of forests on perched dunes is to be expected.

Dating

Radiocarbon analysis of material in the organic layer resulted in a date of 1190–1065 BP for the charcoal (Beta 396269) and 1560–1410 BP for the partial shell of *Neohelix albolabris* (Beta 396270). The "reservoir effect" is the tendency for shells to appear older than they are as a result of incorporating old limestone, which is depleted of ^{14}C. Although this effect may be insignificant for smaller shells (Pigati *et al.* 2010), *Neohelix* is relatively large (about 30 mm in diameter) and, thus, we consider the charcoal dates to be more reliable.

Survey results

All sites had unique species, and the numbers of species varied among sites. The pre-settlement site had the greatest snail diversity, with 23 species, including a number that did not occur in the comparison sites: *Carychium exile*, *Euconulus fulvus*, *Gastrocopta armifera*, *Gastrocopta corticaria*, *Vallonia parvula*, and *Vertigo* sp. (Table 1). Without correcting for area, the pre-settlement sample had 161 individual snails and the comparison sites had 27 to 352 (Table 1). Using the correction factor, the pre-settlement sample had 2684 individuals. Thus the pre-settlement sample not only had higher diversity and distinct composition, but also the greatest number of snails.

Discussion

Periodic burial of forest on dunes is to be expected, and dating of apparent burial in this case suggested that the buried layer from which the snails were obtained preceded the arrival and settlement of Europeans in the Great Lakes region (i.e., after 1600 or 335 BP). Consequently, the samples are appropriate for a comparison of pre-settlement and post-settlement faunas.

The variation in the snail assemblages at the comparison sites suggests that none can be considered representative of the snail fauna that existed in any larger area at any particular time. This applies also to the pre-settlement site, which is simply a snapshot of a past fauna. This does not prevent comparisons; it simply means that the comparison has limits in broad application and the results can only be viewed as evidence of a local phenomenon.

The different composition, higher diversity, and greater snail density of the pre-settlement sample suggests that conditions may have been different at that time. We speculate that the soil's upper organic horizon was much thicker and this hosted higher diversity, different species, and larger numbers of snails. A decline (sometimes total elimination) of the O horizon has been associated with invasion by European earthworms (e.g., Hale *et al.* 2005, 2008), and this affects a variety of forest floor animals (e.g., Frelich *et al.* 2006; Migge-Kleian *et al.* 2006; Schlaghamersky *et al.* 2014). Although there are no studies that specifically point to declines in terrestrial molluscs as a result of invasive earthworms, this seems likely (Norden 2010); our own casual observations in other deciduous woods in southern Ontario seem to suggest this. Other foreign animals were also frequent in the comparison sites, including predacious ground beetles, pill bugs, and slugs, which may also have negatively affected native snails, leading to lower diversity and density than before their introduction from Europe.

TABLE 1. Species of terrestrial snails and summary of diversity found in buried, pre-settlement, organic layers on the baymouth bar at Sandbanks Provincial Park, Ontario, and 4 contemporary woodland sites. To avoid double-counting, numbers of specimens in parentheses were not included in total number of species for some sites.

Species	Pre-settlement site	Contemporary sites 1	2	3	4
Anguispira alternata (Say, 1817), Flamed Tigersnail	6	4	7	1	
Carychium exile H.C. Lea, 1842, Ice Thorn	1				
Cepaea sp.			1		
Cochlicopa lubrica (Müller, 1774), Glossy Pillar	3	45	1		48
Columella edentula (Draparnaud, 1805), Toothless Column		3	2		
Discus catskillensis (Pilsbry, 1896), Angular Disc	8	88			
Euchemotrema fraternum (Say, 1824), Upland Pillsnail	1	16	37		
Euconulus fulvus (Müller, 1774), Brown Hive	1				
Euconulus polygyratus (Pilsbry, 1899), Fat Hive	4	27	4	6	
Gastrocopta armifera (Say, 1821), Armed Snaggletooth	4				
Gastrocopta contracta (Say, 1822), Bottleneck Snaggletooth	16	22		1	
Gastrocopta corticaria (Say, 1816), Bark Snaggletooth	1				
Gastrocopta holzingeri (Sterki, 1889), Lambda Snaggletooth	5		2	1	1
Gastrocopta pentodon (Say 1822), Comb Snaggletooth	1	3	1		
Glyphyalinia indentata (Say 1823), Carved Glyph	1	10	11	9	1
Glyphyalinia rhoadsi (Pilsbry 1899), Sculpted Glyph		7			
Haplotrema concavum (Say, 1821), Grey-foot Lancetooth		1	4		
Hawaiia minuscula (A. Binney, 1841), Southeastern Gem	23	8	2	1	2
Helicodiscus parallelus (Say, 1817), Compound Coil	5		3	3	2
Mesodon thyroidus (Say, 1817), White-lip Globe		47			
Neohelix albolabris (Say, 1817), Whitelip	2	9	88	2	
Nesovitrea binneyana (Morse, 1864), Blue Glass	4	12			
Nesovitrea sp.	(3)		1		
Punctum minutissimum (I. Lea, 1841), Small Spot	1	3			
Pupilla muscorum (Linnaeus, 1758), Widespread Column				1	1
Strobilops labyrinthicus (Say, 1817), Maze Pinecone	39	17		2	2
Vallonia costata (Müller, 1774), Costate Vallonia				28	
Vallonia gracilicosta Reinhardt, 1883, Multirib Vallonia	25	1			
Vallonia parvula Sterki, 1893, Trumpet Vallonia	3				
Vertigo sp.	3				
Vitrina angelicae Beck, 1837, Eastern Glass-snail		38			1
Zonitoides nitidus (Müller, 1774), Black Gloss		10	5		3
Zonitoides sp.	9	(3)			1
Immature Polygyridae	(5)	(16)		(1)	
Total no. species	23	20	15	11	10
Total no. specimens	161–2684*	352	169	27	89

* Corrected for area.

The interpretation of results presented here rests on many assumptions, making the comparison and explanation little more than a partly supported hypothesis. Regardless of the extent or cause of the difference, it appears that major erosional and depositional events occurred on Great Lakes shoreline dunes in the past and that they can be used to study postglacial mollusc faunas and past ecological processes with some possibly significant results. The success of such an endeavour will depend on the extent to which methods can be developed to reduce assumptions and extend results.

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Ancient Lake Maxima and Substrate-dependent Riverine Migration Have Defined the Range of the Mudpuppy (*Necturus maculosus*) in Southern Ontario Following the Wisconsinan Glaciation

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The Mudpuppy (*Necturus maculosus*) is an entirely aquatic salamander whose geographic range is thus defined by immigration routes in watersheds that permit feasible travel. Significant barriers, such as large waterfalls, effectively bar this species from further colonization upstream. We compared the contemporary distribution of Mudpuppies in southern Ontario with varying post-glacial ancient lake maxima and riverine outlet-flow conditions. Topography does not appear to be a range-limiting factor, but the type of river grade (waterfalls versus riffles) does. The distribution of modern records of this species in Ontario aligns closely with maxima from the Nipissing phase occurring 4000–5000 years ago, leading us to suggest that this is when Mudpuppies invaded and proliferated in the Great Lakes Basin.

Key Words: Mudpuppy; *Necturus maculosus*; Great Lakes; Wisconsinan glaciation; colonization; distribution

Introduction

The Mudpuppy (*Necturus maculosus* [Rafinesque, 1818]) is a large and entirely aquatic salamander. Adults differ from many other salamander species in that they are pedomorphic, retaining their gills into and throughout adulthood. Logically, this limits this species' immigration and range expansion capabilities because they are unable to overcome significant barriers, such as waterfalls, as substantiated by Cochran's (1991) work on the Mississippi River.

During the Wisconsinan glaciation, the Great Lakes region was completely inhospitable to ectotherms, which survived in refugia (Haffer 1969) to the south where more suitable climates prevailed (Mandrak and Crossman 1992a). As the Laurentide Ice Sheet retreated northward and warmer thermal regimes returned to the Great Lakes Basin, these species dispersed northward into suitable environments (Holman 1995). The Mudpuppy would have been one of these species, although unlike other terrestrial herpetofauna, its route of colonization was via waterways only (Hecht and Walters 1955; Mandrak and Crossman 1992a).

We tested whether the Mudpuppy's current distribution in southern Ontario aligns with this understanding of post-glacial aquatic dispersal and is in fact an expression of its ability to move through lacustrine and riverine pathways as ancient water levels and flow directions changed over time. If so, we expected to be able to suggest when and where the species entered the Great Lakes Basin, facilitating colonization.

Methods

Sight record information for the Mudpuppy was obtained from the Ontario Reptile and Amphibian Atlas initiative covering the years 1858–2001 (Ontario Nature 2015). Each record is associated with latitude and longitude coordinates, which were qualitatively compared with the various maxima of the ancient Great Lakes (USGS 1917; Clark *et al.* 2012) using ArcGIS software (ArcGIS Desktop Version 10.3.1., Environmental Systems Research Institute, Redlands, CA, USA). To this end, Mudpuppy sight record information from the Ontario Reptile and Amphibian Atlas was compiled into a spatial database. This was amalgamated with a base map of Southern Ontario showing land elevation and waterbodies (MNR 2012, 2013). The approximate extent of historical lakes was then displayed over the base map to allow qualitative assessment of the relation between Mudpuppy records and lake maxima and outlet flow. The maps of Clark *et al.* (2012) show the changing lake maxima and outlet flow patterns of the ancient Great Lakes for the last 16 000 years. These were our basis of reference to determine whether the Mudpuppy's contemporary distribution aligns with some rational model of post-glacial dispersal.

We required three main conditions to conclude that our hypothesis was supported. The first was that connectivity to the Mississippi River system must have occurred at some point previous to facilitate spread of Mudpuppies from their Wisconsinan refugium (Hecht and Walters 1955) into the Great Lakes.

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The second was that ancient lake maxima that extended significantly beyond current Mudpuppy range must have existed before Mudpuppy invasion. Otherwise, the greater flooded extent of these ancient lake maxima should have derived current Mudpuppy distribution. We regard this as a safe assumption because otherwise we would need to invoke the non-parsimonious explanation that either i) the Mudpuppy was present in these more-ancient Great Lakes, but perfectly contracted its range with the receding shoreline as water levels fell and did not colonize newly forming inland lakes as this happened, or ii) the Mudpuppy was extirpated from each and every inland lake in which it was left behind and all record of their previous inhabitance was erased. The presence of glacial relict fish (e.g., Lake Trout [*Salvelinus namaycush*], Spoonhead Sculpin [*Cottus ricei*]) in inland bodies of water in southern Ontario (Scott and Crossman 1973) suggests that there is no reason to believe any such catastrophe took place in these lakes so as to cause widespread extirpation.

Last, we assumed that the maxima that align most closely with the current distribution of the Mudpuppy are the most likely to have been present when this species entered the Great Lakes. This is because Cochran (1991) concluded that this species' ability to move upstream (and thus away from a shoreline defined by a maximum) is limited. However, we have been mindful that if colonization occurred and was followed by a period of higher water, this assumption must be questioned. Thus, the Mudpuppy's range was forecast to be largely determined by the highest lake maxima since its time of colonization. We used the Mudpuppy's southern Ontario range to validate our inferences about meltwater flow and lake extent.

In addition to these core assumptions, we also assumed that Mudpuppies fully colonized what was available to them and that they have been "deposited" in contemporary inland waterbodies as the ancient maxima fell. This baseline, combined with any upstream immigration, should define their current distribution. Upstream immigration into inland areas should be more pervasive where the substrate is softer and the river grade less violent.

We calculated the average elevation of Mudpuppy records from the Ontario Nature (2015) database (n 466, $\mu = 150$ m). Locations of duplicate records were only included once. We then generated an equal number of random points within a polygon formed by the most peripheral Mudpuppy records (a polygon with no convex angles that included all records), and calculated the same metric for each of these points. A Student's t-test run in Excel (Microsoft, Redmond, WA, USA) was used to assess any significant relationships.

Results

Our Student's t-test revealed a significant difference ($P < 0.001$), and suggests that the Mudpuppy's range has been influenced in a topographical sense by some phenomenon in a non-random way.

Among the eight major lake phases as modeled by Clark *et al.* (2012), the Nipissing Phase's shoreline maxima (USGS 1917) occurring between 4000 and 5000 years ago appears to align most closely with the inland edge of the Mudpuppy's contemporary range when assessed qualitatively. Figure 1 illustrates this tendency for contemporary Mudpuppy records to fall near or within lake maxima from the Nipissing Phase, particularly on the Canadian Shield. The Mudpuppy has been recorded at depths of 27 m (Reigle 1967); thus, it is important to note that the current range of this species certainly extends out into larger and open parts of the various Great Lakes. These areas do not appear on the map because of the highly unlikely incidence of recording one at these great depths. Thus, the in-shore records that appear in Figure 1 can be considered the inland extent of their range.

Discussion

The significance of our statistical analysis regarding the elevation of Mudpuppy records supports the notion that a particular phenomenon, such as ancient lake maxima, has had a common influence on this species' range in southern Ontario. Our attempts to identify which maxima this could have been are discussed below.

13 000 years ago the water level of Lake Algonquin was very high and flooded what is now Parry Sound, Muskoka, and Simcoe counties, as well as Manitoulin Island and the Bruce Peninsula (Chapman and Putnam 1984; Clark *et al.* 2012; Drzyzga *et al.* 2012). Had the Mudpuppy been in this ancient lake, we should expect current records from inland lakes and rivers at or near its maximum. However, there is no trend to support this. "Inland extreme" records of the Mudpuppy from Simcoe, Muskoka, and Parry Sound counties fall farther west than this maximum.

The Mudpuppy's absence from the lakes at this time can be strengthened further by making smaller-scale inferences about meltwater patterns. Harrison (1972) was able to pinpoint the closing date of the Fossmill outlet as 9860 ± 270 years ago (calibrated to 1950). This was a major drainage route for Lake Algonquin at the southern edge of the retreating Laurentide glacier that flowed northwest-to-southeast across topographical fissures in the highly elevated and gneiss-dominated Algonquin Dome, forming the modern-day Petawawa River valley (Chapman 1954). Had the Mudpuppy been present in Lake Algonquin at this time, it would have been deposited along the flow of the Fossmill, as were other glacial lake fish and crustacean species (Martin and Chapman 1965). Although absence is harder to detect than presence, multiple decades of fisheries research and a professional naturalist staff have failed to locate the Mudpuppy on the Algonquin Dome and the upper Petawawa River.

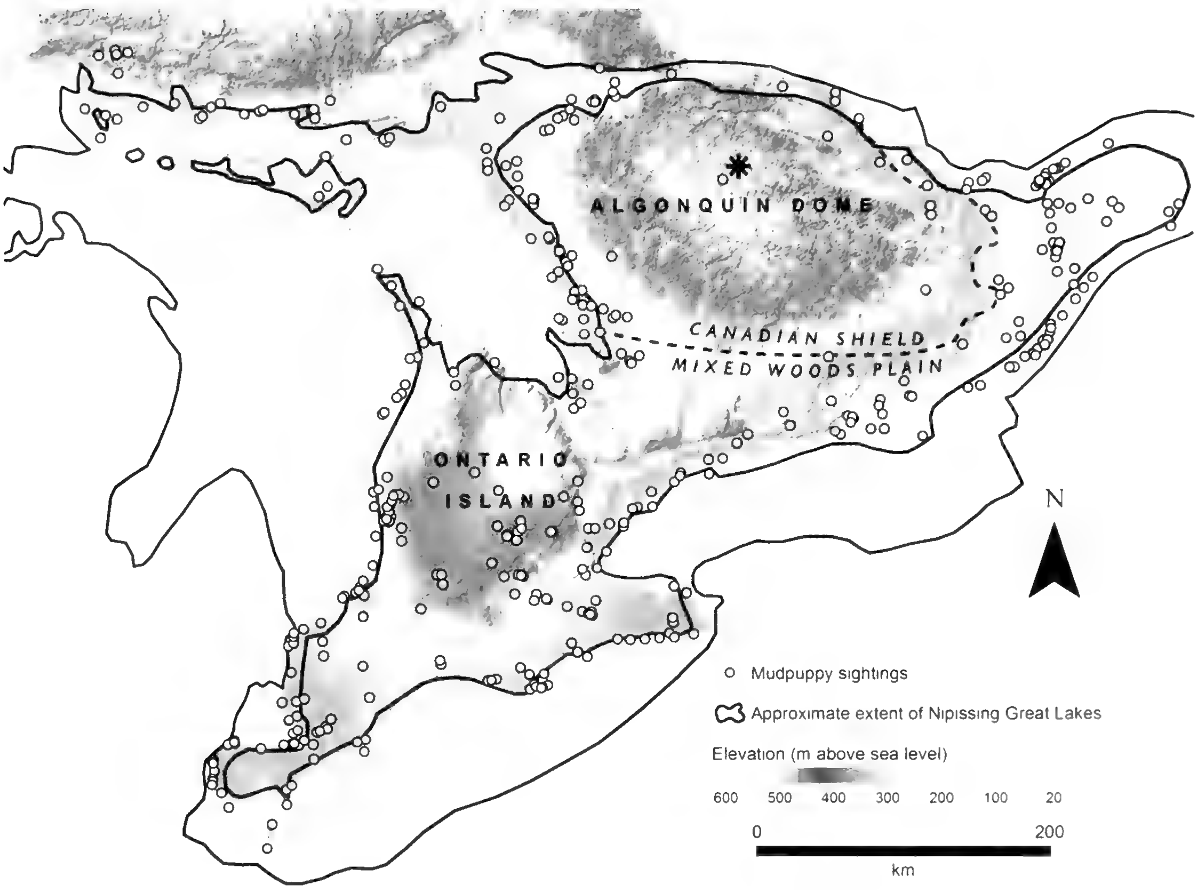

FIGURE 1. Distribution of the Mudpuppy (*Necturus maculosus*) in southern Ontario in relation to topographical relief/river grade and ancient (Nipissing Phase) and current lake levels, shown in blue. *questionable record from 1945.

Between 13 000 and 11 800 years ago, Lake Superior drained from the Brule outlet into the Mississippi River (Clark *et al.* 2012). This also could not have been the Mudpuppy's time and point of entry to the Great Lakes Basin because this species is currently absent from the Mississippi River upstream of St. Anthony Falls (Cochran 1991), a stretch of river downstream from this once-outlet that should then have been easily colonized.

By 11 800 years ago, lake levels were significantly lower even than current levels (Clark *et al.* 2012). With the higher-level Nipissing maximum coming in the future, it would be impossible to say with certainty whether the Mudpuppy was in the lakes at this time, because this range-defining maximum would have been erased with the yet-to-come higher Nipissing maximum. However, the Great Lakes Basin had no connection to the Mississippi River system at this time (Mandrak and Crossman 1992a; Clark *et al.* 2012), so feasible dispersal was not possible. Arguments made for the Mudpuppy's entrance into the Great Lakes from the west via ancient Lake Superior are unlikely because the latter was still bound by the Laurentide Ice Sheet at this time.

Although the finer details are still controversial, glacial Lake Agassiz flowed directly into Lake Superior through what is now the Lake Nipigon area approximately 10 000 years ago (Fenton *et al.* 1983). There is no evidence of the Mudpuppy along this drainage route in Ontario today, suggesting it was not present in Lake Agassiz at that time and thus also not in the Great Lakes Basin. This path of flow would have covered what is now contemporary Lake Nipigon. This region's fish have been studied and are exploited both commercially and recreationally (MNR 2009) and yet there are no Mudpuppy records. Mudpuppies are often captured by anglers where they are present (Bishop 1926; Pfingsten and White 1989; Holman 2012), and it seems hard to believe they could have been overlooked here, given the angling culture and work done by the fisheries assessment unit. Further confounding the notion that the Mudpuppy could have been present at this time is the fact that ancient Lake Michigan was also too low to permit a connection to the Mississippi River (Clark *et al.* 2012) to allow dispersing individuals access into the Great Lakes Basin.

Between 4000 and 5000 years ago (the Nipissing Phase) the maxima of the lakes (USGS 1917) are, for the first time, a close fit with the contemporary distribution of the Mudpuppy on the Canadian Shield. This would be expected if this was a time of colonization. There should be little upstream migration into inland areas on the rocky Canadian Shield, and thus the ancient range edge defined by the maxima should still be largely visible. At this time, ancient Lake Michigan had a connection to the Mississippi system via the Sag Channel at its southern extreme (Hansel *et al.* 1985). Thus, the three conditions are satisfied at this time: there was a connection to the Mississippian refugia to allow dispersal, the maxima of the lakes more-or-less aligns with current records of the Mudpuppy, and there is no logical suite of circumstances that preceded this moment that can offer a better entrance-and-colonization model.

Dispersal routes would have been easily available into ancient Lakes Huron and Superior, which were at the same level as ancient Lake Michigan at this time (Clark *et al.* 2012). The North Bay outlet, flowing west to east through the Mattawa and Ottawa River basins (Clark *et al.* 2012), would have been easily traversed by Mudpuppies because of its connectivity to ancient Lake Huron and downstream flow. Saltwater from the Champlain Sea had retreated by this time (Chapman and Putnam 1984) and thus did not influence or halt colonization. Eventually, downstream routes into Lakes Erie and Ontario became available as the Port Huron outlet opened (Coleman *et al.* 1994; Clark *et al.* 2012).

Thus, we suggest that Lake Ontario Mudpuppies have arrived there by one or two downstream routes: via the Mattawa/Ottawa/St. Lawrence systems or through the ancient St. Clair and Erie waterway (this would require surviving the drop over Niagara Falls). Because the Nipissing Phase represents the most recent high-water phase of the Great Lakes Basin (Clark *et al.* 2012), there have likely been only incremental changes in the Mudpuppy's range in the interim, all achieved by surpassing reasonably sized barriers.

The Mudpuppy on the Canadian Shield

It is clear that the inland records of the Mudpuppy in the northern portions of the map (Figure 1) on the Canadian Shield are less pervasive than further south on the Mixed Woods Plain. On the Canadian Shield, the Algonquin Dome's high elevation and hard rocky substrate (Crins *et al.* 2009) effectively barred the Mudpuppy from entry to this region (and continues to do so) because of the ragged headwater spillway rivers that drain out from this region.

There is a record for the Mudpuppy in Algonquin Park in the dataset provided by Ontario Nature's herpetofaunal atlas program (Ontario Nature 2015); however, we find this record highly questionable. It is via C. E. Hope in 1945 and is associated with Lake-of-Two-Rivers (marked with an asterisk in Figure 1). Hope is mentioned in the acknowledgements of the *Check-list of Amphibians and Reptiles of Canada and Alaska* (Logier and Toner 1955), which does indeed include this Lake-of-Two-Rivers record from Algonquin Park. However, there are too many other unusual elements regarding this record to uphold its integrity. Lake-of-Two-Rivers sits at 393 m above sea level and is in one of the highest-elevated areas in Southern Ontario, making it one of the least likely lakes in which Mudpuppies would be found. We have examined photographs of this specimen and it is indeed a Mudpuppy (Royal Ontario Museum #7533, adult, snout-vent-length 204 mm [measurement via digital photograph using ImageJ open-source software]), gray with black dorsal spotting). The specimen tag makes no mention of Lake-of-Two-Rivers, so the origin of the locale information remains questionable. The coordinates 45.83333°N, 78.5°W are associated with this record in an external database, but do not appear on the tag itself; they were certainly added after the fact, and their origin is a mystery (Amy Lathrop, personal communication). In addition, Lake-of-Two-Rivers is located at approximately 45.5°N, making the suggested latitude many kilometres off target to the north. Even though there is good evidence that Hope was present at Lake-of-Two-Rivers in 1945, we suggest this record is erroneous in some way. No other specimens have been found at this location in the interim after intensive searches (Brad Steinberg, personal communication) and it does not appear that Mudpuppies became established, bred, multiplied, persisted, etc., if they were introduced. It is of interest that Petranka (2010) shows an absence in the distribution of the Mudpuppy in the Adirondack Mountains of New York — a region also with heightened elevation and similar geology to the Algonquin Dome.

The Mudpuppy on the Mixed Woods Plain

Inland records of the Mudpuppy are more pervasive in the southern portions of the map (Figure 1) on the Mixed Woods Plain than further north on the Canadian Shield, and conformity to the Nipissing Phase maxima is poor. For example, there are a handful of records of the Mudpuppy from the highly elevated "Ontario Island" in Perth, Wellington, and Waterloo counties (Figure 1). Like the high-elevation record at Lake-of-Two-Rivers on the Algonquin Dome, these records may also be questionable. However, high-elevation records of this species off the Canadian Shield, as here, are more likely. Because soft glacial till covers this portion of the province to large depths (Crins *et al.* 2009), river systems transport massive amounts of sediment, which form graded riffles at points of relief (Wohl 2000). These are easier to traverse in an upstream direction than the more difficult barriers, such as waterfalls, perpetuated by the unyielding gneiss and other rock of the Canadian Shield, as found at Lake-of-Two-Rivers. Some fish species that also face these same barrier-challenges show a similar distribution pattern (see "species distribution pattern C" in Mandrak and Crossman 1992a). For example, the Johnny Darter (*Etheostoma nigrum*) and the Central Mudminnow (*Umbra limi*) are found in highly elevated watersheds off the Canadian Shield, but are naturally absent from upland waterbodies on the Canadian Shield (Mandrak and Crossman 1992b). All of the above factors considered, we propose that even pervasively inland records in the Mixed Woods Plain region simply represent populations of the Mudpuppy that were able to steadily climb relatively gentle river grades from initially lower elevations at the levels of the Great Lakes.

Other anomalies in the record database (high-altitude records) that depart geographically from this general model of entrance into and dispersal within the Great Lakes during the Nipissing Phase are probably best explained by changing topography resulting from post-glacial isostatic adjustment, anthropogenic changes to watersheds (e.g., canals), as well as Mudpuppies naturally overcoming some barriers. Other apparently anomalous records in the atlas may be attributable to amateur naturalists identifying various superficially similar organisms — catfishes (*Ictaluridae*), sculpins (*Cottidae*), gobies (*Gobiidae*), mole salamander larvae (*Ambystomatidae*), newts (*Salamandridae*), etc. — incorrectly as Mudpuppies. The likelihood of misidentification should always be considered when dealing with data derived from citizen-science initiatives.

Conclusion

Until now, the Mudpuppy has been considered an early, primary invader of the Great Lakes Region following the Wisconsinan glaciation (Holman 2012). However, this notion appears to be based only on this species' ability to be active in cold water. Our more involved work here provides a different explanation for arrival in the Great Lakes Basin. The Nipissing Phase is the most plausible time of entry into the Great Lakes by the Mudpuppy because (i) its maxima most closely align with current distribution records, in particular in rugged regions where upstream, inland migration is hindered; (ii) there was a connection to its Mississippian refugia, which would facilitate spread into the Great Lakes at this time; and (iii) there is no logical ancient suite of circumstances that fit the conditions better.

Our findings suggest that the presence of the Mudpuppy in Ontario can be rationally predicted from knowledge of water flow and flooding during the Nipissing Phase. In short, the Mudpuppy is currently found in all Great Lakes, sparingly inland from Nipissing Phase maxima on the Canadian Shield, and well inland along reasonably traversable river systems on the Mixed Woods Plain. This understanding could be used to evaluate the validity of existing records of this species in the Great Lakes Basin.

Finally, the discussion of the Lake-of-Two Rivers Mudpuppy record presented here (ROM #7533) illustrates the dangers associated with inferring species ranges without knowledge of the biogeographic factors that led to its distribution on the land and waterscape. We encourage the removal of this record from outputs derived from the Ontario Reptile and Amphibian Atlas database.

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Note

Second Report of the Gray Fox, *Urocyon cinereoargenteus*, in New Brunswick

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McAlpine, Donald F., Jonathan Cormier, and Isaac G. MacLean. 2016. Second report of the Gray Fox, *Urocyon cinereoargenteus*, in New Brunswick. Canadian Field-Naturalist 130(2): 164–166.

The Gray Fox, *Urocyon cinereoargenteus*, is listed federally as a threatened species in Canada, but has been undergoing a range expansion, with the first New Brunswick occurrence recorded in 2007. Here we document a second recent New Brunswick occurrence (2014) and suggest that monitoring the species in the province may be warranted.

Key Words: Gray Fox; *Urocyon cinereoargenteus*; conservation; dispersal; range expansion

Zooarchaeological evidence demonstrates that during the Uren Middle Iroquoian stage (1300–1350 AD; see Dodd *et al.* 1990) the Gray Fox, *Urocyon cinereoargenteus,* reached the northern limit of a wide North American distribution in southern Ontario (Wintemberg 1921). However, by the time of European colonization of North America, the Gray Fox had essentially disappeared from Canada as a resident breeding mammal. It has been suggested that the species range contracted because of deforestation during the early European settlement period or cooling of the climate that lasted from about 1500 to 1850 (the Little Ice Age; Bozarth *et al.* 2011). However, since 1930–40, the Gray Fox has been undergoing a range expansion, possibly in response to warming climate and forest changes that have provided suitable habitat (Palmer 1956; Judge and Haviernick 2002; Bozarth *et al.* 2011). Reduced winter snowfall has also been suggested as a factor encouraging Gray Fox expansion along the northern margin of its range (Jolicoeur *et al.* 2011).

In Canada, as recently as 2002, it was suggested that the Gray Fox was limited as a resident breeding mammal to Pelee Island, Ontario, with a small number of dispersing animals from the United States recorded in southeastern Manitoba and southern Ontario (COSEWIC 2002). There is a single anomalous report from northern Alberta (Moore 1952).

The first Gray Fox from New Brunswick was reported in the southwest of the province in 2007, about 135 km northeast of Bangor. This is the region from which the most northerly Gray Fox sightings in Maine were known at that time (McAlpine *et al.* 2008). Recent evidence suggests a small, but increasing, number of Gray Fox in Ontario and Quebec (Jolicoeur *et al.* 2011; Van den Broeck, personal communication) and Manitoba (Dean Berezanski, personal communication), with breeding now likely in the Rainy River-Thunder Bay region of northwestern Ontario (COSEWIC 2015; Van den Broeck, personal communication),in addition to Pelee Island. Here we document a second report of the Gray Fox in New Brunswick.

On 19 September 2014, using a motion activated infrared camera, IGM recorded a single Gray Fox inspecting an apple-flavoured salt lick placed on a stump at the north end of Oromocto Lake, York County, New Brunswick (45.6455°N, 67.0102°W). The location is about 36 km north of the previous New Brunswick Gray Fox sighting near Rolling Dam, Charlotte County, and 123 km east of Lincoln, Maine, the site of a March 2013 Gray Fox occurrence also captured on a trail cam and reported in the media (Holyoke 2013). A still photograph taken from a 16-s segment of the New Brunswick video (02:52:18–02:52:34; Figure 1) shows the dark muzzle, dark dorsal stripe, dark tail tip, and relatively short legs characteristic of the species (Naughton 2012). The area includes a mosaic of 30-year-old mixed forest dominated by fir (*Abies* sp.) and birch (*Betula* sp.), more recent cutovers, hay fields, and rural residences and farms. Oromocto Lake is about 600 m distant from the trail cam site.

In 2002 it was estimated, with little supporting data, that the Canadian population of the Gray Fox consisted of 30–250 mature individuals (COSEWIC 2002). Although no current reliable population estimates exist, it is now suggested that fewer than 110 mature individual Gray Fox are present in Canada (COSEWIC 2015). Accordingly, the species continues to be ranked as threatened in Canada (COSEWIC 2015), and NatureServe has ranked this species as critically imperilled (N1) in Canada. COSEWIC (2015) suggests that it is mortality from trapping that is likely preventing the establishment of breeding subpopulations of the Gray

Figure 1. Still photograph extracted from a 16-s video of a Gray Fox, *Urocyon cinereoargenteus*, at the north end of Oromocto Lake, York County, New Brunswick, on 19 September 2014. Arrows mark the dark muzzle and tail tip characteristic of the species. Photo: I. G. MacLean.

Fox in much of the Canadian range outside Pelee Island. The Gray Fox is not currently considered to be a native New Brunswick furbearer; hence the New Brunswick Fish and Wildlife Act refers only to "fox". New Brunswick regulations for harvest of Red Fox (*Vulpes vulpes*) therefore, unintentionally, include the Gray Fox. Although listed as threatened under the Ontario Species-at-Risk Act, the Gray Fox receives no specific protection in Manitoba or New Brunswick, probably because of its perceived vagrant or "occasional" status in these latter jurisdictions (COSEWIC 2015). Trapping and hunting of the species is prohibited in Quebec, but the Gray Fox has no designated conservation status in that province. Nonetheless, Jolicoeur *et al.* (2011) acknowledge that the species is expanding its range in Quebec and that there is a need to monitor it there. The 2 recent occurrences of the Gray Fox in New Brunswick suggest that monitoring in New Brunswick may also be warranted.

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The History of Elk (*Cervus canadensis*) Restoration in Ontario

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Hamr, Josef, Frank F. Mallory, and Ivan Filion. 2016. History of Elk (*Cervus canadensis*) restoration in Ontario. Canadian Field-Naturalist 130(2): 167–173.

Elk (*Cervus canadensis*) historically inhabited southern Quebec and central Ontario, but, by the early 1900s, the species was extirpated from this region. Attempts to re-establish an Elk population in Ontario during the first half of the 20th century had limited success. We reviewed historical documents, population census records, and a previous study pertaining to Elk reintroduced to Ontario in the early 1900s for clues to the cause(s) of their limited population growth. After an apparent rapid population increase in the 1940s followed by unregulated hunting during the subsequent 3 decades, Elk abundance in Ontario had not appreciably changed from 1970 to 1997, most likely because of the small founding population, unsustainable hunting, and accidental mortality. After the abolition of legal hunting in 1980, natural mortality appeared to be the main limiting factor. A limited sample of pregnancy and calf recruitment rates, body measurements, and physical condition parameters collected in 1993–1997, suggested that adults were healthy, reproducing successfully, and not limited by food availability; thus, it was concluded that remnant Elk populations could be augmented by introducing additional animals. A renewed Elk restoration effort, conducted from 1998 to 2001, imported 443 Elk from Elk Island National Park in Alberta to 4 release areas across central Ontario (Lake of the Woods, Lake Huron North Shore, Nipissing/French River, and Bancroft/North Hastings), resulting in a provincial population of about 800 Elk by 2013.

Key Words: *Cervus canadensis*; Elk; history; mortality; Ontario; restoration; population status

Introduction

Before the arrival of Europeans, an estimated 10 000 000 Elk (*Cervus canadensis*) were present across North America (Seton 1927). Historically, Elk, or Wapiti, ranged throughout the Eastern Deciduous Forest biome and the Great Lakes–St. Lawrence ecotone, including southern Quebec and central Ontario (Lett 1884; Peterson 1957, 1966; Bosveld 1996; Bowyer 1996). However, by the end of the 1800s to the early 1900s, Elk were extirpated from eastern North America (Larkin *et al.* 2001). In Ontario, sparse observations suggested that the headwaters of the Ottawa River may have been the last region inhabited by indigenous Elk (Lett 1884; Smith 1901; Peterson 1966).

The decline of Elk across North America was attributed mainly to overharvest and habitat loss (O'Gara and Dundas 2002). By the late 1970s, approximately 500 000 Elk remained, primarily in the western part of the continent (Bryant and Maser 1982). Since the extirpation of Elk from the eastern part of their North American range, numerous reintroductions have been attempted with varying degrees of success, including several failed efforts (O'Gara and Dundas 2002). Efforts to reintroduce Elk in Pennsylvania, Michigan, Arkansas, and more recently Kentucky, Wisconsin, and 2 regions of Ontario, can be considered successful, based on the establishment self-sustaining populations (Larkin *et al.* 2001; Popp *et al.* 2014).

Attempts to introduce Elk from Alberta into Ontario during the first half of the 20th century had limited success (Ontario Department of Game and Fisheries 1933; Peterson 1957; Ranta 1979). Although the source population was the prairie environment, Ranta (1979) presumed that the animals used as founders were of the Rocky Mountain subspecies (*C. c. nelsoni*), originally acquired from Yellowstone National Park. However, mitochondrial DNA analysis has shown that all extant populations of Elk east of the Rocky Mountains, including the so-called Manitoban Elk (*C. c. manitobensis*), are genetically identical to the Rocky Mountain subspecies, *C. c. nelsoni* (Polziehn *et al.* 1998, 2000). Although viable DNA could not be obtained from several museum specimens of Eastern Elk (*C. c. canadensis*), it is questionable whether indigenous Ontario elk were genetically different from those in Manitoba, given that they appeared to form a contiguous population around the Great Lakes provinces and states (Seton 1927; Peterson 1957). Only Tule (*C. c. nannodes*) and Roosevelt Elk (*C. c. roosevelti*) have shown distinct DNA structural differences from Elk populations east of the Rocky Mountains (Polziehn *et al.* 2000). In view of these findings, the transfer of Rocky Mountain Elk to Ontario can be considered a reintroduction of animals originating from the same genetic clade.

A remnant population of 40–50 Elk originating from earlier reintroductions persisted in the Burwash–French River area of central Ontario until the late 1900s (Ranta 1979; Rosatte *et al.* 2007). Here, we provide a review of historical information (late 1800s to 1997) on the status of reintroduced Elk in Ontario and identify potential threats and limiting factors responsible for historical population declines.

Methods

We searched files and correspondence of the Department of Lands and Forests (Ontario Ministry of Natural Resources and Forestry [OMNRF]), Burwash Industrial Prison Farm (Ministry of Government Services), and Ontario Veterinary College (University of Guelph), as well as newspaper articles, for historical information pertaining to Elk in Ontario. We obtained sporadic Elk harvest and population survey records from 1950 to 1989 from OMNRF. Several people who had hunted Elk during the 1960s and 1970s provided information on Elk kill dates, numbers, and locations. Former Burwash Industrial Farm employees provided information on the numbers of Elk kept at the facility and released into the wild. We also reviewed pertinent historical information summarized by Ranta (1979).

Results

An unsuccessful 1897 reintroduction of an unknown number of Elk into Algonquin Provincial Park (Ranta 1979) likely constitutes the first attempt by the provincial government to restore Elk to Ontario. Subsequently, Elk from the 660-km^2 Buffalo National Park (now Canadian Forces Base) near Wainwright, Alberta (Lothian 1987), were introduced at several locations in southern and central Ontario in the early 1930s. Sites in Ontario, where Elk from the captive Wainwright population were released, included the Pembroke Game Preserve, the Nipigon-Onamon Game Preserve, the Chapleau Game Preserve, the Goulais River Ranger Lake Game Preserve, and the Burwash Industrial Farm (Ranta 1979; Figure 1). During the 1930s and 1940s, a captive population was raised near Pembroke and used as a source for introductions into Algonquin Provincial Park, the Bruce Peninsula, the Nipissing Game Preserve, Redbridge, Apsley, the Abitibi Crown Game Preserve, Latchford, and Lake Wanapitei Provincial Park (Figure 1). By the late 1940s, Elk ranged freely at most of these Ontario sites and were still held captive at Burwash and Pembroke (Ranta 1979). The Burwash Industrial Farm (a medium security prison), located 20 km south of Sudbury, Ontario, received 2 shipments of

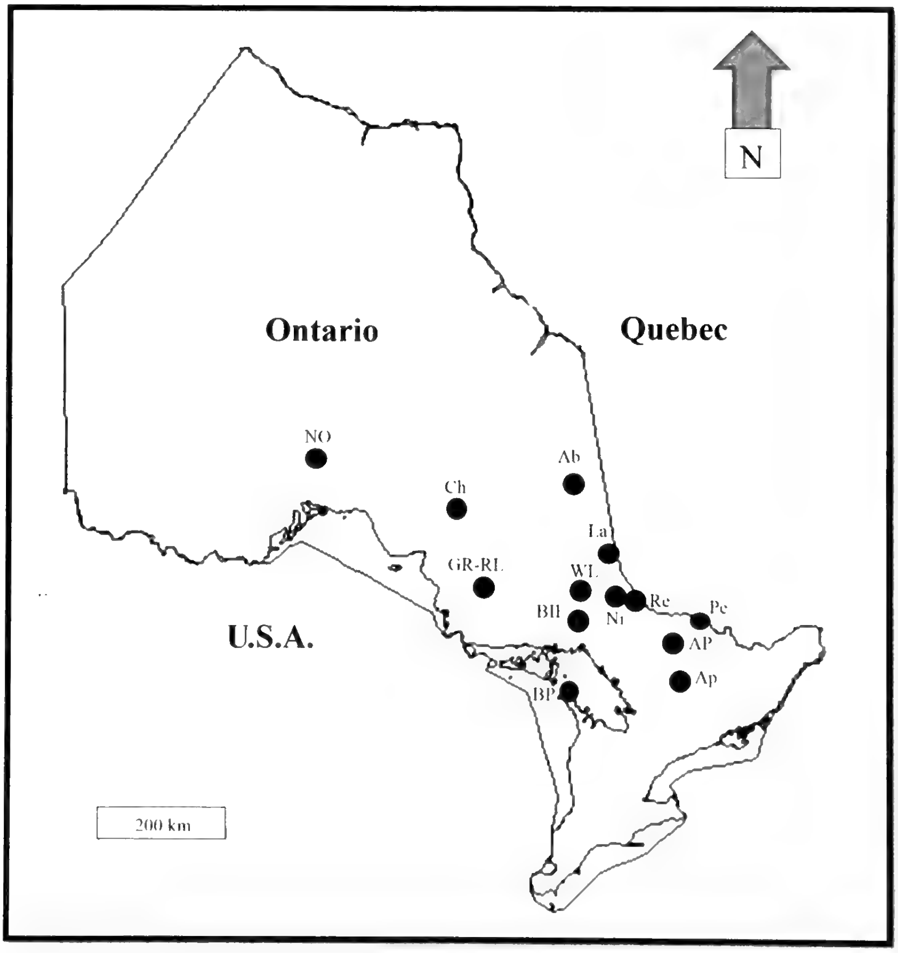

FIGURE 1. Sites of introduction of western Elk (*Cervus canadensis*) into Ontario during the 1930s and 1940s. Note: Ab = Abitibi, Ap = Apsley, AP = Algonquin Park, BIF = Burwash Industrial Farm, BP = Bruce Peninsula, Ch = Chapleau, GR-RL = Goulais River-Ranger Lake, La = Latchford, Ni = Nipissing, NO = Nipigon-Onamon, PE = Pembroke, Re = Redbridge, WL = Wanapitei Lake. Source: Ranta (1979).

approximately 50 Elk each from Wainwright in 1933 and 1934 (OMNRF files). Estimates of Elk numbers (captive and wild) at the Burwash Industrial Farm in the mid-1940s, provided by former employees, ranged from 300 to 1000 animals, with 300 thought to be the more accurate estimate in view of the size of the relatively small holding facility. Similar population increases were reported from other reintroduction sites, but no quantitative information was found (Ranta 1979).

In the late 1940s, Giant Liver Fluke (*Fascioloides magna*) was reported in Elk and cattle at the Burwash Industrial Farm, and the provincial government implemented a large-scale extermination program (Kingscote 1955). As a result, an estimated 300 Elk were slaughtered at the Burwash Industrial Farm between 1949 and 1950 (Lumsden 1955) and a legal harvest of free-ranging Elk, between 1950 and 1979, aimed to eliminate rather than manage the remnant animals (Kingscote 1955). In 1955, after 5 years of this extermination effort, an estimated 200–250 free-ranging Elk remained, distributed across 10 administrative districts in central Ontario, about 30% of the province's total area (Lumsden 1955; Figure 2). However, individual Elk populations were small, their distributions were highly localized, and approximately 66% of these animals were reported from the Sudbury area (Table 1). By the mid-1970s, Elk presence could be confirmed only in the Sudbury area (Ranta 1979). In 1980, the government called for a moratorium on Elk hunting as a result of Ranta's (1979) research and successful lobbying by the Ontario Federation of Anglers and Hunters. Ranta (1979) reported that the Sudbury area Elk population was very small (30-50 animals), but healthy and subjected to unsustainable hunting pressure during the 1970s.

By the early 1980s, occasional reports of Elk in various parts of the province virtually ceased. Between 1971 and 1989, the OMNRF conducted several aerial surveys for Moose (*Alces americanus*) and Elk between January and March throughout the presumed Elk range.

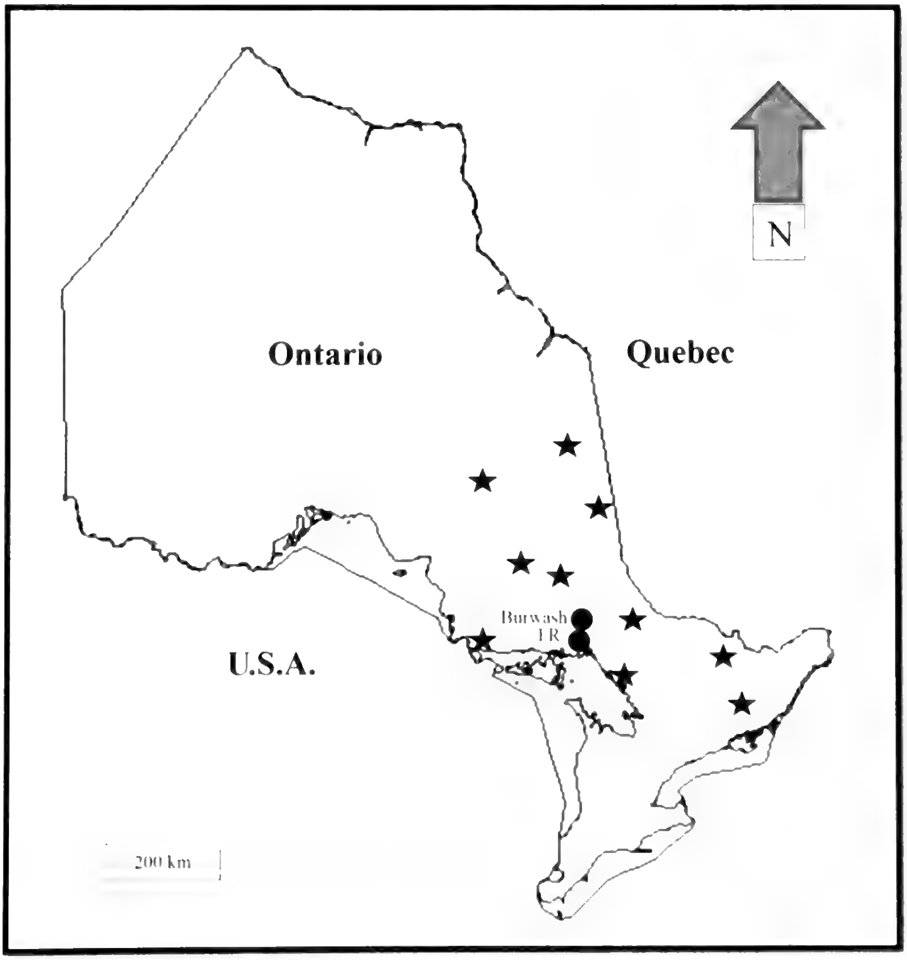

FIGURE 2. Reported presence of free-ranging Elk (*Cervus canadensis*) in 10 Ontario Ministry of Natural Resources administrative districts during 1955. Note: stars = free-ranging Elk, circles = Burwash French River (FR) remnant Elk range. Seven other surveyed districts reported no Elk. Source: Lumsden (1955).

TABLE 1. Reported status of Elk (*Cervus canadensis*) in 10 administrative districts* of Ontario in 1955.

Administrative district	Estimated no. Elk present	Estimated no. Elk/km^2	No. legally harvested Elk (1954)
Kapuskasing	few	0.06	0
Chapleau	few	0.06	0
Cochrane	27	0.10	0
Swastika	few	0.10	2
Sault Ste. Marie	18	0.06	0
Sudbury	100–150	0.10	11
North Bay	15	0.06	0
Parry Sound	few	0.06	0
Lindsay	45	0.10	10
Pembroke	few	0.06	0
Total	205–300		23
Mean		0.08	

Source: Lumsden (1955).
*Seven other surveyed districts reported no elk.

During this 18-year period, 203 Elk were observed in groups ranging from 2 to 22 (Table 2). Ranta (1979) studied range and habitat relations of the Elk near Sudbury by following tracks and conducting systematic aerial surveys and reported a mean group size of 3.5 (± 1.2 SD; Ranta 1979, 1981). He observed 43 groups and recognized at least 29 different individuals (4 adult bulls, 10 adult cows, 9 calves, and 6 yearling cows or bulls) and estimated the bull:cow:calf ratio at 1:4:2. Although a management plan for the remnant population was proposed in 1975, it was never adopted (Love 1975).

One year after abolition of legal Elk hunting in Ontario in 1980, 43 Elk were detected during 5 fixed-wing aircraft flights in the Sudbury area (Ranta 1981; Table 2). In March 1984, ground and fixed-wing aerial surveys estimated the total Elk population in the Sudbury area at 50 animals: 40 in the French River range and 10 in the Burwash range (Bennet and Echle 1984). A fixed-wing aircraft survey conducted in winter 1985 reported 39 free-ranging Elk in the French River area and only 1 Elk in the Burwash area (Haarmeyer 1985; Table 2). Sporadic aerial and ground surveys by the OMNRF during the late 1980s continued to report Elk sign and sightings in the Sudbury area; however, no reliable population estimates were produced (Table 2). Although sporadic unconfirmed sightings of Elk were reported by loggers and truck drivers in the Chapleau area up to the 1990s (G. Haarmeyer, personal communication), the persistence of Elk in the Chapleau area after the 1990s is suspect.

Historical review also revealed several causes of mortality of Elk, in addition to agricultural-related and legal harvest, that likely contributed to their observed low abundance from the 1970s to the 1990s. Several train accidents involving free-ranging Elk in the Bur-

TABLE 2. Results of Elk (*Cervus canadensis*) aerial surveys in the Sudbury District, Ontario, 1971–1989.

Year	Burwash sightings	French River sightings	Largest no. of Elk seen per flight (no. flights)	Area surveyed, km^2	Total no. of Elk seen (population estimate)	Source*
1971	n/a	n/a	n/a (6)	n/a	22 (n/a)	Anonymous (1971)
1976	n/a	n/a	11 (14)	1536	14 (50)	Anonymous (1976)
1977	7	n/a	7 (1)	n/a	7 (about 100)	Haarmeyer (1977)
1981	5	38	22 (5)	400	43 (> 29)	Ranta (1981)
1984	n/a	32	17 (4)	300	32 (50)	Bennett and Echle (1984)
1985	1	39	15 (3)	1000	40 (< 50)	Haarmeyer (1985)
1988	n/a	9	9 (1)	n/a	9 (n/a)	Gross (1988)
1989	10	23	23 (3) 3 bulls, 8 cows, 12 unsexed	1000	33 (50)	Hamr, direct observation
Mean	5.3	28.2	11.6 (5.2)	847.2	25.2 (53.3)	

Note: n/a = not available.
*Ontario government documents from the 1970s and 1980s contained no explanation of how authors estimated total Elk population from the number of animals seen/minimum known alive. As no systematic survey method was used, and there were no marked animals in the populations, the estimates were "educated guesses." However, the 1980s estimates correspond closely to the mark-and-resight survey results obtained during the 1990s (Table 3).

wash area were reported during the 1950s and 1960s by train engineers, and drowned Elk were sporadically found throughout the 1970s, 1980s, and 1990s in the French River (E. Chevrette, R. Desrochers, P. Schennach, personal communication). In the early 1970s, the annual Elk harvest in the Sudbury area was 6–12 animals from a 640-km^2 area (Cheley 1974; Love 1975).

Several drowned Elk (2 in the French River and 7 in the Wanapitei River) were reported during the winter of 1973 (Love 1975). In addition, in the fall of 1973, 6 free-ranging Elk died in the Burwash range (5 harvested, 1 roadkill) and 2 were shot by hunters in the French River area (Cheley 1974). Ranta (1979) recorded 4 Elk shot in 1976, whereas in 1977, hunters saw 5–8 Elk and harvested 2. The Crombie Bay Hunt Club located in the French River area harvested 3 and observed 10 Elk between 1962 and 1977, and most kills were likely accidental while hunters were seeking White-tailed Deer (*Odocoileus virginianus*). Annual losses to poaching were estimated to be small and confined primarily to the vicinity of the previously (1975) abandoned Burwash Industrial Farm (Ranta 1979).

An unknown number of free-ranging Elk shot in the 1950s and 1960s tested negative for bovine tuberculosis, Brucellosis, and Giant Liver Fluke (Kingscote 1955). Ranta (1979) also found no evidence of Giant Liver Fluke in the livers of 6 Elk shot between 1975 and 1978 and no Meningeal Worm (*Parelaphostrongylus tenuis*) larvae in 14 fecal samples. One confirmed and 1 suspected Gray Wolf (*Canis lupus*) kill were reported during the late 1970s and it was suspected that American Black Bears (*Ursus americanus*) also killed newborn Elk calves (Ranta 1979). The chief natural cause of mortality (up to 15% of the estimated population in some years) during the 1970s appears to have been drowning through river ice in both the Burwash and French river areas (Cheley 1974; Ranta 1979). No mortality information was available for the 1980s.

In the 1990s, the remnant Burwash–French River Elk population occupied 2 distinct ranges located 25–30 km apart and was estimated at 36–55 animals by Brown (1998; Table 3). Further research using radiotelemetry confirmed drowning through ice (4 of 8 collared Elk deaths), mortality of calves during winter (3 deaths), and accidents with trains (1 death) as the main mortality factors (Jost 1997; Brown 1998; Jost *et al.* 1999). Predation by American Black Bears on newborn Elk calves was confirmed by Zuchliski (1995).

A recent provincial Elk restoration project, conducted from 1998 to 2001, saw 443 Elk from Elk Island National Park, Alberta, introduced at 4 locations in central Ontario: Lake of the Woods, Lake Huron North Shore, Nipissing-French River, Bancroft-North Hastings (Rosatte *et al.* 2007). By 2012, the provincial Elk population was estimated at 800-1000 animals (Rosatte 2013).

TABLE 3. Herd composition and Lincoln-Peterson mark–resight estimates for the Burwash and French River Elk (*Cervus canadensis*) herds obtained from systematic helicopter surveys during the winters of 1993–1997.

Year	Sightings (no. flights)		Minimum no. Elk known alive (both areas)	Calf:cow: bull ratio (both areas)	No. marked Elk present	Total population estimate ± SD
	Burwash	French River				
1994	27 (2.0)	14 (1.0)	24.0	1 : 1.9 : 0.3	0.0	n/a
1995	46 (4.0)	33 (2.0)	37.0	1 : 3.3 : 1.2	6.0	36.0 ± 5.5
1996	61 (5.0)	63 (5.0)	39.0	1 : 2.1 : 0.3	11.0	54.9 ± 9.5
1997	21 (2.0)	24 (2.0)	25.0	1 : 1.8 : 1.2	9.0	43.5 ± 7.1
Means	39 (3.0); 13 flight	34 (2.5); 14 flight	31.3	1 : 2.3 : 0.8	8.7	44.8 ± 7.4

Note: SD = standard deviation.
Sources: Lancia *et al.* (1996); Jost (1997); Brown (1998).

Discussion

Historical documents suggest that the initial Elk restoration efforts of the 1930s and 1940s were well on their way to re-establishing Elk in Ontario, until concerns over Giant Liver Fluke infestation prompted a province-wide Elk extermination campaign by the OMNRF, which was recommended by the Ontario Veterinary College in the early 1950s (Kingscote 1950, 1955). The official estimates of the Elk population of Ontario remained at 100–150 animals from the mid-1950s to the 1980s (Haarmeyer 1977). However, we were not able to find any empirical evidence supporting these numbers. As such, we suggest that the 30-year (1950–1979) Elk extermination campaign was largely successful and that consistent overestimation by the OMNRF was responsible for the view that Elk numbers in Ontario declined rapidly during the 1980s and early 1990s, when systematic aerial surveys were implemented. This is evident from the similar results of aerial Elk population surveys obtained in the 1970s (Haarmeyer 1977; Ranta 1981; Table 2) and those 20 years later. A density of only about 0.03 Elk/km^2 could be deduced from the early surveys. Detailed survey information (locations, numbers, sex, and age) was not available for most of the early surveys, but it was evident that the entire Elk range, estimated at about 1200 km^2 during the 1990s (Brown 1998), was covered by some flights (1976, 1985, and 1989). The total number of Elk spotted during these surveys varied from 14 to 40 and suggested a minimum of 30–40 Elk present across the entire range during the 1980s.

The reason for fewer reported Elk sightings at Burwash than at the French River site was likely lower visibility of Elk because of greater conifer forest coverage at the former site than on the sparsely treed Georgian Bay shoreline at the French River delta. Also, most likely as an anti-predator strategy, Elk in the French River delta tended to concentrate on small islands surrounded by fast-flowing, open water during the winter, which made them easier to spot from aircraft (J. Hamr, personal observation). Although all of the aerial surveys in the 1980s and 1990s were conducted from low and slow-flying helicopters, Elk often remained bedded or standing in the shelter of conifers, which made their detection difficult. Consequently, the aerial survey results should be considered as potential gross underestimates of the true population size. McIntosh *et al.* (2007) developed a "sightability" model based on radio-collared animals known to be in the area. However, the model could be implemented only after the introduction of new Elk from Alberta (1998–2001).

The Giant Liver Fluke, which originated in North America, naturally infects cervids and bovids (Kingscote 1950; Foreyt and Todd 1976). Three wild North American cervids contribute significantly to the persistence and spread of the fluke as definitive hosts: White-tailed Deer, Elk, and Caribou (*Rangifer tarandus*; Pybus 2001). Historically, the only indigenous North American primary definitive host of this fluke is White-tailed Deer, as both Elk and Caribou are of Eurasian origin and entered North America across the Bering land bridge during the Pleistocene. Elk and Caribou most likely gradually acquired the parasite as they spread over the continent and their ranges overlapped with endemic White-tailed Deer in some parts of North America (Pybus 2001). Because White-tailed Deer historically occupied the eastern half of North America, it is most likely that the Giant Liver Fluke was present in Ontario well before the reintroduction of Elk there in the 1930s. The presumption by Kingscote (1950) that the parasite was introduced into Ontario by reintroduced Elk from western Canada was almost assuredly erroneous. Epidemiology of the Giant Liver Fluke and other endoparasites spread by snails as intermediate hosts indicates that infestations become more pronounced with increasing densities of ungulates (Foreyt and Todd 1976). Housing large numbers of Elk in breeding enclosures at several sites in central Ontario in the 1930s and 1940s likely created ideal propagation conditions for these parasites. As soon as Elk were released into the wild and dispersed over the landscape, Giant Liver Flukes could no longer be found in animals harvested during the 1950s, 1960s, and 1970s (Kingscote 1955; Ranta 1979). The decision to embark on a province-wide Elk extermination program in 1950 was, thus, bound to fail in its objective to eliminate the Giant Liver Fluke from the province, and, in hindsight, was a questionable measure to manage the prevalence of this parasite in the province's ungulate community.

The 3-decades-long extermination attempt nearly succeeded in eliminating all the formerly reintroduced Elk from Ontario. The numbers of dead animals (harvested and accidentally killed) reported in the Sudbury area during the 1970s (Cheley 1974) represented a minimum known annual mortality of about 30%, out of an estimated population of 50–60 Elk. In 1973, hunting was responsible for 41% of the reported annual population losses (Cheley 1974). Collisions with trains, drowning through ice, and predation also contributed to population reduction. The estimated annual removal of more than a third of a small Elk population clearly would have been unsustainable in the long term (Taber *et al.* 2002). The 1980 moratorium on Elk hunting probably stopped, or slowed, the population decline, but, by this time, the small population was more susceptible to natural (i.e., climate) and anthropogenic (i.e., train kill) stochastic events, as well as low levels of predation and apparent competition, which likely caused the population to stagnate. Combined with inbreeding depression in the long term, the situation would likely have led to eventual extinction (Pulliam 1988). The renewed restoration efforts from 1998 to 2001 augmented numbers and genetic diversity of the remnant population of reintroduced Elk in Ontario, thus bolstering its viability (Rosatte *et al.* 2007).

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Note

Head-bobbing in the Ring-billed Gull (*Larus delawarensis*)

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Many birds bob their head as they walk or run on the ground. The functional significance of this behaviour is unclear, but there is strong evidence that it plays a significant role in enhancing visual perception. If head-bobbing is advantageous, however, then it is a puzzle that some birds do not head-bob. As a group, gulls (Laridae) are among the birds that reportedly do not head-bob, yet here we report head-bobbing among Ring-billed Gulls (*Larus delawarensis*), observed and filmed in Ontario, when walking relatively slowly while foraging on the ground. This suggests that head-bobbing plays a key role in the visual detection of food items in this species. We suggest that head-bobbing may be a relatively common behaviour in foraging Ring-billed Gulls and speculate that other gulls (and indeed other birds) previously thought not to head-bob may in fact do so under certain circumstances.

Key Words: Ring-billed Gull; *Larus delawarensis*; head-bobbing; behaviour; foraging; head movement; head stabilization; motion parallax; visual perception

Introduction

Many birds display characteristic head movements as they walk and run on the ground. Called head-bobbing, this behaviour involves repeated backward and forward movements of the head (termed the "hold" and "thrust" phases, respectively; Frost 1978) with respect to the moving body, but not the surrounding environment. During the hold phase, when the head appears to be moving backward, it is actually held stationary while the body continues to move forward (Dunlop and Mowrer 1930; Frost 1978). During the thrust phase, the head is rapidly moved forward, catching up with the constantly moving body. Head-bobbing has been reported in a wide range of birds (Dunlop and Mowrer 1930; Whiteside 1967; Friedman 1975; Dagg 1977; Frost 1978; Cronin *et al.* 2005; Necker 2007; Hancock *et al.* 2014) and is most commonly associated with walking and running, although some water birds (such as grebes, loons, moorhens, and mergansers) also head-bob during swimming and/or when diving under water (Lindroth and Bergström 1959; Dagg 1977; Necker 2007; Gunji *et al.* 2013).

Although head-bobbing may play a role in gait stabilization and the maintenance of balance (Daanje 1951; Dagg 1977; Fujita 2002, 2003), there is strong evidence that it enhances visual perception significantly in 2 important ways (Dunlop and Mowrer 1930; Walls 1942; Lindroth and Bergström 1959; Friedman 1975; Frost 1978; Davies and Green 1988; Troje and Frost 2000; Cronin *et al.* 2005; Necker 2007). First, during the hold phase when the head and the eyes are stabilized, the image on the retina is also stabilized, which will improve both object recognition and the ability to distinguish between self-motion and object motion. Second, the rapid forward movement of the head during the thrust phase might allow a bird to perceive depth cues through motion parallax. Motion parallax is a phenomenon in which objects at different distances from an observer moving through space appear to move across the visual field at different rates, with close objects moving more quickly than objects further away.

Although head-bobbing has been observed in a number of avian taxa, a range of birds reportedly do not head-bob (Whiteside 1967; Dagg 1977; Fujita 2004; Necker 2007). Head-bobbing is presumed to be beneficial because it requires energy and because this behaviour is present in a wide variety of avian species (Dagg 1977). If head-bobbing is advantageous in terms of visual perception or in some other way, then it remains a puzzle why some species of bird head-bob while others apparently do not (Dagg 1977; Fujita and Kawakami 2003; Necker 2007). To identify ecological and behavioural correlates of head-bobbing across species, which in turn may help us understand the functional significance of this behaviour, it is important to determine which bird species head-bob and which do not, and also under what circumstances head-bobbing occurs (Fujita and Kawakami 2003; Fujita 2006; Necker 2007).

Gulls (Laridae) are among the birds that have been consistently reported as non-head-bobbers (Whiteside 1967; Dagg 1977; Fujita 2004; Necker 2007). However, Fujita (2006) reported that Black-headed Gulls (*Chroicocephalus ridibundus*) do occasionally head-bob under specific conditions when foraging on the ground. This led us to predict that other gulls may also head-bob. We tested this prediction by observing and filming Ring-billed Gulls (*Larus delawarensis*) foraging on the ground in a riverside park in Brockville, Ontario, in August 2014.

The Ring-billed Gull is a medium-sized gull that is very common along the St. Lawrence River and throughout the Great Lakes region of eastern Canada, where its numbers have increased dramatically since the 1940s (Ludwig 1974; Lévesque *et al.* 2000). This species is a highly opportunistic feeder and has adapted extremely well to human activity (del Hoyo *et al.* 1996; Olsen and Larsson 2003). In Brockville, these gulls are commonly found in parks along the St. Lawrence River during summer months, where they forage in short grass, chase insects, and beg for food from picnickers.

Methods

Ring-billed Gulls were both observed and filmed in Hardy Park, Brockville (44°35'N, 75°41'W). For filming, we used either a Rebel T1i or a Rebel SL1 digital SLR camera (Canon Inc., Tokyo, Japan), supported on a tripod; the resolution was 1280 × 720 pixels and the progressive frame rate was 30 (Rebel T1i) or 60 (Rebel SL1) frames/s. Films were downloaded to a computer and edited so that only sequences showing birds walking in an approximately horizontal direction perpendicular to the optical axis of the camera were used for analysis (Fujita 2006). Using ImageJ (Wayne Rasband, Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA), landmark positions on the head (the eye) and body (e.g., the anterior or posterior tip of the wing, the tip of the tail feathers, or a prominent wing colour patch) were digitized for each frame (Fujita 2003, 2006; Fujita and Kawakami 2003). In addition to the head and body landmarks, the position of a static environmental landmark, such as a rock or piece of vegetation, in approximately the same plane as the bird was also digitized (Fujita 2006), allowing us to correct for displacements in the positions of the head and body landmarks resulting from panning movements of the camera. The head length of each bird was also measured, from the tip of the beak to the back of the head, allowing walking speed to be expressed in head lengths/s.

Results and Discussion

Approximately 30 individual gulls were observed. Both immature and mature gulls were present (as determined by plumage differences), but adults made up the majority of the group. Over several hours of observation, all of the gulls displayed head-bobbing repeatedly while foraging in short grass (Figure 1A, B, D; Video S1). However, in contrast to some birds, such as pigeons, the gulls did not head-bob all of the time when walking (Figure 1C, E). Rather, head-bobbing occurred only when gulls were walking slowly and foraging. When the same gulls were walking quickly or running, they did not head-bob. These observations were confirmed by analysis of head and body position in immature and mature gulls, based on 22 videos, half of which showed head-bobbing (Table 1). A comparison of walking speeds (calculated by dividing the total distance travelled by the body marker by the time of the film sequence and expressed in head lengths/s) revealed that walking speeds during head-bobbing were slower (2.56 ± 0.66 head lengths/s, $n = 11$) than during non-head-bobbing (3.98 ± 1.48 head lengths/s, $n = 11$). Our finding that head-bobbing only occurs at slow walking speeds in Ring-billed Gulls is consistent with previous results for Black-headed Gulls (Fujita 2006), Bar-tailed Godwits (*Limosa lapponica*; Dagg 1977), and Japanese Night-herons (*Gorsachius goisagi*; Fujita and Kawakami 2003). Moreover, Little Grebes (*Tachybaptus ruficollis*), a species that head-bobs when diving under water, tend to head-bob only when swimming slowly (Gunji *et al.* 2013). This suggests that across many species, head-bobbing is particularly advantageous to birds looking for food while moving at relatively slow speeds, perhaps because the visual functions of head-bobbing are most beneficial at these speeds.

This is the first account of head-bobbing in Ring-billed Gulls, and only the second report of such behaviour in any species of gull. In a previous study, Fujita (2006) found that Black-headed Gulls head-bob, but only occasionally under specific conditions, namely when foraging while wading slowly on a submerged mud substrate. Fujita (2006) suggested that one possible reason for this is that it is difficult to see a submerged substrate and, thus, under these conditions, Black-headed Gulls may head-bob to better visually assess the condition of the substrate they are walking on. In contrast, head-bobbing in Ring-billed Gulls appears to be a relatively common behaviour when these birds are foraging on grass. As flat grass is not as difficult to see or move on as submerged mud, we believe that Ring-billed Gulls use head-bobbing primarily for the detection of food items, as opposed to visualizing the substrate.

Indeed, we were surprised to find how common head-bobbing is in Ring-billed Gulls, given that these birds are among those that supposedly do not head-bob. Because ground foraging is the most common foraging method in gulls (Burger 1988), we speculate that many other species may also use head-bobbing when feeding on the ground. There are other examples of birds originally thought to be non-head-bobbers, but reclassified as more evidence became available. For example, herons and stilts, initially classified as non-head-bobbers by Dagg (1977), have since been shown to head-bob commonly as they walk (Fujita 2003; Fujita and Kawakami 2003). Therefore, we recommend that the walking behaviour of other gulls (and indeed other birds currently considered to be non-bobbers) be subjected to greater scrutiny to determine whether they truly are non-head-bobbing species. Given how abundant and easy-to-observe many species of gull are, there are opportunities for both amateur and professional ornithologists to collect useful information on the head-bobbing behav-

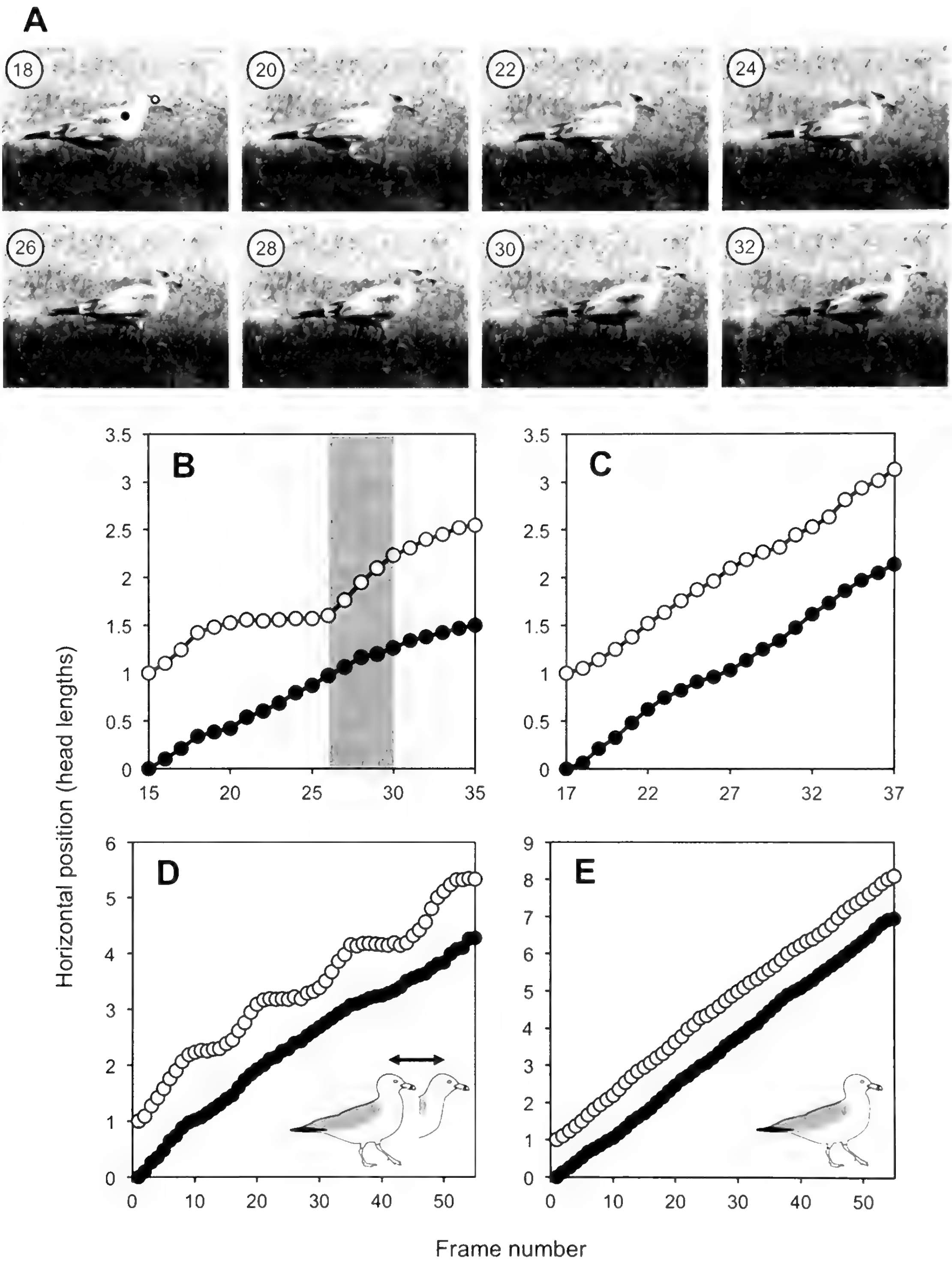

FIGURE 1. A. Series of 8 frames from a video (2 frames apart) showing 1 complete head-bob by a juvenile Ring-billed Gull (*Larus delawarensis*). In frame 18, the landmark positions on the head (eye, white circle) and body (white patch on shoulder, black circle) are shown. B. Plot of the horizontal position of the head (white) and body (black) against time (frame number) for the same series of frames shown in A. During the hold phase (light grey) the head is held stationary while the body continues to move forward; during the thrust phase (darker grey) the head is rapidly thrust forward at a speed greater than that of the forward-moving body. C. In a plot of the horizontal positions of the head and body in a gull walking without head-bobbing across the same number of frames, both the head and the body move forward together at a constant speed. D and E. Plots of horizontal head and body position over longer periods (55 frames) illustrate walking with (D) and without (E) head-bobbing. In D, 4 head-bob cycles with distinct hold and thrust phases can be seen. Photos: Tom Lisney.

TABLE 1. Number of immature and mature Ring-billed Gulls (*Larus delawarensis*) filmed head-bobbing and non-head-bobbing and included in the analysis.

	No. gulls filmed		
Category	Head-bobbing	Non-head-bobbing	Total
Immature gulls	3	4	7
Mature gulls	8	7	12*

*3 adult gulls were filmed displaying both behaviours.

iour of these birds. Such information is essential if we are to determine the functional significance of head-bobbing in birds and solve the puzzle of why some birds head-bob while others do not.

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SUPPLEMENTARY MATERIAL:

VIDEO S1. Footage of an adult Ring-billed Gull head-bobbing while walking and foraging (Quicktime movie).

https://youtu.be/6DCj2z06hRc

Book Reviews

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

ZOOLOGY

Free-ranging Cats – Behavior, Ecology, Management

By Stephen Spotte. 2014. John Wiley and Sons, Ltd., Southern Gate, Chichester, West Sussex, UK, PO19 8SQ. 320 pages, 123.95 CAD, Cloth.

The topic of free-ranging cats ranks right up there with religion and politics: keep quiet and a fight won't break out. However, Stephen Spotte is ready, very ready, for the fight. The book started out though, by making this indoor cat enthusiast worried, for the dedication was to "Puddy, Tigger, Miss Sniff, Wilkins, Beavis and Jinx"...I'm assuming these aren't the author's children, so with an armada of loved cats as his dedicatees, I was assuming the worst. I was very wrong.

The numbers are staggering...millions upon millions of free-roaming cats (outside housecats, strays and ferals) in the world, hundreds of millions of needlessly killed birds, small mammals and more. I had no idea that so much research was being done on these cats... the reference list for this book alone comprises ~800 papers. This is a very well researched book.

One of Spotte's strengths is that he is not only appropriately critical of the shoddy procedures of some of the other researchers, but also of their interpretations. For example, how can someone claim that cats are social, when they don't follow the definition of "social"? And the claim that cats are promiscuous: females whose offspring are sired by only one male doesn't suggest monogamy at all according to Spotte (as it did to another author), it more simply suggests limited access to other breeding opportunities. There are many other examples of Spotte's skill at interpreting the results of others.

Quite frankly, there seems to be a lot of dogma (catma?) in the stray feline literature, which Spotte questions time and again. Where is the evidence? Do males guard oestrous females? Is there a hierarchy among males? Is it appropriate to refer to groups of cats as "colonies" when really they're just aggregating around an abundant resource (normally food)?

Several chapters start with an exhaustive review of cats' basic biology, which is then followed by the extrapolation of at least some of the basic biology to free-roaming cats. But only sometimes. For example, I'm not sure why a table of the amino acid composition of milk, as it changes during lactation of captive cats, was included. If those data were compared to similar data from free-ranging cats, that would then make this important to include, perhaps. The book is subtitled *Behaviour, Ecology, Management*, and it's unclear how this, and some of the sections on physiology, fit.

The chapters are presented in a logical order, with the first two chapters largely debunking ideas of dominance and space use. From there, chapters go into some detail about interactions, then reproduction and development (both during weaning and after). The penultimate chapter on foraging provides a framework for the clearly explained ideas in the last chapter dealing with management, and it is this chapter that most people will read with greatest interest. The rest of the book is a framework for this chapter; legislators should read this, if nothing else.

In the final chapter, Spotte is unequivocal about the solution to the problem of feral and stray cats...eradication. Neutering and releasing is a highly vaunted strategy that makes some people feel good (that is, they don't have a death on their hands, but in reality, they have the deaths of many small mammals and birds blood-staining them), but those same people ignore the facts. The odd thing about this chapter is that more examples of foraging, the subject of the previous chapter, are included here. It's important information to include, with many examples of tragedies for bird species, extinctions included, though the information should have been in the appropriate chapter.

Spotte spends a lot of space writing on why Trap-Neuter-Release (TNR) programs are not only ineffective, they are detrimental. Neutered cats still kill, they are still vectors of disease, and so on. Spotte backs this information up with many studies, those same studies which are conveniently ignored or sarcastically denigrated by supporters of TNR. The book winds up with eradication, methods and rationales.

This book will be relished by wildlife enthusiasts, and despised by the misguided.

RANDY LAUFF

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BOTANY

Twice the Species at Half the Heft: A Review of Keys to the Lichens of North America: Revised and Expanded

By Irwin M. Brodo. 2016. Yale University Press, New Haven, CT, USA. 427 pages, 29.95 USD, Paper.

In 2001, the beautifully-photographed *Lichens of North America* (Brodo *et al.* 2001) was called "a gold mine", "a book to love", and "one of the great natural history books of this or any age". The brief-but-thorough species' descriptions, range maps, and photographs made this hefty tome a must-have for lichenologists and naturalists alike. Since its publication however, lichen nomenclature and knowledge of species' distributions have evolved. Despite Brodo's efforts at updating the original (http://www.lichen.com/book.html), this evolution, in combination with interest by readers and workshop participants, led him to write the *Keys to the Lichens of North America: Revised and Expanded* (hereafter referred to as the Keys). The Keys consists almost entirely of improved identification keys to North American lichens, organized alphabetically by genus, and prefaced with a set of twelve 'keys to the keys'. The Keys includes 2,028 species (approximately twice that in the original book), or about 40% of the currently-described lichen flora of North America. A selection of figures is included as well as a glossary to enable the keys to be used on their own, both of which are almost identical to those included in the original *Lichens of North America*. Soft-covered, stripped of photos, maps and species accounts, and with spiral-binding rather than a spine, the Keys is well-suited for the laboratory. The Keys may not have the beauty of its predecessor, but the elegance of the couplets, the additional species covered, and the modest price means this book is a well-built workhorse, one that you won't mind spattering with a bit of personal data, or marking up in the margins.

When I had the opportunity to review the Keys for Brodo prior to its publication, I noted a few aspects of the book that make it an indispensable companion to the original volume. One of Brodo's strengths is his ability to see past the phenotypic plasticity to critical morphological differences and communicate those differences concisely. This ability, combined with the herbarium study done to support this book, means that the Keys is ripe with useful, novel observations. I often consult the Keys to ask, "how DO you tell those two species apart?", much as I might ask a trusted mentor. The book is a great place to become gently acquainted with the nomenclature changes of the past decade and a half. Recent synonymies follow species' names and are included in the nomenclatural index, and many keys provide literature references for nomenclatural changes as well as more specialized literature. While many of the taxonomic changes summarized in Esslinger (2015) are incorporated, changes Brodo deemed unstable and didn't adopt are documented in handy notes at the beginning of or within genus keys. In addition, any corrections to the names ascribed to the original 2001 photographs also are noted throughout.

While the Keys has value for anyone interested in lichen identification, the book may be most valuable as a classroom or workshop teaching aid for areas without regional keys, a condition that describes much of North America. The book is valuable outside the classroom for those that want another opinion on a puzzling specimen, and for those participating in forays in regions new to them. Just remember best practises when keying out a species new to you: read through a species description after working through a key to ensure you haven't taken a 'wrong turn', and compare your lichen to a herbarium specimen identified by a trusted lichenologist. And of course the Keys represents a great starting point to develop your own regional keys.

There are a few missed opportunities in the Keys. Some of the keys would benefit from additional illustrations to better convey cryptic or difficult-to-describe traits. This problem is not unique to the Keys however, and few lichenologists have tackled this (but see Goward 1999). The taxonomic completeness of each key is not noted, so users are advised to check the breadth by comparing the species included in the book to resources such as Esslinger (2015). Finally, in the quest for completeness, some of the expanded keys may be too specialized for beginners and prove frustrating without additional illustrations or species' descriptions. Conversely, as you gain experience Brodo acknowledges that you'll likely move towards more specialized keys or creating your own keys. However, the Keys still occupies a useful middle-ground for novices and experts alike. After all, few experts are experts in everything!

In summary, the Keys is a welcome addition to my library, especially in combination with the original 2001 book. The format is conducive to updates, so I suspect Brodo will treat us to future revisions and expansions. It is true that there are excellent guides to floras for regions of North America, but just as many lichens do, Brodo's Keys occupies a broad but rarified niche by allowing users to compare species across the continent. Many will be grateful for this monumental effort.

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DIANE L. HAUGHLAND

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Pacific Seaweeds – A Guide to Common Seaweeds of the West Coast (Expanded Edition)

By Louis Druehl, and Bridgette Clarkston. 2016. Harbour Publishing, PO Box 219, Madeira Park, BC, Canada, V0N 2H0. 320 pages, 28.95 CAD, Paper.

I have a copy of Clarkston's plasticized pamphlet "A Field Guide to Seaweeds of the Pacific Northwest" and I really like it. It is handy, portable, lightweight and clear. It covers about four dozen of the commonest species, identifying many to the genus level only.

This re-issue of Druehl's original book, published 15 years ago, covers 150 species, found from Homer, AK to Point Conception, CA. Considering the oceans cover 70 percent of our earth, we really know little of the "plant" life in this zone. New species are constantly being identified, and this is reflected in the changes in this edition from the first. This edition also benefits from the fine photographs, taken largely by Clarkston.

There is the expected "Field Guide" section where individual species, like the lovely rosy *Rhodymenia californica*, are depicted, described and compared to similar species. As many species cannot be identified without microscopic examination, these are also taken to the genus level only. An easy-to-use thumbnail photo-key gets the reader started.

However, the book is way beyond a field guide. It has sections on seaweeds in general, explaining their biology, morphology and their place in our universe. For example, seaweeds come in three basic forms; red, green and brown. While red and green are plants, the brown seaweeds are part of the Chromista, a separate kingdom that includes chlorophyll-containing algae. Seaweed ecology is covered in some depth. It describes the reproduction of these organisms, of course. Ever since I crouched over a wave-tossed pool (safely) at Peggy's Cove, Nova Scotia, and listened to a Dalhousie professor's vivid explanation, I knew the sex life of these plants was far more imaginative than the rest of life on earth. The authors have chosen to include some "terrestrial" plants that live in the inter-tidal zone too. Sea grass, *Salicornia* (now called *Sarcocornia*) and one of the ancestors of our commercial strawberries are included.

The surprise comes with the chapters on the cultivation and use by humans, their nutritional value and how to cook them. There are about 20 recipes ranging from soup to salad. The seaweed is generally used as flavouring, as in dried, crumbled dulse on potatoes. The authors make a strong case for the nutritional value of adding seaweed to our diet, but go on to plea for stringent conservation. Seaweed is best bought from regulated, commercial sources. I wondered about toxic seaweeds; after all, there are many toxic terrestrial plants. This does not seem to be the case. If you over indulge in kelp you take in excess iodine. More bizarre is *Desmarestia*, a brown seaweed, which exudes sulphuric acid when taken captive (exposed to air).

I not only like the information packed in this book, I very much enjoyed the writing style. Stating that "brown seaweeds stand out like an orphaned elephant that has been adopted by a family of mice" is cute, but it also is a good method of explanation. Even funnier is "a zoologist walks into a store with a parrot on his shoulder and the clerk asks 'Where did you get that?' and the parrot responds 'It started as a wart on my butt.'" (Used to clarify parasitism in seaweeds.)

The authors frequently describe the work of others and the important contributions they have made. I was impressed how often those researchers were young people doing their PhD theses. In fact, this is a fertile area for new graduates to study and make their mark on science.

While seaweeds do not have the pizzazz of orchid flowers, fall maples or fly agaric, they are a fascinating group and worthy of study and admiration. This book will help in your hunt for new and old species. It is still small enough (14 × 21.5 mm or 5.5 × 8.5 inches) to carry in the field and in the glove box. I enjoyed reading it more than other, more typical field guides.

One last point: my grandfather said a weed is just a plant in the wrong place. These weeds of the sea are definitely a vital component of ocean life and deserve a better name than "weeds".

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NEW TITLES

Prepared by Roy John

† Available for review * Assigned
Currency Codes – CAD Canadian Dollars, USD U.S. Dollars, EUR Euros, GBP British Pound

ZOOLOGY

Reptile Ecology and Conservation. Edited by C. K. Dodd. 2016. Oxford University Press Canada, 8 Sampson Mews, Suite 204, Don Mills, ON, Canada, M3C 0H5. 512 pages, 225.00 CAD, Cloth.

BOTANY

Carnivorous Plants of Britain and Ireland. By Tim Bailey, and Stewart McPherson. 2016. Redfern Natural History Productions Ltd., 61 Lake Drive, Poole, Dorset, UK, BH15 4LR. 200 pages, 12.99 GBP, Cloth.

OTHER

Boundary Layer: Exploring the Genius Between Worlds. By Kem Luther. 2016. Oxford University Press Canada, 8 Sampson Mews, Suite 204, Don Mills, ON, M3C 0H5. 186 pages, 22.70 CAD, Paper.

*****Complexity – The Evolution of Earth's Biodiversity and the Future of Humanity**. By William Burger. 2016. Prometheus Books, 59 John Glenn Drive, Amherst, NY, USA, 14228. 380 pages, 17.33 USD, Cloth.

Time and a Place – An Environmental History of Prince Edward Island. Edited by Edward Macdonald, Joshua MacFadyen, and Irené Novaczek. 2016. McGill-Queen's University Press, 1010 Sherbrooke West, Suite 1720, Montreal, QC, Canada, H3A 2R7. 460 pages, 34.95 CAD, Paper.

CHILDREN

Baldy & His Big Friends. By Kent L. Gordon. 2016. LongTime Publishing, PO Box 72, Green Mountain Falls, CO, USA, 80819. 24 pages, 15.95 USD, Cloth.

Baldy & His Little Friends. By Kent L. Gordon. 2016. LongTime Publishing, PO Box 72, Green Mountain Falls, CO, USA, 80819. 24 pages, 15.95 USD, Cloth.

Baldy & His Feathered Friends. By Kent L. Gordon. 2016. LongTime Publishing, PO Box 72, Green Mountain Falls, CO, USA, 80819. 24 pages, 15.95 USD, Cloth.

News and Comment

Upcoming Meetings and Workshops

American Fisheries Society Annual Meeting

The 146th annual meeting of the American Fisheries Society to be held 21–25 August 2016 at the Sheraton Kansas City, Kansas City, Missouri. The theme of the conference is: 'Fisheries Conservation and Management: Making Connections and Building Partnerships'. Registration is currently open. More information is available at http://2016.fisheries.org/.

2016 Moose Conference and Workshop

The 2016 Moose Conference and Workshop to be held 6–10 September 2016 at the Victoria Inn Hotel and Conference Centre, Brandon, Manitoba. The theme of the conference is: '21st Century Moose Management and Human Dimensions'. Registration is currently open. More information is available at http://mwf.mb.ca/2016MooseConference/.

2016 XXV International Congress of Entomology

The 2016 XXV International Congress of Entomology, hosted by the Entomological Society of America, to be held 25–30 September 2016 in Orlando, Florida. The theme of the conference is: 'Entomology without Borders'. Registration is currently open. More information is available at http://ice2016orlando.org/.

The Wildlife Society's 2016 Annual Conference

The 23rd annual conference of the Wildlife Society to be held 15–19 October 2016 at the Raleigh Convention Center, Raleigh, North Carolina. Registration is currently open. More information is available at http://www.twsconference.org/.

2016 Raptor Research Foundation Conference

The 2016 Raptor Research Foundation Conference, hosted by the New Jersey Audubon Society's Cape May Bird Observatory and the Cape May Raptor Banding Project, to be held 16–20 October 2016 at the Grand Hotel, Cape May, New Jersey. Registration is currently open. More information is available at http://www.raptorresearchfoundation.org/conferences/current-conference/.

Student Conference on Conservation Science – New York (SCCS-NY)

The 7th annual Student Conference on Conservation Science – New York to be held 20–22 October 2016 at the American Museum of Natural History, New York, New York. Registration is currently open. More information is available at http://www.amnh.org/our-research/center-for-biodiversity-conservation/convening-and-connecting/conferences-and-symposia/2016-sccs-ny.

Ontario's Environmental Review Tribunal upholds the decision to halt the Ostrander Wind Farm Project on the grounds of serious and irreversible harm to the Blanding's Turtle

Last year we reported on the landmark decision to halt the Ostrander Wind Farm Project on the grounds that the project would cause serious and irreversible harm to a threatened wildlife species: the Blanding's Turtle (*Emydoidea blandingii*). This was the first time that a renewable energy project, approved under the *Ontario Green Energy Act* and *Environmental Protection Act*, was stopped because it could endanger an at-risk species (Canadian Field-Naturalist 129: page 214). The Ostrander Wind Farm Project was initially halted in July 2013, when its Renewable Energy Approval was revoked by the Environmental Review Tribunal. In February 2014, the Divisional Court set aside the Tribunal's decision, and reinstated the Renewable Energy Approval. The Ostrander Wind Farm Project was halted again in April 2015, when the Court of Appeal for Ontario restored the Tribunal's decision.

However, this is not the end of the story. The decision to halt the Ostrander Wind Farm Project was further reviewed by the Environmental Review Tribunal from September 2, 2015 to January 15, 2016. The Prince Edward County Field Naturalists continued to oppose this project, with support from the Prince Edward County South Shore Conservancy, while the Ministry of the Environment and Climate Change and Ostrander Point GP Inc. wanted the Renewable Energy Approval reinstated. Among other items, the Tribunal reviewed Ostrander's proposed measures to mitigate the project's impact on the Blanding's Turtle population found at the intended wind farm site, which focused on reducing mortality associated with development of access roads as part of the wind farm infrastructure. There were two sets of road mitigation measures proposed: (1) measures to keep turtles off the road, including exclusionary fencing, underground passages at high-frequency crossing locations, and creation of artificial nesting sites to discourage use of roads for nesting and (2) measures to limit traffic on these roads, through an 'Access Road

Control Plan' that would prevent public vehicles from using the access roads. The Tribunal found these measures to be insufficient to mitigate the negative effects of road mortality on the resident Blanding's Turtle population.

The Tribunal issued its decision to revoke the Renewable Energy Approval for the Ostrander Point Wind Farm on June 06, 2016. Interestingly, this decision to halt the Ostrander Point Wind Farm falls in line with the goal of the recently proposed Recovery Strategy for the Great Lakes/St. Lawrence population of the Blanding's Turtle: to reverse the population's decline by addressing threats to it. Both land conversion for development and road networks have been identified as significant threats to the Blanding's Turtle, and thus managing threats from these sources has been ranked as high concern. Additionally, this decision provides precedent for future renewable energy projects, suggesting that companies must seriously consider the potential risks their projects pose for wildlife species. The benefits of renewable energy generation do not take precedence over other environmental concerns, including wildlife protection.

Article based on information obtained in:

Environment Canada. 2016. Recovery Strategy for the Blanding's Turtle (*Emydoidea blandingii*), Great Lakes/St. Lawrence population, in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, Ontario, Canada.

Environmental Review Tribunal. 2016. Prince Edward County Field Naturalists v. Ontario (Environment and Climate Change). Case No. 13-003. Accessed 16 June 2016. http://elto.gov.on.ca/ert/decisions-orders/.

The Ottawa Field-Naturalists' Club Awards for 2015, presented April 2016

ELEANOR ZURBRIGG, IRWIN BRODO, JULIA CIPRIANI, CHRISTINE HANRAHAN, ANN MACKENZIE, and KAREN MCLACHLAN HAMILTON

On April 2nd, 2016 members and friends of the Ottawa Field-Naturalists' Club gathered for the Club's Awards Night at St. Basil's Church in Ottawa to celebrate the presentation of awards for achievements in the previous year. Awards are given to members or non-members who have distinguished themselves by accomplishments in the field of natural history and conservation, or by extraordinary activity within the Club. Four Club awards were presented for 2015, for: (1) furthering the knowledge of natural history in the Ottawa area, (2) promoting a communications plan for the Club, (3) long time service as Book Review Editor for one of the Club's publications, and (4) protecting ecologically valuable land in the Ottawa area.

As well, two President's Prizes were presented in recognition of unusual support of the Club's finances and operations, and Club communications.

Honorary Member: Robert E. Lee

This award is presented in recognition of outstanding contributions by a member or non-member to Canadian natural history or to the successful operation of the Club. Usually people awarded an honorary membership have made extensive contributions over many years.

The Ottawa Field-Naturalists' Club, the Ottawa community, and indeed the country has benefitted from the skill, dedication, and vision of Robert E. Lee. For 30 years, Rob has been leader of the Macoun Field Club, the OFNC-sponsored natural history club for youths 8–18 years of age. By so doing, he has created an entire generation of conservationists, biologists, chemists, and teachers in the field of natural history. He has done this by virtue of his love and respect for children and their natural curiosity, his keen interest in the natural world, and his superb organizational skills, not to mention his wit, imagination, and humanity. To have such an extraordinary person in our midst is a gift to be treasured and applauded.

But Rob Lee is not only the inspired and inspiring leader of a natural history club for children. His accomplishments also include insightful observations, carefully executed experiments, and well-written reports on a broad realm of nature, including worms, frogs, plants, and lichens. His documentation of the changes in the Greenbelt area near Stony Swamp over a 40-year period with detailed and accurate, periodically updated vegetation maps has given researchers an unparalleled look into the evolution of suburban natural areas over time. It is perhaps the most complete documentation of its kind in the country.

His knowledge of lichens has allowed him to do research and prepare status reports on a number of rare lichens for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), doing innovative investigations that deserve more recognition than they've received.

As a young man, Rob attended the University of Guelph and then travelled through the Arctic by himself, making discoveries and following in the footsteps of his archeologist father, Dr. Thomas E. Lee. His exceptional skills as a writer were put to good use when he served as scientific editor and writer and, later, when helping young writers in the Macoun Field Club prepare their first scientific contributions published in the club's own journal, *The Little Bear*.

The Ottawa Field-Naturalists' Club previously recognized Rob's contributions to the Club over the years by awarding him the 1990 George McGee Service Award and 2008 Mary Stuart Education Award, both for his work with the Macoun Club; and the 2000 Anne Hanes Natural History Award for his studies of Leopard Frogs. The OFNC is now delighted to add Rob Lee to its list of distinguished Honorary Members.

(Prepared by Irwin Brodo)

Member of the Year: Lynn Ovenden

The Member of the Year award recognizes a member judged to have contributed the most to the Club in the previous year.

We are recognizing Lynn Ovenden as this year's Member of the Year for her energy, initiative, and willingness to support the Club. Her contributions include:

- overseeing and actively participating in the development of the OFNC communication plan, which includes a proposal for a re-design of the Club's website;
- inviting students from Ottawa and Carleton Universities to write blogs for the OFNC site to report on the Club's activities;
- suggesting and planning several outings for the Events Committee, all of which were very well attended; and

- stepping up to support the decision to refresh the Fletcher Wildlife Garden Interpretation Centre.

With the goals of attracting and retaining members to support the Club's work, and of strengthening and simplifying the Club's online presence, Lynn and the Education and Publicity Committee hired a consultant to support their initiative. After months of work focused on surveying members and distilling the data from members, their report was tabled at the May 2015 Board meeting. Recommendations included modernizing the OFNC web site, centralizing and coordinating communication, promoting a word of mouth campaign to grow membership, and broadening the Club's use of social media. Since the Board's acceptance of the recommendations, Lynn and members of the Education and Publicity Committee have dedicated hundreds of hours to consultation and committee work to move the action plan along.

Under Lynn's leadership, the Education and Publicity Committee has been posting blogs on ofnc.wordpress.com, spreading the word and reporting on the Club's outings, monthly meetings, reports from participants in Ontario Nature's Youth Summit, and other topics of interest to members.

Lynn supported the Events Committee on a few occasions over the course of 2015. On the May long weekend, she coordinated a series of outings which included a visit to the Gervais property close to Westmeath on the Ottawa River, an afternoon of birding at Westmeath Provincial Park with the Pembroke Area Field Naturalists Club, an evening of mothing with Diane Lepage at the Shaw Woods Outdoor Education Centre, and a guided walk through the old growth forest in Shaw Woods the next day. Participants were invited to camp in the area or stay in one of the local motels.

When the decision was made to refresh the Fletcher Wildlife Garden Interpretation Centre and to replace some of the furniture in the Centre last fall, Lynn joined the group working to clear out the Centre, decide what items to keep, prepare the space for painting, and then put it all back together.

Beyond her committee work in 2015, Lynn volunteered at the Fletcher Wildlife Garden, weeding and supporting Ann Prescott, who staffs the sales table at monthly meetings.

It is for her commitment to the Club and her energetic approach to every project she has tackled that we are recognizing Lynn Ovenden as Member of the Year for 2015.

(Prepared by Julia Cipriani)

George McGee Service Award: Roy John

The George McGee Service Award is given in recognition of a member who has contributed significantly to the smooth running of the Club over several years.

Most members have either met or heard of Roy John over the years, for his contributions to the Club are extensive. He has been an active member of the OFNC, in various capacities, even when he did not reside in Ottawa.

To OFNC members, Roy is probably most recognized for his book reviews published in *The Canadian Field-Naturalist (CFN)*. He assumed the role of Book Review Editor in 2003, stepping in when the former editor died suddenly, and continued in this position until 2016. Throughout the years he has read and reviewed more than 250 books, 145 articles, and 120 popular publications, as well as several handbooks, book chapters, and consultant reports. The range of topics covered is as wide as his personal experiences: from birds and field guides to botany, mycology, zoology, and even anthropology. His reviews often contain personal insight and include interesting bits of information that only someone familiar with the subject would know. The reviews are thoughtful, candid, and a pleasure to read.

Another responsibility as Book Review Editor was to compile a list of titles that may be of interest to *CFN* readers. Constantly finding new books is a difficult task on its own, let alone finding someone to review them; however, more often than not, readers would find a new title review in the next or the following issue of *CFN*.

Many know Roy for his birding and photographic skills. He is a passionate birder and an intrepid traveler, missing only a handful of countries. He has led countless local birding field trips and has been involved in the biennial Pelee trip these past few years. Roy has also given numerous talks, often willing to fill in at a moment's notice, and has introduced Club members to parts of the world few have managed to see. His passion for birds has led to his being Editor of *The Blue Jay* (the Saskatchewan Natural History Society) and *OFO News* (Ontario Field Ornithologists), and being a contributor to the *Atlas of the Breeding Birds of Ontario*. In addition, Roy gives presentations about birds at seniors' residences throughout Ottawa.

Roy has been active on the Council (now Board) in numerous capacities. Since joining the OFNC in 1984, he served on the Council in 1987, was Recording Secretary in 1988, and was Vice-President in 1989–1990 and 2000–2003. In 1991 he served as President. He was Chair of Excursions and Lectures (Events) in 2001–2003.

It is for all these reasons that we are awarding Roy John the George McGee Service Award for 2015.

(Prepared by Karen McLachlan Hamilton, with input from Francis Cook and Frank Pope)

Conservation Award – Non-Member: Miller Paving Limited

This award is given in recognition of an outstanding contribution by a non-member to the cause of natural history conservation in the Ottawa Valley, with particular emphasis on activities within the Ottawa District. We are recognizing Miller Paving Limited for noteworthy ecological land protection measures in the Braeside Quarry.

The aggregate industry has long had a bad name amongst those wishing to preserve natural habitats. It is not difficult to understand the dismay when a quarry operator moves in and forests and meadows vanish. So it's not surprising that the proposal by Miller Paving to expand their long-standing Braeside Quarry operation into a portion of Renfrew County's Braeside Alvar caused considerable concern in and about the Arnprior area. Local residents presented a variety of arguments against the quarry expansion, many addressing the protection needs of the rare alvar vegetation and flora. Miller Paving undertook the lengthy process of biophysical investigation of the site required to satisfy a wide range of provincial environmental regulations. Considerable discussion, debate, and controversy took place amongst numerous interested parties as these investigations unfolded. Ultimately, as is often the case, the issue was heard before the Ontario Municipal Board (OMB).

In October 2015 the OMB concluded that Miller Paving's natural environment conservation plan satisfied the necessary provincial environmental protection requirements. The Board disapproved of some parts of the development proposal but ruled that its ecological protection measures were sound. What is of particular interest to naturalists and conservations, however, is the unusual – apparently unique – degree to which the project's conservation plan provides for the protection of significant ecological features and functions.

The quarry expansion plan establishes an ecologically self-sustaining Significant Wildlife Habitat Protection Area of over 24 ha consisting primarily of globally rare alvar forest, as well as a comprehensive set of the regionally significant floral and faunal features known from the much larger Braeside Quarry property. Importantly, the Protection Area is legally fixed in place by both the project's approved Site Plan and municipal bylaws. A particularly intriguing aspect of the plan is that, even after quarry expansion is completed (likely 80 or more years away), the Protection Area will continue to sustain the largest populations of provincially rare Ram's-head Orchid (*Cypripedium arietinum*) and Neglected Milk-vetch (*Astragalus neglectus*) known anywhere. In addition, the plan includes a substantial allowance for wildlife corridors and ground water protection, and provides for a decade-long monitoring program of the site's ecological integrity.

The key to the success of the Braeside protection plan was the property owners' early recognition (even before the OMB process was initiated) of the exceptional ecological values present there and exceptional measures that would be required to protect them. They quickly accepted a recommendation that approximately half of the core alvar should be protected from disturbance. This greatly exceeds the normal size of aggregate Protection Areas. Indeed, Miller Paving's OMB-certified development proposal represents the most robust ecological protection plan of any aggregate development in eastern Ontario, if not the whole province.

It is important that examples of enlightened resource management be acknowledged and celebrated. Doing so encourages others in the aggregate and associated industries to produce their own Braeside-like protection plans. Miller Paving has set a new and important conservation standard for its industry. It is accordingly a most worthy recipient of the 2015 OFNC non-member Conservation Award.

(Prepared by Christine Hanrahan, based on material provided by Dan Brunton)

President's Prize: Ken Young

This award is given at the President's discretion for singular contributions to our Club that do not quite fit the other Club awards categories.

Being the Treasurer of any organization is a demanding job. Being the Treasurer of a club the size and complexity of the OFNC is almost a full time assignment. Since January 2012 Ken Young has made sure that all our bills are paid and the money is accounted for.

Our Club was recently the beneficiary of a very generous bequest from Violetta Czasak. Ken took on the role of Trustee, hired a lawyer, and together they handled this sizeable bequest. It was a huge job. So when we delight in our ability to undertake many worthwhile projects due to this generous bequest, we have Ken's diligence and good sense to thank for it.

This is not all he has done on our behalf. Because the subscription manager of the CFN moved away, the records of the CFN subscribers and authors had not been kept up-to-date. Again, Ken stepped in and sorted it all out… another huge job. Now we know who has paid for their subscriptions and which authors are in arrears.

As a member since 1985, Ken has contributed in other ways. Previously he tracked the money spent by the Fletcher Wildlife Garden, chaired the Finance Committee, and was active on the Conservation Committee. His reasoned comments around the Board table are always appreciated.

Before Ken and his wife Judy move to Maryland I wish to express our appreciation for all that Ken Young has done on our behalf, and that is why I am pleased to present Ken with the President's Prize.

(Prepared by Fenja Brodo, President)

President's Prize: Linda Burr

This award is given at the President's discretion for singular contributions to our Club that do not quite fit the other Club awards categories.

We badly needed an editor for a special Club publication. When I said so at a monthly meeting in 2013, Linda Burr volunteered. The project was the final editing and publication of the Larose Forest booklet, which was almost finished and had been mostly written by Gillian Marsten and Christine Hanrahan. Linda took that on, a tricky job that involved diplomacy as well as writing skills and working with printers. We now have a lovely publication to show for her efforts.

Linda has also been a mainstay of the Education and Publicity Committee, representing our club at various events around the city. Then she and Lynn Ovenden discovered Heather Badenoch and convinced the Board to hire Heather to help us analyze where we are going as a Club. Linda worked with Heather to formulate an appropriate survey and gather the results. As a result, we now have a Communications Plan and a vision that involves a revamped webpage (in the works) that will give us better communication within our Club and more visibility in our community.

For her inspiration and dedication to the several projects that she has taken on so successfully, I would like to honour Linda Burr with the President's Prize.

(Prepared by Fenja Brodo, President)

Editorial

I began my role as Editor in Chief in 2010, managing new submissions for volume 125. I am indebted to Francis Cook, retired CFN Editor in Chief, for his excellent mentorship and support throughout my tenure. Francis understood fully the daily challenges and rewards of editing *The Canadian Field-Naturalist*. It is now time that I pass on the torch. I welcome our new Editor in Chief Dr. Dwayne Lepitzki, an expert in malacology, parasitology. Dwayne has a well-earned reputation of team leading and getting the job done effectively.

I am grateful for the support I have received from the OFNC Board of Directors and Publications Committee, and honoured to have worked with a top-notch team of Associate Editors. I especially wish to thank the CFN core staff, who were conscientious, worked effectively as a team, and remained good-humoured in the face of unexpected last-minute challenges: Wendy Cotie, Jay Fitzsimmons, Sandy Garland, William Halliday, Roy John, Amanda Martin, Liz Morton, Trina Rytwinski, and Ken Young.

It has been an honour to help carry on the 136 year tradition of *The Canadian Field-Naturalist,* which plays an important role as one of the world's few journals dedicated to advancing natural history research. CFN will continue to publish natural history science, to serve as a link between scientists and members of the public interested in natural history, and to provide mentorship to the next generation of natural history scientists.

CAROLYN CALLAGHAN, outgoing *Editor in Chief*

I am humbled, honoured, and excited to begin this new chapter in *The Canadian Field-Naturalist* and in my career. One of my first publications was in this journal and I still remember the thrill of my first professional paper become part of "the literature". I hope to maintain that thrill as both new and more seasoned scientists, amateur and professional, complete the final step of their investigations or observations: publication. There will be some changes but I will also maintain the tradition of high quality publication in all the various fields of natural history, the backbone of ecological and conservation science. The biggest change will be the transition to the Online Journal System (OJS) for submission and review of manuscripts; however, we'll still accept manuscripts the way it's been done for over a century. There will be a few new names and faces as Associate Editors (AE) join the team and a few others retire from their duties as AEs. I will miss the opportunity to work with those who are stepping down but look forward to continuing to work with those who are staying. We'll also update the Instructions to Authors, tweaking a little here and a little there. The Publications Committee, production team, and I also will look into using the OJS for the other steps of the process. Lastly, while I eagerly awaited the arrival of each new issue in the past, I now have the opportunity to see the observations and studies on their journey to publication. Keep those manuscripts coming!

DWAYNE LEPITZKI, incoming *Editor in Chief*

Editor's Report for Volume 129 (2015)

Mailing dates for issues in volume 129 are as follows: 5 May 2015; 4 August 2015; 23 October 2015; 30 January 2016. A summary of the distribution of memberships in the Ottawa Field-Naturalists' Club, who all receive access to *The Canadian Field-Naturalist*, and subscribers to *The Canadian Field-Naturalist* for 2015 is provided in Table 1. Institutional subscribers potentially represent many thousands of users. The number of articles and notes in Volume 129 is summarized in Table 2 by topic. Totals for book reviews and new titles are given in Table 3, and the distribution of content by page totals per issue is provided in Table 4. Sixty-one manuscripts were submitted to *The Canadian Field-Naturalist* in 2015. Of these, 51 were accepted for publication. A total of 28 Articles, 19 Notes, and 1 Tribute was published in 2015.

Trina Rytwinski, Assistant Editor, edited content and proofread galleys. We are grateful for the service Trina gave to the journal, and wish her well on her new endeavours. We welcomed Amanda Martin as the journal's new Assistant Editor, who functioned in this role for most of volume 129. Sandra Garland proofed and edited manuscripts. Wendy Cotie typeset galleys, provided corrections for page proofs, and created pdfs; Roy John requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings; Jay Fitzsimmons and Ken Young, managed financial accounts, issue mailing and requests for back issues. We thank Jay Fitzsimmons for his contribution as Journal Manager and wish him well on the new phase of his career. We welcomed William Halliday as the new Journal Webmaster. William provided digital content to subscribers, posted tables of contents, abstracts, and pdfs on the CFN website, and prepared the Index with proofreading by Frank Pope. Our Associate Editors managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. The Publication Committee, chaired by Jeff Saarela and consisting of Paul Catling, Tony Gaston, William Halliday, Karen McLachlan Hamilton, Frank Pope, and David Seburn effectively guided the operation of the journal. I am indebted to our very dedicated team.

The following Associate Editors managed, assessed and reviewed manuscripts published in volume 129: I. Adams, Cranbrook BC (1); P. M. Catling, Agriculture and Agri-Food Canada, Ottawa ON (5); F. R. Cook, Emeritus Research Associate, Canadian Museum of Nature, Ottawa ON (8); J. Foote, Algoma University, Sault Ste. Marie ON (7); A. J. Gaston, Environment Canada (emeritus), Ottawa ON (5); T. Jung, Yukon Government, Whitehorse YT (3); D. F. McAlpine, New Brunswick Museum, Saint. John NB (1); G. Mowat, Government of British Columbia, Nelson BC (2); D. W. Nagorsen, Mammalia Biological Consulting, Victoria BC (6); M. Obbard, Ontario Ministry of Natural Resources and Forestry, Peterborough ON (1); C. Renaud, Canadian Museum of Nature, Ottawa ON (4); J. M. Saarela, Canadian Museum of Nature, Ottawa ON (5); J. Skevington, Agriculture and Agri-Food Canada, Ottawa ON (1).

The following referees reviewed manuscripts published in volume 129 (number of manuscripts reviewed >1 in parentheses): Charles Argue, St. Paul MN; Erik Beever, US Geological Survey; Bruce Bennett, Government of Yukon; Peter Bernhardt, Saint Louis University; Doug Bertram, Environment Canada; Eric Blomberg, University of Maine; Gabriel Blouin-Demers, University of Ottawa; Jeff Bowman, Ontario Ministry of Natural Resources (2); Irwin Brodo, Canadian Museum of Nature (emeritus); Rod Brook, Ontario Ministry of Natural Resources and Forestry; Ronald J. Brooks, University of Guelph (emeritus); Donald Brown University of Wisconsin-Madison, USDA Forest Service; Dan Brunton, Ottawa ON; Jacques Cayouette, Agriculture and Agri-Food Canada; Joseph Buchanan, Washington Department of Fish and Wildlife; Colleen Cassady St. Clair, University of Alberta; Peter Cott, Fisheries and Oceans Canada; Nick Demma, Alaska Department of Fish & Game; Mark Drever, Environment Canada; Kyle Elliott, McGill University; Scott Findlay, University of Ottawa; David Galbraith, Royal Botanical Garden (2); John Gilhen,

TABLE 1. The 2015 circulation of *The Canadian Field-Naturalist* (2014 in parentheses). Compiled by Ken Young from the subscription list for 129(4).

Subscriber Type	Canada		USA		Other		Total	
OFNC Members	61	(112)	3	(8)	1	(1)	65	(121)
Subscriptions:								
Individual	12	(78)	6	(28)	0	(3)	18	(109)
Institutional	107	(116)	158	(167)	19	(22)	284	(305)
Total	180	(306)	167	(203)	20	(26)	367	(535)

*Volume 129 figures show a sharp drop from 128 following a cleanup of the subscribers list in 129(1) to remove subscribers who had not paid for some years.

TABLE 2. Number of research articles and notes published in *The Canadian Field-Naturalist*, Volume 129, by major field of study.

Subject	Articles	Notes	Total
Mammals	7	6	13
Birds	7	5	12
Amphibians and Reptiles	2	3	5
Fish	4	2	6
Plants	5	2	7
Insects	1	0	1
Other	2	1	3
Total	28	19	47

TABLE 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, Volume 129, by topic.

	Reviews	New Titles
Zoology	18	26
Botany	3	2
Miscellaneous	14	19
Total	35	47

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, Volume 129 (2015), by issue.

	Issue				
	1	2	3	4	Total
Editorials	0	3	0	0	3
Articles	59	66	44	72	241
Notes	30	16	30	14	90
Book Reviews*	15	10	14	4	43
News and Comment, Reports**	3	9	16	7	35
Tributes	7	0	0	0	7
Index	–	–	–	7	7
Total	114	104	104	104	426

*Includes reviews and new title listings.

**Includes CFN Editor's report, Minutes of the OFNC Annual Business Meeting, and OFNC Awards report.

Nova Scotia Museum (emeritus); Scott Gillingwater, Upper Thames River Conservation Authority; Jean-Francois Giroux, Université du Québec à Montréal; Trevor Goward, University of British Columbia; Claire Gower, Montana Fish, Wildlife and Parks; Patrick Gregory, University of Victoria; Arthur Haines, New England Wild Flower Society; Mark Harvey, University of Western Australia; Steve Hecnar, Lakehead University; Philippe Henry, University of Northern British Columbia; Mark Hipfner, Environment Canada; Erling Holm, Royal Ontario Museum; Garrett Hughes, University of Arizona; Mike Jimenez, US Fish and Wildlife Service; Tom Jung, Government of Yukon; Amanda Kahn, University of Alberta; Peter Knamiller, University of Alberta; Erin Koen, Trent University; Kathy Kuletz, US Fish and Wildlife Service; Mark A. Lazzari, Maine Department of Marine Resources; Eric Lofroth, British Columbia Ministry of Environment; Stephen Lougheed, Queens University; Jerry MacDermott, British Columbia Fish and Wildlife Branch; Audrey Magoun, The Wolverine Foundation; Frank Mallory, Laurentian University; Nicholas Mandrak, University of Toronto; Don McAlpine, New Brunswick Museum; Retha Meier, Saint Louis University; Heather Milligan, McGill University; Gail Michener, University of Lethbridge (emeritus); Ken Morgan, Environment Canada; Jan O. Murie, University of Alberta (emeritus); Susan Palta, Wyoming Game and Fish Department; Melanie Percy, Alberta Parks; Gerhard Pohle, Huntsman Marine Science Centre; Kim Poole, Aurora Wildlife Research; Joyce Reddoch, Ottawa; Allan Reddoch, Ottawa; Claude Renaud, Canadian Museum of Nature; Tony Reznicek, University of Michigan; Jim Richards, Orono ON; Helen Schwantje, British Columbia Fish and Wildlife Branch; C. J. Sheivak, New York State Museum (emeritus); Stephen Sjogren, US Fish and Wildlife Service; Doug Smith, US Parks Service; Paul Smith, Environment Canada; James A. Sulikowski, University of New England; Amy Symstad, US Geological Survey; Carl Taylor, Smithsonian Natural History Museum; Paul Venturelli, University of Minnesota Twin Cities; Mark Vinson, US Geological Survey; Andrew Walker, BC Fish and Wildlife Branch.

The journal was printed at Gilmore Printers, Ottawa. Thanks to Mike Datson and Guylaine Duval of Gilmore Printers for overseeing production and printing. I am grateful to Ottawa Field-Naturalists' Club President Fenja Brodo and the club's Board of Directors for their support of the journal. I am also grateful to all of the individual subscribers and authors who support our team as we strive to provide a high-quality scientific journal on natural history. Finally, we thank our families/partners for being patient and supportive throughout many evenings and weekends of working on the journal.

CAROLYN CALLAGHAN, *Editor in Chief;*

AMANDA MARTIN, *Assistant Editor*

Book Reviews

Mailing date of the previous issue 130(1): 17 June 2016

THE CANADIAN FIELD-NATURALIST Volume 130, Number 2 2016

(continued on inside back cover)

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The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

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

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

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The Canadian Field-Naturalist

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The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: Townsend's Solitaire (*Myadestes townsendi*) 10 May 2015, in Kugluktuk, Nunavut. See article in this issue pages 207–211 by Myles M. Lamont and Michelle Knaggs. Photo: M. Lamont.

The Canadian Field-Naturalist

Volume 130, Number 3 July–September 2016

A Range Extension for *Carex sartwellii* in Interior Alaska

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Winterstein, Mark, Teresa N. Hollingsworth, and Carolyn Parker. 2016. A range extension for *Carex sartwellii* in interior Alaska. Canadian Field-Naturalist 130(3): 191–198.

Our documentation of Sartwell's Sedge, *Carex sartwellii*, on nine shrinking lakes during fieldwork in the central Yukon Flats, Alaska, represents a range extension for this species. Previously, its range extended as far northwest as Yukon, Canada, with a reported, but lost collection, from Alaska in 1895. Two earlier collections from the Yukon Flats have been verified: one was misidentified as *Carex praegracilis* until 2007. *Carex sartwellii*'s assumed absence from Alaska and Yukon flora, misidentification of an earlier collection, and the remoteness of the Yukon Flats may have contributed to the rarity of its collection. In Alaska this species is morphologically similar to *C. praegracilis*, but can be distinguished using traits of the perigynia, leaf sheaths, and the production of true vegetative culms.

Key Words: Alaska; *Carex sartwellii*; Sartwell's Sedge; *Carex praegracilis*; Clustered Field Sedge; Yukon Flats; drying lakes; range extension

Introduction

In summer 2011, while studying shrinking lakes and plant succession in the Yukon Flats (Wahrhaftig 1965), interior Alaska, we observed a sedge, *Carex sartwellii* Dewey (Sartwell's Sedge), that we believed at the time to be undocumented in Alaska. We found *C. sartwellii* in 16 plots on nine shrinking lake basins in the southern portion of the Yukon Flats (Figure 1) and collected nine specimens from seven lakes as vouchers (Table 1). We found this species in two community types: wet/mesic graminoid forb meadows and open tall shrub meadows on lacustrine alkaline soils (Figure 2). These community types are the result of shrinking lakes, which have been documented across Alaska as a potential effect of climate change (Klein *et al.* 2005; Riordan *et al.* 2006; Roach *et al.* 2011; Rover *et al.* 2012).

Previous to our study, there had been only two documented collections of *C. sartwellii*, both from the Yukon Flats. Few studies have documented the flora in the Yukon Flats, Alaska (Johnson and Vogel 1966; Holloway and Alexander 1990; Talbot 1991; Heglund 1992; Larsen *et al.* 2004; Cortés-Burns and Carlson 2006). The remoteness and vastness of the region may have contributed to the rarity of collections, as field studies are logistically difficult. The area is accessible only by snow machine, boat, or small aircraft, and the terrain is difficult to cross on foot. Furthermore, the assumed absence of this sedge from Alaska and Yukon (Hultén 1941–1950) may have contributed to collections being misidentified as *Carex praegracilis* W. Boott (Clustered Field Sedge) and overlooked. *Carex sartwellii* was not included in the treatments of the flora of Alaska or Yukon (Hultén 1968; Welsh 1974; Cody 2000). A. A. Reznicek adapted a Cyperaceae key from the Flora of North America (Ball and Reznicek 2002) for Alaska (Reznicek 2012) that included *C. sartwellii*, and led to the correct identification of our collections.

Carex sartwellii has been documented from New York and Quebec to Colorado and Washington in the west, and north to Northwest Territories and Yukon (USDA 2014). The distribution in Figure 1 (inset map) is based on data from 168 specimens housed in 12 herbaria (Acadia University (ACAD) [3 records], University of Alaska Museum of the North (ALA) [3], University of Alberta Vascular Plant Herbarium (ALTA) [51], Canadian Museum of Nature Herbarium (CAN) [5], University of Connecticut (CONN) [3], Colorado State University (CSU) [2], Field Museum of Natural History (F) [16], Kansas State University (KSU) [7], Missouri Botanical Garden (MO) [1], University of Toronto Mississauga (TRTE) [1], University of British Columbia (UBC) [26], University of Manitoba (WIN)

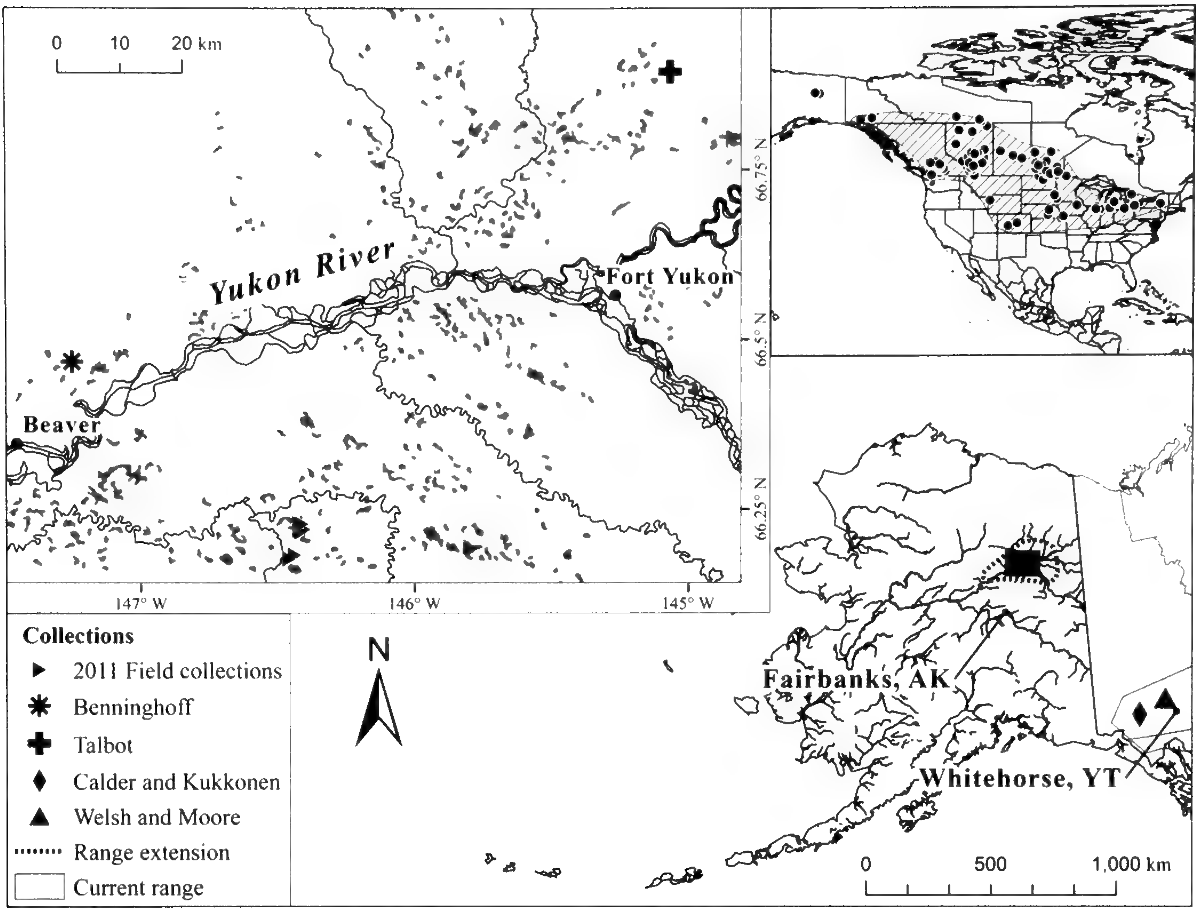

FIGURE 1. Alaska and adjacent Canada showing current range of *Carex sartwellii* including the location of collections in the Yukon Flats. The gray rectangle delineates the area of the expanded view of the Yukon Flats collections (inset, upper left). Black dots (•) on the range map (inset, upper right) indicate collections from the Yukon Flats, GBIF (2014), and Cody (1978).

TABLE 1. Location, date, and habitat of *Carex sartwellii* collections and observations from the Yukon Flats, Alaska.

Collector/ observer	Date	Location °N	Location °W	Community type	Vouchered specimens/ observations
M. Winterstein	17/7/2011	66.3511	146.4449	Open tall shrub meadow	Observed
M. Winterstein	17/7/2011	66.2313	146.3773	Graminoid meadow	ALA V174388
M. Winterstein	20/7/2011	66.2415	146.3662	Graminoid meadow	ALA V174256
M. Winterstein	20/7/2011	66.2414	146.3666	Open tall shrub meadow	ALA V174257
M. Winterstein	19/7/2011	66.2332	146.3587	Graminoid meadow	ALA V173222
M. Winterstein	21/7/2011	66.2420	146.3771	Graminoid meadow	ALA V174258
M. Winterstein	21/7/2011	66.2419	146.3774	Open tall shrub meadow	MICH
M. Winterstein	18/7/2011	66.2304	146.3677	Graminoid meadow	ALA V173223
M. Winterstein	18/7/2011	66.2306	146.3676	Open tall shrub meadow	ALA V173220
M. Winterstein	24/7/2011	66.1957	146.3940	Graminoid meadow	Observed
M. Winterstein	25/7/2011	66.1911	146.3901	Open tall shrub meadow	Observed
M. Winterstein	23/7/2011	66.1917	146.4141	Graminoid meadow	ALA V173221
M. Winterstein	23/7/2011	66.1911	146.4089	Open tall shrub meadow	Observed
M. Winterstein	28/7/2011	66.3562	146.4275	Graminoid meadow	Observed
M. Winterstein	28/7/2011	66.3567	146.4272	Open tall shrub meadow	Observed
M. Winterstein	28/7/2011	66.3545	146.4291	Graminoid meadow	Observed

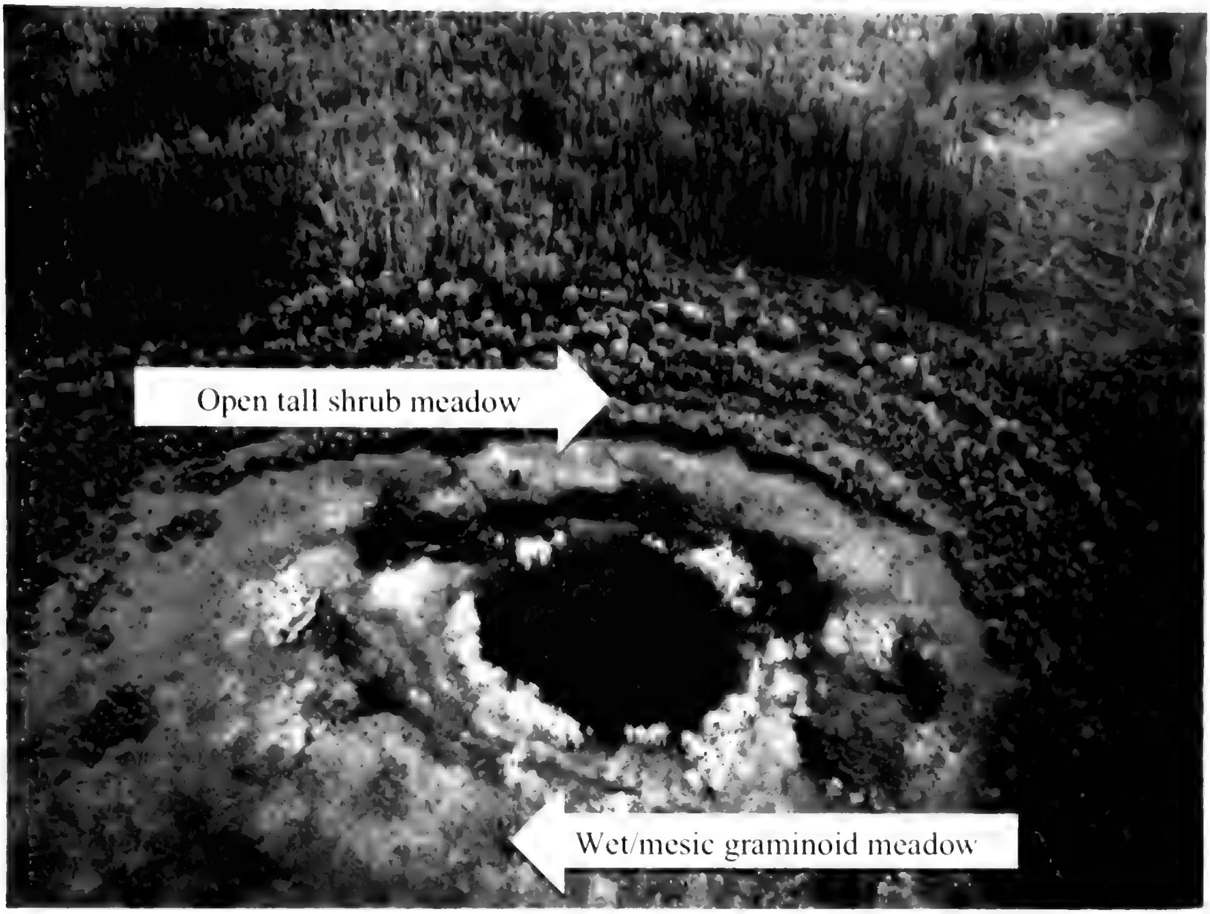

FIGURE 2. Drying lake in the central Yukon Flats, Alaska (66.33°N, 146.41°W). Arrows indicate community types where *Carex sartwellii* occurred within the lake basin. Photo: M. Winterstein.

[68]), extracted from the Global Biodiversity Information Facility (GBIF 2014), and two additional collections from Northwest Territories (Cody 1978) that are not in the GBIF database.

Here we describe the history of collection, ecology, and morphology of *C. sartwellii* in Alaska. Species names follow the Flora of North America (FNA 1993+). Common names follow Viereck and Little (2007) and the United States Department of Agriculture (USDA) Plants Database (USDA 2014). Herbarium abbreviations follow the Index Herbariorum (Thiers, continuously updated).

History of Collection of *Carex sartwellii* in Alaska and Yukon

The first report of *C. sartwellii* in Alaska occurred over a century ago. Kurtz (1895) reported its collection by Aurel Krause in 1882 on a grassy slope by the Klehini River near the village of Kloquan (Klukwan) in southeast Alaska. Hultén (1940) noted that Krause's collections from Alaska had been accessioned by Dr. Frederico Kurtz at the herbarium of the National University of Cordoba, Argentina (CORD), and duplicates were sent to the Botanical Garden and Botanical Museum (B) in Berlin, Germany. Hultén (1941–1950) mentioned the report of *C. sartwellii* by Kurtz (1895) under his treatment of *C. praegracilis*, but noted the specimens supporting this record at B were lost during World War II. However, no duplicate collection of *C. sartwellii* was found at CORD (G. E. Barboza, personal communication, 1 April 2015). Because no collection could be verified, Hultén referred this report to *C. praegracilis* because, at the time, *C. sartwellii* was thought not to occur north of British Columbia, Canada (Hultén 1941–1950).

In 1948, the first documented collection of *C. sartwellii* was made by William Benninghoff in the Yukon Flats near the village of Beaver (Figure 1), but it was misidentified as *C. praegracilis*, by Eric Hultén, until 2007 (Alaska: 12 miles North of Beaver, Chandalar Road, 10 July 1948, *Benninghoff 2104*, MICH 1430605, det. A. A. Reznicek; Figure 3). The second collection of *C. sartwellii* in the Yukon Flats was by Stephen Talbot in 1982 (Alaska: Yukon Flats National Wildlife Refuge, 66.88 N, 145.02 W, 13 August 1982, *Talbot B9-3*, SASK 149366, det. J. H. Hudson; Figure 1; Talbot 1991), 34 years after the Benninghoff collection and the only known collection at that time. Yet, at the time of our

Carex sartwellii Dewey

A A Reznicek, University of Michigan Herbarium 2007

PLANTS OF ALASKA

No. 2104 W.S. Benninghoff July 10, 1948

Carex praegracilis W. Boott.
Det. E. Hultan

Frequent on marshy ground along Chandalar Rd.
12 miles N. of Beaver.

United States Geological Survey

IMAGED

University of Michigan Herbarium
1430605

FIGURE 3. Specimen (MICH 1430605) of *Carex sartwellii* collected by W. S. Benninghoff and identified and mapped as *C. praegracilis* in Hultén (1968). Photo: A. A. Reznicek.

determinations in 2012, it was still thought to be undocumented for Alaska according to two comprehensive taxonomic guides: the USDA Plants Database (USDA 2014) and the Flora of North America (Ball and Reznicek 2002).

The misidentification of early collections of *C. sartwellii* as *C. praegracilis* led to its assumed absence from Alaska and the Yukon flora for several decades. Hultén (1968) mapped the 1948 W. Benninghoff collection of *C. sartwellii* as *C. praegracilis* in his work Flora of Alaska and Neighboring Territories. Similarly, the only two occurrences of *C. sartwellii* from Yukon were collected in 1960 and 1968, but misidentified as *C. praegracilis*, until 2003 (Cody *et al.* 2005) and 2008, respectively (Yukon: Mile 26 road from Whitehorse to Dawson, 9 August 1960, *Calder & Kukkonen 28039*, ALA 43419, det. A. A. Reznicek; Yukon: Alaska Highway milepost 944, 3 July 1968, *Welsh & Moore 7763*, ISC 281218 (on permanent loan at ALA), det. A. A. Reznicek; Figure 1). Like the Alaska specimen, the misidentified Yukon collections were included as *C. praegracilis* in Flora of the Yukon Territory (Cody 2000), although Cody (2005) made an update to the flora to include the 1960 collection by Calder and Kukkonen, then correctly identified as *C. sartwellii*. Stanley Welsh, who made the 1968 collection of *C. sartwellii* in Yukon, also included this and the other misidentified specimens in the range description for *C. praegracilis*, in his work Anderson's Flora of Alaska and Adjacent Parts of Canada (Welsh 1974).

Ecology

Yukon Flats

The Yukon Flats are located to the north of the Yukon–Tanana Uplands (Nowacki *et al.* 2002) and to the south of the Eastern Brooks Range (Figure 1). They were formed by the alluvial fans of the Chandalar and Porcupine rivers and the floodplain of the Yukon River (Williams 1962). The region has a mixed geology of alluvial sediments and aeolian silts and sands, largely deposited during the Pleistocene (Williams 1962; Muhs *et al.* 2003). The area is covered with approximately 40 000 shallow closed basin lakes (Heglund and Jones 2003) and is underlain by discontinuous ice-poor permafrost (Nossov *et al.* 2013). The climate is continental with low precipitation, averaging 16.7 cm annually (Drury and Grissom 2008), and negative potential evapotranspiration (Oechel *et al.* 2000). The vegetation is boreal with patchwork stands of mixed *Betula neoalaskana* Sargent (Alaska Paper Birch) and *Picea glauca* (Moench) Voss (White Spruce), *Populus tremuloides* Michaux (Trembling Aspen) on ridges, and *Salix* spp. (Willow) scrub and *Picea mariana* (Miller) Britton, Sterns & Poggenburg (Black Spruce) in the lowlands (Williams 1955).

Shrinking lakes

Our collections suggest that *C. sartwellii* occurs in a community type that may have been rarer in the recent past. The continental climate of the region, low precipitation, and high potential evapotranspiration (Oechel *et al.* 2000), along with increased annual temperatures and growing season length because of climate change (Chapin *et al.* 2005), are contributing to changes in the hydrology of shallow basin lakes (Riordan *et al.* 2006; Roach *et al.* 2011; Rover *et al.* 2012). Seasonal and interannual shrinking of these lakes results in a distinctive pattern of concentric rings of plant communities (Figure 2). These communities are underlain by lacustrine sediments rich in carbonates and with high pH (Heglund and Jones 2003; M. W., unpublished data), which, in combination with the high potential evapotranspiration, create alkaline soils around the lake margins and a favourable habitat for *C. sartwellii* (Stewart and Kantrup 1972). These plant communities are organized along a moisture gradient and follow the general pattern: lake edge, wet graminoid, wet/mesic graminoid forb meadows, open tall shrubs, forest.

The soils where *C. sartwellii* was collected are of lacustrine origin, highly organic with abundant mollusc shells, moderate to basic pH ranging from 6.78 to 7.97 (M. W., unpublished data), and often with a salt crust on the surface. Although *C. sartwellii* is noted as being an obligate wetland species (Lichvar 2013), we found it on soils that were not inundated with water. This may indicate that the site is seasonally wet and that the lake margins fluctuate with spring snow melt. The species was not found at the lake edge in standing water, although it is possible that vegetative shoots may have been overlooked in some plots because of the infrequency of reproductive shoots (Reznicek and Catling 2002a) and unfamiliarity with the species at the time of sampling.

We found *C. sartwellii* growing in open mesic to wet graminoid/forb meadows and open tall shrub meadows (Figure 2). In wet to mesic graminoid meadows it was commonly associated with *Carex aquatilis* Wahlenberg var. *aquatilis* (Water Sedge), *Carex atherodes* Sprengel (Wheat Sedge), *Carex utriculata* Boott (Northwest Territory Sedge), *Geum macrophyllum* var. *pernicisum* (Rydberg) Raup (Large-leaved Avens), *Persicaria lapathifolia* (L.) Delarbre (Curlytop Knotweed), *Chenopodium rubrum* L. (Red Goosefoot), *Rubus arcticus* L. (Arctic Raspberry), *Rumex* spp. (dock), and *Calamagrostis* spp. (reedgrass). In open tall shrub meadows, it was commonly associated with *Salix bebbiana* Sargent (Bebb's Willow), *Salix pseudomonticola* C. R. Ball (Park Willow), *Calamagrostis canadensis* (Michaux) Palisot de Beauvois (Bluejoint), *Chamerion angustifolium* (L.) Scopoli subsp. *angustifolium* (Fireweed), and *Rubus arcticus* L. (Arctic Raspberry).

Morphology

Carex sartwellii (*Carex* sect. Holarrhenae) and *C. praegracilis* (*Carex* sect. Divisae) share many similar morphological traits (Reznicek and Catling 2002a,b). Both species have unisexual or androgynous spikes;

TABLE 2. Comparison of morphological characteristics of *Carex sartwellii* and *C. praegracilis*.

Characteristic	*C. sartwellii*	*C. praegracilis*
Perigynia	Veined on both faces, ovate	Veined abaxially, broadly ovate
Leaf sheath, front	Veined nearly to sheath apex	Smooth, lacking veins
Leaf sheath apex	Prolonged, 1–4.5 mm	Not prolonged
Vegetative shoots	Forms tall tristichously leaved vegetative shoots with distinct nodes and internodes, aphyllopodic	Leaves basal, no tall shoots

beaked perigynia of similar size and shape; an abaxial suture arising at the beak; and both are aphyllopodic and loosely rhizomatous. However, there are diagnostic differences that can be observed in the field to separate them. The four easily identifiable differences in morphology between the two species are in the venation of the perigynia, the leaf sheath fronts, the leaf sheath apices, and the presence of true vegetative stems in *C. sartwellii* (Table 2, after Ball and Reznicek 2002).

The perigynia of *C. sartwellii* are veined on both faces whereas, on *C. praegracilis*, they are only veined abaxially. The leaf sheath front is a region located opposite and just below the disarticulation point of the leaf blade from the culm. In *C. sartwellii*, green veins of the culm continue into the leaf sheath fronts nearly to the sheath apex and are uniform in appearance with the rest of the leaf sheath around the culm, whereas, in *C. praegracilis*, the leaf sheath fronts are veinless and membranous and differentiated from the rest of the leaf sheath. The apices of the leaf sheath fronts in *C. sartwellii* are prolonged 1–4.5 mm but they are not prolonged in *C. praegracilis*. Finally, *C. sartwellii* produces true vegetative culms that are tristichously leaved and have the distinctive venation described above on the leaf sheath fronts. *Carex praegracilis* does not produce vegetative stems, but produces a basal rosette of leaves when growing vegetatively. In addition, there are differences in the ligule, which is more pronounced in *C. sartwellii* (2.2–8 mm), than in *C. praegracilis* (0.6–2.6 mm).

Reznicek (2012) distinguishes the sections that include these two species in the Alaskan Cyperaceae with the following key:

40. Upper leaves of culms with fronts of sheaths green-veined essentially to apex, not differentiated from rest of sheath; true vegetative stems present ...... Sect. Holarrhenae [includes *C. sartwellii*]

40. Upper leaves of culms with fronts of sheaths with at least a narrow hyaline or whitish-hyaline band extending at least half length of sheath; vegetative shoots not true stems, consisting only of overlapping leaf sheaths .... Sect. Divisae [includes *C. praegracilis*]

from Alaska at herbaria; yet this is not the case. However, the misidentification of the Benninghoff specimen by E. Hultén and Hultén's assumption (Hultén 1940–1951) that *C. sartwellii* did not occur north of British Columbia, Canada, did have a cascading effect on subsequent treatments of the flora in Alaska and Yukon (Hultén 1968; Welsh 1974; Cody 2000).

It may also be that this species is more abundant now because of increases in favourable habitat in the Yukon Flats as a result of climate change. It is unusual that there were only two single collections made in 63 years in the Yukon Flats, but we collected it at nine plots in seven lakes across a distance of approximately 15 km. We targeted drying lakes in our sampling efforts which likely increased our collections, but there are differences in the abundance of favourable habitat between the north and south sides of the Yukon River. The Benninghoff and Talbot collections were made on the north side of the Yukon River, where there are fewer drying lakes (Rover *et al.* 2012), whereas our collections were on the south side (Figure 1).

Our collections, the Benninghoff collection, and the Talbot collection represent separate populations from the nearest documented collections of *C. sartwellii*, which are about 850 km away in Yukon, Canada. What is not clear is whether, collectively, these are a fragmented population in the Yukon Flats or they are connected by habitat across the interior of Alaska to the collections in Yukon. For the extension of the range in Alaska, we outlined the geographic area of the Yukon Flats (Figure 1) because of its distinct climate (Oechel *et al.* 2000), geologic history (Wahrhaftig 1965; Muhs *et al.* 2003), and the pattern and extent of shrinking lakes (Riordan *et al.* 2006; Roach *et al.* 2011; Rover *et al.* 2012). These factors have created a patchwork of habitats for this species across the region. This sedge should be looked for in areas of similar habitats elsewhere in Alaska.

Conclusion

Based on the 1948 Benninghoff and 1982 Talbot collections, this species has occurred in Yukon Flats for some time, and our 2011 collections are not likely a result of a recently established population. It is likely that the vast terrain, limited access to the region, and few field studies have contributed to the rarity of collections over the years. Furthermore, if the lack of collections of *C. sartwellii* in the past were a result of misidentification as *C. praegracilis*, then we would expect more corrected identifications of *C. sartwellii*

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Note

First Record of the Land Snail *Pristiloma idahoense* (Gastropoda: Pristilomatidae) for Montana

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Hendricks, Paul. 2016. First record of the land snail *Pristiloma idahoense* (Gastropoda: Pristilomatidae) for Montana. Canadian Field-Naturalist 130(3): 199–201.

The land snail *Pristiloma idahoense* (Pilsbry, 1902) is reported from Montana for the first time. Five live individuals were found under downed wood beneath a mature coniferous forest canopy at 1670 m elevation in the Big Creek drainage of the Bitterroot Mountains, Ravalli County, Montana. This location extends the known range approximately 75 km east and over the crest of the Bitterroot Mountains from the nearest sites in Idaho County, Idaho and supports the hypothesis that the terrestrial mollusc fauna of Montana west of the continental divide has been strongly influenced by a molluscan radiation, which developed in a northern Idaho Pleistocene refuge. The probable route of dispersal for *P. idahoense* between the Bitterroot Mountains of Montana and the adjacent Lochsa River drainage of Idaho was over the lower mountains to the north in the Lolo Pass area.

Key Words: Distribution; Montana; *Pristiloma idahoense*; Pristilomatidae; range extension; terrestrial gastropod; land snail

Pristiloma idahoense (Pilsbry, 1902), the Thinlip Tightcoil, is a small land snail found primarily in northern Idaho, with additional records from northeastern Oregon and northeastern Washington (Pilsbry 1902; Baker 1932; Frest and Johannes 1995, 1997; Bosworth 2012; Burke 2013). NatureServe (2015) lists *P. idahoense* with a global rank of G2G3 (vulnerable to imperilled), and a state rank of S1 (critically imperilled) in Idaho, S2? (imperilled) in Washington, and SNR (not ranked) in Oregon. Recent surveys by the Idaho Department of Fish and Game (M. Lucid, personal communication) show that the species is widely distributed, although relatively rare, across the northern Idaho Panhandle and also extant in extreme northeastern Washington. Extensive surveys for land molluscs in Montana west of the continental divide began in 2005 and resulted in detections of a number of rare taxa of the Washingtonian Province with ranges primarily in Idaho (Frest and Johannes 2000; Hendricks *et al.* 2007; Hendricks 2012; Burke 2013). However, *P. idahoense* was not one of the species found during the Montana surveys, nor has it been recorded previously in the state. Here, I document the first occurrence of *P. idahoense* in Montana and discuss the biogeographic significance of this discovery.

On 2 June 2015 I found five live *P. idahoense* at one location in the Selway-Bitterroot Wilderness, Ravalli County, Montana, just north of the juncture of the trails leading to Big Creek Lakes and South Fork Lake in the Big Creek drainage of the Bitterroot Mountains. The site (46.48790°N, 114.34541°W) is on the eastern side of the Bitterroot Mountains (the crest of which forms the boundary between Idaho and Montana) about 1.0 km southeast of the outflow of Big Creek Lakes at 1670 m elevation. Two of the five snails were collected and preserved in 95% ethyl alcohol and later deposited in the mollusc collection at the Carnegie Museum of Natural History (CM 144502). The Montana voucher specimens are typical in size and external morphology for *P. idahoense* (Burke 2013; T. Burke, personal communication). The shells are low conic, 3.2 and 3.5 mm in diameter and 1.8 and 2.1 mm in height, tightly coiled with about 6.0 and 6.25 whorls, possess distinct shoulders, and are imperforate (Figure 1). *Pristiloma idahoense* is readily distinguished by its imperforate shell and distinct shoulder from the other *Pristiloma* species reported previously in Montana (Berry 1919; Russell and Brunson 1967; Hendricks 2012): *P. chersinella* and *P. wascoense*.

The Montana location extends the range of *P. idahoense* about 75 km east and over the crest of the Bitterroot Mountains from the closest known Idaho locality at Dipper Creek (46.35553°N, 115.29161°W) 5 km northeast of the historical Lochsa Ranger Station in Idaho County (Bosworth 2012; M. Lucid, personal communication), where John Slapcinsky collected a single shell (Florida Museum of Natural History: FLMNH 444802) on 9 July 2010. Forest canopy cover at the Montana site was about 70%, composed predominantly of mature Engelmann Spruce (*Picea engelmannii*), Subalpine Fir (*Abies lasiocarpa*), and Douglas-fir (*Pseudotsuga menziesii*), with a ground cover including patches of ferns and moss. The snails were under a piece of wood on the forest floor within 50 m of a small seepage.

Other mollusc species found in close proximity (< 30 m) were *Udosarx lyrata* (Lyre Mantleslug), *Radiodiscus abietum* (Fir Pinwheel), and *Discus whitneyi* (Forest Disc). Habitat at the Montana site differs

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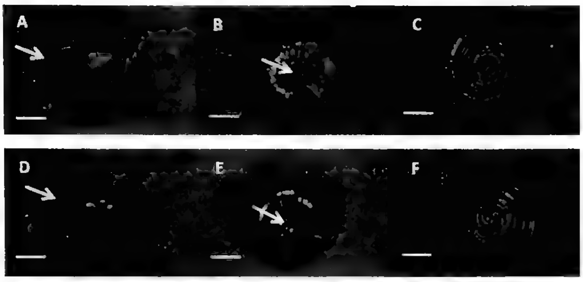

FIGURE 1. The two voucher specimens of *Pristiloma idahoense* (Carnegie Museum of Natural History: CM 144502) from the Big Creek drainage in the Bitterroot Mountains, Ravalli County, Montana. The prominent shoulder on the shells is indicated by arrows in A and D, the imperforate shell (lack of an open umbilicus) by arrows in B and E, and the number of whorls in C and F. Scale bar = 1 mm. Photo: T. Burke.

somewhat from those described elsewhere for the species, which indicate that *P. idahoense* has been found most often at lower elevations in moist forest zones under mature, closed-canopy Ponderosa Pine (*Pinus ponderosa*), Douglas-fir or Grand Fir (*Abies grandis*), and Pacific Yew (*Taxus brevifolia*), sometimes in mossy talus and under coarse organic debris, and sometimes in association with limestone and basalt (Baker 1932; Frest and Johannes 1995, 1997, 2000; Bosworth 2012; Burke 2013).

The discovery of *P. idahoense* in Montana is not surprising, but the location of this first occurrence is unexpected. *Pristiloma idahoense* has been documented within 2 km of Montana on the Idaho side of Lookout Pass (1440 m elevation) near Mullen, Shoshone County (Bosworth 2012; M. Lucid, personal communication), about 150 km northwest of the Montana location. The mountains of Montana along the boundary with Idaho north of Lookout Pass include the low-elevation valleys of the Clark Fork and Kootenai Rivers (at about 645 m and 555 m, respectively) and a number of low-elevation passes between 1440 m and 1525 m, thus affording suitable routes for dispersal into Montana. *Pristiloma idahoense* probably occurs in Montana north of Lookout Pass and efforts to confirm occurrence in that region should be made. From Lookout Pass south to Lolo Pass (1596 m), the boundary between Montana and Idaho is generally higher than 1920 m, with no river valleys and only a few passes dropping below 1825 m elevation. Nevertheless, it is possible that *P. idahoense* has reached Montana across this mountainous divide because it is forested in many places; additional surveys for the species are warranted in this area.

South of Lolo Pass to Lost Trail Pass (2138 m), the crest of the Bitterroot Mountains (which is part of the granitic Idaho Batholith) has numerous summits between 2500 and 2830 m near or above tree line and rarely drops below 2100 m, such that the Bitterroot Mountains form a significant alpine barrier to land mollusc dispersal between Idaho and Montana. Furthermore, most drainages in the Bitterroot Mountains, including Big Creek where *P. idahoense* was discovered, were glaciated during the Pleistocene from the crest down to 1220 m, below which elevation the Bitterroot Valley was inundated by water from Glacial Lake Missoula (Alden 1953), unlike many of the documented *P. idahoense* sites in Idaho, which appear to have remained unflooded and ice-free. Thus, the probable route of dispersal for *P. idahoense* between the Bitterroot Mountains of Montana and the adjacent Lochsa River drainage of Idaho is over the lower mountains to the north in the Lolo Pass area.

The presence of *P. idahoense* in Montana is yet another indication that the terrestrial mollusc fauna in the state west of the continental divide has been strongly influenced by a molluscan radiation, which developed in a northern Idaho Pleistocene refuge (Leonard *et al.* 2003; Shafer *et al.* 2010). *Pristiloma idahoense* can be added to the Montana list of regional endemic mollusc taxa with close affinity to northern Idaho (Frest and Johannes 1995, 2000; Hendricks 2012; Burke 2013), which includes the slugs *Hemphillia camelus* (Pale Jumping-slug), *Hemphillia danielsi* (Marbled Jumping-slug), *Kootenaia burkei* (Pygmy Slug), *Magnipelta mycophaga* (Magnum Mantleslug), *Prophysaon humile* (Smoky Taildropper), *Udosarx lyrata*, and *Zacoleus idahoensis* (Sheathed Slug), and the land snails *Allogona ptychophora* (Idaho Forestsnail), *Cryptomastix mullani* (Coeur d'Alene Oregonian), *Polygyrella polygyrella* (Humped Coin), and *Radiodiscus abietum*.

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Selection of Agricultural Foods by Eastern Grey Squirrels (*Sciurus carolinensis*): Implications for a New Introduction in British Columbia

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The recent introduction of the Eastern Grey Squirrel (*Sciurus carolinensis*) into south-central British Columbia occurred within an important agricultural zone. As repercussions for the fruit-growing sector are currently unknown, we conducted trials with captive squirrels to understand the range of fruits consumed and their preferences. The squirrels consumed a portion of every food item offered, although the order in which the foods were used was inconsistent (with sharp contrasts between animals). Of the fruit types offered, apples appeared to be of greatest overall interest. However, seeds and nuts tended to be used first when presented in combination with fruit, suggesting opportunities to use these food types to deflect or remove Eastern Grey Squirrels from orchard crops. We caution that our results may not reflect the food items that free-ranging Eastern Grey Squirrels will target or disregard once densities in the introduced population become higher and the availability of food on a local scale begins to exert an effect.

Key Words: Eastern Grey Squirrel; Eastern Gray Squirrel; *Sciurus carolinensis*; diet; food trial; invasive species; agriculture

Introduction

The Eastern Grey Squirrel (*Sciurus carolinensis*) is indigenous to the eastern forests of Canada and the United States, but it has been introduced at numerous locations around the globe, including areas in North America considerably distant from its native range (Lowe *et al.* 2000). In Canada, introduced populations of these animals have existed for decades on the west coast and in cities of the prairie provinces. After their earliest introduction in Vancouver, British Columbia, in the early 1900s, grey squirrels rapidly populated the area (Robinson and Cowan 1954). In the 1960s, a few Eastern Grey Squirrels on Vancouver Island escaped captivity and established another stable population (Guiguet 1975; Nagorsen 2005).

In 2006, a new point of introduction for the Eastern Grey Squirrel in interior British Columbia was verified, although anecdotal reports date back to at least 2004 (K. W. L., unpublished data). The species is now established in the Okanagan Valley, particularly in Kelowna (49.88°N, 119.44°W). The source population is most likely from Vancouver, approximately 300 km away with mountainous terrain between, strongly suggesting that humans transported the founding individuals of this relatively new population. This recent introduction has raised environmental and economic concerns (ISCBC 2012), although, to date, control measures have not been entertained. Because the Okanagan is one of the major agricultural regions of western Canada (particularly for fruit and vineyards), the potential exists for Eastern Grey Squirrels to affect commercially valuable crops. However, there is scant scientific literature focusing on specific ecological or economic effects of the Eastern Grey Squirrel in British Columbia, other than those predicted by Bruemmer *et al.* (2000).

In its native habitat, the Eastern Grey Squirrel has a broad diet, including fruit, nuts, seeds, flowers, buds, bark, fungi, and insects, as well as bird eggs and nestlings (Moller 1983; Koprowski 1994; Shealer *et al.* 1999; Spritzer 2002; Gurnell *et al.* 2004). This wide array enables the squirrels to exploit a variety of habitats including forested, urban, and cultivated areas (Riege 1991; Goheen *et al.* 2003; Gonzales 2005). Despite claims that the Eastern Grey Squirrel does not have a significant impact on agriculture in its native habitat (Woods 1980), a number of reports describe their destruction of corn, wheat, and vegetable crops in the United States, in some cases leading to implementation of a bounty (Schorger 1949; Byrne 1979; Koprowski 1994). In North America, introduced Eastern Grey Squirrels have been shown to raid fruit crops and gardens in urban areas (Bruemmer *et al.* 2000; Salmon *et al.* 2005). In Europe, Eastern Grey Squirrels damage timber and fruit trees by stripping their bark (Kenward and Parish 1986; Bruemmer *et al.* 2000), a behaviour not yet documented in non-native populations in North America.

Fruits consumed by Eastern Grey Squirrels include apples, cherries, blueberries, wild grapes, plums, and apricots (Banfield 1974; Byrne 1979; Salmon *et al.* 2005). As apples, cherries, and commercial wine grapes are widely produced in the Okanagan (Statistics Cana-

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da 2014), the potential exists for Eastern Grey Squirrels to become an agricultural pest in this region. To date, however, their preferences for various commercially grown fruits in this region have not been studied. The objective of our study was to present captive Eastern Grey Squirrels with a range of food items, focusing on fruit crops produced in the Okanagan, to document their preferences and the breadth of their selection.

Methods

In early June 2014, three Eastern Grey Squirrels (one male and two females) were captured in Kelowna, British Columbia using live traps (Model 201, Tomahawk Live Trap, Hazelhurst, Wisconsin, USA) and transferred to the British Columbia Wildlife Park in Kamloops for housing. Neutering procedures were performed at the park's veterinary clinic as a precaution against escape. Each animal was also tagged with a standard numeric small-mammal ear tag (Monel #1, National Band & Tag Company, Newport, USA) to permit individual identification. Three weeks of post-surgical recovery were allowed before testing.

The three animals were housed in separate but adjacent cages. Each cage consisted of an outdoor screened enclosure (about 2 m × 2 m × 3 m tall) containing logs, climbing poles, and nest boxes, connected via a small doorway (20 cm × 20 cm) to an indoor screened feeding cage (60 cm × 30 cm × 45 cm tall) where food was provided. Motion-detecting wildlife cameras (Trophy model 119477, Overland Park, Kansas, USA) were positioned inside each feeding cage to record feeding activities and allow us to determine order of food preference. During periods between trials with different food combinations (minimum two days), the squirrels were maintained on a daily diet of half a cup of Laboratory Rodent Diet 5001 (LabDiet, St. Louis, Missouri, USA) and three peanuts. Fresh drinking water was always available. The small sample size (n = 3) was due in part to a desire to provide large, individual semi-natural environments that enabled the squirrels to roam larger areas and feed at times of their own choosing.

Each squirrel was presented with 11 combinations of three foods, chosen from 11 items (Table 1), and each combination was presented to each squirrel in three replicate trials, conducted over three consecutive days (one trial/day), resulting in 99 trials over the course of the study (June to October 2014). Because fruit was the main type of food under consideration, the order in which these locally grown items were presented in the trials corresponded to their seasonal availability (e.g., strawberries and cherries were used in early trials, and wine grapes and apples were introduced toward the end of the growing season). Two non-fruit foods were also included in the trials (peanuts and a commercial bird seed mix – Nyjer® brand, Wild Bird Feeding Industry, West End, USA) to test choice between these high-energy items and fruit. Because of constraints on food availability and scheduling, each food item used in the study was not included in an equal number of trials.

Table 1. Foods, codes, and combinations used to evaluate preferences of three Eastern Grey Squirrels (*Sciurus carolinensis*), between June and October 2014.

Food	Code	Food combinations
Apple	AL	PN, BS, SB
Apricot	AP	PN, CH, AP
Bird seed	BS	PN, PC, AP
Cherry	CH	PN, CH, PC
Peach	PC	AP, CH, PC
Peanut	PN	PN, AL, PR
Pear	PR	BS, AL, PR
Red wine grape (Cabernet-Franc)	RG	BS, RG, WG
White wine grape (Riesling)	RI	AL, RG, WG
Strawberry	SB	PR, RG, WG
White wine grape (Gewürztraminer)	WG	AL, RG, RI

For each trial, ~50 g (± 1 g) of each food was presented in a row of small ceramic dishes so that each dish was 30 cm from the feeding cage entrance. The order of the foods was rotated from left to right every trial to minimize the effect of location on the order of selection. Fruit items were presented intact (e.g., strawberries) or cut into large pieces (e.g., peaches) to approximate the situation found in orchards. Access to the feeding cages and the food items was allowed for approximately 24 h, after which the door was shut and the video recording retrieved from the cameras. The order in which the three food items were taken over the course of each trial (regardless of the amount taken) was used to designate first, second, and third food choice "preference." Because of an inherent delay in the camera's motion sensor, the subjects could enter the cage, grab a food item, and exit the cage before the camera recorded the full event. In most of these cases, order of selection was determined by visible changes in the amount of food in the dishes. Where this was not possible to discern, the trial was aborted and repeated the next day or the earliest possible date.

Realizing the limitations of our data, we simply report the proportion of trials where each food was chosen first, second, and third (using only the trials where that food item was present). In other words, we divided the number of times a food item was selected first (or second, or third) by the total number of trials in which that food item was offered. We also calculated the binomial probabilities for the frequencies at which the squirrels selected a particular food item first (i.e., $P = 0.33$ [or one out of three food types], $q = 0.66$), using only those trials in which the food item was included.

Results

All of the food items offered to the captive squirrels were eaten by at least one squirrel on at least one occasion. Feeding and/or plundering (i.e., food item removed but uncertain when it was consumed) of food from the feeding cages occurred primarily between 0400 and 0900 and between 1500 and 2100, with little interest shown between 2100 and 0400.

No single food item emerged as clearly preferred by all three squirrels (Figure 1); bird seed and peanuts were chosen first relatively often, but even this pattern varied among squirrels. Apple was the fruit that, on average, was most frequently chosen first, although this was not consistent (chosen first in only 42% of all trials involving apple). An example of extreme variation occurred with cherries: Squirrel 2 selected cherries first in all of the trials in which this fruit was included, but Squirrel 1 did so in only two of nine trials (Figure 1; Table 2). The squirrels appeared relatively uninterested in strawberries, wine grapes of all types, and apricots. Strawberries was the only food item never selected first in any trial, by any squirrel (and selected second in only one trial, by one squirrel); however, trials using this fruit were limited in number.

Similar patterns were reflected by the binomial probabilities calculated for the food choices demonstrated by the squirrels (Table 2). Low probabilities ($P < 0.10$) suggesting a predilection for a food type were seen for particular squirrels for certain food items (e.g., Squirrel 1 and peanuts, Squirrel 2 and cherries), but not consistently for all three animals or any one food item. Peanuts came closest to this pattern, with low associated binomial probabilities, on average (0.07), but largely because two of the three squirrels chose peanuts first relatively often (14/15 and 9/15 trials). The bird

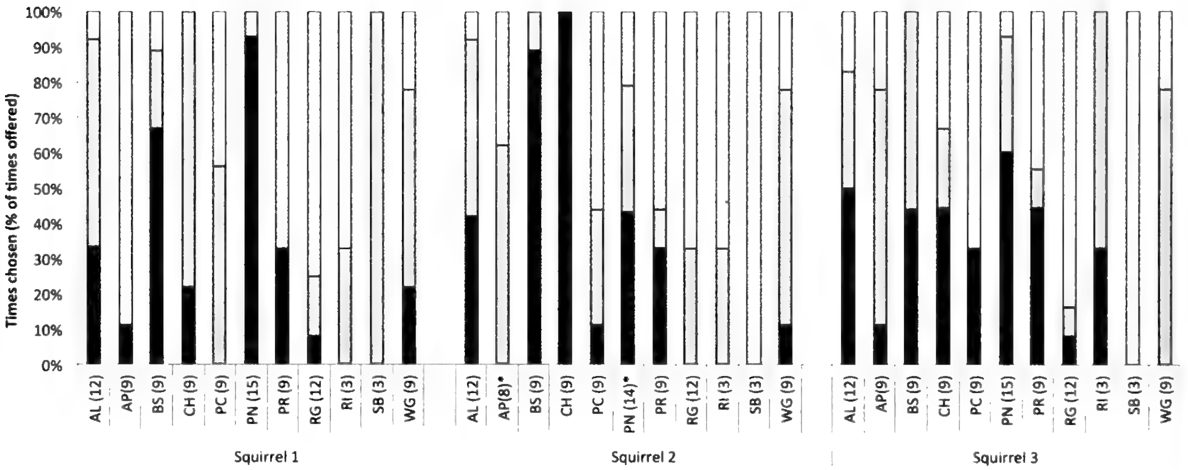

FIGURE 1. Food preferences of three Eastern Grey Squirrels (*Sciurus carolinensis*). Each food combination was presented to each squirrel in an equal number of trials (shown in brackets), except for two situations* where Squirrel 2 received one less trial. Note: AL = apple, AP = apricot, BS = bird seed, CH = cherry, PC = peach, PN = peanut, PR = pear, RG = red wine grape (Cabernet-Franc), RI = white wine grape (Riesling), SB = strawberry, WG = white wine grape (Gewürztraminer). Bar shading represents the proportion of trials involving each food type where it was chosen first (solid), second (grey) or third (white) among the choices available.

TABLE 2. Number of trials in which each food was selected first by an Eastern Grey Squirrel (*Sciurus carolinensis*) as a proportion of the number of times it was offered and the binomial probability associated with that outcome (Binom *P*). A minus sign in the last column indicates a situation in which all three animals chose the food first in fewer than half the trials. No reverse situations existed where a food was consistently selected more often than expected.

	Squirrel 1		Squirrel 2		Squirrel 3		
Food	First/trials	Binom *P*	First/trials	Binom *P*	First/trials	Binom *P*	Direction
Apple	4/12	0.24	5/12	0.18	6/12	0.11	
Apricot	1/9	0.12	0/8	0.03	1/9	0.12	–
Bird seed	6/9	0.03	8/9	< 0.01	4/9	0.20	
Cherry	2/9	0.24	9/9	< 0.01	4/9	0.20	
Peach	0/9	0.03	1/9	0.12	3/9	0.27	–
Peanut	14/15	< 0.01	6/14	0.16	9/15	0.02	
Pear	3/9	0.27	3/9	0.27	4/9	0.20	–
Red grape (Cabernet-Franc)	1/12	0.05	0/12	< 0.01	1/12	0.05	–
White grape (Reisling)	0/3	0.30	0/3	0.30	1/3	0.44	–
Strawberry	0/3	0.30	0/3	0.30	0/3	0.30	–
White grape (Gewürztraminer)	2/9	0.24	1/9	0.12	0/9	0.03	–

seed trials had a similar pattern, albeit a higher P value generated by Squirrel 3. Conversely, consistent low probabilities associated with infrequent selection of food types were seen for red grapes. Low probabilities were not associated with the selection frequencies for other types of grapes, but this was likely because of the relatively scant number of trials involving these fruits.

Discussion

The three captive Eastern Grey Squirrels ate each of the 11 food items presented to them (in 11 different combinations). This wide selection was not surprising, given that the species is able to exploit diverse ecosystems (Riege 1991; Goheen *et al.* 2003; Gonzales 2005). Logistics and the seasonality of different fresh fruit crops prohibited rigorous cafeteria-style food trials where foods are tested equally against one another (Lobo *et al.* 2009; Plantan *et al.* 2012). Also in our case, we were attempting to understand how Eastern Grey Squirrels may target different foods at different times during the summer (i.e., apples will not likely coincide with peaches). Although these conditions prevent us from commenting strongly on the food preferences demonstrated by this species at this location, our results still indicate that squirrels may eat all of the regional fruits represented in our study, including wine grapes. Also, even our small sample size revealed strong differences in dietary preferences among animals for some foods such as cherries. Exposure to different food types by our squirrels before captivity may have contributed to this variation, but detecting such correlates would require more elaborate testing.

Our study did not include an exhaustive sampling of all potential foods (and combinations thereof) available in the Okanagan region. To attempt this would be unrealistic, given the broad omnivorous diet of this species and local availability of different foods likely has a large effect on the feeding behaviour of individual animals or subpopulations. Further, as the population of Eastern Grey Squirrels increases in the Okanagan, pockets of animals will exist in areas dominated by different crops, exposing them to a narrower choice and possibly resulting in considerably greater impacts on specific crops (Salmon *et al.* 2005). The Okanagan Valley has a semi-arid summer climate, and water requirements may drive Eastern Grey Squirrels to consume whatever fruit is available, a situation we did not attempt to simulate.

Thus, the infrequent use of certain foods by our study animals does not necessarily mean those foods would be avoided in the wild by free-ranging Eastern Grey Squirrels. This is particularly so given our small sample size and the marked variation in selection by individuals. However, our captive squirrels tended to choose peanuts and bird seed (high-energy food items) over fruit, suggesting that these items should prove successful in luring or trapping squirrels that are having an impact on fruit crops. This tactic may be less effective if the targeted crops are other nuts, as has already been seen in the Okanagan for walnut and hazelnut crops (N. Bothe, personal communication, 2014).

The loss of habitat of the Eastern Grey Squirrel in its native range (Goheen *et al.* 2003) may adversely affect the reproductive success of native nut-bearing trees (Goheen and Swihart 2003). Conversely, Eastern Grey Squirrels may have an negative impact on the regeneration of oaks (Fuchs *et al.* 2000; Steele *et al.* 2005), with possible implications in the fragmented stands of the endangered Garry Oak ecosystem in coastal British Columbia. However, in the Okanagan Valley, nut-bearing trees are primarily non-native and farmed; thus, Eastern Grey Squirrels foraging on these trees will have greater economic than ecological effects. The impact is likely to be more significant than that caused to date by the native Red Squirrel (*Tamiasciurus hudsonicus*), partly because the social system of the Eastern Grey Squirrel allows it to achieve higher urban densities. A close relative, the Eastern Fox Squirrel (*Sciurus niger*) was introduced in the Okanagan in the 1980s and has not been studied with regard to economic or ecological impacts, although agricultural damage is suspected by non-native populations in the United States (Frey *et al.* 2013).

This study provides a preliminary examination of food preferences of Eastern Grey Squirrels introduced into this region of Canada. Our work was done on a small number of captive animals, significantly limiting interpretation of the results. Still, it seems clear that the spread of the species throughout the agricultural region of the Okanagan Valley will likely not be impeded by the availability of food (at least during the fruit-growing season). Other landscape features, such as land-use patterns, natural barriers, and climate will likely affect extension of the species' range in this region. Further work, particularly in the field, is needed to address the potential and realized impacts of invasive tree squirrels in western Canada.

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Note

New Northern Records for Townsend's Solitaire (*Myadestes townsendi*) in Nunavut and the Northwest Territories

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On 10 May 2015, a Townsend's Solitaire (*Myadestes townsendi*) was observed near the hamlet of Kugluktuk in the Kitikmeot region of Nunavut. This represents the first record for the territory and the first observation above the Canadian tree line. We discuss new data from the Northwest Territories of singing males recorded by autonomous recording units, which may represent breeding evidence at the northeastern limit of the species' range. We summarize other observations of this species across northwestern Canada and describe the ecology of the lower Coppermine River.

Key Words: Townsend's Solitaire; *Myadestes townsendi*; species distribution; Nunavut; Kugluktuk; Kitikmeot; Yellowknife; Coppermine River; Northwest Territories; breeding

Introduction

Found predominantly throughout the western portion of North America, the Townsend's Solitaire (*Myadestes townsendi*) has a wide distribution, ranging from the Sierra Madre mountains of Mexico to the Brooks Range in Alaska and the Richardson Mountains in the Yukon (Godfrey 1986; Bowen 1997). There are two recognized subspecies, *M. t. townsendi*, which breeds in the United States and Canada, and *M. t. calophonus*, the southern resident breeding population, found in the mountains of the Sierra Madre Occidental from Chihuahua to Zacatecas in Mexico (Moore 1937; Howell and Webb 1995).

The breeding range of *M. t. townsendi* covers most of western North America, from New Mexico to Alaska, east to Colorado, Wyoming, and Montana, with a small breeding population in the Cypress Hills between Alberta and Saskatchewan (Semenchuk 1992; Bowen 1997). Although Campbell *et al.* (1997) have suggested a gap in the breeding range (latitudes 53°N to 59°N) in northwestern British Columbia, results from recent breeding bird surveys indicate that this range may not be discontinuous after all (Davidson and Lamont 2014).

The species typically overwinters at lower altitudes throughout much of its range, excluding the northern Canadian and Alaskan breeders, which migrate south to overwinter; the length of these migrations and stopover locations of these northern breeders remain unknown. It has been speculated that they venture only as far south as suitable numbers of juniper (*Juniperus* sp.) and other fruiting berry species can be found (Bent 1949; Lederer 1977; Bock 1982; Podar and Lederer 1982; Campbell *et al.* 1997).

Townsend's Solitaire is normally associated with montane environments and coniferous forests, particularly those composed of pine (*Pinus* sp.), fir (*Abies* sp.), hemlock (*Tsuga* sp.), and spruce (*Picea* sp.), but also use other forest types between 350 m and 3500 m elevation (Bowen 1997; Collar 2015). Although little has been described regarding the northern ecology of this species, in the Yukon, it uses patches of conifers and taller vegetation along creeks or wet draws above the timber line (Sinclair *et al.* 2003). Along the Dempster Highway, it occupies cliffs, talus slopes, and drier habitats with southern exposure, likely where snow free patches emerge in early spring (Frisch 1994). Although not usually believed to be associated with areas above the tree line or occupying rocky alpine environments (Bowen 1997), such as those seen in the Canadian tundra, montane environments above the timber line with tundra vegetation are used in northwestern British Columbia (M. M. L., personal observation) and elsewhere across its range on occasion (Bowles and Decker 1927).

Results

On 10 May 2015, an adult Townsend's Solitaire was observed near the community of Kugluktuk, Nunavut, on a rock outcrop near the mouth of the Coppermine River (67.81°N, 115.09°W) approximately 1 km from the coast of the Arctic Ocean (Figure 1). Multiple photographs (Figure 2) and subsequent sightings of this bird were made over three days after the initial observation. During several hours of monitoring, foraging and perching were the activities observed most often. Feeding occurred mainly among heather and low-lying shrubs, such as Black Crowberry (*Empetrum nigrum* L.), Dwarf

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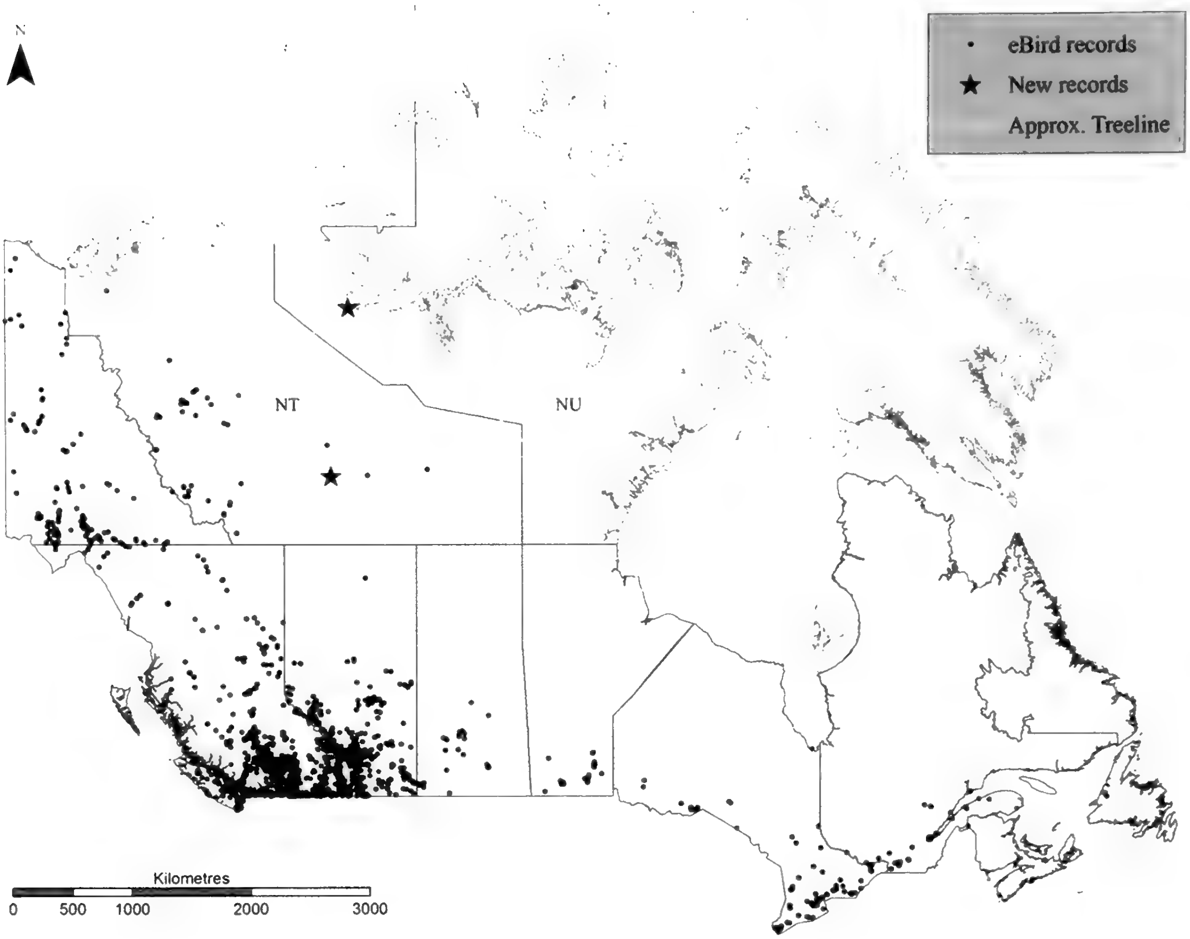

FIGURE 1. All Canadian records of Townsend's Solitaire (*Myadestes townsendi*) from 1953 to 2015 in eBird (2015), with two recent records from Nunavut and Northwest Territories.

FIGURE 2. Townsend's Solitaire (*Myadestes townsendi*) photographed in Kugluktuk, Nunavut, on 10 May 2015. Photo: M. Lamont.

Birch (*Betula glandulosa* Michaux), Alpine Bearberry (*Arctostaphylos alpina* (L.) Niedenzu), Arctic Willow (*Salix arctica* Pallas), and Arctic White Heather (*Cassiope tetragona* (L.) D. Don). No singing or other territorial behaviour was observed.

To the best of our knowledge, this sighting represents the first documented observation of a Townsend's Solitaire above the Canadian tree line and the first for Nunavut. Of additional interest was the presence of a Northern Wheatear (*Oenanthe oenanthe*) at the same location as the Townsend's Solitaire in Kugluktuk, but it was observed for only one day. This is one of the few records for this species in the western Kitikmeot.

Discussion

A review of all observations for Townsend's Solitaire reported to eBird (2015; Figure 1) from across Canada between 1953 and 2015 revealed 11 221 sightings, most from British Columbia, Alberta, and Yukon. A total of 76 sightings occurred in the Northwest Territories over this same period, the closest of which was approximately 500 km from Kugluktuk in Deline: a single bird in 2004. According to this dataset, only three other observations had been made at a higher latitude than that of Kugluktuk in the previous 63 years; all three were within the boreal region of North America.

Given the significant amounts of snow cover still present on the ground in early May, the Townsend's Solitaire observed in Kugluktuk was likely feeding on berries from the previous year. A few species of Arachnids and Hymenoptera are also present on exposed tundra in early May, but in very sparse numbers (Cutler 1982; Dondale *et al.* 1997; M. M. L., personal observation). Townsend's Solitaire is monotypic; hence, the sex of this bird was undetermined. Insufficient close observations were made to attempt to delineate a molt pattern; the greater primary coverts did appear to have buffy edges, suggestive of a second-year bird (Bowen 1997).

Both sexes are known to sing and defend territories on both breeding and wintering grounds and during migration (Hanford 1917; George 1987). During the breeding season, males will sing louder and more often than females (Bowen 1997). Singing rates peak twice in the year, once from April to May and again from September to November (Sullivan 1976). We played songs of conspecifics on three occasions over 2 hr in an attempt to elicit a response call or to determine whether the bird showed any territorial behaviour; however, these attempts resulted in little behavioural response, and no signs of agitation were perceived. Stochastic and sudden changes in weather events are known to cause the arrival or sudden dispersal of migrating boreal birds (see Newton 2006; Gordo 2007; Strong *et al.* 2015). A review of the weather patterns at Kugluktuk airport for the three weeks before the 10 May sighting revealed an average daily temperature of −10.3°C with no significant weather events recorded (Environment Canada 2016).

In Nunavut, Kugluktuk is one of the closest communities to the treeline. Pockets of trees can be found as close as 40 km south of Kugluktuk where sheltered valleys allow small stands of White Spruce (*Picea glauca* (Moench) Voss) to grow, the species whose frequency defines the treeline. More homogeneous stands of spruce are found further south, approximately 80 120 km south of Kugluktuk. Willow (*Salix* spp.), particularly *Salix alexnsis* (Andersson) Coville var. *alaxensis* is also found in sheltered valleys and ravines (J. M. Saarela, personal communication). The river valley forms a corridor from the tree line, with a bird community similar to that of the northern boreal region. Other species found within boreal ecosystems, such as Moose (*Alces americanus*), American Marten (*Martes americana*), and Common Muskrat (*Ondatra zibethicus*), are also found in the Coppermine River Valley, north to the Arctic coastline along with many species of boreal vascular plants (Kelsall 1972; Cody *et al.* 2003; J. M. Saarela, personal communication).

Twenty-six vascular plants are at their northern range limit for Nunavut within the Kugluk/Bloody Falls Territorial Park, 13 km outside Kugluktuk (J. M. Saarela, personal communication). In addition, the lower Coppermine River Valley has 70% of the known vascular plant diversity found in Nunavut, at the family level, and many boreal species only previously known from the James Bay region. The known northern extent of Common Juniper (*Juniperus communis* L.) in Nunavut is only a few kilometres from the location where we observed Townsend's Solitaire (J. M. Saarela, personal communication). The distribution of juniper continues south along the length of the Coppermine River, eventually reaching the tree line. The presence of juniper and other boreal plant species not found elsewhere on mainland Nunavut lends some credence to the possibility that the Coppermine River Valley supports small numbers of Townsend's Solitaire and other boreal bird species in the Kitikmeot.

According to eBird data, three other observations of Townsend's Solitaire have been made near Yellowknife: two in August outside the known breeding season (Bowen 1997) and the third in mid-June, but including no notes on breeding activity. Townsend's Solitaire has also been detected in the Northwest Territories recently, as part of a joint Environment Canada and University of Alberta Bioacoustics' Unit songbird monitoring program. The program, initiated in 2015, surveys songbirds using audio recorders with the long-term goal of monitoring songbird use of northern forests recovering from forest fire.

Two males were recorded singing over three days of sampling from 23 to 26 June 2015 between 0330 and 0430 on Song Meter SM3 automated recording units (Wildlife Acoustics, Maynard, Massachusetts, USA).

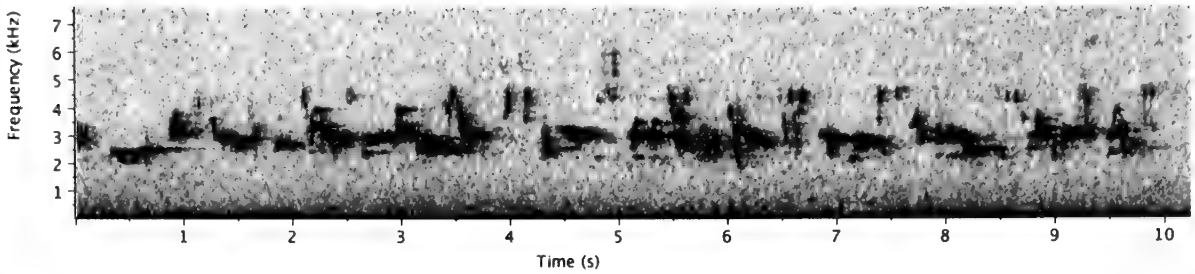

FIGURE 3. Spectrogram of Townsend's Solitaire (*Myadestes townsendi*) primary vocalizations recorded on 23 June 2015 between Behchokǫ̀ and Fort Providence, Northwest Territories.

Recordings were made about 100 km west of Yellowknife, between Behchokǫ̀ and Fort Providence, Northwest Territories (65.51°N, 116.45°W, Figure 1). During June 2015, 364 locations between Behchokǫ̀ and Fort Providence were surveyed. For each sampling location, two 3-minute dawn recordings, made within a four day period, were interpreted manually for songbird primary vocalizations by trained observers using acoustic software. Spectrograms were produced from recordings and compared to known spectrographs to verify species identification (Figure 3). Habitat was composed primarily of Jack Pine (*Pinus banksiana* Lambert) and Trembling Aspen (*Populus tremuloides* Michaux) within an area burned in 2014, resulting in a mix of low to high tree mortality. Recording sites were at least 300 m from a nearby highway; one recording location was adjacent to an abandoned gravel pit.

The discovery of more than one male exhibiting territorial behaviour during the breeding season between Behchokǫ̀ and Fort Providence suggests that the true breeding range for this species within the Northwest Territories may not be well defined. Additionally, preliminary results from the 2016 field season suggest that at least one singing male returned to the same location as detected in 2015. These captured audio recordings are of interest, as they may be some of the most northeasterly evidence of breeding across the species known range.

Although survey data are lacking for the northern portion of the Townsend's Solitaire's range, a noticeable decline has been observed since the 1970s (Environment Canada 2014). With the advent of mobile acoustic recording devices, obtaining basic information on avian presence and abundance in these northern regions may now be possible (Acevedo and Villanueva-Rivera 2006; Celis-Murillo *et al.* 2009; Venier *et al.* 2012). Poleward range extensions of boreal birds is expected to occur with climate change, which will have a pronounced impact on these species (Auer and King 2014; Virkkala and Lehikoinen 2014). Delineating species distributions and documenting northern limits and potential range expansions are vital in trying to understand how climate change may affect northern boreal and arctic ecosystems and the species that inhabit them (see Virkkala *et al.* 2008, 2010; Virkkala and Lehikoinen 2014). The western Kitikmeot, particularly on the mainland, is poorly known ornithologically, with most studies occurring in the Qikiqtaaluk and the Kivalliq regions (Hussell *et al.* 2012; Lecomte and Giroux 2015). A current gap in our understanding of many avian species at their northern extremities across Canada, particularly in Nunavut, exists. Efforts to encompass these northern and poorly surveyed areas in long-term monitoring projects are highly desirable from a conservation standpoint.

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Note

Estimating the Age of Male Gray Wolves (*Canis lupus*) Using Baculum Measurements

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Morphological characteristics of the bacula of 62 Gray Wolves (*Canis lupus*) harvested in Wisconsin were related to age estimates generated from cementum annuli analyses. Baculum analysis suggested that 47 of 62 wolves (75.8%) were correctly classified as the appropriate age category (pup, yearling, adult) assessed by cementum analyses; however, this success was limited for yearlings (53.5%) and adults (38.5%). Results could not corroborate future use of this approach for rapid aging of dead wolves. There remains a need for a wolf-aging technique that can be broadly implemented in a timely and cost-effective manner, while also preserving the inherent trophy value of an intact skull.

Key Words: Gray Wolf; age determination; baculum; canid; *Canis lupus*; cementum annuli; Wisconsin

Introduction

Understanding the age structure of wildlife populations is central to many monitoring and management programs (Mills 2013). Information on the age or age structure of a population can be used to assess numerous factors, such as population growth rates and trajectories (Skalski *et al.* 2011), harvest dynamics (Jensen 2000), and survival rates (Udevitz and Ballachey 1998). Numerous techniques exist for estimating the age of animals including patterns of tooth wear (Gipson *et al.* 2000), tooth replacement (Severinghaus 1949), and morphometrics (Brooks *et al.* 1998).

For harvested species, age-structure information is most commonly estimated by laboratory analysis of cementum annuli rings (Ballard *et al.* 1995). Although considered one of the most reliable methods available to age wolves (Landon *et al.* 1998; Gipson *et al.* 2000), accuracy is limited to 80–90% because of irregular and indistinct annuli (Matson's Laboratory 2016). In addition, its application may be hindered by the expensive and time-consuming process of exporting samples for professional laboratory analysis. Wildlife managers could greatly benefit from approaches that allow rapid age assessment in a more cost-effective and timely manner.

Thus, our objective was to determine whether we could accurately estimate the age of male Gray Wolves (*Canis lupus*) in Wisconsin based on baculum morphometrics. We were particularly interested in developing a statistical model of wolf age that would not rely on the subjective nature of age determination based on inspection of tooth wear and staining patterns (e.g., Landon *et al.* 1998). The baculum is a bone found in the penis of canids and many other mammals that, for example in marine mammals, has been shown to exhibit distinct growth patterns that can serve as a useful predictor of age (Stewardson *et al.* 2010).

Methods

We collected samples from 59 male wolves harvested by trapping or hunting in Wisconsin during the 2012–2013 and 2013–2014 seasons between 15 October and 23 December. Three wolves incidentally collected by the Wisconsin Department of Natural Resources (one roadkill collected in November 2013 and two illegally killed wolves seized in May and November 2012) were also included in the analysis.

We extracted a premolar tooth and removed the baculum from each wolf ($n = 62$). Teeth were aged by cementum annuli analysis at a commercial laboratory (Matson's Laboratory, Manhattan, Montana, USA). Bacula were processed by simmering for 12–24 h in water to remove fur and flesh. They were subsequently soaked in soapy water for approximately seven days, placed in a drying oven for 2 h, soaked again in soapy water for 2–3 days, and air dried at room temperature for 24 h. They were then soaked in hydrogen peroxide for 2–3 days and air dried for 24 h. Bacula were weighed on an Ohaus Explorer digital scale (± 0.01 g precision; Ohaus Corporation, Parsippany, New Jersey, USA), and length and width were measured with calipers (± 0.01 cm precision).

We used two approaches to relate baculum morphometrics to wolf age determined by cementum annuli. First, we developed a multiple regression model of age that included both baculum length and weight as covariates. We evaluated the support of alternative models that included only one of the two covariates using the Akaike information criterion (Burnham and Anderson 2002). Second, we collapsed estimated ages into three developmental age classes (pup < 1 year, yearling ≥ 1 year to < 2 years, and adult ≥ 2 years) that are often used in demographic modeling of canids (Webb *et al.* 2011). We then developed a multinomial model of age classes, again using both baculum length and weight as covariates and a model selection framework for determining the support of reduced models. We evaluated model predictions of absolute ages and age classes based on analyses of cementum annuli. Statistical analyses were conducted using R version 0.97.551 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Samples were assessed from 62 wolves ranging in age from zero to five years; they included 34 pups, 15 yearlings, and 13 adults. Mean age based on cementum aging was 0.90 (standard error [SE] 0.17) years. Mean baculum length and weight was 8.98 (SE 0.16) cm and 1.88 (SE 0.16) g, respectively (Table 1).

Our best multiple regression model, according to our model selection criteria, had moderate predictive power (R^2 0.57) and included only weight as a covariate (β_w 0.83, t 9.10, $P <$ 0.01). This model generally under-predicted the age of wolves, particularly older wolves (Figure 1). Post-hoc visual inspection of diagnostic plots for this model suggested minimal departures from constant variance, with no points exhibiting excessive leverage based on Cook's distance.

As with our linear regression model, our best multinomial model also included only baculum weight (g) as a covariate (Table 2). This model assigned the correct age class to five of 13 adults, eight of 15 juveniles, and 33 of 34 pups, a total success rate of 75.8% among all wolves in our sample (Figure 2).

TABLE 1. Weight and length of harvested Gray Wolf (*Canis lupus*) bacula collected in 2012–2014 in Wisconsin. Age class determination was based on a multinomial model.

	Baculum weight, g			Baculum length, cm		
Age class	Minimum	Maximum	Mean (SE)	Minimum	Maximum	Mean (SE)
All	0.48	5.55	1.88 (0.16)	6.25	12.83	8.98 (0.16)
Pup	0.48	2.10	0.95 (0.08)	6.25	9.99	7.80 (0.17)
Yearling	1.62	3.91	2.73 (0.18)	9.14	11.48	10.24 (0.17)
Adult	2.30	5.55	3.33 (0.27)	9.58	12.83	10.62 (0.27)

Note: SE = standard error of the mean.

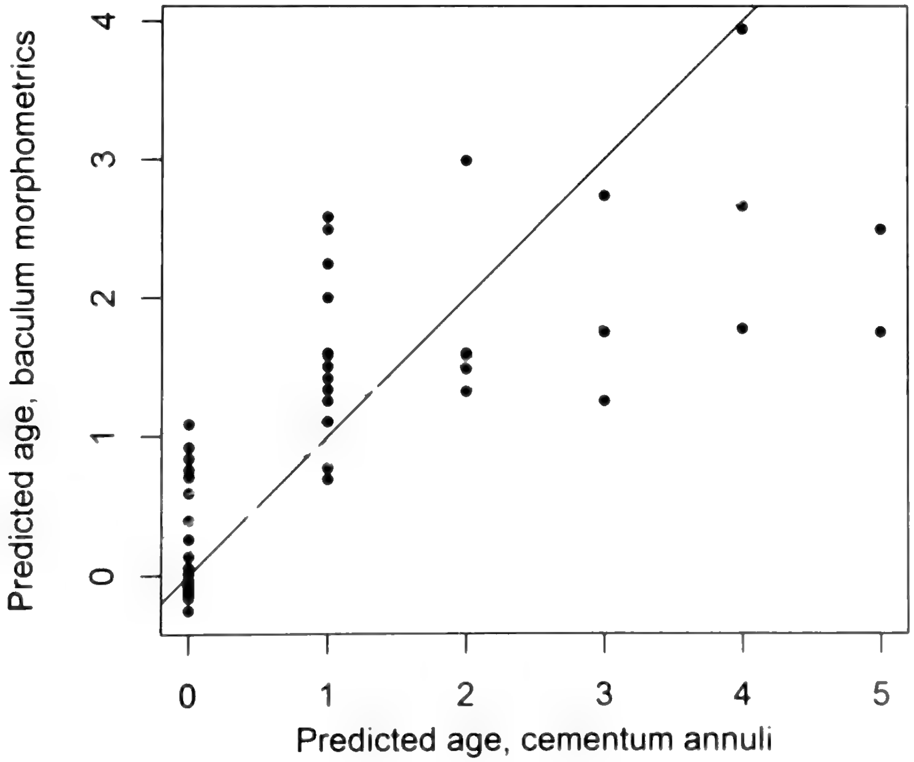
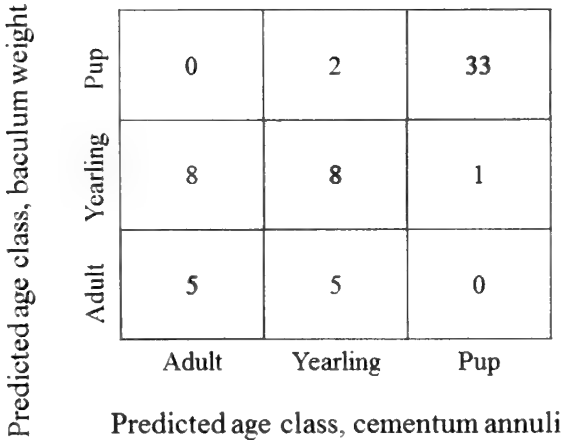


FIGURE 1. Scatterplot of estimated Gray Wolf (*Canis lupus*) ages, in years, based on cementum annuli (x axis) and baculum length and weight (y axis) of samples collected in Wisconsin, 2012–2014. The black line indicates concordance between the two approaches. The gray line indicates the predicted trend relation between the two approaches based on a linear model, while the dashed lines indicate 95% prediction intervals.

TABLE 2. Multinomial model results of baculum morphometrics based on baculum weight (g) collected from Gray Wolves (*Canis lupus*) harvested in 2012 2014 in Wisconsin.

	Intercept		Weight	
Class	β (SE)	*P*	β (SE)	*P*
Juvenile	2.94 (1.66)	0.040	−0.93 (0.54)	0.040
Pup	14.21 (4.29)	> 0.001	−6.68 (2.14)	0.001

Note: SE = standard error of the mean.



Predicted age class, baculum weight	Adult	Yearling	Pup
Pup	0	2	33
Yearling	8	8	1
Adult	5	5	0

FIGURE 2. Predicted age class of Gray Wolf (*Canis lupus*) samples collected in Wisconsin, 2012–2014, based on baculum weight (g) versus predicted age class based on cementum annuli analysis. Gray boxes indicate concordance between the two approaches. Sample sizes were 34 pups, 15 yearlings, and 13 adults.

Discussion

We found that we could fairly accurately classify wolf pups using baculum length and weight, but we were unable to assign correct ages to adults and yearlings. Our more accurate classification of pups was similar to the finding of a previous study of pinniped ages and baculum development, where classification of individuals that had not yet reached breeding status was more accurate than for individuals that had already reached breeding status (Stewardson *et al.* 2010). This is likely because baculum development occurs rapidly during the period in which an animal matures sexually, but is relatively limited during earlier developmental stages, making those early developmental stages easier to identify. Although for some species the binary distinction between sexually mature and immature may be sufficient for population modeling efforts (Skalski *et al.* 2005), we consider this to be a drawback of using baculum morphometrics to estimate age structure in wolves. However, it should be noted that the cementum annuli approach, to which we were comparing our results, is known to have somewhat limited accuracy for classification of wolves as well, particularly older age classes (Gipson *et al.* 2000). Thus, our measures of accuracy should be interpreted with caution, as the true ages of our samples were unknown.

Several methods exist for estimating the age of wolves, with varying levels of accuracy and precision (Gipson *et al.* 2000; Mech 2006). The use of baculum to age wolves appears to be sufficient for pups; however, the precision of our approach is limited for yearlings and adults. Perhaps the predictive ability for older wolves could be improved with a larger sample size or by including additional baculum measurements (e.g., diameter and mass) that have shown strong relation to animal age in other species (Miller *et al.* 1999; Dyck *et al.* 2004). However, at present we cannot recommend this baculum aging technique as an improvement over other established aging methods.

The proposed benefits of baculum aging are that measuring and weighing bacula can be completed in a more timely and cost-effective manner than sending samples for cementum analyses at commercial laboratories, and it requires minimal training. Although these benefits could assist management agencies that use age-structure information in monitoring wildlife populations (Skalski *et al.* 2005), the underwhelming accuracy of this approach precludes our recommendation for future use. Further, it is limited to dead male wolves. There remains a need for a wolf-aging technique that is both quantitative and easy to use by various personnel (unlike tooth-wear analysis) and can be applied to either sex and to live or dead wolves. For harvested animals, such an approach should also preserve the inherent trophy value of the skull, which is compromised by the removal of a tooth for cementum analysis.

Acknowledgements

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Known Range Expansion and Morphological Variation in the Southern Flying Squirrel (*Glaucomys volans*) in Quebec

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New records of the Southern Flying Squirrel (*Glaucomys volans*) in Quebec expand its known range in the province 150 km east to the Appalachian foothills and farther west than previously assumed. We obtained individuals through live trapping, trapper collaboration, and opportunistic discoveries. Species identification was confirmed with morphological traits and molecular analysis. Individuals were smaller in the eastern part of the province in terms of mass, total length, and tail length. Some live captures also seem to corroborate the fact that Southern Flying Squirrels are mainly associated with mature hardwood forests.

Key Words: Southern Flying Squirrel; *Glaucomys volans*; range expansion; habitat; morphology

De nouvelles mentions du petit polatouche (*Glaucomys volans*) au Québec permettent d'étendre son aire de répartition connue jusqu'à 150 km à l'est dans les contreforts des Appalaches et plus à l'ouest que présumé. Les spécimens ont été obtenus via des captures vivantes, la collaboration des trappeurs et des découvertes opportunistes. L'identification de l'espèce a été confirmée sur des bases morphologiques et moléculaires. Les individus étaient plus petits dans l'est de la province en considérant la masse, la longueur totale et celle de la queue. Les quelques captures d'animaux vivants semblent corroborer que le petit polatouche est davantage associé, au niveau de l'habitat, aux peuplements de feuillus matures.

Mots clés : Petit polatouche; *Glaucomys volans*; expansion; habitat; morphologie; répartition

Introduction

The genus *Glaucomys*, which belongs to the flying squirrel tribe (Pteromyini, family Sciuridae), is found in North America, including Mexico and some parts of Central America (Arbogast 2007). The two species of this genus are the Southern Flying Squirrel (*G. volans*) and the Northern Flying Squirrel (*G. sabrinus*). The latter is widespread in Canada, with its range extending to the northern tree line (Wells-Gosling and Heaney 1984). In contrast, a review of the status of the Southern Flying Squirrel (COSEWIC 2006) identified two distinct populations in Canada: the Great Lakes Plains population in Ontario and Quebec and the Atlantic (Nova Scotia) population. Although the status of both was assessed as "not at risk" (COSEWIC 2006), in Quebec, *G. volans* is classified as "susceptible to being designated threatened or vulnerable" under the provincial act on threatened or vulnerable species (MFFP 2001). The known range of *G. volans* in Quebec is limited to small parts of the Outaouais, Laurentides, and Montérégie regions (Dolan and Carter 1977; MFFP 2001; COSEWIC 2006). South of the Canada–United States border, *G. volans* is present in the New England states (Cameron 1976; Weigl 1978; Fridell and Litvaitis 1991; Stapp and Mautz 1991); however, according to J. Litvaitis, its presence in the north of these states, closer to Quebec, is uncertain (COSEWIC 2006: 9). Nevertheless, members of the Committee on the Status of Endangered Wildlife in Canada believed it was "likely present" in the Estrie region, as far east as Sherbrooke and Mont-Mégantic (COSEWIC 2006).

A few studies describe *G. volans* habitat in temperate zones outside of Quebec. The species is associated with old-growth deciduous or mixed forests, containing mast-producing trees (Weigl 1978; Taulman 1999; Lavers 2004). Younger forests (< 40 years) and pine plantations are avoided (Taulman 1999; Taulman and Smith 2004), but Holloway and Malcolm (2007) found higher *G. volans* densities in logged sites (which presumably have more abundant mast) than in old forest in Algonquin Park, Ontario.

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The main objective of our study was to update the range of *G. volans* in Quebec. Given the little effort devoted to the study of this species in the past, it is essential to report a more accurate distribution and possible connections with nearby populations and, eventually, clarify the species' status. We also wanted to verify, within the context of our study, the assumption that *G. volans* is associated with mature deciduous forests. Taking advantage of the specimens at hand, we documented phenotypic variation in *G. volans* based on four morphological traits, because morphological data from Quebec specimens of *G. volans* have yet to be collated and published. Species identification was further confirmed by genetic analyses.

Methods

Live captures

Trapping periods were from 30 October to 18 November 2013 and from 18 August to 8 October 2014. Four sites were explored, one in eastern Montérégie and three in Estrie: Parc national de la Yamaska (45°26'N, 72°34'W), Sherbrooke (45°25'N, 71°54'W), Kingsbury (45°35'N, 72°09'W), and Johnville Bog and Forest Park (45°21'N, 71°45'W). We developed and followed a standard protocol available from the Ministère des Forêts, de la Faune et des Parcs du Québec (MFFP; Tessier *et al.* 2015). The goal was not to estimate density from captures; thus, we targeted groups of trees or single trees that offered potential for capture based on criteria described in the literature (i.e., large or decaying trees, dense and connected canopy), but we also explored various types of stands with different species composition and age structure.

Tomahawk traps, models 102, 103 and 202 (Tomahawk Live Trap, Hazelhurst, Wisconsin, USA) were placed at stations about 30 m apart. Horizontal wooden platforms were installed 1.5–2 m above ground on trees with a diameter at breast height of at least 38 cm and attached to the trunk using 122-cm tie-wraps. Traps were placed on the platforms and covered with a corrugated plastic shell, leaving the main opening free. These covers protect the trapped animal from bad weather and limit escape attempts that may cause injuries. Traps and covers were fixed in place using bungee cords. A handful of cotton wool was put in the back of each trap as insulation for the animals; it was changed after each capture. Bait consisted of a piece of apple with a half-teaspoon of peanut butter. Traps were pre-baited a week in advance to allow animals to become familiar with them before trapping began (Rodas *et al.* 2009).

During trapping periods, traps were visited every day. We opened them within 2 h before sunset and verified and closed them within 2 h after sunrise; thus, traps were inactive during the day. Two people were needed to facilitate handling. After transferring an animal to a fabric bag, we obtained a tissue sample, marked the squirrel with an ear tag or, temporarily, by cutting hair on the back, weighed it with a 100-g or 300-g Pesola balance (Pesola, Schindellegi, Switzerland), and identified it from ventral hair. Tissue samples were taken from the ear with a sterilized 3-mm punch and immediately put into 95% alcohol.

Between 17 and 40 traps were set simultaneously at a given site. Sampling effort totalled 1540 trap nights. We trapped from seven to 10 days at each site. One site, Johnville Bog and Forest Park, was visited both years, and many locations were explored within the park. The Kingsbury site had been sampled in 2012 (Bourgouin *et al.* 2012) with a similar method.

Trapping and handling were in accordance with a scientific permit and an animal care certificate provided by MFFP for each trapping season.

Trappers' accidental catches

In 2010, the MFFP solicited participation by trappers throughout the province, and this collaboration has been renewed in each subsequent trapping season. Trappers participated by sending us the carcasses of flying squirrels accidentally caught in their traps. These quick killing traps were set primarily to capture American Martens (*Martes americana*) during the commercial fur trapping season, mainly in November and December.

Morphological identification

Morphological identification was based on three criteria. First, the hairs on the belly of *G. volans* are completely white, from base to tip (Dolan and Carter 1977), whereas the ventral hairs of *G. sabrinus* are grey at the base and white at the tip (Wells-Gosling and Heaney 1984; Dolan and Carter 1977). Second, the species differ in mass: *G. volans*, 46–85 g; *G. sabrinus*, 95–110 g (Dolan and Carter 1977; Jeff Bowman, personal communication). Third, total length is 198–255 mm for *G. volans* and more than 260 mm for *G. sabrinus* (Dolan and Carter 1977; Hall 1981). Therefore, to identify specimens and document phenotypic variation, four morphological traits were measured: total length (nose to end of tail), tail length, hind foot length, and mass. Lengths were measured with a simple ruler and weight was obtained with an electronic balance (Scout Pro, SP401, Ohaus Corp., Parsippany, New Jersey, USA). Each trait was separately compared between sexes and regions using non-parametric Kruskal-Wallis tests.

Genetic identification

The two species of flying squirrels can also be distinguished based on molecular criteria (Arbogast *et al.* 2005; Rogic *et al. in press*). With the simple morphological identification process, there is a risk of confusion between *G. volans* and juvenile *G. sabrinus*. Some carcasses were also in bad condition and were harder to identify. In addition, there is no unequivocal way to identify hybrids (Garroway *et al.* 2010). In such cases, genetic analyses with species-specific primers can confirm the species identity.

DNA was extracted from tissue samples using quick lysis (Olsen *et al.* 1996). For each sample, we amplified three specific primers: two for the cytochrome B

(Cytb) mitochondrial gene and one for the cannabinoid receptor type 1 (CNR1) nuclear gene. Polymerase chain reaction (PCR) was done in 10 μL containing 100–250 ng of DNA extract, 1× reaction buffer, 2.5 mmol/L $MgCl_2$, 0.25 mmol/L of each dNTP, 0.6 μmol/L of each primer, 0.5 U (1 U ≈ 16.67 nkat) Taq polymerase, and 6.74 μL sterile water. Amplification was done using a GeneAmp PCR System 9700 thermal cycler (Applied Biosystems now part of Thermo Fischer Scientific, Waltham, Massachusetts, USA) programmed with an initial denaturation at 94°C over 120 s, followed by 12 cycles of 30 s at 94°C, 30 s at 55°C (reduction of 1°C/cycle), and 40 s at 72°C. The second step consisted of 25 cycles of 30 s at 94°C, 30 s at 50°C, and 40 s at 72°C. Final extension lasted 600 s at 72°C. A mix of bromophenol blue and SYBR Green I nucleic acid gel stain (Invitrogen Inc., Burlington, Ontario, Canada) was added to the PCR product and migrated on 2% agarose gels. Amplification success was visualized with an ultraviolet lamp. These techniques can identify first-generation hybrids. In this case, hybrids can be genotyped using microsatellites SF-15 where two discriminant alleles could be observed. These methods are described in Rogic *et al.* (*in press*).

Results

Glaucomys volans was found in Estrie (n = 13), Montérégie (n = 9), and Outaouais regions (n = 73); the city of Sherbrooke is now the easternmost location reported for this species in Quebec (Figure 1). The western limit of the species has also expanded from the previous known range based on confirmation of *G. volans* being trapped at many locations in the Lac-Nilgaut area.

All live captures (n = 10) occurred in Estrie (nine in Kingsbury and one in Sherbrooke). The relative abundance of *G. volans* and *G. sabrinus* in live captures is shown in Table 1. No live captures occurred in Parc national de la Yamaska and only *G. sabrinus* was trapped in Johnville.

The distribution of *G. volans* and *G. sabrinus* differed in relation to stand type (Fisher's exact test, $P < 0.001$). Although *G. sabrinus* was captured alive in various stand types (uneven-aged deciduous n = 2, uneven-aged mixed n = 12, even-aged coniferous n = 4), all our *G. volans* live captures occurred in uneven-aged deciduous forest stands.

In all, 759 dead flying squirrels were submitted, the vast majority coming from trappers' accidental catches with a few opportunistic finds of citizens. Of the catch-

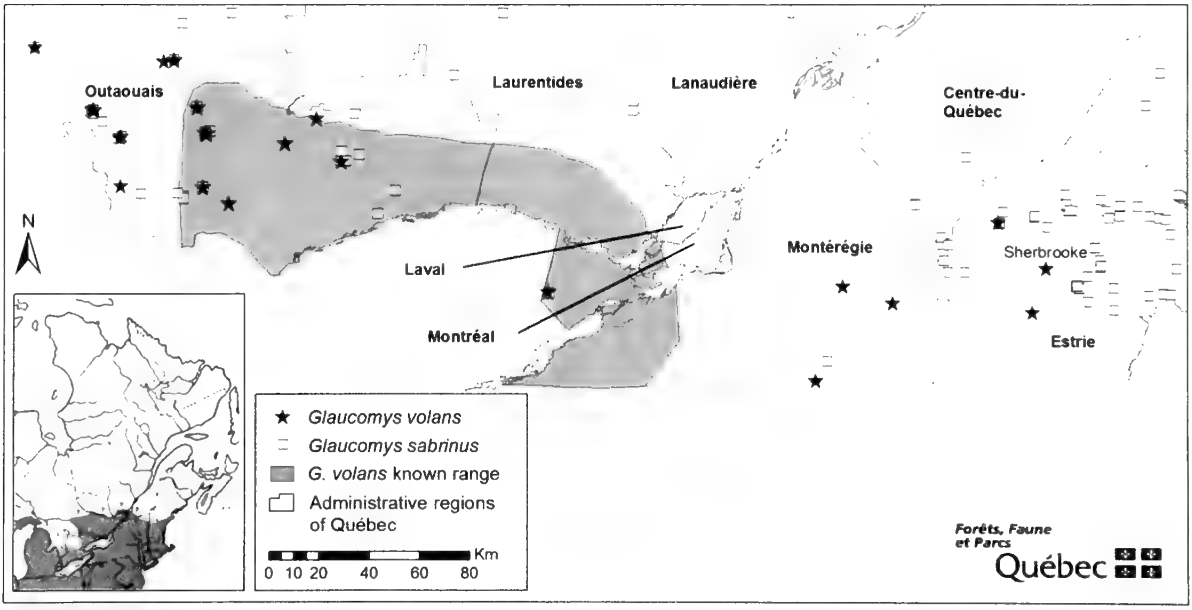

FIGURE 1. Current known range of the Southern Flying Squirrel (*Glaucomys volans*) in Quebec and locations of Southern (black stars) and Northern (*G. sabrinus*; grey squares) Flying Squirrels captured from 2009 to 2015. Inset map shows distribution of the Southern Flying Squirrel in the northeast part of its range (COSEWIC 2006).

TABLE 1. Relative abundance of Southern (*Glaucomys volans*) and Northern (*G. sabrinus*) Flying Squirrels at four sites in southern Quebec based on live-trapping effort (2013–2014).

Location	Trap nights	*G. volans* per 100 trap nights	*G. sabrinus* per 100 trap nights
Parc nationale de la Yamaska	210	0.00	0.00
Sherbrooke	169	0.59	0.00
Kingsbury	398	2.26	0.25
Johnville Bog and Forest Park	763	0.00	1.57

es, 11% ($n = 85$) were confirmed to be *G. volans* (see Table 2 for a breakdown by region). Measurement of 71 squirrels produced the following means (± standard deviation): mass 65 ± 11 g, total length 231 ± 14 mm, tail length 100 ± 7 mm, and hind foot 31 ± 2 mm. It was not possible to measure all four variables on all individuals. No significant differences were detected between males and females for the four variables tested (mass $\chi^2 = 3.78$, $P = 0.052$; total length $\chi^2 = 2.07$, $P = 0.150$; tail length $\chi^2 = 0.39$, $P = 0.531$; and hind foot $\chi^2 = 0.40$, $P = 0.525$). On the other hand, regional differences were detected for total length ($\chi^2 = 6.39$, $P = 0.041$), tail length ($\chi^2 = 9.07$, $P = 0.011$), and mass ($\chi^2 = 9.94$, $P = 0.007$). Comparing mean values between regions revealed that *G. volans* from Outaouais were 24% heavier (67 ± 10 g versus 54 ± 11 g), 19% longer (233 ± 12 mm versus 195 ± 7 mm), and had 12% longer tails (101 ± 7 mm versus 90 ± 12 mm) than those from Estrie. In contrast, hind foot length was constant throughout the regions ($\chi^2 = 1.59$, $P = 0.450$). Morphological identification was effective and reliable for the most part and showed concordance with genetic identification 297 times out of 301.

Table 2. Number of dead Southern (*Glaucomys volans*) and Northern (*G. sabrinus*) Flying Squirrels submitted from 10 administrative regions of Quebec (2010–2014).

Region	*G. volans* (%)	*G. sabrinus*
Abitibi-Témiscamingue	0 (0.0)	31
Bas-Saint-Laurent	0 (0.0)	10
Capitale-Nationale	0 (0.0)	12
Chaudière-Appalaches	0 (0.0)	7
Côte-Nord	0 (0.0)	16
Estrie	3 (1.7)	177
Laurentides	0 (0.0)	103
Mauricie	0 (0.0)	1
Montérégie	9 (45.0)	20
Outaouais	73 (24.6)	297

Genetic identification was performed on a subset of 369 squirrels. After Cytb multiplex amplification, the presence of a single band at 408 bp indicated that the sample was that of *G. volans*. The presence of two bands, a standard one at 408 bp and a small specific band at approximately 104 bp, revealed the sample to be that of *G. sabrinus*. For the CNR1 multiplex amplification, the presence of a band at 208 bp designates an individual as *G. sabrinus*; *G. volans* amplifies the standard band at 466 bp but lacks the 208 bp band. Of the 369 samples, 54 were identified as *G. volans* and 315 as *G. sabrinus*. Three of these specimens were morphologically misidentified as *G. volans* when they were in fact *G. sabrinus*. Furthermore, our genetic methods helped resolve the identification of 16 carcasses, whose morphological measurements were incomplete and, thus, unidentifiable without genetic methods. The results obtained for both mitochondrial and nuclear DNA for each individual were congruent, suggesting that no F1 hybridization was apparent within our dataset.

Discussion

The new range of *G. volans* in Quebec extends to Sherbrooke and North Hatley, 150 km east of the previous known range and farther into the range of *G. sabrinus*. There is also evidence that the range has expanded by at least 60 km west of the current limit in the Outaouais region. Since the first discovery of *G. volans* in Quebec (Youngman and Gill 1968), near Gatineau, Outaouais, it has been unclear whether its range expansion is real or simply an artifact of limited sampling efforts. Although limited sampling might explain some of our discoveries, expansion of *G. volans*' range has been documented in Ontario and Michigan (Bowman *et al.* 2005; Myers *et al.* 2009), and expansion could also be occurring in Quebec. However, as stated by Bowman *et al.* (2005), the northern edge of *G. volans*' range is dynamic and could contract if harsh conditions, such as cold temperatures and reduced mast crop, affect the region and slow the long-term expansion of the species.

This update on the range of *G. volans* in southern Quebec shines a new light on potential links with populations in neighbouring provinces and states. It seems plausible that a more or less continuous distribution from Outaouais to Estrie contributes to maintain a stronger connection between the Great Lake Plains population and the one in the Appalachian forests of New England. The possibility that there is a link with the Atlantic population remains weak despite this expansion, as that population is isolated by the geographic bottleneck effect of the Chignecto isthmus, and *G. volans* is considered absent from this area, despite reported search efforts (COSEWIC 2006; Lavers *et al.* 2006).

At the habitat level, our results are in line with previous studies that showed that *G. volans* is mostly dependent on deciduous forests with mast-producing trees (Weigl 1978; Taulman 1999; Lavers 2004; Taulman and Smith 2004) and that *G. sabrinus* is more of a generalist (Weigl 1978, 2007; Trudeau *et al.* 2011). However, our sampling method was biased toward what we deemed to be good habitat for flying squirrels, and our limited sample size is not enough to confirm a species-related preference in our study area. This information would be useful for the management of deciduous forests because *G. volans* could be used as an indicator species in studying the impact of timber harvest in the southern part of the province. The use of flagship species is one of the tools used by the MFFP to achieve their goal of sustainable management of natural resources.

Morphologically, all measurements of *G. volans* caught in Quebec fall within the range reported in Dolan and Carter (1977), who also mention that sexual dimorphism is not conspicuous in this species. Three out of four measurements were significantly smaller in the eastern region of Estrie compared to the more western specimens. This trend makes sense when viewed in a larger context. Namely, comparing our results with those reported by Lavers (2004) revealed that *G. volans* in Quebec have longer tails (100 ± 7 mm) than those in Nova Scotia (81.1 ± 5.5 mm), but tail length is similar to those in Ontario (101 ± 9.1 mm). Specimens from Nova Scotia also weigh less (58 ± 7 g) than those from Quebec (64 ± 9 g), but are closer to the mean weight of our eastern specimens (54 ± 11 g). Data for *G. sabrinus* from the same regions present a similar longitudinal trend only in terms of tail length ($\chi^2 = 7.92$, $P = 0.019$). Tails of Outaouais specimens are approximately 3.7% (or 4 mm) longer than those of specimens from the other two regions (unpublished data).

In conclusion, we believe that the range of *G. volans* should be updated based on the results of our study. This information will also be useful when re-evaluating the species' status. Investigating *G. volans* abundance and population dynamics, not just presence or absence, is a further step to be taken toward a better understanding of the species' ecology. Its discovery in the same regions as *G. sabrinus* also opens up new possibilities for research on its ecological role, habitat use, and further range expansion in light of climate change.

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Note

Longevity and Mortality of Boreal Woodland Caribou (*Rangifer tarandus caribou*) of the Dehcho Region, Northwest Territories

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Larter, Nicholas C., and Danny G. Allaire. 2016. Longevity and mortality of boreal Woodland Caribou (*Rangifer tarandus caribou*) of the Dehcho region, Northwest Territories. Canadian Field-Naturalist 130(3): 222–223.

As part of an ongoing study of the ecology of boreal Woodland Caribou (*Rangifer tarandus caribou*), we investigated death sites of collared caribou to collect biological samples and determine a cause of death. The teeth collected from 25 adult females that had died since being radio collared were aged by cementum analysis. The age at death for one caribou was 22 years; this was only the second caribou tooth among 42 776 aged at a commercial laboratory found to be that old. An additional six of the 25 caribou were 13–17 years old at time of death. All but one of these seven female caribou had calved at least once during the period they were radio collared and monitored.

Key Words: Woodland Caribou; *Rangifer tarandus caribou*; Dehcho region; old age; cementum aging; Northwest Territories

As part of an ongoing study of the ecology of boreal Woodland Caribou (*Rangifer tarandus caribou*), female caribou have been captured and outfitted with satellite or Global Positioning System (GPS) radio collars since 2004. Collars deployed since 2005 have been outfitted with programmable mechanisms that release after four or five calving seasons. The movements and fate of collared females are monitored to estimate adult female survival, calf production, recruitment, and annual rate of population increase (Larter and Allaire 2015).

When collared animals die, we attempt to investigate as soon as possible to determine cause of death and collect teeth to establish an accurate age for the animal. However, our study area extends over some 80 000 km^2 of remote boreal forest in the Dehcho region of the southwestern Northwest Territories (Figure 1), which makes accessing death sites logistically challenging. Of the 67 deaths to date, 53 have been successfully investigated. Once we arrive at a death site, we attempt to collect any teeth associated with the caribou remains. We have located teeth at 25 of the 53 (47%) sites visited. These teeth were forwarded to a commercial laboratory (Matson's Laboratory, Manhatten, Montana) where they were aged by cementum age analysis (Matson 1981; Matson's Laboratory n.d.).

The caribou population of the Dehcho is subject to natural predation and subsistence harvest. Gray Wolves (*Canis lupus*), American Black Bears (*Ursus americanus*), Wolverines (*Gulo gulo*), and Canadian Lynx (*Lynx canadensis*) are potential predators. Wolf predation is suspected in the deaths of 41 collared caribou (61%), and American Black Bear predation is suspected in the death of one collared caribou (1%) in our study. Six of the 67 collared caribou (9%) that died were harvested. Every year, most female caribou in the study have successfully calved; the mean estimated annual female survival rate has been about 0.8. Low levels of common parasites and exposure to common diseases are not considered to be of significant concern (Johnson *et al.* 2010) to Woodland Caribou in this area; however, recently, evidence has been found of exposure to the bacterium *Erysipelothrix rhusiopathiae*, which has been implicated in caribou mortalities in northern British Columbia.

Of the 25 dead caribou for which we have recovered teeth, seven were 13 years or older, with the oldest aged 22 years. Based on mean adult female survival rate in this study, liberally, fewer than 1% of adult females in the population should reach 22 years. As of August 2016, 45 014 caribou teeth from North America have been aged by Matson's Laboratory, and only one other animal has been aged at 22 years: a caribou from Alaska, aged in 1989 (C. Nistler and G. Matson, personal communication). Wolf predation is the suspected cause of death for all seven long-lived caribou, possibly with old age being a factor. These seven animals were captured throughout the study area, two in the same group, and all but one had at least one calf during their final years.

What is significant about the oldest caribou is that she was captured and collared 27 months before her death, i.e., she was collared longer than any of the other long-lived caribou. She successfully bore calves at age 20 and 21 years, on 17 May 2013 and 16 May 2014, respectively. The calf born in 2013 did not survive to the following March but the calf born in 2014 did survive to March 2015. We were unable to determine whether the adult calved at 22 years.

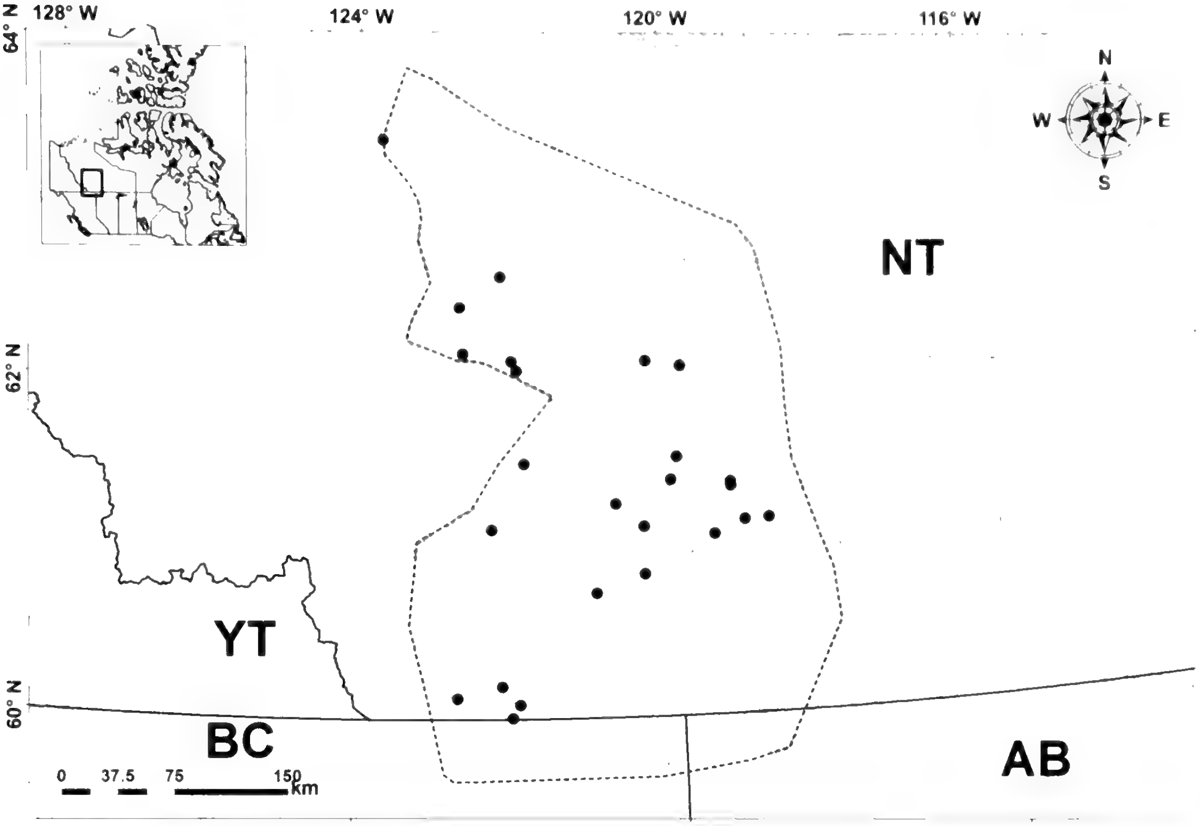

FIGURE 1. The area where collared boreal Woodland Caribou (*Rangifer tarandus caribou*) were located during this study. The 25 death sites where teeth were recovered are indicated with black dots (●). Note: AB = Alberta, BC = British Columbia, NT = Northwest Territories, YT = Yukon.

We would expect fewer caribou to become pregnant and bear calves as they age. Yet, all of the long-lived caribou that we could monitor during a calving period had calves. This implies a high pregnancy rate throughout their lifetime. A population with long-lived females that maintain high productivity would produce more calves over their lifetime, and the population would have more resilience to disturbance and change.

Acknowledgements

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Morphology and Timing of Spawning of Umatilla Dace (*Rhinichthys umatilla*) in the Slocan River, British Columbia

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Porto, Louise, and Crystal Lawrence. 2016. Morphology and timing of spawning of Umatilla Dace (*Rhinichthys umatilla*) in the Slocan River, British Columbia. Canadian Field-Naturalist 130(3): 224–230.

Umatilla Dace (*Rhinichthys umatilla*, Cyprinidae) are endemic to the Columbia River Basin. In Canada, this species is assessed as "threatened". Little is known about its life history, especially with respect to spawning in the wild. A total of 688 specimens were captured, including 39 mature males and females displaying spawning colouration and tubercles, during minnow trapping and electrofishing surveys conducted on the Slocan River in southern British Columbia, Canada. Fertilized eggs were not observed, but eggs and milt were expressed from ripe individuals. Spawning was estimated to occur from mid-July to mid-September. Aquatic macrophytes and flooded terrestrial vegetation were important habitat features for mature Umatilla Dace leading up to the spawning period on the Slocan River. To our knowledge this is the first time that Umatilla Dace have been captured in spawning condition and observed with spawning colouration and tubercles in the wild in Canada. Results of this study will aid the development of recovery plans and management for this species in British Columbia.

Key Words: Umatilla Dace; *Rhinichthys umatilla*; spawning morphology; spawning time; Slocan River; Species at Risk Act; special concern; threatened status

Introduction

Few studies have reported on dace spawning in the wild or under laboratory conditions, and those that exist have focused on widespread species, such as Longnose Dace (*Rhinichthys cataractae*; e.g., McPhail 2007), Western Blacknose Dace (*Rhinichthys obtusus*; Gibbons and Gee 1972), and Speckled Dace (*Rhinichthys osculus*; e.g., Kaya 1991).

In Canada, Umatilla Dace (*Rhinichthys umatilla*) are listed federally under the Species At Risk Act as "special concern" (SARA Registry 2016) although they were reassessed by the Committee on the Status of Endangered Wildlife in Canada in 2010 as "threatened" (COSEWIC 2010). Reasons for its designation as "threatened" included a limited distribution within a habitat extensively modified by hydroelectric development, climate change, water extraction, and aquatic invasive species. They are endemic to the Columbia River Basin and are thought to have habitat and spawning requirements similar to those of the more common Longnose Dace (Harvey and Brown 2011). However, in Canada, Umatilla Dace are present only in British Columbia and little is known about their life history, especially with respect to reproductive biology (Peden and Hughes 1988; Haas 2001; McPhail 2007; Harvey and Brown 2011; Dr. Brian Sidlauskas, personal communication). Previous studies in the Canadian Columbia Basin have reported Umatilla Dace from the lower portion of the Columbia River as well as in the Slocan River (McPhail 2007). As for many dace species, Umatilla Dace are sexually mature at age two years and spawning occurs in summer (Haas 2001; McPhail 2007). However, eggs have not been located in the wild and adult spawning characteristics within a natural setting have not been described.

General habitat use by Umatilla Dace has been examined. Adults are found in areas with large boulders, at depths greater than 1 m and bottom water velocities of 0.05 m/s (Peden and Orchard 1993; McPhail 2007). Juveniles are typically found in nearshore, shallow areas (10–70 cm deep) over large gravel or boulder substrates (McPhail 2007). The Umatilla Dace's spotty distribution, low abundance, and range fragmentation (by hydroelectric dams) make some populations vulnerable (McPhail 2007).

The objective of this study was to describe spawning morphology and timing of Umatilla Dace in a wild population within an unregulated river system. Information reported here was part of a larger study with multiple objectives conducted for BC Hydro (AMEC Environment & Infrastructure 2014) and may help conservation efforts to prevent extirpation of this species from the Canadian portion of the Columbia River Basin.

Study Area

The Slocan River in the southeast interior of British Columbia drains Slocan Lake and flows approximately 65 km south to join the lower Kootenay River (Figure

1). The Slocan River study area (AMEC Environment & Infrastructure 2014) encompassed approximately 44 km of river length from north of Winlaw to the confluence of the lower Kootenay River. Inflows to the study area are from tributaries, most notably the Little Slocan River. The Slocan River follows a sinuous pattern with peak freshet occurring in May or June and annual low flow through the fall and winter.

Methods

Sample sites and timing

Sites sampled on the Slocan River were approximately 100 m in length and varied in width depending on seasonal flows. Sampling was conducted over three years (2011–2013), with timing focused on the projected spawning and larval rearing period for Umatilla Dace (biweekly: July through September; McPhail 2007).

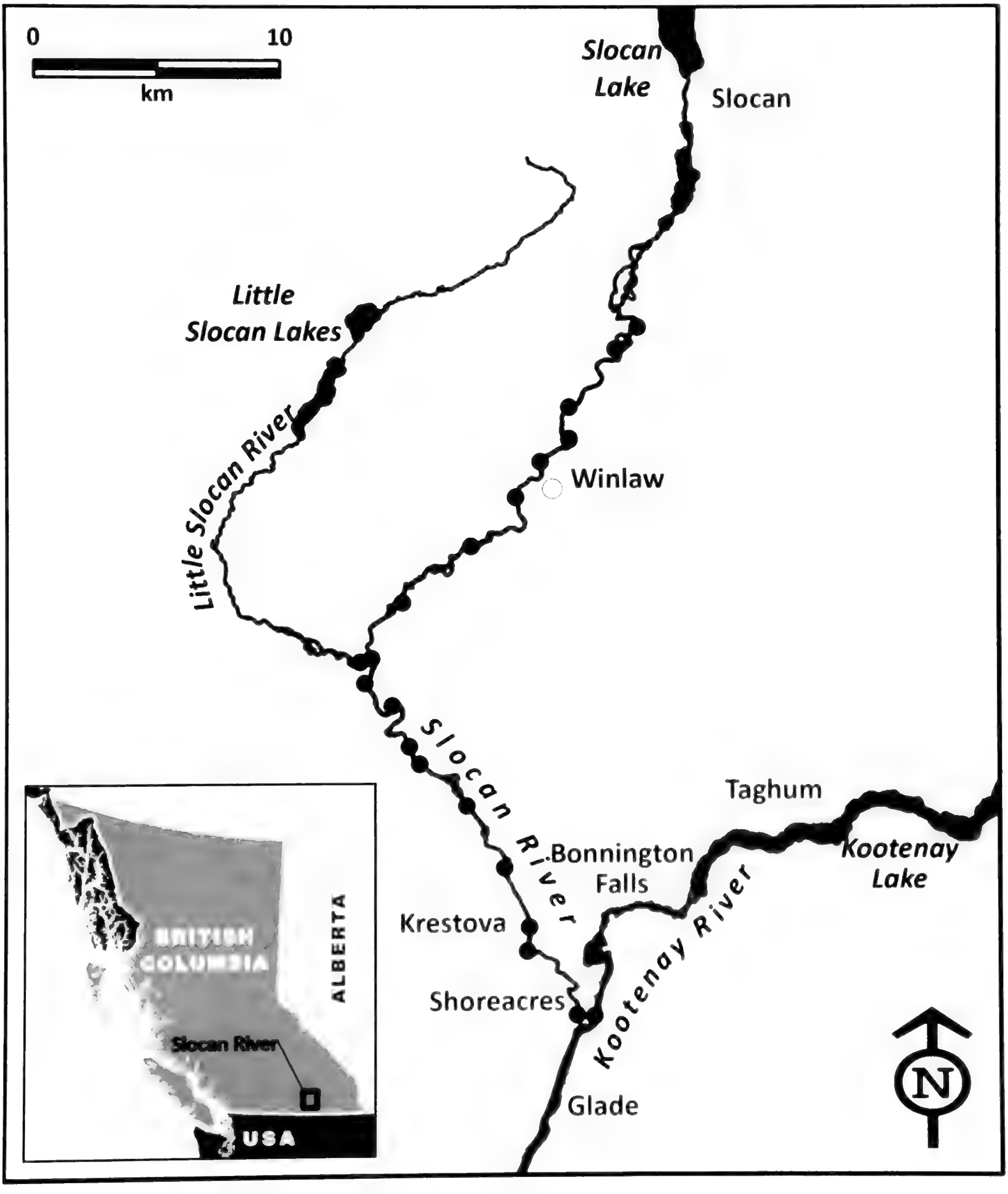

FIGURE 1. Overview of the Slocan River showing Umatilla Dace (*Rhinichthys umatilla*) sampling locations (black dots).

Capture methods

Sites were sampled repeatedly using a combination of backpack electrofishing and minnow trapping techniques (Murphy and Willis 1996). A total of 15.3 h of single-pass electrofishing was carried out in nearshore habitat at depths < 1.5 m and water velocities < 1.5 m/s. We also carried out 11 553 h of minnow trapping using Gee-40 (Tackle Factory, Fillmore, NY, USA) galvanized minnow traps (42 cm long and 19.5 cm diameter) baited with salmon roe wrapped in aluminium foil. Traps were set overnight for 16–24 h at depths of 0.1–5 m and water velocity < 1.0 m/s. The minimum girth of fish captured by minnow trap was limited by mesh size (0.64 cm) and the maximum girth was limited by the trap entrance (2.54 cm). Captured fish were identified, measured (fork length in mm), and inspected for sexual maturity.

Life stage and maturity

Captured Umatilla Dace were assigned a life stage (adult > 45 mm; juvenile 35–45 mm; young-of-the-year < 35 mm) based on life history characteristics (Haas 2001; McPhail 2007; Keeler *et al.* 2010; AMEC Environment & Infrastructure 2014). Maturity stage was also assigned to adults (Ricker 1971; McPhail 2007). Sexually mature adults displayed external characteristics including tubercles on their dorsal surface, colouration, and/or extrusion of gametes. Extruded eggs were qualitatively evaluated (for colour and size), with average egg diameter (to the nearest millimetre) recorded for four individuals.

Habitat use and environmental variables

Habitat measurements were taken at the point of fish capture: water depth (m), average column water velocity (m/s) taken at 60% depth, substrate type, percentage of substrate embedded within other substrates, as well as type and presence of vegetation (i.e., aquatic macrophytes, flooded terrestrial vegetation, woody debris). Substrate categories included silt (< 0.6 mm), sand (0.6–4 mm), gravel (>4–64 mm), cobble (>64–256 mm), or boulder (> 256 mm). Slocan River discharge records were obtained from the Water Survey of Canada gauge near Crescent Valley (station no. 08NJ013) and water temperature was collected at one index site by Hobo Tidbit v2 loggers (accuracy ± 0.2°C; Onset, Bourne, Massachusetts, USA), set to record water temperature every hour.

Spawning time

Spawning time was estimated based on the capture of sexually mature adults and the back-calculation of incubation times from the capture of young-of-the-year Umatilla Dace (Haas 2001; McPhail 2007). The incubation period for Umatilla Dace is 5–7 days at 18°C and eggs hatch over a two-day period (Haas 2001). Fry are 7 mm long at hatching, and emerge from the egg stage approximately one week later at 10 mm (McPhail 2007).

Results

In total, 688 Umatilla Dace were captured during this study, including 39 that were classified as mature. Other captured species are listed in Table 1.

Spawning observations

A total of 39 mature Umatilla Dace were captured by minnow trapping ($n = 38$) and backpack electrofishing ($n = 1$) in the Slocan River during this study (Table 2). Of these, nine were classified as male and six as female based on the expression of gametes (Table 2). Two other adults were classified as females based on swollen urogenital pores (see below). The remaining 22 fish were of unknown sex, but had external features suggesting that they may spawn or had spawned that season (Table 2).

Ripe males that expressed milt had orange colour on their lips and/or operculum as well as on their pectoral, pelvic, and/or anal fins and fin insertions (Figure 2). In addition to these traits, two mature males, captured 13 June and 9 July 2013, also had tubercles on scales above the lateral line.

TABLE 1. Total number of fish captured by species in the Slocan River, British Columbia, 2011–2013.

Common name	Scientific name	No. caught
Redside Shiner	*Richardsonius balteatus*	1306
Longnose Dace	*Rhinichthys cataractae*	832
Northern Pikeminnow	*Ptychocheilus oregonensis*	722
Torrent Sculpin	*Cottus rhotheus*	723
Umatilla Dace	*Rhinichthys umatilla*	688
Sculpin	*Cottus* sp.	491
Shorthead Sculpin	*Cottus confusus*	460
Sucker	*Catostomus* sp.	345
Rainbow Trout	*Oncorhynchus mykiss*	137
Prickly Sculpin	*Cottus asper*	53
Columbia Sculpin	*Cottus hubbsi*	28
Mountain Whitefish	*Prosopium williamsoni*	11
Dace	*Rhinichthys* sp.	7

TABLE 2. Fork length (mm) of mature male and female Umatilla Dace (*Rhinichthys umatilla*) captured in the Slocan River, British Columbia, 2011–2013.

Sex	Sample size	Fork length (mm) Mean ± SD	Fork length (mm) Range
Female	8	95 ± 7	87–110
Male	9	82 ± 9	70–93
Unknown	22	77 ± 11	55–96
Total	39	82 ± 12	55–110

Note: SD = standard deviation.

External characteristics of ripe females expressing eggs included red colouration on lips and pelvic and pectoral fin insertions (Figure 2). One of these females also had tubercles on scales above the lateral line. However, one female, captured on 17 July 2013, did not have tubercles or display any red colouration, but expressed three eggs that were opaque white and 1 mm in diameter. One female displaying red pigment on the upper lip had eggs that were either opaque and 1 mm in diameter or yellow and 1.3–1.5 mm in diameter. A spent female, captured on 12 August 2013, displayed tubercles on scales above the lateral line and red colour on the snout; this fish had a soft, hollow abdomen and expressed only two eggs (non-described), suggesting spawning was complete. Two females, captured on 7 September 2011 and 13 August 2013, had slight red colouration on their lips and did not express eggs, but had flaccid abdomens and swollen urogenital pores and were likely spent. Fertilized eggs were not observed during this study.

Unidentified young-of-the-year dace were observed in the Slocan River in early August, but their small size (< 18 mm fork length) confounded identification to the species level. Confirmed young-of-the-year Umatilla Dace were observed beginning in September through October during all three study years.

Spawning habitat

Mature Umatilla Dace were captured at depths of 0.2–1.5 m and average column velocities of 0–0.3 m/s over silt substrates associated with aquatic macrophytes and flooded terrestrial vegetation and, to a lesser degree, over silt and cobble substrates without vegetation (Table 3). Males were not captured at sites with flooded vegetation, whereas females were equally captured at sites with flooded vegetation and with aquatic macrophytes (Table 3).

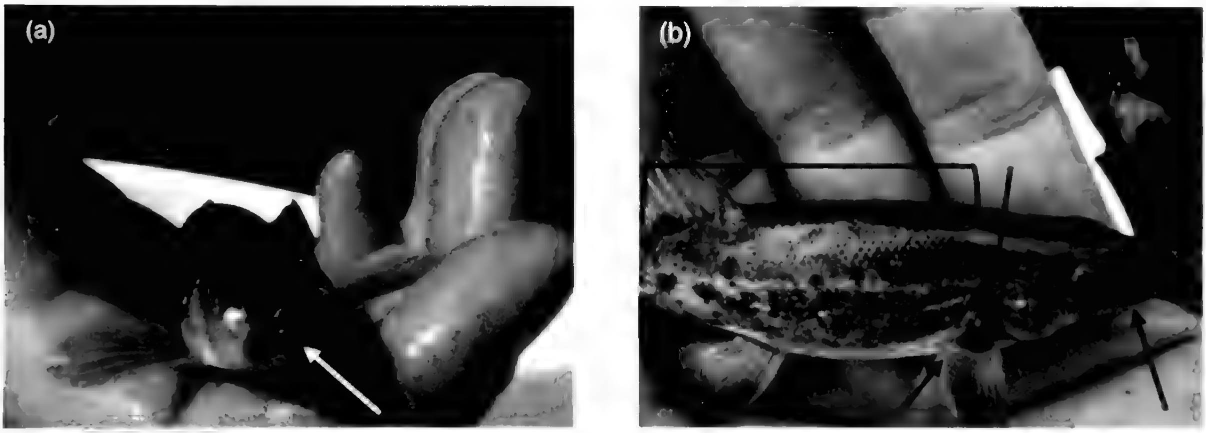

FIGURE 2. Sexually mature Umatilla Dace (*Rhinichthys umatilla*) observed on the Slocan River, British Columbia. Female (a) with red pigment on lips and snout (white arrow) observed on 9 August 2011 and male (b) with orange pigment on lips, pectoral fin insertions, operculum (black arrows), and tubercles (black bracket) on dorsal surface observed on 14 June 2013. Photos: L. Porto.

TABLE 3. Habitat characteristics at minnow trap locations* where mature Umatilla Dace (*Rhinichthys umatilla*) were captured in the Slocan River, British Columbia, 2011–2013.

Sex	Sample size	Water depth (m) Mean ± SD	Water depth (m) Range	Water velocity (m/s) Mean ± SD	Water velocity (m/s) Range	Substrate composition (% of total) Aquatic macrophytes	Substrate composition (% of total) Flooded terrestrial vegetation	Substrate composition (% of total) Silt	Substrate composition (% of total) Cobble
Female	8	0.7 ± 0.3	0.3–1.0	0.07 ± 0.12	0.0–0.3	38	38	12	12
Male	9	0.6 ± 0.3	0.2–1.2	0.03 ± 0.07	0.0–0.2	67	0	33	0
Unknown	21	1.0 ± 0.4	0.2–1.5	0.01 ± 0.02	0.0–0.1	43	38	19	0
Total	38	0.8 ± 0.4	0.2–1.5	0.02 ± 0.07	0.0–0.3	29	47	21	3

Note: SD = standard deviation.

* Habitat data were not recorded for the single mature Umatilla Dace captured by electrofishing.

Spawning time

The estimated spawning period for Umatilla Dace extends from early July to mid-September when water temperatures are between 10°C and 21°C soon after peak freshet on the Slocan River (Figure 3). Peak spawning may occur between 16°C and 21°C based on the presence of ripe fish.

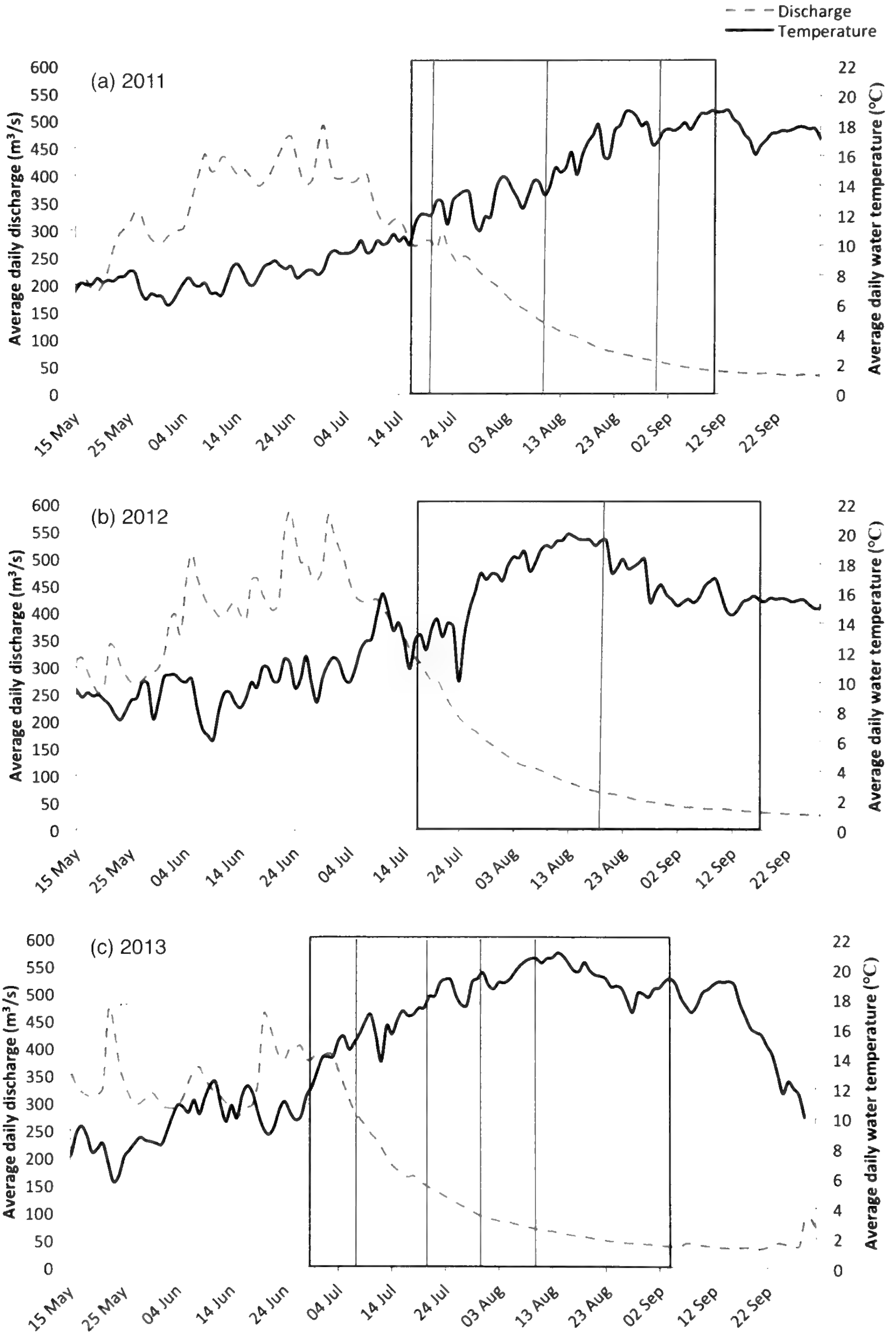

FIGURE 3. Discharge volume, water temperature, and estimated spawning period (boxes) for Umatilla Dace (*Rhinichthys umatilla*) in the Slocan River, British Columbia, in (a) 2011, (b) 2012, and (c) 2013. Red vertical lines within the boxes represent dates when ripe individuals were collected.

Discussion

To our knowledge, this is the first time that the Umatilla Dace has been captured in spawning condition and observed with spawning colouration and tubercles in the wild in Canada (D. McPhail, personal communication). Males in spawning condition displayed orange pigmentation on their lips and/or operculum as well as on their pelvic, pectoral, and/or anal fin insertions, and many expressed milt when slight pressure was applied to their abdomen. Females in spawning condition displayed bright red colouration on their lips, snout, pectoral, and or pelvic fin insertions, and some females with these characteristics also expressed eggs. Spawning tubercles were observed on mature males (22%) and females (25%). Development of dorsal tubercles and red-orange colouration observed on mature Umatilla Dace are not uncommon features for dace species in spawning condition (i.e., Longnose Dace; McPhail 2007), but these characteristics have not been previously reported for Umatilla Dace (McPhail 2007).

Although we did not directly observe spawning or find fertilized eggs, spawning likely begins soon after peak freshet over the period of annual maximum water temperature based on the presence of ripe individuals. On the Slocan River, ripe Umatilla Dace were captured at water temperatures between 16°C and 21°C from mid-July to late August. This confirms that Umatilla Dace spawn in mid-summer because near-ripe individuals were collected in July, and the closely related Leopard Dace (*Rhinichthys falcatus*) and Speckled Dace species also spawn at this time (Peden and Hughes 1981, 1984; Peden 1991; McPhail 2007). Direct spawning observations for Umatilla Dace have been made only under laboratory conditions, but detailed spawning behaviour and external characteristics were not documented (Haas 2001).

Baited minnow traps were the best method to capture Umatilla Dace during the spring/summer period (AMEC Environment & Infrastructure 2014), and it is likely that mature Umatilla Dace were artificially attracted to the minnow traps set close to spawning locations. Whether these fish were drawn into the baited traps to feed, seek shelter, or spawn remains unknown at this time.

Information obtained during this study has added to our knowledge of the life history of the Umatilla Dace, a species that is often misidentified and assumed to be similar to the more common Longnose Dace (Harvey and Brown 2011). This new information on spawning time will aid in recovery plans and management of this species in other, more regulated portions of the Columbia River Basin in British Columbia.

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Square-stalked St. John's-wort, *Hypericum tetrapterum*, in Peel Region, Ontario: a New Non-native Vascular Plant Species for Eastern North America

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Cecile, Charles P., and Michael J. Oldham. 2016. Square-stalked St. John's-wort, *Hypericum tetrapterum*, in Peel Region, Ontario: a new non-native vascular plant species for eastern North America. Canadian Field-Naturalist 130(3): 231–235.

The Eurasian Square-stalked St. John's-wort (*Hypericum tetrapterum* Fr.: Hypericaceae) was found growing in an open Eastern White Cedar (*Thuja occidentalis* L.) swamp in Caledon, Regional Municipality of Peel, Ontario. This is the first record for eastern North America; previous North American occurrences have been on the Pacific coast in Vancouver, British Columbia, Canada (1991), and in Wahkiakum County, Washington State, USA (2003).

Key Words: *Hypericum tetrapterum*; Square-stalked St. John's-wort; Hypericaceae; vascular plant; Peel Region; Ontario; Canada; new record; non-native

During July 2015 field surveys for the Credit Valley Conservation Natural Areas Inventory Program, a few hundred plants of Square-stalked St. John's-wort, *Hypericum tetrapterum* Fr. (Hypericaceae or sometimes placed in Clusiaceae or Guttiferae), were discovered growing in a wooded swamp on private property close to provincial Highway 10, approximately 20 km north of Brampton, in Caledon, Regional Municipality of Peel, Ontario. This species has not previously been documented in Ontario (Morton and Venn 1990; Newmaster *et al.* 1998) or elsewhere in eastern North America (Gillett and Robson 1981; Kartesz 2015; Robson 2015).

In its native range, this rhizomatous herbaceous perennial grows in damp to wet habitats, including marshes, streamsides, open ditches, wet meadows, and springs (Robson 2002). *Hypericum tetrapterum* is most easily distinguished from other North American *Hypericum* species by its square stem, which is conspicuously winged on the four corners and by its lanceolate sepals (Figures 1–3). Black glands occur on the yellow petals, anthers, and stem leaves. The clasping leaves have translucent dots. *Hypericum tetrapterum*, also known as St. Peter's Wort, is a common native species in central and southern Europe, western Asia, and northwestern Africa (Robson 2002). It has been introduced into New Zealand (Heenan 2014) and parts of Australia, where it has been declared an invasive weed (Australian Government n.d.).

The first North American report was by Lomer (1997) who found the species in 1991 growing as a weed in a ditch and along a small stream in the University of British Columbia Botanical Garden, Vancouver, British Columbia. Zika (2004) reported it from Wahkiakum County, Washington, where he found it in 2003 rooted on drift logs in a freshwater intertidal marsh and as a weed in sunny disturbed ground. The species is mentioned by Robson (2015) in the Flora of North America, volume 6, but only in the introduction to the genus *Hypericum*, where it is reported from British Columbia and Washington.

In the Peel Region, Ontario, several nearby populations of *H. tetrapterum*, each made up of a few dozen plants, were found growing in an open Eastern White Cedar (*Thuja occidentalis* L.) swamp. The swamp appeared to have been disturbed in the past, as evidenced by an old non-operational dam at the private property boundary where a small cold water stream flowed. In addition, an abundance of non-native species, such as Coltsfoot (*Tussilago farfara* L.) and Purple Loosestrife (*Lythrum salicaria* L.), and the weedy, native Field Horsetail (*Equisetum arvense* L.), were found throughout the site. The open nature of the swamp suggests that logging, grazing by livestock, or both, have occurred in the past. No recent disturbance was evident.

Hypericum tetrapterum grows in association with many native species, including Royal Fern (*Osmunda regalis* L.), Clinton's Wood Fern (*Dryopteris clintoniana* (D. C. Eaton) Dowell), Water Horsetail (*Equisetum fluviatile* L.), Dwarf Scouring-rush (*Equisetum scirpoides* Michaux), Smooth-sheathed Sedge (*Carex laevivaginata* (Kükenthal) Mackenzie), Bristle-stalked Sedge (*Carex leptalea* Wahlenberg), Fringed Brome (*Bromus ciliatus* L.), Short-tailed Rush (*Juncus brevicaudatus* (Engelmann) Fernald), American Marsh Pennywort (*Hydrocotyle americana* L.), Common Boneset

(*Eupatorium perfoliatum* L.), Spotted Joe Pye Weed (*Eutrochium maculatum* (L.) E. E. Lamont), Bog Goldenrod (*Solidago uliginosa* Nuttall), Glossy-leaved Aster (*Symphyotrichum firmum* (Nees) G. L. Nesom), Great Blue Lobelia (*Lobelia siphilitica* L.), and Lesser Clearweed (*Pilea fontana* (Lunell) Rydberg).

One can only speculate why these *H. tetrapterum* populations are found at this location and not elsewhere in eastern North America. The site is not immediately near any human settlements or railways. Pioneer farmers settled in this area starting in 1820 with the first concessions opened along Hurontario Street, now prov-

FIGURE 1. Square-stalked St. John's-wort (*Hypericum tetrapterum*) growing in a moist opening in an Eastern White Cedar swamp, Peel Region, Ontario. Photo taken on 29 July 2015. Photo: C. P. Cecile.

FIGURE 2. Note the winged stem, lanceolate sepals, and black glands on stem and leaves of this Square-stalked St. John's-wort (*Hypericum tetrapterum*). Photo taken in Peel Region, Ontario, on 29 July 2015. Photo: C. P. Cecile.

FIGURE 3. Note the lanceolate sepals and black glands on the anthers of this Square-stalked St. John's-wort (*Hypericum tetrapterum*). Photo taken in Peel Region, Ontario, on 11 August 2015. Photo: M. J. Oldham.

incial Highway 10 (Caledon n.d.). These early settlers came primarily from the British Isles where *H. tetrapterum* is a common native species (Stace 1997).

Further investigation would be needed to ascertain why the related non-native *Hypericum perforatum* has become so widespread in eastern North America while *H. tetrapterum* has not. It is of interest that another Eurasian *Hypericum* species, Hairy St. John's-wort (*H. hirsutum* L.), was recently reported for the first time in North America, also from the Greater Toronto Area (Heydon *et al.* 2011).

Voucher Specimens

Canada, Ontario, PEEL REGIONAL MUNICIPALITY, Town of Caledon, Forks of the Credit Road, west of Highway 10, few hundred plants growing in open canopy Eastern White Cedar swamp in wet organic muck soil, 27 July 2015, *Charles Cecile 139* (HAM, OAC); west of Hurontario Street (Highway 10), south of Forks of the Credit Road, 50–100+ scattered flowering plants in open moist Eastern White Cedar woods, 11 August 2015, *M. J. Oldham and C. P. Cecile 43130* (BABY, CAN, DAO 903346 (barcode 01-010006939 75), MICH 1514513, NHIC, TRT).

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The Credit Valley Conservation Natural Areas Inventory Program collects and analyzes information on the species and biological communities that exist in natural areas of the Credit River watershed and Peel Region. Many private landowners have generously given permission to survey their properties. Peter Zika and Frank Lomer provided useful information on *Hypericum tetrapterum*, and Paul Catling and Peter Ball provided helpful comments on an earlier draft of the manuscript.

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Distributional Status of an Introduced Land Snail *Discus rotundatus* (Rotund Disc, Mollusca: Discidae) in Canada

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Forsyth, Robert G., John E. Maunder, Donald F. McAlpine, and Ronald G. Noseworthy. 2016. Distributional status of an introduced land snail *Discus rotundatus* (Rotund Disc, Mollusca: Discidae) in Canada. Canadian Field-Naturalist 130(3): 236–247.

First collected in North America in 1937 on the Avalon Peninsula of the Island of Newfoundland, the introduced, primarily European land snail, *Discus rotundatus*, has now been recorded from the Island of Newfoundland, Nova Scotia, New Brunswick, Quebec, Ontario, and British Columbia. We review all known records from Canada, demonstrate that *D. rotundatus* is more widespread than was previously recognized on the Island of Newfoundland, and report the first record from New Brunswick.

Key Words: *Discus rotundatus*; Mollusca; terrestrial snail; gastropod; new provincial record; New Brunswick; Newfoundland and Labrador; biogeography

Introduction

Discus rotundatus (Müller, 1774), the Rotund Disc, is a distinctive land snail that is native to the Euro-Mediterranean region, where it is widespread, almost ubiquitous, and commonly synanthropic (Taylor 1909; Umiński 1962; Kerney and Cameron 1979; Gittenberger *et al.* 1984; Kerney 1999; Wiktor 2004; Welter-Schultes 2012; Wiese 2014). It reaches its eastern limit in Latvia, Belorussia, and Ukraine, including Crimea (Umiński 1962; Sysoev and Schileyko 2009). Outlying occurrences in Algeria (Umiński 1962), as well as Turkey (Örstan 2003; Örstan and Kösemen 2011), Malta (Giusti *et al.* 1995), the Azores (Backhuys 1975; Martins 1995; Cameron *et al.* 2001), and Madeira (Seddon 2008) are almost certainly introductions. In the Southern Hemisphere, *D. rotundatus* is introduced to the vicinity of Melbourne, Australia (GBIF 2015) and Western Cape province, South Africa (Herbert 2010).

In the United States, where *D. rotundatus* is also introduced, the species was first recorded in Massachusetts in 1939 (Clench and Banks 1939; Pilsbry 1948) and has since been found in Maine (Gleich and Gilbert 1976; Martin 2000), Vermont (Lee 2009), New York (Jacobson 1951; Jacobson and Emerson 1961), New Jersey (Freed 1953; Jacobson 1954; Steury and Steury 2011), Pennsylvania (Pearce 2008, 2015; Steury and Steury 2011), Washington, DC (Steury and Steury 2011), Washington state (Forsyth 2004), Oregon (Anonymous 2015), and California (Roth 1982; Hertz 1996). Dundee (1974) summarized some of the records from the eastern United States. Additional unpublished records exist for Connecticut (Carnegie Museum of Natural History database), Ohio (GBIF 2015), Michigan (Carnegie Museum of Natural History database), Mississippi, Tennessee, Georgia, and Alabama (National Museum of Natural History, Smithsonian Institution database; Carnegie Museum of Natural History database).

In Canada, *D. rotundatus* has been found in six provinces (Figure 1). Here, we report and discuss both old and new records from Atlantic Canada, including the first record for the species from New Brunswick, and review all other Canadian records.

This small species (diameter up to 6.2 mm in Canadian material; elsewhere to 7 mm [e.g., Umiński 1962; Wiese 2014]; or even 8 mm [*fide* Germain 1930]) is distinguished by a flattened, opaque, ribbed, grey-brown shell that is usually marked by somewhat regularly spaced, red-brown blotches (Figures 2 and 3A,B). Although Taylor (1909) reported that these blotches are occasionally absent, we have not seen any specimens from Canada or Europe that lack this characteristic. Örstan (2012) claimed that his specimen lacked spots, but unusually pale blotches are present in his figured specimen. Several other species of *Discus* occur in Canada (*D. whitneyi, D. catskillensis, D. patulus,* and *D. shimekii*), but none has red-brown blotches. The only other Canadian land snail species with a similar colour pattern is the native *Anguispira alternata*, but it is much larger (up to about 25 mm; Pilsbry 1948), with less tightly coiled whorls (Grimm *et al.* 2010). At maturity, both species have about 5½ to 6 whorls (counted by the method used by Kerney and Cameron [1979]), but *D. rotundatus* is much less than half the size of *A. alternata* even when it attains the maximum number of whorls. *Discus rotundatus* was treated comprehen-

FIGURE 1. Distribution of *Discus rotundatus*, the Rotund Disc, in North America. Shading indicates provinces and states where it has been introduced. Black circles show Canadian occurrences: 1, Vancouver; 2, Toronto; 3, Montreal; 4, Saint John; 5, Halifax; 6, Brigus, Ferryland, and St. John's. White circles show United States occurrences according to Jacobson (1951,1952); Freed (1953); Dundee (1974); Gleich and Gilbert (1976); Roth (1982); Hertz (1996); Pearce (2008); Lee (2009); Steury and Steury (2011); Anonymous (2015); GBIF (2015); database records of Carnegie Museum of Natural History, Field Museum, National Museum of Natural History (Smithsonian Institution), Royal British Columbia Museum, R. Forsyth, and R. Noseworthy.

FIGURE 2. *Discus rotundatus*, the Rotund Disc, McLarens Beach, Saint John, New Brunswick (45°14'15.2"N, 66°06'4.2"W): collected by RGF, 24 June 2015, NBM 009144. Photo: R. Forsyth.

sively by Taylor (1909), as *Pyramidula rotundata*, and was compared with other European representatives of the genus *Discus* by Umiński (1962).

The lifestyle, population dynamics, and ecology of *D. rotundatus* were described by Kuźnik-Kowalska (1999), who wrote that is was originally a woodland species, associated with rotting wood and living in leaf litter, but that it has invaded anthropogenic habitats (such as parks and ruins). The same author confirmed its known highest altitude at 2700 m above sea level in the European Alps. Boycott (1929, 1934) described the species as a generalist, living wherever

FIGURE 3. Live examples *Discus rotundatus*, the Rotund Disc, Newfoundland and Labrador. A. Near wharf at Brigus, 10 May 2008; B. Masonic Terrace, St. John's, 22 August 2014; C. Anglican Cemetery, Brigus, 25 May 2008, with terrestrial isopods *Oniscus asellus* Linnaeus, 1758 and *Porcellio scaber* Latreille, 1804. Photos: J. E. Maunder.

there is sufficient moisture and shelter, and as one of the "forty or so [British] species to which we cannot assign specific habitats" (Boycott 1929: 213).

Materials and Methods

We consulted the following institutional collections, where material exists or was deposited: New Brunswick Museum (NBM), Saint John; Royal British Columbia Museum (RBCM), Victoria; Canadian Museum of Nature (CMNML), Gatineau, Quebec; Nova Scotia Museum (NSM), Halifax; and The Rooms Provincial Museum (formerly the Provincial Museum of Newfoundland and Labrador; NFM), St. John's. Other collections consulted, where no material exists, were Royal Ontario Museum, Toronto, and Manitoba Museum, Winnipeg. We also consulted the private collection of George P. Holm (New Westminster, British Columbia), and undertook a survey of the literature. Because of the distinctiveness of *D. rotundatus,* we did not consider it critical to verify all collections, although we did verify most (Table 1).

Individually, we have made a number of new collections during general reconnaissance fieldwork for terrestrial molluscs over many years. Specimen and data collection procedures varied. Most material was collected by hand, killed in alcohol, removed and allowed to dry, and then stored as dry shells. Some of the material held at NFM has been fixed and stored in ethanol.

All known records and voucher specimens of *D. rotundatus*, from Canada, are listed in Table 1.

Results

Newfoundland and Labrador

Brooks and Brooks (1940) reported the first confirmed North American collection of *D. rotundatus*, made in 1937 from the ruins of an old Church of England church in Ferryland, on the Avalon Peninsula of the Island of Newfoundland. As a result of subsequent collecting, primarily by JEM and RGN, three general occurrence groupings are currently known in the province, all of them on the eastern Avalon Peninsula: Ferryland (2 sites), Brigus (3 sites; Figure 4A), and St. John's (8 sites; Table 1).

Nova Scotia

Discus rotundatus was first reported from Nova Scotia in simple lists of species without supporting data, including specific locality (Davis 1990, 1992). An earlier list by the same author did not include this species (Davis 1985). The NSM does have one lot of *D. rotundatus* from Halifax, from 2000, which post-dates Davis' abovementioned publications, but no earlier-collected material is held in the collection. In 2010, DFM made one additional collection, from Halifax (Table 1).

New Brunswick

Discus rotundatus was unknown from New Brunswick until 2015 when RGF found it in Saint John (Table 1).

Quebec

Örstan (2012) reported *D. rotundatus* from Mont Royal, Quebec, a Montreal municipal park established in 1876. RGF provisionally identified material based on an image of Örstan's material (Grimm *et al.* 2010), with Örstan (2012) stating that shells lacked the characteristic reddish marks of the species. Örstan (2012) collected five shells in 2008 (live) and 2011 (fresh dead), reporting that casual searches did not reveal *D. rotundatus* elsewhere on Mont Royal. More recently, DFM collected 44 live *D. rotundatus* shells at two additional sites from under downed woody debris in mature Red Oak (*Quercus rubra* L.)–Sugar Maple (*Acer saccharum* Marshall) forest on Mont Royal during 60 minutes of searching. Each of these new sites is about 0.5 km from the site reported by Örstan (2012) and together with the ease of collection, suggests abundance, widespread occurrence, and persistence of *D. rotundatus* on Mont Royal (Table 1). Nearly all of the shells in the recent *D. rotundatus* collections from Quebec are clearly distinguished by the characteristic reddish marks of the species.

TABLE 1. Canadian records of *Discus rotundatus*, the Rotund Disc, by province. ANSP = Academy of Natural Sciences of Drexel University; CMNH = Carnegie Museum; CMNML = Canadian Museum of Nature; NBM = New Brunswick Museum; NFM-MO = The Rooms Provincial Museum [Newfoundland and Labrador]. RBCM = Royal British Columbia Museum.

Collection catalogue no.	Locality	Collection date	Collector	Latitude	Longitude	Publication	Habitat	Comments
NEWFOUNDLAND AND LABRADOR								
CMNH 149351, ANSP 169889	Ferryland: ruins of the Church of England church	1937	S. T. and B. W. Brooks	47°01'31.5"N†	52°53'05.8"W†	Brooks and Brooks (1940)		
CMNH 149352	Ferryland	July 1937	Cath Morry	47°01'31.5"N†	52°53'05.8"W†			
NFM MO-459*	Ferryland: grounds of the old, stone, Catholic church	8 August 1983	JEM and RGN	47°01'31.5"N	52°53'05.8"W		Relatively untended grassy bank, littered with old boards and stones	
NFM MO-2064*	Ferryland: grounds of the old, stone, Catholic church	23 August 1986	JEM and RGN	47°01'31.5"N	52°53'05.8"W			
NFM MO-2074*	St. John's: Waterford Bridge Road: General Protestant Cemetery	23 August 1986	JEM and RGN	47°32'40"N	52°43'29"W		Well-tended, well-treed, urban cemetery	
NFM MO-2067*	St. John's: Bowring Park, south end, near river, below old Squires property	22 August 1987	JEM and RGN	47°31'18.0"N	52°45'15.1"W		Mature, mainly deciduous woods, at the edge of an old estate, in steep valley, near small river	
NFM MO-1412*	St. John's: Bowring Park, north end, near "The Duck Pond"	8 June 1988	JEM	47°31'40.1"N	52°44'42.3"W		Variously, under wood, associated with an old concrete foundation, and on the stone abutment of an old railway bridge, all in mature, semi-open, mixed-woodland, in a large, long-established, urban park	
NFM MO-2065*	St. John's: Bowring Park, north end, near "The Duck Pond"	21 June 1988	JEM	47°31'40.1"N	52°44'42.3"W			
NFM MO-1414*	St. John's: Bowring Park, north end, near "The Duck Pond"	28 September 1988	JEM	47°31'40.1"N	52°44'42.3"W			

TABLE 1. *(continued)*

Collection catalogue no.	Locality	Collection date	Collector	Latitude	Longitude	Publication	Habitat	Comments
NFM MO-2072*	St. John's: near Waterford River, just south of Syme's Bridge	27 August 1988	JEM and RGN	47°32'33"N	52°43'31"W		Open, grassy, shrubby river floodplain, above usual flood level	
NBM 8354*	St. John's: near Syme's Bridge off Waterford Bridge Road	30 August 2005	DFM and JEM	47°32'37.0"N	52°43'28.2"W		Open, grassy, shrubby river floodplain, above usual flood level	
NFM MO-2073*	Brigus: near "The Tunnel"	7 October 1989	JEM	47°32'5.5"N	53°12'18.5"W			
Photos of live animals by JEM (Figure 3A)	Brigus: near government wharf	10 May 2008	JEM	47°32'24"N	53°12'24"W		Open, damp, grassy-weedy slope just above a the beach of a small, saltwater harbour	
Photos of live animals by JEM (Figure 3C)	Brigus: Anglican Cemetery	25 May 2008	JEM	47°32'05"N	53°12'23"W		Fairly well tended cemetery	
NFM MO-2070*	Brigus: small park opposite the "Bartlett Memorial"	15 June 2008	JEM	47°32'08"N	53°12'18"W		Small, shady, municipal park with mature deciduous trees	
NFM MO-2071*	St. John's: Waterford River, just south of the bridge joining Leslie Street and Blackhead Road	30 June 2008	JEM	47°32'49"N	52°43'11"W		Variously in deciduous woods, under rocks and wood, in an urban river valley	
Photos of live animals by JEM (Figure 3B)	St. John's: Masonic Terrace	22 August 2014	JEM	47°33'57.0"N	52°42'26.0"W		Under rocks and boards in a well-tended urban garden	
NFM MO-2076*	St. John's: Waterford Bridge Road	5 October 2014	JEM	47°32'30.25"N	52°43'41.0"W		Variously in deciduous woods, under rocks and wood, in an urban river valley	
NFM MO-2069*	St. John's: near Waterford River, just south of Syme's Bridge	3 June 2015	JEM	47°32'33.0"N	52°43'31.0"W		Variously in deciduous woods, under rocks and wood, in an urban river valley	

TABLE 1. *(continued)*

Collection catalogue no.	Locality	Collection date	Collector	Latitude	Longitude	Publication	Habitat	Comments
NFM MO-2068*	St. John's: Signal Hill, just south of Gibbet Hill, overlooking the harbour	8 June 2015	JEM	47°34'11.6"N	52°41'22.5"W		Very exposed, open, grassy-weedy, rocky, meadow near an old concrete foundation	
NFM MO-2066*	St. John's: near Empire Avenue, just above Kelly's Brook, between Rennies Mill Road and Carpasian Road	24 July 2015	JEM	47°34'23.5"N	52°42'40.8"W		Damp, sheltered gully, with open deciduous woods, above small brook; urban setting	
NEW BRUNSWICK								
NBM 009144*	Saint John: McLarens Beach	24 June 2015	RGF	45°14'15.2"N	66°06'4.2"W		About 1 m above sea level, ≤ 3 m from high-water mark along the semi-exposed storm beach; under pieces of wood and in low vegetation which was dominated by *Equisetum* sp. and *Ranunculus* sp., on wet, cobble gravel behind the beach ridge	
NOVA SCOTIA								
?	Unspecified					Davis (1990, 1992)		Details unknown, see text
NSM 15948*	Halifax: Waegwoltic Avenue	22 November 2000	Barry Wright	44°38'18"N‡	63°35'54"W‡			
NBM 009143*	Halifax: 2720 Gottingen Street	27 August 2010	DFM	44°39'31.2"N	63°35'38.0"W		Urban, treed wasteland; few shrubs and weeds under some mature deciduous trees; a few old boards, a bit of rubbish, heavily shaded; not much ground cover	
QUEBEC								
CMNH 118700	Montréal: La croix du Mont Royal	2008 and August 2011	Aydin Örstan	45°30'30"N	73°35'17"W	Örstan (2012)	"Woods"	

TABLE 1. *(continued)*

Collection catalogue no.	Locality	Collection date	Collector	Latitude	Longitude	Publication	Habitat	Comments
NBM 009145	Montréal: Parc du Mont Royal: 0.42 km north-northwest of Chalet du Mont Royal	16 November 2015	DFM	45°30'20.4"N	73°35'31.4"W		Under woody debris in mature Sugar Maple–Red Oak parkland	
NBM 009146	Montréal: Parc du Mont Royal, adjacent to chemin Olmsted	17 November 2015	DFM	45°30'14.7"N	73°35'08.1"W		Under woody debris in mature Sugar Maple–Red Oak parkland	
ONTARIO								
CMNML 91756*	Toronto: south Rosedale	30 November 1953	D. Montgomery Wood	—	—			
CMNML 59922*	Toronto: north slope of Rosedale Ravine at Glen Road footbridge	14 October 1970	F. Wayne Grimm and J. Cavanaugh	43°40'23"N§	79°22'30"W§			
NBM 8729*	Toronto: Rosedale Ravine, north side of Rosedale Valley Road	20 September 2007	DFM	43°40'22.6"N	79°22'21.4"W		Deciduous forest, Norway Maple, *Fagus*, Red Oak, sparse understory except along verge; Japanese Knotweed, Virginia Creeper, and *Solidago* sp. *Discus rotundatus* ubiquitous under old cardboard and discarded clothing	
NBM 8735*	Toronto: Rosedale Ravine, north side of Rosedale Valley Road	20 September 2007	DFM	43°40'17.4"N	79°21'53.7"W		Open deciduous woods, some areas with a carpet of English Ivy and knotweed stands	
NBM 8740*	Toronto: Rosedale Ravine, south side of Rosedale Valley Road	20 September 2007	DFM	43°40'23.2"N	79°22'43.1"W		Open area with *Rhus*, *Solidago*, and Japanese Knotweed	
	Toronto: western beach, Bluffers Park	19 April 1994	Frederick W. Schueler	43°42'15.0"N	79°14'19.1"W	Karstad (1995)	Shell in beach drift	
BRITISH COLUMBIA								
CMNML 97166*	Victoria	Before 1940	Not recorded	—	—			Hanham collection; see text

TABLE 1. *(continued)*

Collection catalogue no.	Locality	Collection date	Collector	Latitude	Longitude	Publication	Habitat	Comments
CMNML 91841*	Esquimalt, Vancouver Island	20 December 1954	D. Montgomery Wood	—	—			Data presumed to be wrong: see text
Holm collection, CM106205	Vancouver: Queen Elizabeth Park: close to Cambie Street West 35th Avenue	5 March 2010	George P. Holm	49°14'26"N[¶]	123°06'51"W[¶]	Holm (2010)	Under fallen branches and decaying leaves at side of wooded trail (Holm, personal communication)	
RBCM 015-00492-002*	Vancouver: Queen Elizabeth Park, sunken garden at base of waterfall	28 December 2010	Patrick and Chloë Williston	49°14'33"N**	123°06'50"W**	Forsyth and Williston (2012)	Mature urban gardens of native and exotic trees and shrubs; deep litter and quantities of dead wood debris	
RBCM 015-00491-001*	Vancouver: 515 East 31st Street	11 May 2010	Patrick and Chloë Williston	49°14'35.1"N	123°05'37.6"W	Forsyth and Williston (2012)	Urban garden and adjacent alleyway; on asphalt and soil beneath lavender shrubs; on soil between cobbles; on stone retaining wall	
RBCM 015-00493-002*	Vancouver: Little Mountain: Queen Elizabeth Park, upper edge, Sunken Garden	26 September 2013	RGF	49°14'33.8"N	123°06'52.1"W		Mature, rocky garden of mature native and exotic trees and shrubs; under dead wood	
Holm collection	Vancouver: Everett Crowley Park, along middle east west trail	5 April 2012	George P. Holm	49°12'38"N[¶]	123°02'11"W[¶]	Holm (2012)	Under branches and pieces of wood (Holm, personal communication)	
RBCM 015-00494-005*	Vancouver: Champlain Heights Park, along Butler Street	25 September 2013	RGF	49°12'48.8"N	123°01'59.1"W		"Islands" of native trees and shrubs, with introduced weeds surrounded by lawn; under dead wood	

*Material examined.

[†] Subsequently derived herein; used same geoposition as recorded by later collectors.

[‡] Subsequently derived herein and approximate; geoposition taken at mid-point along the length of the road.

[§] Subsequently derived herein and approximate; geoposition taken at Glen Road bridge over Rosedale Ravine.

[¶] Subsequently derived herein and approximate.

**Approximate centre of area searched (Forsyth and Williston 2012).

FIGURE 4. Examples of the varied habitat of the Rotund Disc, *Discus rotundatus*, in Canada. A. Brigus, Newfoundland and Labrador; B. Mont Royal, Montreal, Quebec. Photos: J. E. Maunder (A) and D. F. McAlpine (B).

Ontario

Discus rotundatus was first found in Ontario by D. M. Wood and associates. Material in the CMNML collection is from the Rosedale Ravine and was collected in 1954 and 1970. Recently, DFM re-collected the species from this ravine, where it is widespread and abundant (Table 1). The discovery of this species in beach drift at Bluffers Park, Toronto, was noted by Karstad (1995).

The late F. W. Grimm (Grimm 1996; Grimm *et al.* 2010) reported this species from Ottawa. RGF has reviewed Grimm's collections, now in CMNML (including those in the backlog, as well as his final collection donated to the museum after his death) and has not located any *D. rotundatus* material from that city.

British Columbia

Discus rotundatus was undetected in British Columbia for many years, and even extensive surveys in urban areas of Vancouver and Victoria by Forsyth (1999) failed to find it. Forsyth (2004) included it in the province based on an unpublished museum lot (CMNML 91841) purportedly collected at Esquimalt (a suburb of Victoria), Vancouver Island, on 20 December 1954. However, Forsyth and Williston (2012) contacted the collector of this material, D. M. Wood, who was adamant that he could not have collected those specimens on Vancouver Island at that time (D. M. Wood, personal communication). Assuming that the date and collector's name are correct, those specimens seem contemporaneous with others collected by D. M. Wood in Toronto the preceding year; thus, it is possible that they were also from Toronto and that the locality data were incorrect. We suspect, then, that this series of specimens and the data have become wrongly associated.

However, there is also a single specimen of *D. rotundatus* (CMNML 097166) from "Victoria" (with no additional data). Presumably this material is from the A. Hanham collection and, if correct, would seem to pre-date the discovery of this species in Newfoundland, because Hanham died in 1944 after dispersing his mollusc collection in 1940 (Drake 1963). However, it is also possible that this specimen was wrongly labelled at some time, as is often the case in old shell collections. Although these two records provide the tantalizing possibility that *D. rotundatus* is, or was, present on Vancouver Island, this species remains unconfirmed from there.

Discus rotundatus is, however, present in the City of Vancouver. From Queen Elizabeth Park, Holm (2010) reported the first recent, confirmed records from British Columbia. Forsyth and Williston (2012) independently found the species in the same park and at another site, on East 31st Street, about 1 km away. Since then, two additional sites (at least 5.5 km southeast of the East 31st Street site) were found in two conjoining parks, Everett Crowley Park (Holm 2012) and adjacent Champlain Heights Park, with collection sites probably less than 500 m apart (Table 1).

Discussion

Although long known to be introduced in North America since at least the first records from Newfoundland in the 1930s (Brooks and Brooks 1940), *D. rotundatus* has not yet become as generally widespread and common as certain other introduced European snails, such as *Oxychilus* spp., and occurrences — as far as we know — still seem to be clustered. Given the frequency of interceptions of *D. rotundatus*, by the United States Plant Protection and Quarantine Division (1.08% of all interceptions between 1993 and 1998; Robinson 1999), it is surprising that the species is not much better established on this continent.

In Newfoundland, *D. rotundatus* has persisted for at least 79 years. However, it remains restricted to just three clusters of occurrences: at Ferryland; in Brigus (Figure 4A), where it is generally common; and in St. John's.

In British Columbia, fieldwork by RGF in urban areas of Vancouver and Victoria and their suburbs (Forsyth 1999) failed to locate this species until recently, and then only at two sites in Vancouver. We do not expect that these occurrences represent recent introductions, but rather that the species was missed in prior years. *Discus rotundatus* is not uncommon at Queen Elizabeth Park, but was not found during multiple visits to a different area of the same park while looking for *Aegopinella nitidula*, another introduced snail (Forsyth *et al.* 2001). If *D. rotundatus* were more generally distributed, it would have been encountered along with the dozen introduced species of snails found in British Columbia over the last couple of decades (including some new provincial, Canadian, or North American records; e.g., Forsyth 1999, 2008; Forsyth *et al.* 2001). Here, as perhaps elsewhere in Canada, this species may have a very local distribution, perhaps confined to a few hundred square metres.

We do not have much data on *D. rotundatus* from Ontario or the other provinces where it has been found, but it is noteworthy that, although several collectors have been active in Ontario over many years (F. W. Grimm, F. W. Schueler, Michael J. Oldham, and RGF) and together have examined at least several hundred sites, the species has not been found outside Toronto and the Rosedale Ravine. Although Grimm said that he had found it in Ottawa, we found no evidence supporting this claim. Our new record of *D. rotundatus* from Halifax, Nova Scotia, suggests that the species could be more generally spread, especially if Davis' earlier mention of the species from Nova Scotia represents one or more undocumented finds from the province.

The mode and source of terrestrial mollusc introductions are little known (Grimm *et al.* 2010), but *D. rotundatus* has likely been introduced to North America on a number of occasions. All three occurrence clusters in Newfoundland are closely associated with saltwater harbours, which at least in years past have received significant trans-Atlantic sea traffic. Transportation via ships' ballast material is possible. In this respect, Lindroth (1957) reported *D. rotundatus* at ship ballasting places at Dartmouth, England.

However, the plant trade is recognized as a major vector for introductions of terrestrial snails (Bergey *et al.* 2014), and in southwestern British Columbia cities, Forsyth (1999) noted considerable localized transport of snails (although not *D. rotundatus*) in garden waste, soil, rock, wood, and other debris that was dumped in vacant lots and undeveloped parks. Some New York occurrences of *D. rotundatus* were apparently associated with outdoor, ornamental plantings or greenhouses (Jacobson 1954; Karlin and Naegele 1960). Vancouver's Queen Elizabeth Park, the site of a former quarry, is planted with a variety of native and exotic trees, shrubs, and garden plants. In Newfoundland, the main nucleus for the St. John's *D. rotundatus* occurrences is almost certainly Bowring Park, a long-established urban park planted with numerous, mainly imported, tree species, as well as many imported garden plants. This park also happens to be a short distance (3–4 km) upstream from the city harbour, near the upper reaches of the sheltered Waterford River Valley, along the whole length of which *D. rotundatus* also commonly occurs.

In Canada, *D. rotundatus* is found in habitats (Figure 4A,B) almost as varied as those in Europe, confirming Boycott's (1929, 1934) view that it may live anywhere there is shelter and moisture.

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Book Reviews

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

BOTANY

Flora of Florida Volume II (Dicotyledons, Cabombaceae through Geraniaceae) and Volume III (Dicotyledons, Vitaceae through Urticaceae)

By Richard P. Wunderlin, and Bruce Hansen. 2015. University Press of Florida, 15 NW 15th Street, Gainesville, FL, USA, 32603. 383 pages (Volume II) and 327 pages (Volume III), 69.95 USD (each), Cloth.

In 1998, Richard Wunderlin published *Guide to the Vascular Plants of Florida* (1998), an annotated key to the entire flora of the state. It was an important achievement, providing the first comprehensive review of one of the most floristically diverse areas of North America. But that was just the start. Two years later, a 20-year effort by Donovan Correll, Wunderlin and others bore fruit with the publication of the first part of a comprehensive state flora (*Flora of Florida Volume I, Pteridophytes and Gymnosperms*; Wunderlin and Hansen 2000). In addition to the treatment of 170 native and non-native species, the first volume included introductions to the physical setting and vegetation of Florida and a history of its floristic investigation. That and proposed future volumes offered great promise to investigators of this botanically extraordinary region of North America. When more than a decade passed without another volume appearing, however, it seemed that the task might have just been too big an order.

Accordingly, the publication of Volumes II and III importantly demonstrates that the *Flora of Florida* project is indeed alive and well. The authors, in fact, foresee the final seven volumes being produced by 2020, with Volume IV in press (Wunderlin *et al. in press*) and Volumes V and VI currently in preparation (R. Wunderlin, personal communication, 2016).

Volumes II and III continue the format and structure of Volume I. All three are sturdily bound, hard-cover books with small but easily-readable type. The native and non-native species of the 65 families covered in Volumes II and III are each provided with detailed, clear physical descriptions employing precise but not overly technical terminology. Most readers will find that they rarely need to refer to a botanical glossary. That's good, as no glossary is provided in these volumes. Nor are any illustrations. Representative generic illustrations are tentatively planned for future volumes, however (R. Wunderlin, personal communication, 2016).

Unfortunately, there are no floristic synopses for Volumes II or III, unlike Volume I (appendix), so the number of taxa covered in each is unclear. Using the species per page coverage of Volume I as a measure, however, it seems there are approximately 460 species treated in Volume II and 400 in Volume III. Volumes I through III then, treat over 20% of the more than 4,700 vascular plants reported in the Atlas of Florida Plants to occur here. These treatments include taxa in large and/or important families such as Euphorbiaceae, Ranunculaceae, Fagaceae, Violaceae, Fabaceae, and Rosaceae. Perhaps surprising to Canadian readers, many of the species discussed are regularly encountered in northern portions of the continent as well.

Effective species identification keys taken or updated from Wunderlin's (1998) *Guide to the Vascular Plants of Florida* are placed immediately after each genus description. Alphabetically arranged species treatments follow, each beginning with a comprehensively annotated list of synonyms. The detail of some of these lists is truly impressive – like that for *Oxalis corniculata* (Volume II, page 190), which goes on for over a page. This provides a valuable history of the taxonomic/nomenclatural complexity for many taxa.

It can be difficult, however, to quickly find the treatment of particular groups. Genera are listed alphabetically within families that, in turn, are arranged 'naturally' (following the 2009 proposal of the Angiosperm Phylogeny Group III); thus, to quickly locate many (particularly smaller) genera the reader is more reliant on the index than is desirable. This could have been avoided if the *Flora* had page headers that identify the family to which that page's treatments apply.

After the technical descriptions and a brief but usually clear habitat description, a statement of the taxon's distribution within and beyond Florida is presented. The absence of Florida range maps for each taxon somewhat reduces the clarity of these distributional statements, however. That limitation is exacerbated by the absence of a Florida county map like the very helpful one appearing on the inside front cover of Wunderlin's (1998) *Guide to the Vascular Plants of Florida*. (The Index to Families on the inside back cover of the Guide is also a helpful feature that is not repeated in Volumes II and III.) Accordingly, readers are required to go 'off-site' for more detailed distributional information. Fortunately, the on-line *Atlas of Florida Plants* (Wunderlin *et al.* 2016) serves this purpose admirably. As the *Flora of Florida* authors are major participants in the *Atlas* as well, these two information sources work well together.

And that's the bottom line … the volumes of the *Flora* "work well together". We can only hope that Wunderlin and Hansen will achieve their ambitious goal of completing the remaining seven volumes in the next four years or so. Achieving that will be important for floristic investigations across North America. Its significance applies both to questions concerning total diversity (Florida ranks third amongst North American states and provinces) and in regards to the continental diversity of particular families and genera. The completion of this important work will also provide an invaluable tool for the identification of plants from many parts of the floristically complex and important Southeast.

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OTHER

Boundary Layer: Exploring the Genius Between Worlds

By Kem Luther. 2016. Oregon State University Press, 121 The Valley Library, Corvallis, OR, USA, 97331-4501. 240 pages, 19.95 USD, Paper, 11.99 USD, E-book.

Boundary Layer: Exploring the Genius Between Worlds is, in essence, an ecological travelogue that also combines philosophical reflection on the dynamics between people and nature. The series of eight essays varies in focus from biological (e.g., moss, fungi and lichens), ecological (e.g., dune systems, plant associations and parks) to human constructs of nature (e.g., land ethic, the human biome and classification). Each essay tells multiple stories but uses a single 'boundary layer' (as described below) as its narrative focus.

The author explains his fascination with the boundary layer, both physical and conceptual, as a space that is neither one thing nor the next; it is a place that defines its own rules and should be valued accordingly. It is where things act upon each other and instability is constant.

He describes these areas of high dynamism for each of his essays. They can be natural, such as the mutualism between fungi/algae or mycorrhizae and tree roots, or the shifts in dune ecosystems. Such delineations can also be constructed, such as what is 'wild' versus not, and classification systems, such as British Columbia's biogeoclimatic zones. All visited sites are in British Columbia, with many on Vancouver Island where the author now lives.

The book is more than a naturalist study, travel description or philosophical introspective, as the author often gives as much space to describing his companions on nature excursions as he does to ecological examinations. His fascination with the drive of naturalists is interestingly contrasted with the ecology that each studies. Their history, motivation and personal idiosyncrasies are all committed to paper. He also draws out the importance of the European plant sociology schools, brought to Canada by Vladimir Josef Krajina of Czechoslovakia, who used these "methods to organize the ecosystems of Canada's West Coast" (p. 59). This story is told against a landscape of shifting 20th century politics.

The author endeavours to present each essay from a scientific and humanities perspective. His way of explaining interrelationships between things as well as basic biology is engaging. The first person, journalistic style of writing is accessible through most of the book until the last essay, which delves deeply into philosophical constructs of nature. To account for his shift in language, this essay would have better been divided into two pieces focussing on wilderness reserves for preservation and the changing construct of nature. It is in this last chapter that his graduate training in analytic philosophy and Hegel's writings is evident.

The book includes black and white photos in each chapter, alongside some line drawings and diagrams. These are not always well explained or integrated into the text layout. There is a detailed list of works cited and index. It is a very portable book and the division into essays means a reader can start and stop at will. For me, the first essays, which focus more on defined biological and ecological interactions, are the strongest. I enjoyed the author's explanations of how things work and his weaving of the people sharing nature with him into his narrative. Not every essay followed this pattern as tightly. I also liked the amount of history included in each chapter to frame the understanding of the ecology. This combination helped provide a much more rounded narrative than other nature essays that I have read. Supplementary content, including bios of Luther's 'companions into nature', can be found at www.stegnon.com.

TREMAYNE STANTON-KENNEDY

Ottawa, ON, Canada

Wolf Land

By Carter Niemeyer. 2016. Bottlefly Press, 3314 Cherry Lane, Boise, ID, USA, 83705. 256 pages, 18.00 USD, Paper.

Carter Niemeyer's new book *Wolf Land* was a very enjoyable read, highlighting his experiences capturing and following wolves throughout Montana, Wyoming (including Yellowstone National Park), Idaho, and (more recently) Oregon. He retired from his positions as Idaho wolf manager for the US Fish and Wildlife Service and government trapper for Wildlife Services. He is a recognized expert on wolves, livestock depredation, and trapping.

Niemeyer was a major factor in the reintroduction of wolves into the Northern Rockies in the mid-1990s, responsible for coordinating capture operations in Alberta and British Columbia, which he describes at length in his first book *Wolfer* (2010) and summarizes in *Wolf Land* (pp. 11–17). These accounts include a rather comical situation of having a wolf-skinning contest in the living room of a Canadian trapper's cabin. With stories like that, Niemeyer is a perfect person to provide a first-hand account of one of North America's greatest wildlife success stories. His likeable personality literally enabled the first wolves to make it from Canada to the US, securing buy-in to the project from local Canadian trappers. In *Wolf Land*, Niemeyer's second memoir, he takes us across the rugged West as he tracks wolves, shares in their lives, and seeks middle ground for these iconic animals, both on the land and in our hearts. The book clearly demonstrates his sense of humor with many funny accounts that get one to laugh out loud (for instance, in his suggestion to watch for butterflies when looking for wolf scat, or sleeping in his car with Yellowstone Wolf Project Manager Dr. Doug Smith under a stinky horse blanket, or his use of swearing in descriptions of certain experiences). He has a unique ability to interact with all kinds of people from the stereotypical opposites – conservative ranchers and liberal environmentalists – to all groups of people in between, most just wanting to quietly learn to live with the West's newest predator.

In some respects, this book was deeply personal for me as I have observed and written about, in my book *My Yellowstone Experience*, some of the wolves that Niemeyer discussed, including the Rose Creek, Crystal Creek, Druid, and Nez Perce wolves. Learning his special insights about how he was contracted to capture and radio-collar members of these wolf packs was fascinating, including his connection to the Rose Creek pack members' original capture in Canada and their eventual reintroduction to Yellowstone. The following statement from the book (p. 91) completely resonated with me and my past 15–20 years: "The vast and magnificent Lamar Valley (in Yellowstone) kept popping in and out of my life, or more precisely, I seemed to be making periodic pilgrimages to it". Niemeyer went from foothold trapping some of the Rose Creek pups when they escaped from their acclimation pen (designed to hold the wolves inside an acre area to keep them from roaming too far once when released) to darting other packs from helicopter. In fact, he helped pioneer darting wolves in Yellowstone in winter, which eventually became a standard way to capture wolves for research. There is a fascinating account, among many others, of a formerly ostracized (another wolf pack killed most of his pack) sub-adult male wolf (#6, p. 101) becoming one of the largest wolves – at 141 pounds – documented in the Northern Rocky Mountains. He and his progeny formed the Mollies pack in the central part of Yellowstone, which is still an existing social unit.

In other passages, I read equally mesmerizing accounts of wolves from ranch lands of Montana and wilderness areas of Idaho, places I have yet to visit. Given that he has driven about one million miles while on the job (p. 8) in the Northern Rockies, it is no surprise that most people, even residents of the area, would be familiar with some – but not all – of the areas that Niemeyer takes us. And it is no surprise that a man who would drive that far would practically live in his truck. As he stated (p. 189), he was married to his job, probably the reason over the years why so many wolf biologists end up divorced and living alone.

At the heart of *Wolf Land* is recognizing that Carter Niemeyer, an Iowa native (p. 40), is a trapper. In fact, he put himself through college and helped provide for his family by killing animals, like foxes, for the price of their pelts. He was then hired by the US government to kill problem wildlife such as skunks and then coyotes. He was particularly good at it too, as he skinned more than 6,000 coyotes in his career (as told in *Wolfer*). However, as we transition to *Wolf Land* we go on a journey of Niemeyer mostly trapping wolves for research purposes whereby foothold trapping and aerial darting became his specialty. This allowed biologists to radio-collar and then track those study subjects.

Wolf Land is also about one man's personal transformation from a trapper for the US government program Wildlife Services, whereby he killed for a living, to becoming a vocal champion for wolves and anything wild when he became the wolf recovery coordinator in Idaho. Niemeyer provides enough background material, without redundant rehashing of information from his first book *Wolfer* (which describes his entire career beginning in the farmlands of Iowa), to give us a good grasp of his transition from government trapper to advocate for predators, wolves in particular. His philosophical shift was a gradual one, taking years to fully bear out. At first he believed that he simply needed to do whatever he could to make sure wolves got a fair shake, since most ranchers and his colleagues simply wanted to blame wolves for a kill so the rancher could be reimbursed and the trapper could be employed to kill the "problem wolf". But Niemeyer (p. 45) believed a wolf didn't deserve to die just because it was a wolf. And he also just got tired of killing for a living, believing that it was bad for the soul (p. 83).

For Niemeyer, being told what to think and do made his hackles go up (p. 83). Over time he also realized that killing animals didn't solve anything, as year after year Wildlife Services would come back to the same allotments to do more predator control, a euphemism for killing. Niemeyer asked important questions (p. 210), such as "Why don't ranchers have to do a better job of taking care of their animals?" and "Why should the government be involved in killing predators, especially on public land?". Public land is holy ground to Niemeyer, as it is to millions of Americans from all walks of life. And, perhaps equally important, Niemeyer notes how ironic the anti-Fed attitude of many western ranchers is, given that they directly benefit from government programs (p. 40), not to mention that their rural lifestyle is often subsidized by the US government. But the key to *Wolf Land* is that Niemeyer points out these absurdities and hypocritical viewpoints but doesn't dwell on them. The backbone of the paperback is Niemeyer's travels to areas where wolves live and how he would get to know those pack members so he could figure out how to get wolves to come to an area of a few square inches, so they would step on a hidden trap and become entangled and eventually captured for research purposes.

At the beginning of the book Niemeyer says that the reintroduction of wolves in Yellowstone and Idaho in 1995–1996 changed the course of his life (p. 7), from contracted killer for the government to utilizing his skills to help wolves recover. He eventually became top man for Idaho wolf recovery, and during his tenure as the leader of the wolf recovery program, the Idaho wolf population increased but the number of wolves killed by the government and the number of livestock lost to wolves declined. Niemeyer can be credited for much of this success; unfortunately, western politics often got in the way of truth and reason and wolves were vilified and eventually slaughtered when wolf management reverted back to state control around 2010.

Wolf Land is a great book. It is easy to read and is of interest to people fascinated with wildlife, especially predators, and western adventure. It has 14 chapters that are distinct from one another but flow in a readable path. A minor complaint might be that the book kind of just starts: there is no Table of Contents or Introduction. However, it was so easy to read, especially since I had already read *Wolfer*, that I felt that I knew Carter Niemeyer as a long-lost friend. It is a credit to his writing style, as well as having the stories to make the book sell! I highly recommend the investment in *Wolf Land*. It is well worth your time.

References

Niemeyer, C. 2010. Wolfer. Bottlefly Press, Boise, Idaho, USA.
Way, J. 2013. My Yellowstone Experience. White Cottage Publishing, Trinidad, Colorado, USA.

JONATHAN (JON) WAY

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Complexity: The Evolution of Earth's Biodiversity and the Future of Humanity

By William C. Burger. 2016. Prometheus Books, 59 John Glenn Drive, Amherst, NY, USA, 14228. 367 pages, 26.00 USD, Cloth.

Complexity is a readable popular science book. The subtitle of this book, "The evolution of Earth's biodiversity and the future of humanity", provides some insight into the content. I would liken the general approach of this book to a 21st Century update of Darwin's *Origin of Species*. The narrative walks the reader through the origin of life and evolution of life histories, and hits with the punch line of preservation of biodiversity.

After an introduction to our planet, its formation, plate tectonics, and all of the features that have formed to make Earth habitable by carbon-based life, Burger introduces the evolution of prokaryotic and eukaryotic organisms.

Burger has packed some very interesting facts into this book. For example, viruses are not life. I suspect that many readers will find this hard to understand until they realize that viruses are unable to replicate themselves without the benefit of a host cell. Also, there are approximately 380,000 species of beetles. Such high speciation suggests that evolution has shown some favour to these interesting insects.

In the "Geography of Species Richness" we are introduced to the biomes of the earth. The discussion ranges from the arctic to the tropics but excludes, interestingly, the vast land of Africa south of the Sahara. A presentation and discussion of the Sahel would have been a great addition here, considering the human impacts that have been wrought on that region.

In Chapter 5, the concept of biodiversity hotspots is introduced. Table 5-2 (p. 126) has some interesting information. For example, the highest number of vascular plant species (45,000) and endemic vascular plant species (20,000) is in the tropical Andes. The same area also has the highest number of bird species (1,666). However, the highest number of mammal species (551) occurs in the Guinean forests of Africa.

Overall, *Complexity* is a good popular science book to introduce evolutionary biology and ecology. The book discusses human evolution but, in my opinion, falls short in treatment of what humans have done to biodiversity and can do in the future. Climate change is interwoven throughout the book but deserves a more thorough and complete treatment, preferably a chapter. I would also prefer to see a bibliography rather than notes, but realize this is more an editorial decision than the author's preference. Also, pictures would have added value to the book. It would not need to be relegated to a coffee-table volume dominated by pictures, but some color pictures of some of the earth's fascinating biota and maps showing our planets biogeography would have helped.

If readers are looking for a book to supplement a non-major course in general biology, ecology, or evolutionary biology, *Complexity* can be recommended. Also, if you just want to read an up-to-date treatment of evolutionary biology, biogeography, or ecology, I can recommend this highly readable work.

Roger D. Applegate

Antioch, TN, USA

Dead in Good Company: A Celebration of Mount Auburn Cemetery

Edited by John Harrison, and Kim Nagy. 2015. Ziggy Owl Press, Medford, MA, USA. 320 pages, 23.95 USD, Paper. 9.95 USD, E-book.

Dead in Good Company is a fascinating account of America's first landscaped graveyard, Mount Auburn Cemetery in Cambridge, Massachusetts. It was created in 1831 with the intent of being more than just a burial ground, with a beautifully designed setting that inspires all who visit, comforts the bereaved, and commemorates the dead in an area of exceptional beauty (p. xviii). Today, over 200,000 people visit and about 5,000 burials take place annually on the 175 acres of 'Sweet Auburn'. It is also an exceptional area for wildlife observation, especially birds, as it is a sea of green in an otherwise urban environment. Thousands of wildlife watchers visit in spring and fall to see migratory birds (most notably the many species of warblers), while a sizable number of people remain year-round to seek out resident birds such as Red-tailed Hawks and Great Horned Owls, among many others.

The book description does a great job of summarizing the text as well as giving insight into the collection of diverse contributors, by noting "*Dead in Good Company* is a compelling collection of essays, poems and wildlife photographs of Mount Auburn Cemetery in Cambridge, Massachusetts. Sweet Auburn, as it is affectionately known, is America's first garden cemetery. An amazing group of authors have come together to celebrate this unique resource…". In total, I counted 60 chapters with 56 people contributing to this unique resource (the bios of the authors alone took up the last 18 pages of the book!), which is printed on beautiful glossy paper. I also tallied 202 colour photographs within this 320-page manuscript, mostly by editor and contributor John Harrison. I was very impressed with many of the images, and that they were often shown within a chapter and directly related to a given story, especially the images of birds and historical markers (like specific gravestones). John's skill at identifying and photographing birds is impressive, including Cape May Warblers, Cedar Waxwings, Brown Creepers, Scarlet Tanagers, Indigo Buntings, and Yellow-rumped Warblers, among dozens of other species found within the covers of the tome. My favorite images, considering that I am biased to mammals, were of the Eastern Coyotes (or Coywolves), including stunning images of 'Big Caesar' and his pack, as well as other locally "famous" individuals who are personalized as identifiable members of the Mount Auburn wildlife community (p. 119) - including Red Foxes, Wild Turkeys, Red-tailed Hawks, Great Horned Owls, Great Blue Herons, many species of songbirds, and even Spotted Salamanders. These critters are fortunate to live within the sanctuary of this cemetery. And the biologist in me marvels at how many animals can be seen on just over a quarter of a square mile, about the size of a summer-time rendezvous site for a family of Eastern Coyotes.

The book is inspiring in that so many people contributed to the manuscript, ranging from naturalistic accounts to historical pieces that include some of the famous and prominent people who are buried there. The lives of so many who made an impact on our nation are detailed on the headstones, monuments, and plaques (p. 210): inventors, scientists, inspiring preachers, Civil War and other military generals, Harvard College presidents, Supreme Court justices and other outstanding jurists, governors, congressmen, senators, artists, writers, musicians, and even great baseball players. Being in this company, along with the natural beauty of this historic place, gives visitors to Mount Auburn Cemetery a genuine sense of past achievement and accomplishment (p. 210). While there are thousands of stories to be told within the confines of this special area, the reader gets to experience and be inspired by five dozen of these short stories, including many wonderfully illustrated photo-essays. *Dead in Good Company* is also important to the field of ecology as it clearly illustrates the importance of cemeteries like Mount Auburn as green spaces and wildlife habitats, especially in urban areas. It would be a great reference to quote when discussing the concept of urban green spaces or the history of landscaped cemeteries.

I marveled at how the editors, John Harrison and Kim Nagy, were able to assemble such a large, diverse, and well-respected group of contributors. John Harrison deserves special mention as many people in their reflections (in each of their contributing chapters) credited John with introducing them to this special area. Most notable for me were the many bird watchers who congregate to and write about Sweet Auburn. May is frequently discussed as the time to visit, as spring and bird migration is in full swing. A cloudy or stormy day is frequently mentioned, as many birds, most notably warblers, are grounded due to the weather affecting their migration navigation (termed a 'fallout', see p. 110), so they flock to Mount Auburn both for the resources it provides and also because it is a haven in a sea of concrete. Migrants arriving over these urban areas will concentrate at Mount Auburn in much greater numbers and variety than in a similar sized area in outer suburban and rural towns (p. 139).

I highly recommend *Dead in Good Company* to all readers, especially folks interested in Boston, history, cemeteries, and nature. It is a local gem in that area of the world. It is beautifully written with barely any grammatical errors throughout its 300+ pages. For some reason, the website listed in the book (www.DeadIn GoodCompany.com) was not set up or working at the time of review, but interested readers can find the book on Amazon.com or via Facebook. My only critique would be for the editors to add a map(s) to the front or end of the book so interested readers can find all of the place names (like the 'Dell'), the many roads and graves, natural features such as the "tree" used by the red-tails, and other areas, such as ponds, that are often mentioned by the numerous authors. Other than that, the text is easy to read, well organized and will serve as a superb 6 × 9-inch coffee table book, given the spectacular pictures that can be found within its covers.

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NEW TITLES

Prepared by Barry Cottam

† Available for review * Assigned

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

ZOOLOGY

***Being a Bird in North America, North of Mexico (BABINA), Volume I: Waterfowl to Shorebirds**. By Robert Alvo. 2015. Friesens, One Printers Way, Altona, MB, Canada, R0G 0B0. 256 pages (illustrated), ~35.00 CAD, Cloth.

Biology and Evolution of Crocodylians. By Gordon Grigg, and David Kirshner. 2015. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA. 672 pages (illustrated), 149.95 USD, Cloth.

Birds: A Complete Guide to Their Biology and Behaviour. By Jonathan Elphick. 2016. Natural History Museum, Cromwell Road, London, England, SW7 5BD. 280 pages and 200+ photos, 18.00 GBP, 26.35 CAD, Paper.

Birds of Western Ecuador: A Photographic Guide. By Nick Athanas, and Paul Greenfield. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 448 pages, 45.00 USD, Paper.

Butterflies: A Complete Guide to Their Biology and Behavior, 2nd Edition. By Dick Vane-Wright. 2015. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA. 128 pages, 19.95 USD, Paper.

Handbook of Larval Amphibians of the United States and Canada. By Ronald Altig, and Roy W. McDiarmid. 2015. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 368 pages, 75.00 USD, Cloth.

***Heart of a Lion: A Lone Cat's Walk Across America.** By William Stolzenburg. 2016. Bloomsbury Publishing Inc., 1385 Broadway, 5th Floor, New York, NY, USA, 10018. 256 pages, 27.00 USD, Cloth.

Insects and Other Arthropods of Tropical America. By Paul E. Hanson. Photographs by Kenji Nishida. 2016. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 384 pages, 37.95 USD, Paper.

***Reptile Ecology and Conservation: A Handbook of Techniques**. By C. Kenneth Dodd. Oxford University Press, 198 Madison Avenue, New York, NY, USA, 10016. 512 pages, 59.95 USD, Paper.

Silent Sparks: The Wondrous World of Fireflies. By Sara Lewis. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 240 pages, 29.95 USD, Cloth.

What a Fish Knows: The Inner Lives of Our Underwater Cousins. By Jonathan Balcombe. 2016. Scientific American / Farrar, Straus and Giroux, 18 West 18th Street, New York, NY, USA, 10011. 304 pages, 12.99 USD, E-book, 16.00 USD, Paper, 27.00 USD, Cloth.

BOTANY

Flora: An Artistic Voyage Through the World of Plants. By Sandra Knapp. 2016. Natural History Museum, Cromwell Road, London, England, SW7 5BD. 224 pages and 36 frameable prints, boxed set, 30.00 GBP, Cloth.

Trees: A Complete Guide to Their Biology and Structure. 2016. By Roland Ennos. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 128 pages, 19.95 USD, Paper.

CONSERVATION

Tropical Conservation: Perspectives on Local and Global Priorities. Edited by A. Alonso Aguirre, and Raman Sukumar. 2016. Oxford University Press, 198 Madison Avenue, New York, NY, USA, 10016. 520 pages, 99.00 USD, Cloth.

Cat Wars: The Devastating Consequences of a Cuddly Killer. By Peter P. Marra, and Chris Santella. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 216 pages, 24.95 USD, Cloth.

OTHER

***Blooms: An Illustrated History of the Ornamental Gardens at Ottawa's Central Experimental Farm.** By Richard Hinchcliff. 2016. Sanderling Press, 20670 Eigg Road, Alexandria, ON, Canada, K0C 1A0, in partnership with the Friends of the Experimental Farm, Building 72, The Arboretum, Central Experimental Farm, Ottawa, ON, Canada, K1A 0C6. 304 pages, 35.00 CAD, Cloth.

Bushmaster: Raymond Ditmars and the Hunt for the World's Largest Viper. By Dan Eatherley. 2015. Arcade Publishing, Skyhorse Publishing, Inc., 307 West 36th Street, 11th Floor, New York, NY, USA, 10018. 320 pages, 24.99 USD, E-book or Cloth.

***Crossing Home Ground: A Grassland Odyssey through Southern Interior British Columbia.** By David Pitt-Brooke. 2016. Harbour Publishing, PO Box 219, Madeira Park, BC, Canada, V0N 2H0. 288 pages, 32.95 CAD, Cloth.

Do Elephants Have Knees? And Other Stories of Darwinian Origins. By Charles R. Ault, Jr. 2016. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 240 pages, 27.95 USD, Cloth.

***Time and a Place – An Environmental History of Prince Edward Island**. Edited by Edward MacDonald, Joshua MacFadyen, and Irené Novaczek. 2016. McGill-Queen's University Press, 1010 Sherbrooke West, Suite 1720, Montreal, QC, Canada, H3A 2R7. 442 pages, 34.95 CAD, Paper.

News and Comment

Upcoming Meetings and Workshops

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Wildlife Species Assessment Meeting

The next Wildlife Species Assessment Meeting of COSEWIC to be held 27 November–2 December 2016 at the Lord Elgin Hotel, Ottawa, Ontario. See how COSEWIC assigns 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.gc.ca.

The Society for Integrative & Comparative Biology Annual Meeting

The Society for Integrative & Comparative Biology Annual Meeting to be held 4–8 January 2017 at the Hilton New Orleans Riverside, New Orleans, Louisiana. Registration is currently open. More information is available at http://www.sicb.org/meetings/2017/index.php.

Canadian Conference for Fisheries Research

The Canadian Conference for Fisheries Research to be held 5–8 January 2017 at the Hyatt Regency Montréal, Montréal, Quebec. Registration is currently open. More information is available at http://www1.uwindsor.ca/glier/ccffr/ccffrccrp-2017.

Science, Practice & Art of Restoring Native Ecosystems Conference

The Science, Practice & Art of Restoring Native Ecosystems Conference to be held 13–14 January 2017 at the Kellogg Center, East Lansing, Michigan. Registration is currently open. More information is available at https://www.stewardshipnetwork.org/2017-stewardship-network-conference.

Society for Range Management Annual Meeting, Technical Training & Trade Show

The 70th Society for Range Management Annual Meeting, Technical Training & Trade Show to be held 29 January–2 February 2017 at the Dixie Convention Center, St. George, Utah. Registration is currently open. More information is available at http://rangelands.org/srm17/.

Obituary – John Crosby 1925–2016

John Crosby, zoological artist and illustrator perhaps best known for illustrating *The Birds of Canada* (1966, 1986), passed away peacefully in Ottawa on 3 October 2016 at the age of 91. John joined the staff of the National Museum of Canada in 1951 where he became familiar with Canadian birds from coast to coast, and from Point Pelee to the High Arctic. While working within and for the science of ornithology, John put his appreciation of birds before all else. A keen and active birder who loved a rare bird as much as anyone, he was interested first and foremost in the *feel* of the bird – only later to be called 'gizz' – and reflected that beautifully in his ecologically accurate and reflective portraits of these animals. The talented national museum crew (Earl Godfrey, John Crosby, Stewart MacDonald) who produced two editions of *The Birds of Canada* are all gone now.

RON PITTAWAY and DAN BRUNTON

Obituary – Edward Bousfield 1926–2016

Curious about the world around him, detailed in his observations, and well-suited to a career as a biologist, particularly as a taxonomist, Ed earned degrees at the University of Toronto (B.A. and M.A.) and at Harvard (Ph.D.), and had a long career at the National Museum of Natural Sciences (Canadian Museum of Nature) in Ottawa. He conducted extensive research along the Atlantic and Pacific coasts – his young family nearly always in tow – and participated in the historic voyage of the *CSS Hudson* in 1969–70. An internationally respected specialist, he described and drew hundreds of new species of amphipod crustaceans in more than 150 books and papers, but in contrast to all those amphipod publications, also published the useful *Canadian Atlantic Seashells* (1960). In 1985 he received a Public Service Outstanding Achievement Award for his work. After retirement in 1986, he remained active in science, as an external advisor to M.Sc. and Ph.D. students around the globe and as a research associate at the Royal Ontario Museum in Toronto, Royal BC Museum in Victoria, and Canadian Museum of Nature in Ottawa – his final work visit being in February 2016, 66 years after he first began there. From penning his own illustrated nature stories as a young teen to spending Saturdays leading Macoun Field Club outings as a museum researcher to his death on 7 September 2016, Ed retained his curiosity and his love of science.

MARJORIE BOUSFIELD

Please see our upcoming issues for Tributes honouring these men, and their many contributions to our understanding of Canadian birds and invertebrates.

Roy John steps down after a distinguished contribution as Book Review Editor

When long-serving Book Review Editor, Wilson Eedy (appointed in 1975), died suddenly in 2003 he left a vacancy that seemed impossible to fill (see *Canadian Field-Naturalist* 124: 181–182 for Roy John's tribute to Wilson), until Roy volunteered. Wilson had built the book review section to effectively cover an increasing number of publications, both popular and technical, that were of interest to a variety of naturalists and professional biologists, with volunteer reviews by both specialists and generalists. Wilson was proactive and obtained books from publishers that were requested by potential reviewers, as well as finding reviewers for suitable books submitted unsolicited from publishers. He prepared quarterly lists of new titles, including those assigned to reviewers, available, or merely of interest. Roy was well qualified to handle this intense workload.

Born in 1942 in Wattstown, Wales, Roy's early years were spent in London, where he survived the air raids, even one which brought down the ceiling of his room. As is common with many naturalists, his early influences were extremely important. He would join his grandmother when she worked on a farm in Kent every summer, and there he would explore fields, orchards, ponds, and forests. On after-supper walks with his grandfather he asked innumerable questions about the plants and animals he saw. Later, his family lived in Borehamwood, the "British Hollywood" where over 250 films were produced. In 1961, Roy went to Loughborough University to take Industrial Chemistry (a blend of 70% Chemistry and 30% Chemical Engineering). Loughborough is in Leicestershire, in the East Midlands of England, and its university traces its roots to 1909 when it was founded as the Loughborough Technical Institute, which eventually morphed into Loughborough College of Technology and then a university.

His initial employment was in the laboratory at the Esso Refinery near Fawley. This is on the west shore of Southampton Water, on the edge of the Solent, and at 5 mi^2 it is the largest refinery in the UK. The waste water treatment included a couple of retention ponds and a large fresh water lagoon surrounded by woods. This was a great attraction to many water birds, and he spent many lunch times watching Pochards, Tufted Ducks, and the like. Sometimes he drove to Ashlett Creek, to the south of Fawley, where the road past the 16th-century mill petered out in some bushes that overlooked a mudflat where there was always something to see. Here he learned the value of learning one bird's song very well to identify warblers. A little further south, the Calshot shingle spit was good for observing sea ducks. Fawley was a great place as a base, because it was on the edge of the New Forest, a complex of woods and heathland. He also often went to Keyhaven, a small village edged by salt marsh which was a fine place to see seabirds flying by or milling around the west end of the Isle of Wight (i.e. at The Needles). A friend at work drove him to interesting birding locations in Wales, Portland Bill, and Dungeness. At university he met "Ned" (now Dr. David Larkin, professor emeritus at Towson University, Baltimore, Maryland) and together they took a week holiday in Scotland to visit Aviemor, Loch Morlich, Cairngorm, Rothiemurchus, and Inshriach Forests, and to go birding together.

A visit to Loughborough by a recruiter from Montreal looking for electrical engineers led him to request an interview, in which he asked many questions about Canada. To his surprise he got a job offer from Northern Electric in Laschine. So he came to Canada in 1965 (for a two-year period that morphed into 50). In Canada he continued his formal education, taking courses in Business Administration at the University of Western Ontario. He was employed primarily as an environmental manager for multidisciplinary projects, dealing with environmental, social, economic, developmental, and human impacts, and with assessment of hazardous material impacts on human health and safety. He has experience with mining, metal refining, oil refining, airports, road corridors, pulp and paper, fisheries, dairy and food processing plants, shipbuilding and fishing fleets, real estate, chemical production facilities, and the nuclear fuel cycle. He taught university courses in auditing and hazardous materials management, and has completed over 150 audits (including 35 ships). As well as holding various positions in the private sector, Roy served the Federal Government from 1983 to 1987 as manager of the National Uranium Tailings Program at CANMET, and between 1987 and 1991 as Head of Agreements and Data Interpretation at the Environment Canada Water Quality Branch. Subsequently he managed a program to certify that organizations were in compliance with the international environmental management system standard ISO 14001, the occupational health and safety specification OHS 18001, and he ran food safety management system certifications for Ontario, Alberta, and Manitoba, on behalf of the federal government (the Canadian General Standards Board).

Roy has been an active member of natural history clubs while living in Ottawa, Saskatoon, and Halifax, and served them in a multitude of key positions including President of the Ottawa Field-Naturalists Club, Chairman of its Excursions and Lectures Committee, Editor of *The Blue Jay* published by the Saskatchewan Natural History Society, and editor of OFO News.

He has traveled extensively over the world, missing only a few countries (among them Afghanistan), and over the past 35 years has led short- to long-term trips (four days or more) to observe birds, mammals, reptiles, and wildflowers in several parts of Canada and the U.S. (including pelagic trips), as well as many day trips in several Canadian provinces. He went on nature trips as an observer, including trips to the Antarctic (twice), the Arctic (four trips: three in Canada, one in Svalbard), Argentina, Brazil, Canada (all provinces and territories), China, Costa Rica, Ecuador (Galapagos), Egypt, Europe (Austria, Britain, France, and Spain), India, Yugoslavia, Kenya, Tanzania, Madagascar, North Africa, Peru, South Africa, Polynesia, Ukraine, Russia, and U.S.A. (44 states).

Roy has written over 250 book reviews, not all of them on bird guides (though his wide travel experience prepares him particularly well for judging these), 145 articles, 11 peer reviewed papers, two book chapters, 120 popular publications in environmental science, and numerous consultant reports. He has also written one book (*A Naturalist at the Poles – Antarctica*).

For his exceptional service as Book Review Editor, in addition to his other contributions to the OFNC, Roy was awarded the George McGee Service Award for 2015.

FRANCIS R. COOK condensed in large part
on extensive information from Roy John

Minutes of the 137th Annual Business Meeting of the Ottawa Field-Naturalists' Club March 21, 2016

Place and time: Fletcher Wildlife Garden, Ottawa, Ontario, 7:00 pm
Chairperson: Fenja Brodo, President of the OFNC

Over 20 attendees spent the first half-hour reviewing the minutes of the previous ABM, the financial statements, the OFNC committees' annual reports for 2014-2015 and the newly updated Terms of Reference for each committee. The meeting was called to order at 7:30 pm.

1. Minutes of the Previous Annual Business Meeting

It was moved by Annie Bélair and seconded by Diane Lepage that the minutes of the 136th Annual Business Meeting be accepted as distributed.

Carried

2. Business Arising from the Minutes

Ann gave an update on the review of the constitution and bylaws of the club. (See item 8 in the minutes of the 2015 ABM.)

The club started updating its constitution and bylaws because the Ontario government had announced that it would amend the Ontario Not-for-Profit Corporations Act. However, the act has not been proclaimed yet and the accompanying regulations have not been written. Ann explained that her committee has decided to continue to update the By-Laws regardless of the legal requirement to do so.

3. Communications Relating to the Annual Business Meeting

Nil.

4. Treasurer's Report by Ken Young

Copies of the financial statements, a summary table of the financial statements, and the 2016 budget were made available to all attendees.

Ken reminded everyone that the fiscal year runs from October 1 to September 30.

He then presented the financial statements, which were reviewed by the accounting firm of Welch LLP. He said that the club's financial position is pretty good, and explained that the major sources of revenue are membership fees, donations and bequests, and *The Canadian Field-Naturalist*, which, except for bequests, have all increased in 2015.

Ken pointed out that the entirety of the Czasak bequest is now showing in the financial statements; the net disbursements to the club from the entire estate totals $1,235,226.

The increase in revenue in the last two years led to some larger expenses in 2014-2015 such as: a donation of $200,000 to the Nature Conservancy of Canada towards the purchase of land near Westmeath (the Gervais Caves), the creation of the OFNC Research Grants ($15,000 yearly), a donation of $5000 to the Mississippi Valley Field Naturalists to help cover the cost of the appeal to the Ontario Municipal Board to stop a planned housing development that would destroy a portion of the Burnt Lands Alvar, and a donation of $4500 to the Innis Point Bird Observatory to help them hire a bander-in-charge for the 2016 Spring Migration Monitoring Program.

For the 2015-2016 fiscal year, the OFNC is considering donating money to the MacSkimming and Bill Mason Outdoor Education Centres to help pay for buses and some equipment, is working with a contractor to modernize the website, will offer the research grants again, and has renovated the Fletcher Wildlife Garden interpretation centre.

In closing, Ken thanked Frank Pope, past treasurer, and Ann MacKenzie for their continuing help.

Motion: It was moved by Ken Young and seconded by Gord Robertson that the financial statements be accepted as a fair representation of the financial position of the Club as of September 30, 2015.

Carried

5. Nomination of the Accounting Firm

Moved by Ken Young and seconded by Ann MacKenzie that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending September 30, 2016.

Carried

6. Committee Reports

The annual committee reports serve as a record of what the OFNC does throughout the year. A copy of the reports was distributed to attendees at the beginning of the meeting.

Moved by Annie Bélair and seconded by Jakob Mueller that the reports be accepted as distributed.

Carried

7. Updated Terms of Reference of OFNC Committees

Each OFNC committee updated its Terms of Reference in 2015. These Terms of Reference were then formatted by Louis L'Arrivée and published on the OFNC website. Fenja pointed out that if a committee wishes to modify its Terms of Reference, it simply needs to bring it up at a board of directors' meeting.

8. Report of the Nominating Committee Ann MacKenzie

Relevant Excerpts from the OFNC Constitution (revised February 2000)

Article 8 – "The Council shall consist of the officers of the Club and up to eighteen additional members, all members of the Club."

Article 12 – "The officers of the Club and other members of the Council shall be elected annually at the Annual Business Meeting. The nomination of sufficient persons for election to the various offices and membership of the Council shall be the responsibility of the Nominating Committee, which shall act in the manner prescribed in the By-Laws.

The Council shall, at the earliest possible date, appoint chairs and members of Standing and ad hoc committees and Editor and Business Managers, as required for club publications."

NOMINATED OFFICERS	OFFICIAL DUTY
Fenja Brodo	President
Diane Lepage	1st Vice-President
vacant	2nd Vice-President
Lynn Ovenden	Recording Secretary
Ken Young	Treasurer

NOMINATED OTHER MEMBERS (in alphabetical order)

Annie Bélair
Carolyn Callaghan
Owen Clarkin
Barry Cottam
Edward Farnworth
Diane Kitching
Alex MacDonald
Ann MacKenzie
Jakob Mueller
Rémy Poulin
Gordon Robertson
Jeff Saarela
Henry Steger
Eleanor Zurbrigg

Motion: Moved by Ann MacKenzie and seconded by Ernie Brodo that this slate of nominees be accepted as members of the Board of Directors of the OFNC for 2016.

Carried

Fenja thanked Barbara Chouinard, Karen McLachlan Hamilton, Louis L'Arrivée and Julia Cipriani who will not be returning to the Board. She thanked Henry Steger and Eleanor Zurbrigg for their terms as first and second vice-presidents. She also mentioned other changes among the executive committee and chairs of committees:

- Lynn Ovenden is the new recording secretary, taking over from Annie Bélair
- Annie will be the new editor of *Trail & Landscape*
- Gord Robertson is the new chair of Education and Publicity
- Carolyn Callaghan has stepped down as editor-in-chief of *The Canadian Field-Naturalist*, but will remain a director on the Board until a replacement is found
- Diane Lepage is returning to the Board, this time as first vice-president
- Jakob Mueller is the new chair of the Events Committee, taking over from Julia Cipriani
- Mark Patry will attend board meetings as the representative of the Birds Committee (but will not be a director), taking over from Rémy Poulin
- Rémy is now chair of the Finance Committee

The list of committee chairs will be approved by the Board of Directors at the April 2016 meeting.

9. In Remembrance

The OFNC noted with sadness the passing of Dorothy Black, long-time member of the club, on April 12, 2015 and of Garry McNulty, past president of the OFNC, on August 19, 2015.

10. New Business and General Discussion

Nil.

11. Adjournment

Moved by Gord Robertson that the meeting be adjourned at 8:15 pm.

Carried

ANNIE BÉLAIR
Recording Secretary

The Ottawa Field-Naturalists' Club — 2014-2015 Annual Committee Reports

Awards Committee

The Awards Committee manages the process to annually recognize those OFNC members and other qualified persons who, by virtue of their efforts and talents, are deserving of special recognition. In 2015, nominations were received and evaluated (see awards criteria http://www.ofnc.ca/awards.php), resulting in nominees for six awards being recommended to the Board of Directors for approval. Biographies were written for each award winner for publication in the Club's journals and posting on the website. The awards were presented at the annual Awards Night in April. The recipients' names, type of award (in brackets) and rationale for recognition follow below. As well during the year, the committee worked with Mark Brenchley of the Education and Publicity Committee to update the template for the awards certificates.

- Ross Layberry (Honorary Member) – In recognition of lifetime contributions to butterfly conservation
- Natalie Sopinka (Member of the Year) – For revitalizing Club communications via social media, including the blog FieldNotes and Twitter
- Elizabeth Morton (George McGee Service Award) – For twelve years' dedicated service as the Copy Editor for *The Canadian Field-Naturalist*
- Anouk Hoedeman (Conservation – Member) – For creating the Ottawa Chapter of the Fatal Light Awareness Program (FLAP) and bird rescue
- Paul and Cathy Keddy (Conservation – Non-member) – For land conservation achievements in the Lanark area
- Tom Spears (Mary Stuart Education Award) – For years of popularizing natural history topics for the media in the Ottawa area

Committee members: Irwin Brodo, Julia Cipriani, Christine Hanrahan, Ann MacKenzie, Karen McLachlan Hamilton.

ELEANOR ZURBRIGG, Chair

Birds Committee

The Birds Committee and the Club des Ornithologues de l'Outaouais organized another successful Christmas Bird Count in 2014. This event was first held in 1920 and continues to be very popular with club members and the local birding community. This year's Peregrine Falcon Watch continued only at the Heron Road site. Regrettably, most of the buildings adjacent to the downtown nest site no longer allow access to view the nest ledge making any future watch downtown logistically difficult. The Bird Records Subcommittee published a revised checklist of the Birds of Ottawa in 2015 and it is now available. The Ottawa chapter of FLAP (Fatal Light Awareness Program) left the national organization to form Safe Wings Ottawa. Safe Wings Ottawa will carry on the same work and remain affiliated with the OFNC and the Birds Committee. The committee continues to maintain a number of bird feeders in the Ottawa region.

CHRIS TRAYNOR, Chair

Conservation Committee

Three items in particular are worth mentioning:

1. Constance Bay Biothon (http://www.ofnc.ca/conservation/ConstanceBay/index.php):

   We wrapped up field observations for this year-long (2014-2015) bioinventory at Torbolton Forest and the surrounding area. Besides engaging the local community in the practice of active Natural History observation, this project has gathered a baseline of data to compare with historical records. Analysis of data and generation of a report is to be completed over the upcoming winter season.

2. Westmeath (Gervais Caves) Bioblitz (http://www.natureconservancy.ca/en/where-we-work/ontario/featured-projects/gervais-caves-ottawa-1.html):

   On June 13th, a bioblitz inventory of the Gervais Caves property took place, organized by the Conservation Committee in partnership with Nature Conservancy Canada. Though our event only lasted the one day, we observed a number of species which had not been previously documented.

3. Mud Lake Turtle Hatchlings (https://ofnc.wordpress.com/2015/11/13/victory-for-the-snapping-turtles/):

   In early 2015, our committee wrote a letter to the City of Ottawa, proposing that roadside curbs adjacent to Mud Lake be modified to allow passage of wildlife such as turtle hatchlings. We were immensely pleased that later in same year the curbs had been modified. Victory for the Snapping Turtles!

Looking forward:

We are keen to share our collective expertise with local Nature lovers. As we head into 2016, we have planned activities such as:

- Writing short seasonally-relevant "What you can do for Wildlife" articles for T&L
- Surveys of biota at specific sites of interest (e.g., Petrie Island and Marlborough Forest) and the wider landscape
- Continuing our role as an agent for positive stewardship of the landscape through simple actions (e.g., the suggestion of curb modifications at Mud Lake).

OWEN CLARKIN, Chair

Education and Publicity Committee

This committee provides information to the community about natural history and the OFNC itself. This year we brought an OFNC display to several public events: Larose Forest Day in February, the Bird Day Fair at Andrew Hayden Park in May, Bug Day at the Museum of Agriculture and Food in September, and the launch of Ottawa's Urban Forest Management Plan. For youth, we judged projects at the Ottawa Regional Science Fair for OFNC's Special Awards, and presented the awards to Shamus McCoy and Allan Leveille. We selected a local high school student, Sophie Roy, for OFNC to sponsor at Ontario Nature's Youth Summit on Lake Couchiching. Committee members continued to manage the sales table at monthly meetings and OFNC's blog and twitter account. Over 20 social and educational groups in the region requested a nature walk or talk from OFNC; many thanks to those members who respond to such requests and share their knowledge with others.

Late in 2014, OFNC launched an ongoing project to improve its communications both internally with members and with the broader community. For help, we engaged Village PR to conduct a survey of members' preferences and an inventory of OFNC's many communications channels. Village PR recommended several ways that OFNC communications could better meet the information needs of members and support the club's objectives of enhancing the appreciation and conservation of nature.

LYNN OVENDEN, Chair

Events Committee

The Events Committee coordinated 63 outings, five workshops, 10 monthly meetings and the annual awards celebration. The outings and workshops included: amphibians and reptiles (3), birds (32), butterflies and moths (3), other insects (6), plants trees (9), geology (1), photography (3), general natural history (11).

The Events Committee planned, coordinated or supported:

- 61 outings, seven of which were workshops
- 10 monthly meetings, including the annual business meeting; unfortunately the December 2014 monthly meeting was cancelled because the meeting room was not available
- 2015 Awards celebration at St. Basil's Church, held on April 18.

The focus of outings, workshops and monthly meetings included birds (18), plants/trees (16), general natural history (12), amphibians and reptiles (5), travel (4), mineralogy (3) insects (3), photography (3), butterflies and moths (2), conservation (1), fungi (1) and geology (1).

Jon Ruddy led an informal migration watch on Greenland Road and posted results on Facebook over several weeks to track the migration of hawks, eagles, falcons and vultures.

Two outings planned for sparrow spotting on Ottawa airport land were cancelled when access to the area was blocked.

Lynn Ovenden, Chair of Education and Publicity, led the planning of four events over the May long weekend to explore the Gervais property with Ali Giroux, NCC, afternoon birding with Christian Renault, Pembroke Area Field Naturalists, an evening mothing outing with Diane Lepage and a guided tour of Shaw Woods with Grant Dobson.

Sandra Garland and Isabel Nicol led a total of 11 tours – nine of the Fetcher Wildlife Garden, two of the backyard garden.

Monthly meetings were held in Salons A & B of the Neatby Building. The January business meeting was held at the Fletcher Interpretation Centre.

Committee members: Holly Bickerton, Julia Cipriani (chair), Owen Clarkin, Chair of Conservation, Hume Douglas, Jakob Mueller.

If you have ideas for events or would like to lead an outing or event, please contact Jakob Mueller, incoming chair, (jm 890_7 AT hotmail DOT com) or other members of the committee.

JULIA CIPRIANI, Committee Member

Finance Committee

The OFNC's financial reporting systems are operating smoothly and efficiently. In addition the interim financial reports that are prepared several times a year by the Treasurer are also useful. These reports provide the OFNC committees with a snapshot of the year-to-date status of OFNC's revenues and expenses.

The preparation of the 2016 OFNC budget was a less onerous task this year as committees have several years of experience now in preparing a budget. Committees are also using the budget process as a planning tool for the coming year. Special projects and new initiatives are brought forward to the OFNC board for discussion and if approved, the item is included in the budget.

The draft 2016 OFNC budget was discussed in detail at the September 2015 board meeting and the revised budget was approved at the October 2015 meeting. The 2016 OFNC budget forecasts a substantial deficit however the OFNC has the funds to cover the shortfall as a result of the significant bequest to the OFNC.

During the 2015 fiscal year, the Finance Committee responded to issues raised by the board which included donations in kind, investment guideline policy, and preliminary succession planning for the Treasurer position. In addition the Finance Committee updated its Terms of Reference and the OFNC Financial System summary.

The Finance Committee continues to promote fiscal responsibility and the OFNC's financial reports reflect this operating mandate.

BARBARA CHOUINARD, Chair

Fletcher Wildlife Garden (FWG)

Volunteers

Much appreciation was shown by all our visitors for our work in the Back Yard Garden. Comments made about the feeling of serenity that many feel when they visit, as well as their comments on the colourful plants and their placement which adds to its beauty. This is work accomplished by mowing, keeping the paths clear, tending the feeder and birdbath, and the weeding and care of all the plants. This is accomplished by all of our dedicated volunteers who put in a great deal of work to help keep the garden at its spectacular best throughout the spring, summer and fall.

FWG volunteers have come from Volunteer Ottawa; young high school students wishing to fulfill their volunteer hours; and students from Carleton University; Carleton Serves day; the Tamir Youth group; The Ernst & Young community volunteer program.

Over 4000 volunteer hours were used in 2015 to help the Fletcher Wildlife Garden to preserve and protect this unique green space in Ottawa.

Annual Plant Sale

Our annual plant sale raised almost $5000 this year. The success can be partly attributed to help from a Carleton student intern. We continue to sell and donate plants to schools and community gardens, in cooperation with Nature Canada, Evergreen schools programs, and independently. This is one of the FWG's largest activities, providing both additional revenue and good public visibility.

We also continue to sell and donate plants to schools and community gardens, in cooperation with Nature Canada, Evergreen schools programs, and independently.

Visitors, Tours, Walks, and Workshops

We don't have any means of counting the number of visitors that come to the FWG, but the Garden did have a large number of local, out-of-town, and foreign visitors.

We held a series of nature walks every second Sunday afternoon with mixed success. Several walks attracted up to 20 participants and brought us new volunteers and "friends".

A workshop to build simple mason bee boxes was held in April and two boxes were installed in our bee hotel. They were used by Blue Orchard Mason Bees. We also inherited AAFC bee boxes and are working on a cycle of monitoring, cleaning, and storing cocoons safely over winter in consultation with a bee expert from Ottawa University.

Community Outreach

We contributed seeds and plants to the new Canadian Museum of Nature ecozones garden and we helped create a demonstration pollinator planter box next to the Horticulture Building at Lansdowne Park.

New Shed

The tool and equipment inventory for the FWG continues to grow, and storage space had become a problem. A second garden shed (identical to the first one) was purchased to allow more storage space. Items from the Interpretation Centre, the old small tin storage shed and the nursery were moved into the new shed. The company that installed the new shed donated a new bird bath for the Back Yard Garden.

Interpretation Centre (IC)

In the fall of 2015 the Interpretation Centre was cleaned and painted indoors, resulting in a fresh look. The storage area was de-cluttered and new shelving purchased; this work was supported by a donation to the OFNC. The kitchen area was re-organized and enhanced, but the installation of a sink was not possible. Discussions have started about putting a door on the east wall of the IC for safety reasons.

The IC now has internet hook up.

Old Woodlot Rehabilitation

To address the loss of over 50 ash trees from our Old Woodlot, we formed a Tuesday afternoon volunteer group that planted a variety of trees, shrubs, and wildflowers. Invasive species continue to plague all areas, but control measures are improving as we learn more.

A fall Carleton Serves day resulted in another large area of the Old Woodlot being cleared of Dog Strangling Vine (DSV) and gained us another regular volunteer.

To further our role as a Monarch Waystation, last year's Youth Summit participant and her friends planted hundreds of milkweed seeds in the field north of our Old Woodlot.

Memorials

This year a memorial plaque was put on the new bird feeder to commemorate Charles Clifford (an ex OFNC Board member, long time birder, and FWG volunteer). The Cody Trail including the new fern garden was dedicated, and finally, a tree was planted with a plaque to commemorate Laurie Consaul.

The Pond

The pond rejuvenation project was put on hold in November 2014. Two items prevented us from moving forward. We had to get sediment samples to find out if the sediment in the pond is contaminated, and we also needed to get someone from SARA to evaluate the possible risk of having a negative impact on turtles, even though we had no Blanding Turtles visiting the pond since 2010.

The Paterson Group was hired to take sediment samples and have them characterized. The Ottawa Field-Naturalists' Club agreed to cover the expenses. As of December, test results have not been received back.

This summer the pond was covered of vegetation which meant less wildlife was resident. Removal of invasive plants from the pond by four Kemptville Youth Rangers and their leader, together with FWG volunteers, created an opening that attracted ducks that helped reduce the duck weed that was covering the surface of the pond.

Plans to do the "path project" around the pond will continue regardless of the pond rejuvenation work.

Butterfly Meadow (BM)

Work in the Butterfly Meadow occurred most Wednesday evenings throughout the summer. During the first months we removed the dead vegetation and prepared the garden for the season. Throughout the summer we worked at improving the BM by planting flowers and weeding.

The volunteers cleared a few areas where DSV predominated and replaced them with flowers. We also put old newspapers or pool liners around trees and shrubs and then covered them with wood chips. The intention is to minimize weeding in the future years and stop the DSV from spreading.

We also maintained the previously planted areas, and worked at removing the plants that are spreading aggressively. To further our role as a Monarch Waystation, last year's Youth Summit participant and her friends planted hundreds of milkweed seeds in the field north of our Old Woodlot.

Nodes

A new initiative this year was a call for volunteers who are interested in adopting a small area and working independently – with guidance and help from the Management Committee. So far, seven people are tackling "nodes", removing invasives and planting native species. Education nodes, places where we have a "story" to tell our many visitors, have been identified and bilingual signs are being prepared for the 2016 season.

Invasive Species

The buckthorn does not go away, though the remaining trees are much bigger or else they appear from places which are difficult to access. A lot of time was spent on another invasive tree which is proving difficult to control. In the three known sites with *Euonymous europeii* (European Spindle) they are now more widespread and harder to get at than when they were first noticed. The trees are smaller but spread through the roots.

The three volunteers of the Wednesday Invasive Species Group put in over 100 hours in the 2015 season. We continued working eight small plots on the perimeter of the Butterfly Meadow, using several techniques for controlling DSV, including tarping, mowing / reseeding and digging / reseeding. A 100 m^2 test area was cleared just outside the BM with a view to systematically monitoring the effects on DSV of several treatment manual methods. In the New Woods, a large tarp laid down last year was taken up, DSV and other plants growing below it cleared out so the tarp could be put back down. Work removing Asian Bittersweet and other invasives continued in the Birch Grove. Rapidly regenerating non-native birches were pruned back from the surviving native birches planted. A number of other trees in these areas were pruned as needed, to remove dead wood and alleviate crowding by invasives. The AAFC mowed the field south of the pond and resprayed the glyphosate test spray area in the New Woods. Encouraged by the positive results of two years of treatment, we prepared and seeded a 100 m^2 portion of the test area that we will be monitoring for the next few years.

Burdock and Purple Comfrey have been identified as invasive species to address. However, no concerted efforts have been directed towards these invasives as yet.

The Back Yard Garden (BYG)

A lot of work was accomplished this year in the BYG. The usual weeding, transplanting, and mulching was accomplished with a number of new volunteers as well as the ones who have been with us for many years now.

We had many visitors again this year. They included people purposely visiting the garden itself, people making the garden a part of their walk on their way to visit other areas, people walking their dogs, cyclists, birders, photographers, etc. And perhaps, most importantly, people visiting because of "word of mouth"; people who heard about us through friends and family. We left the bird feeder up, for the first time throughout this summer; the feeder was a popular attraction both for birds and photographers. Many people would come just to sit and watch the many birds at the feeder, as well as the squirrels, rabbits, and chipmunks interacting with one another beneath the feeder.

The most interesting and exciting aspect of this year's work was incorporating a Fern Trail in the BYG which honours William J. (Bill) Cody; a beautiful area which has become a major attraction for our many visitors.

We are in the process of getting signs created for all the plants in the garden.

There has been more ongoing work with keeping DSV from invading the BYG. Tarpaulins were laid down at the back of the garden where the problem gets worse each year, as well as in the surrounding areas. The plan is to put down these large tarps, cover them with brush piles, etc., and hope that they help hold back the invasion.

TED FARNWORTH,
committee representative on board of directors

Macoun Club Committee

The Committee, whose members generally all see each other at the weekly events, put together the month-to-month program for the children without the need for committee meetings. The weekly schedule and an illustrated record of what was done were maintained on the Club's website (macounfieldclub.ca). Saturdays, Committee members supervised or gave presentations at the 2-hour-long indoor meetings (held in the Fletcher Wildlife Garden's interpretation centre) or led the 5- to 6-hour-long field trips. Most field trips took place either on private properties in Lanark County or in the Club's nature-study area of 45 years standing in the National Capital Commission's greenbelt (Stony Swamp), but there was also a bus trip to the Montreal Ecomuseum (paid for by the Camfield Memorial Fund). Funds donated in memory of former member Bob Bracken were used to buy enough birding field guides to pass around the table when sharing observations at all indoor meetings. The Committee produced issue no. 69 of the Club's annual publication, *The Little Bear*, and distributed it to members.

Outside the scope of normal activities, the Committee approved and facilitated the participation of Macoun Club members with a graduate student, who was studying children's understanding of, and attitudes toward, climate change. Committee members also scouted out specific locations for the filming of particular forest invasives in the Macoun Nature-Study Area at the request of the Invasive Species Centre, and conducted the video crew and expert narrators to each spot. At summer's end, the Macoun Club led a special field trip in their Study Area for OFNC members.

ROBERT E. LEE, Chair

Membership Committee

The distribution of Club membership for 2015 on 30 September 2015 is shown in the table below, with the corresponding numbers shown in brackets for 30 September 2014. "Other" represent mostly affiliate organizations that receive complimentary copies of the Club's publications. The Board implemented a new policy in 2014 that the family of children in the Macoun Club be given a complimentary membership to encourage interest in the Club in the longer term. The effectiveness of this policy will be reviewed in 2017. The number of new paying members of 133 was consistent with the 130 in 2014. The increase in total paying membership of 19 (Macoun Club members excluded) maintained the growth note in 2014 and was due to higher current-member renewal. The increase in Student Membership to 27 is a positive sign for the Club.

HENRY STEGER, Chair

Publications Committee

The Publications Committee manages publication of the Club's scientific journal *The Canadian Field-Naturalist* (CFN), the Club's newsletter *Trail & Landscape*, and Special Publications. Publications Committee members in 2015 were Dan Brunton, Carolyn Callaghan (Editor-in-Chief, CFN), Paul Catling, Jay Fitzsimmons, William Halliday, Sandra Garland, Tony Gaston, Amanda Martin (Assistant Editor, CFN, vol. 129(2) onwards), Karen McLachlan Hamilton (Editor, *Trail & Landscape*), Frank Pope, Trina Rytwinski (Assistant Editor, CFN, up to vol. 129(1)), Jeff Saarela (Chair), and David Seburn. Committee meetings were held on 5 February and 5 October 2015, and a variety of issues pertinent to the management of the Club's publications was discussed. The committee began a process of evaluating the current formats (the "look and feel") of both *The Canadian Field-Naturalist* and *Trail & Landscape*, with the intent of eventually re-designing one or both of these publications.

Publication of *The Canadian Field-Naturalist* proceeded smoothly and on-time in the last years, and four issues were published in 2015: 128(4) (mailing date 30 January 2015), 129(1) (5 May 2015), 129 (2) (4 August 2015) and 129(3) (23 October 2015). The final issue of volume 129 is expected to be

	CANADIAN		USA		OTHER		TOTAL	
	2015	2014	2015	2014	2015	2014	2015	2014
Individual	359	(354)	9	(10)	0	(0)	368	(364)
Family	309	(296)	1	(0)	1	(1)	311	(299)
Student	27	(20)	0	(0)	0	(0)	27	(20)
T&L	1	(1)	0	(0)	0	(0)	1	(1)
Honorary	24	(23)	0	(0)	0	(0)	24	(21)
Life	44	(45)	3	(3)	1	(1)	48	(49)
Other	30	(25)	0	(0)	1	(1)	31	(26)
Macoun Club	17						17	
TOTAL	811	(764)	13	(13)	3	(3)	827	(780)

published in early January 2016, and upon completion volume 129 will comprise well over 400 pages reporting the results of important natural history research in Canada and on species that occur in Canada, numerous book reviews, and the official minutes of the 136th Annual Business Meeting of the Ottawa Field-Naturalists' Club. In 2015, Assistant Editor Trina Rytwinski retired after completion of 129(1), having served in production of 17 issues of CFN. Trina's work on behalf of the committee and the Club was extremely important during a time of editorial transition. Following Trina's departure, the committee welcomed new Assistant Editor Amanda Martin, who commenced her work with the journal starting with volume 129(2). In late 2015 Roy John, Book Review Editor for CFN, tendered his resignation. Roy served in this capacity since 2003; he has authored over 250 reviews in CFN, and handled all the reviews by others. The new CFN Book Review Editor is Mark Gawn. Ken Young provided extensive and much-appreciated help bringing order to *The Canadian Field-Naturalist* subscriptions, page charge invoices and budget tracking. Jay Fitzsimmons continued to tweet on Twitter on behalf of the journal under the handle @CanFieldNat throughout 2015, in a fun and engaging way, drawing attention to new and earlier papers published in *The Canadian Field-Naturalist*. By the end of 2015 @CanFieldNat had over 2,600 followers.

Four issues of *Trail & Landscape* were produced by Editor Karen McLachlan Hamilton and her team in the current year. *Trail & Landscape* continues to provide an important newsletter function informing Club members of current and upcoming activities, and it is a significant source of documentation of regional biodiversity and conservation needs.

The committee worked with the Bird Records Subcommittee on publication of an updated Bird Checklist for the Club's study area.

In 2015 the Publications Committee started a new initiative: the Ottawa Field-Naturalists' Club Research Grants program. Research grants support field-based research activities that reflect and promote the Club's objectives within eastern Ontario or western Quebec, focused particularly upon the Club's study area – inside the 50 km radius from the Peace Tower in Ontario or Quebec. A total of $15,000 is available each year to fund research proposals. The committee developed guidelines for the research grants, put out the first call for proposals in April 2015, and awarded the first round of research grants in June 2015. The OFNC Research Grants Subcommittee (a subcommittee of the Publications Committee) was established, chaired by Tony Gaston, to receive and evaluate research proposals. The 2016 Call for Proposals went out in November 2015.

In the inaugural year of the program, 11 proposals were received and the following eight were funded:

1. Chelsey Blackman, M.Sc. candidate, Carleton University. Host range of *Lilioceris lilii* and ability of biocontrol agent *Tetrastichus setifer* to find pest on novel hosts. Awarded $2066.
2. Henri Goulet & P.T. Dang, Biodiversity Conservancy International. Study of the Ghost Tiger Beetle (*Ellipsoptera lepida*) population in the Pinhey Sand Dunes. Awarded $2066.
3. Jean Faubert, Société québécoise de bryologie. Flore du parc de la Gatineau/Gatineau Park Flora. Awarded $2066.
4. Stephanie Haas, M.Sc. candidate, University of Ottawa. How do environment and host phylogeny influence mite communities on bumblebee species? Awarded $2066.
5. William Halliday, Ph.D. candidate, University of Ottawa. What ecological factors are most important to habitat selection by Common Gartersnakes (*Thamnophis sirtalis*) in the National Capital Region? Awarded $2066.
6. Marry Ann Perron, M.Sc. candidate, University of Ottawa. Biodiversity in urban stormwater management ponds: effects of pond age and water quality. Awarded $2066.
7. David Seburn, Seburn Ecological Services. Have salamanders declined in eastern Ontario? Awarded $1100.
8. Richard Webster (postdoctoral fellow, Carleton University) and Jim des Rivières (independent researcher). Evidence-based moth catching: designing small, inexpensive and low energy lights for mothing. Awarded $1500.

JEFF SAARELA, Chair

Treasurer's Report

Financial Statements

The financial statements have been prepared by our accounting firm, Welch LLP. They have conducted an engagement review of our financial records.

The Club financial statements are prepared using the fund method of accounting. In the financial statements, the first table (page 2) presents the financial position of all the Club's funds in a consolidated manner. The remaining tables present the statement of operations of the general fund (page 3), the internally restricted funds (page 4) and our one endowment fund (page 5). There is also a cash flow presentation (page 6). The Notes to the financial statements explain the Club's financial policies.

The Notes include a presentation of our long-term investments. Our investments are made according to a policy established by the Board of Directors, and implemented by Ann MacKenzie and our investment advisor, Sue Anderson of BMO Nesbitt Burns.

As in the past, we have received excellent service from our accounting firm, Welch LLP, and our reviewer, Eric Liebmann, to whom I give thanks.

Financial Position

The Club improved its financial position in the 2014-2015 fiscal year as the remainder of Violetta Czasak's bequest was recognized in our accounts. As a result, the total assets of the Club are $1,617,722.

The major sources of revenue for the Club are membership fees, donations and bequests, and subscription charges and authors' charges for the *Canadian Field-Naturalist*.

Both membership and CFN revenues have increased. Donations and bequests, other than the Czasak bequest, are also up.

Expenses were also stable during the year, after allowing for increased donations that the Club has made. In 2015, the Club used revenues from the Czasak bequest to help preserve natural areas and to assist other charities in the area. It also established a research grant program to encourage research in natural history.

Violetta Csazak Bequest

The Club received a large bequest from Violetta Czasak, who died in 2013. Because of the size and complexity of the estate, it has taken a couple of years to liquidate the assets. However, that has been done and the 2014-2015 financial statements reflect the final results, barring anything unexpected.

The net disbursements to the Club total $1,235,226. The gross value of the estate was $1,297,662. Expenses of $62,436 were incurred in liquidating the estate.

Budget for the 2015-2016 Fiscal Year

The Board approves the budget for the Club at the October meeting of the Board of Directors. The budget is attached to the minutes of that meeting and is available on the OFNC website where minutes of Council meetings are kept, at http://ofnc.ca/council/minutes.php.

This year, the budget includes revenues of $122,550 and expenses of $169,005. Therefore we are budgeting for a deficit of over $45,000. This pattern will likely be repeated for at least several years, because we do have to spend the Czasak bequest. There is no rush to do this, but the regulations that govern charities discourage them from sitting on their financial resources.

As I mentioned, the Club has made expenditures that are directly related to our charitable objects. More are planned. The research grant program will continue, and we are exploring the possibility of funding increased use of the MacSkimming Outdoor Education Centre. We are also making some overhead expenditures. For example, we have renovated the Fletcher Interpretive Centre. It is heavily used and the renovation makes it more comfortable and efficient. We are also in the process of modernizing our website.

Routine Events

Most of the Treasurer's duties continue from one year to the next. They include:

- filing the Charities Information Report with the Canada Revenue Agency;
- preparing T4A returns for people receiving honoraria or contract fees from the Club;
- updating the Club's information with our bank, the Canadian Imperial Bank of Commerce, and our online payments processor, PayPal;
- depositing cheques received and writing cheques to pay expenses;
- making financial reports to Council and Committees, such as for the *Canadian Field-Naturalist*, the Seedathon, the Fletcher Wildlife Garden and the Macoun Field Club; and
- assisting the reviewer in the production of the annual financial statements.

I would again like to express my appreciation for all the assistance that I have received from Frank Pope, the past Treasurer, and Ann MacKenzie, who handles the investment activities of the Club.

KEN YOUNG, Treasurer

Review Engagement Report

To The Members of THE OTTAWA FIELD-NATURALISTS' CLUB

We have reviewed the statement of financial position of the The Ottawa Field-Naturalists' Club as at September 30, 2015 and the statements of operations, changes in fund balances and cash flows for the year then ended. Our review was made in accordance with Canadian generally accepted standards for review engagements and accordingly consisted primarily of enquiry, analytical procedures and discussion related to information supplied to us by the club.

A review does not constitute an audit and consequently we do not express an audit opinion on these financial statements.

Based on our review, nothing has come to our attention that causes us to believe that these financial statements are not, in all material respects, in accordance with Canadian accounting standards for not-for- profit organizations.

Welch LLP

CHARTERED ACCOUNTANTS
Licensed Public Accountants

Ottawa, Ontario
February 15, 2016

The Ottawa Field-Naturalists' Club
Statement of Financial Position
September 30, 2015

	2015	2014
ASSETS		
CURRENT ASSETS		
Cash	$ 383,267	$ 228,120
Short-term investments (note 4)	145,803	70,622
Amounts receivable	89,226	16,802
Prepaid expenses	1,079	3,813
	619,375	319,357
LONG-TERM INVESTMENTS (note 4)	998,347	547,883
	$1,617,722	$ 867,240
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Accounts payable and accrued liabilities	$ 2,755	$ 3,382
Deferred revenue	12,481	12,953
	15,236	16,335
FUND BALANCES		
General fund	1,298,752	552,505
Internally restricted funds	266,112	261,337
Martha Camfield endowment fund	37,622	37,063
	1,602,486	850,905
	$1,617,722	$ 867,240

Approved by the Board:

.... President

.... Treasurer

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Statement of Operations and Changes in Fund Balance – General Fund
Year Ended September 30, 2015

	2015	2014
REVENUES		
Membership fees	$ 28,243	$ 27,873
Bequests	973,781	261,987
Donations	4,124	5,068
The Canadian Field-Naturalist		
subscription revenue	22,255	23,357
author charges	41,487	27,645
Pelee trip		14,937
Interest	21,943	13,961
Advertising	675	150
Other	3,754	1,905
	1,096,262	376,883
EXPENSES		
OPERATING:		
Affiliation fees	422	400
Bookkeeping	2,424	3,225
Courier and postage	797	380
Insurance	1,728	1,631
Interest and bank charges	1,379	1,246
Membership	1,201	892
Professional fees	2,723	4,130
Website	2,000	2,078
Maintenance	1,650	1,755
General and miscellaneous	2,237	2,697
	16,561	18,434
ACTIVITY:		
The Canadian Field-Naturalist	76,857	78,758
Fletcher Wildlife Garden	4,360	1,680
Awards committee	523	65
Soiree — net	518	138
Birds committee	5,554	984
Donations	214,500	5,000
Education and publicity	11,441	2,612
Excursions and lectures	136	1,547
Macoun Club	137	241
Pelee trip		12,483
Trail and Landscape	8,059	7,318
Research grants	11,369	
	333,454	110,826
TOTAL EXPENSES	350,015	129,260
NET REVENUE	746,247	247,623
FUND BALANCE, BEGINNING OF YEAR	552,505	317,208
	1,298,752	564,831
Inter-fund transfer - internally restricted funds		(12,326)
FUND BALANCE, END OF YEAR	$ 1,298,752	$ 552,505

The Ottawa Field-Naturalists' Club
Statement of Changes in Fund Balance Martha Camfield Endowment Fund
Year Ended September 30, 2015

	2015	2014
FUND BALANCE, BEGINNING OF YEAR	$ 37,063	$ 36,482
Interest earned	559	581
FUND BALANCE, END OF YEAR	$ 37,622	$ 37,063

Note: The interest above represents half of the interest generated by the fund and is re-invested in the capital of the fund. The other half of the interest generated by the fund is recognized as interest revenue of the Macoun Fund (see Statement of Operations and Changes in Fund Balances Internally Restricted Funds) and is made available for the use of the Macoun Field Club.

The Ottawa Field-Naturalists' Club
Statement of Cash Flows
Year Ended September 30, 2015

	2015	2014
Cash Flows from Operating Activities		
Net revenues all funds	$ 751,022	$ 252,258
Change in the level of:		
Amounts receivable	(72,424)	7,578
Investments	(23,060)	(16,481)
Prepaid expenses	2,734	(3,180)
Accounts payable and accrued liabilities	(627)	(200)
Deferred revenue	(472)	(3,730)
	657,173	236,245
Cash Flows from Investing Activities		
Purchase of investments	(723,905)	(64,568)
Proceeds from maturity of investments	221,320	
	(502,585)	(64,568)
Cash Flows from Financing Activities		
Endowment interest earned	559	581
Increase in Cash	155,147	172,258
Cash at Beginning of Year	228,120	55,862
Cash at End of Year	$ 383,267	$ 228,120

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club

Statement of Operations and Changes in Fund Balances – Internally Restricted Funds

Year Ended September 30, 2015

	General Reserve for Contingencies	Fletcher Wildlife Garden Fund	Manning Fund	Seedathon Fund	Ann Hanes Memorial Fund	De Kiriline Lawrence Fund	Macoun Funds	2015 Total	2014 Total
Revenues									
Donations and grants	$ –	$ 2,145	$ 225	$ 1,438	$ –	$ –	$ –	$ 3,808	$ 1,912
Fundraising	–	4,866	–	–	–	–	–	4,866	4,916
Interest	–	–	3,849	–	–	–	559	4,408	4,527
	–	7,011	4,074	1,438	–	–	559	13,082	11,355
Expenses									
Habitats	–	4,656	–	–	–	–	–	4,656	4,766
Fundraising	–	525	–	–	–	–	–	525	770
Seed	–	–	–	1,295	–	–	-	1,295	1,184
Other	–	–	–	–	–	–	1,831	1,831	–
	–	5,181	–	1,295	–	–	1,831	8,307	6,720
Net Revenues (Expenses)	–	1,830	4,074	143	–	–	(1,272)	4,775	4,635
Fund Balances, Beginning of Year	100,000	12,557	127,737	685	521	13,384	6,453	261,337	244,376
	100,000	14,387	131,811	828	521	13,384	5,181	266,112	249,011
Inter-fund transfer – general fund *	–	–	–	–	–	–	–	–	12,326
Fund Balances, End of Year	$ 100,000	$14,387	$ 131,811*	$828	$521	$13,384	$5,181	$266,112	$ 261,337

*includes principal of $100,000 plus undistributed income of $31,811

(See accompanying notes)

PREPARED WITHOUT AUDIT

The Ottawa Field-Naturalists' Club
Notes to the Financial Statements
Year Ended September 30, 2015

1. Purpose of Organization and Tax Status

The Ottawa Field-Naturalists' Club (the "club") is a volunteer, registered charitable organization incorporated under the Corporations Act of the Province of Ontario. The objectives of the club are to promote the appreciation, preservation, and conservation of Canada's natural heritage and to encourage investigation and dissemination of the results of research in all fields of natural history.

The club's operations are overseen by a Board of Directors (the "board"). Club activities are undertaken by club members participating in standing committees.

As a registered charity the club is exempt from income taxes by virtue of section 149(1)(f) of the Income Tax Act (Canada).

2. Significant Accounting Policies

Basis of accounting

These financial statements have been prepared in accordance with Canadian accounting standards for not-for-profit organizations.

Revenue recognition

(i) Membership fees are recognized as revenue proportionately over the fiscal year to which they relate. The club's membership year is January 1 to December 31. The portion of membership fees that are received but not yet recognized as revenue are recorded as deferred revenue.

(ii) The club follows the deferral method of accounting for contributions. Restricted contributions are recognized as revenue in the year in which the related expenses are incurred. Unrestricted contributions are recognized as revenue when received or receivable if the amount to be received can be reasonably estimated and collection is reasonably assured. Endowment contributions are recognized as direct increases in net assets. The club only recognizes revenue from bequests if the will has been probated, a valuation has been received from the executor of the estate and collection can be reasonably assured. Otherwise, revenue from bequests will be recognized as the amounts are received.

(iii) Subscription revenue and author charges are recognized as revenue at the time of release and shipment of the related Canadian Field-Naturalist publication. The liability for the portion of subscription revenue and author charges invoiced in advance of the release and shipment of the related publication is recorded as deferred revenue.

(iv) Trip revenue is recognized at the conclusion of the related field trip. Amounts collected in advance of field trips that have not yet taken place is recorded as deferred revenue.

(v) Interest income comprises interest from cash and investments. Interest on investments is recognized over their term using the effective interest method. Interest income derived from the investment of restricted contributions, where the contribution agreement specifies that the investment income is restricted, is accounted for the same manner as the restricted contributions.

(vi) Advertising revenue is recognized in the period in which the advertisement is published.

(vii) Fundraising revenue is included in the statement of operations upon completion of the fundraising event.

(viii) Other revenue includes royalties and the sale of other products and services. Revenue from royalties is recognized in accordance with the terms of the related agreement. Revenue from the sale of other products and services is recognized at the time of delivery or when the service has been rendered.

Fund accounting

The Club maintains its accounts in accordance with the principles of fund accounting. Resources are classified for accounting and reporting purposes into funds according to the activity or object specified.

General Fund

The General Fund reports the revenue and expenses relating to general operations and administration activities.

Internally Restricted Funds

(i) General Reserve

The General Reserve for contingencies was established by the Club to fund outstanding operating expenses should the Club discontinue its operations.

(ii) Fletcher Wildlife Garden Fund

The Fletcher Wildlife Garden fund supports the habitat development at the Fletcher Wildlife Garden, with income directed donations and the proceeds for the annual plant sale.

(iii) Manning Fund

The Manning fund was established by a bequest, and the interest generated is used to assist authors to publish articles in the Canadian Field Naturalist.

(iv) Seedathon Fund

The Seedathon fund collects donations from the annual bird sighting event and purchases seed for the Club's bird feeders.

(v) Anne Hanes Memorial Fund

The Anne Hanes Memorial fund was raised in memory of Anne Hanes, the founding editor of Trail and Landscape, and is used to finance the annual winners of the Anne Hanes Natural History Award.

(vi) De Kiriline-Lawrence Fund

The de Kiriline-Lawrence fund was funded by a bequest from the popular author of nature books, and is supplemented by annual donations and used to support conservation efforts.

(vii) Macoun Funds

The Macoun Funds comprises of two internally restricted funds, the Martha Camfield Memorial fund and the Macoun Baillie Birdathon fund. The former is used to support special projects of the Macoun Field Club, a youth club. The latter was raised from donations made during the Baillie Birdathons. Its purpose is to support bird research by a Macoun Field Club youth member.

Martha Camfield Endowment Fund

The Martha Camfield endowment fund was established by the family and friends of Martha Camfield to help continue her efforts to have children study, understand, respect and preserve their natural environment. Under the terms of endowment agreement half of the interest generated by the fund is re-invested in the capital of the fund while the other half is credited to the Martha Camfield Memorial fund and made available for use by the Macoun Field Club. In the Statement of Operations and Changes in Fund Balances – Internally Restricted Funds, the Martha Camfield Memorial Fund and the Macoun Baillie Birdathon Fund have been combined and presented as the Macoun Funds.

Internally restricted net assets

Internally restricted net assets represent the amount approved by the board to be set aside for special purposes. These amounts are not available for unrestricted purposes without the approval of the board.

Financial instruments

The club initially measures its financial instruments at fair value upon initial recognition. The club's cash is subsequently measured at fair value. All other financial instruments are measured at amortized cost at the date of the financial statements.

Donated services

The club is dependent on the voluntary service of many of its members. As there is difficulty in determining the fair value of voluntary services, they are not recognized in these financial statements.

Use of estimates

The preparation of financial statements in conformity with Canadian accounting standards for not-for-profit organizations requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from those estimates.

Management makes accounting estimates in the determination of the club's potentially uncollectible amounts receivable and in the estimation of the club's accrued liabilities.

By their nature, these estimates are subject to uncertainty and the impact on the financial statements of the current future periods could be material.

3. Financial Instruments

The club is exposed to various risks through its financial instruments. The following analysis provides a measure of the club's risk exposure and concentrations as at September 30, 2015.

Credit risk

Credit risk is the risk that one party to a financial instrument will cause a financial loss for the other party by failing to discharge an obligation.

The club's maximum exposure to credit risk represents the carrying value of its cash, amounts receivable and investments totalling $1,616,643 (2014 – $863,427).

The club's cash is deposited with Canadian financial institutions. As a result, management believes the risk of loss on cash to be unlikely.

The company provides credit to authors of the Canadian Field-Naturalist publication in the normal course of operations. It carries out, on a continuing basis, a review of outstanding amounts and maintains a provision for uncollectible accounts. Management has established an allowance for doubtful amounts receivable at September 30, 2015 of $1,500 (2014 – $nil) that represents management's best estimate of potentially uncollectible accounts.

Investments primarily consist of provincial bonds backed by provincial governments and guaranteed investment certificates issued by Canadian financial institutions of high credit quality. Possible changes to the credit quality of these securities exposes the club to credit risk. The club manages its exposure to this risk by holding a diversified portfolio with varied maturities. The club reduces its exposure to credit risk on its amounts receivable by reviewing the accounts on a regular basis, following up on outstanding amounts and creating an allowance for doubtful accounts when applicable.

Liquidity risk

Liquidity risk is the risk that the club cannot meet its debts when they become due. Liquidity risk also includes the risk of the club not being able to liquidate assets in a timely manner at a reasonable price.

The club meets its liquidity requirements by monitoring its expected future cash flow requirements and holding a significant amount of assets that can be readily converted into cash.

Market risk

Market risk is the risk that fair value or future cash flows of a financial instrument will fluctuate because of changes in market prices. Market risk is comprised of currency risk, interest rate risk and other price risk.

(i) Currency risk

Currency risk refers to the risk that the fair value of financial instruments or future cash flows associated with the instruments will fluctuate relative to the Canadian dollar due to changes in foreign exchange rates.

Approximately $2,500 (2014 – $9,000) of club's cash is denominated in U.S. currency. However, the club primarily transacts in Canadian dollars and so management does not believe the club is exposed to significant currency risk.

(ii) Interest rate risk

Interest rate risk refers to the risk that the fair value of financial instruments or future cash flows associated with those instruments will fluctuate due to changes in market interest rates. The club's exposure to interest rate risk arises from its interest bearing assets.

The club's cash includes amounts on deposit with Canadian financial institutions that earn interest at market rates. Fluctuations in market rates of interest on cash do not have a significant impact on the club's financial operations.

The club manages the interest rate risk of its investments by the implementation of prudent investment policies. The club's investments in bonds mature at face value on a staggered basis over the next 14 years. The laddered structure of the maturities helps to enhance the average portfolio yield while reducing the sensitivity of the portfolio to the impact of interest rate fluctuations. Effective interest rates to maturity for these securities range from 2.58% to 4.40% (2014 2.58% to 4.36%).

(iii) Other price risk

Other price risk refers to the risk that the fair value of financial instruments or future cash flows associates with the instruments will fluctuate because of changes in market prices (other than those arising from currency risk or interest rate risk), whether those changes are caused by factors specific to the individual instrument or its issuer or factors affecting all similar instruments traded in the market.

The club is not exposed to other price risk.

Changes in risk

There have been no changes in the club's risk exposures from the prior year.

4. Investments

Short-term investments are comprised of:

	2015		2014
	Market Value	Amortized Cost	Amortized Cost
Province of New Brunswick (zero-coupon bond) – 4.30% yield due December 3, 2015	$ 60,323	$ 60,047	$ -
Equitable Bank (GIC) – 1.45% due February 18, 2016	85,756	85,756	-
Matured in year	–	–	70,622
	$ 146,079	$ 145,803	$ 70,622

Long-term investments are comprised of:

	2015		2014
	Market Value	Amortized Cost	Amortized Cost
Province of New Brunswick (zero-coupon bond) – 30% yield due December 3, 2015	$ –	$ –	$ 60,315
Home Trust Company (GIC) – 2.40% due October 12, 2016	35,835	35,835	34,995
Ontario Hydro (zero–coupon bond) – 4.01% yield due November 26, 2016	28,028	27,643	27,103
Laurentian Bank (GIC) – 1.65% due February 21, 2017	101,009	101,009	–
Province of Ontario (zero-coupon bond) 4.07% yield due December 2, 2017	56,122	52,623	50,565
Province of Ontario (zero-coupon bond) 2.58% yield due December 2, 2018	69,199	66,147	64,483
National Bank of Canada (GIC) 1.86% due February 19, 2019	40,455	40,455	
Province of British Columbia (zero-coupon bond) 3.74% yield due March 5, 2019	32,282	29,575	28,509
Royal Bank of Canada (GIC) 2.51% due September 29, 2019	30,755	30,755	30,000
Newfoundland & Labrador (zero–coupon bond) 4.36% yield due January 7, 2020	49,391	44,223	42,375
Home Trust Company (GIC) 2.15% due February 18, 2020	50,657	50,657	
Province of British Columbia (zero–coupon bond) 3.26% yield due August 23, 2021	73,843	68,092	65,942
Nova Scotia Power (zero-coupon bond) 2.80% yield due February 26, 2022	18,872	18,099	17,606
Province of Manitoba (zero-coupon bond) – 2.60% yield due September 5, 2022	36,347	35,465	34,568
Hydro Quebec (zero-coupon bond) – 3.12% yield due February 15, 2023	45,991	43,794	42,469

4. Investments *(continued)*

Long-term investments are comprised of:

	2015		2014
	Market Value	Amortized Cost	Amortized Cost
Province of Ontario (zero-coupon bond) – 2.90% yield due September 8, 2024	36,922	35,894	–
TD Bank (zero-coupon bond) – 2.93% yield due May 26, 2025	73,954	77,649	–
Province of Manitoba (zero-coupon bond) – 3.82% yield due September 5, 2025	56,058	50,823	48,953
Newfoundland & Labrador (zero-coupon bond) – 2.67% yield due February 27, 2026	63,389	65,384	–
Province of Ontario (zero-coupon bond) – 3.07% yield due June 2, 2026	38,005	36,798	–
Province of British Columbia (zero-coupon bond) – 2.71% yield due Dec 18, 2027	34,897	35,736	–
Bell Canada (zero-coupon bond) – 4.40% yield due May 1, 2029	49,599	51,691	–
	$1,021,610	$ 998,347	$ 547,883

A portion of the club's investments totalling $37,622 (2014 – $37,063) is restricted for endowment purposes. The club has not segregated and identified any particular investment as being held for endowment purposes. Rather, the club allocates a portion of the total interest generated during the year on all of its investments to the endowment fund based upon the opening endowment fund's balance in comparison to the club's opening net assets.

5. Capital Assets

No capital assets have been expensed and included in the statements of operations in either the current or preceding fiscal year.

6. Commitments

Life memberships

The club is committed to provide for regular membership benefits to lifetime members. Since it is not practicable to determine the total liability associated with providing these benefits for the rest of the lives of these individuals, the annual costs are expensed as incurred. Lifetime memberships are no longer being offered by the club. As of September 30, 2015, there were 48 (2014 – 49) remaining lifetime members.

Fletcher Wildlife Garden

The club is committed to maintain the Fletcher Wildlife Garden, a 6.5 hectare property on the Central Experimental Farm in Ottawa, Ontario. The costs to maintain the property are approximately 2,000 hours of voluntary human resources per year, plus regular maintenance and cleaning supplies. The fair value of the contributed human resources are not recognized in these financial statements.

7. Comparative Figures

Certain comparative figures have been reclassified where necessary to conform to the presentation adopted in the current year.

Book Reviews

Upcoming Meetings and Workshops

Obituaries

Tributes

Mailing date of the previous issue 130(2): 30 September 2016

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(continued on inside back cover)

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The Ottawa Field-Naturalists' Club

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Patron

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

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

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The Thomas H. Manning fund, a special fund of the OFNC, established in 2000 from the bequest of northern biologist Thomas H. Manning (1911–1998), provides financial assistance for the publication of papers in the CFN by independent (non-institutional) authors, with particular priority given to those addressing arctic and boreal issues. Qualifying authors should make their application for assistance from the Fund at the time of their initial submission.

COVER: A putative Eastern Wolf (*Canis* sp. cf. *lycaon*) photographed in Algonquin Provincial Park, Ontario (October 2015), the core population of this taxon. The Committee on the Status of Endangered Wildlife in Canada (2015) and the Committee on the Status of Species at Risk in Ontario (2016) recently assessed this wolf as Threatened. See Moldowan and Kitching, pages 351–354 in this issue, for an account of Eastern Wolf food caching in a *Sphagnum* bog. Photo: Hugo Kitching.

The Canadian Field-Naturalist

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Relative Abundance and Diet of Spiny Softshells (*Apalone spinifera*) in a Lake Erie Population

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Populations of the Spiny Softshell (*Apalone spinifera*) in the Great Lakes are of conservation concern despite being secure elsewhere in their North American range. We examined the relative abundance of Spiny Softshells among the turtle fauna at Presque Isle, a peninsula on the Pennsylvania shoreline of Lake Erie. We also compared male and female diets to determine the presence of invasive Zebra and Quagga Mussels (*Dreissena* spp.). The Spiny Softshell was the fifth most common of six turtle species captured (2% of captures). In the peninsula's largest bay there was a significant increase in capture rate and proportion of Spiny Softshell captures in late summer (5% of five species of turtles) compared to early summer (3% of all turtles). Recapture was considerably lower for Spiny Softshells (5%) than for four other turtle species suggesting that either its relative abundance is higher than trapping data indicate or that they are a mobile species with less habitat fidelity than other residents. Prey from fecal samples were quantified using an Index of Relative Importance (IRI). Males ($n = 26$) ate primarily unidentified insects (IRI = 59), followed by algal stalks (IRI = 35) and caddisfly larvae (IRI = 4). Females ($n = 5$) ate primarily algal stalks (IRI = 54), followed by crayfish (IRI = 22) and fish (IRI = 19). Only two turtles, one male and one female, passed Zebra and Quagga Mussels in fecal samples, thus Spiny Softshells do not appear to make significant use of these invasive molluscs.

Key Words: Turtle; Testudines; Trionychidae; *Dreissena*; recapture rate; Presque Isle State Park

Introduction

The Spiny Softshell, *Apalone spinifera* (LeSueur, 1827), is a widely distributed freshwater turtle in the Mississippi-Ohio-Missouri drainage, several smaller Gulf Coastal rivers to the east and west of the lower Mississippi, and the St. Lawrence/Great Lakes drainage and its tributaries (Iverson 1992). In the St. Lawrence/Great Lakes watershed, Spiny Softshells have declined in number and disappeared from some areas, such that their range in the watershed has become fragmented (Fletcher 2002; Vermont Fish and Wildlife Department 2009).

The Spiny Softshell was assessed as a Threatened species in 1991 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and again 11 years later (Fletcher 2002). COSEWIC has reassessed it as Endangered in April 2016 but this change in status has yet to be recognized under the Canadian *Species at Risk Act* (SARA Registry 2016). The species has also been listed as Threatened in Vermont since 1987 (Vermont Fish and Wildlife Department 2009). They are not listed by other Great Lakes states, reflecting their wider distribution outside the St. Lawrence/Great Lakes drainage, in particular in New York, Pennsylvania, and Ohio (Hulse *et al.* 2001; Wynn and Moody 2006; Gibbs *et al.* 2007).

Canadian populations of Spiny Softshells are restricted to the lower St. Lawrence/Great Lakes drainage and are considered to have declined in recent decades. The two major Canadian subpopulations are believed to number between 600 and 1500 adults, with most of them in Ontario and fewer than 100 adults in Quebec (Environment Canada 2016). Spiny Softshell populations in Vermont were estimated to number 100–200 in the area of Missiquoi Bay of Lake Champlain and ~60 near the mouth of the Lamoille River (Graham and Graham 1997; Vermont Fish and Wildlife Department 2009).

The Eurasian invasives, the Zebra Mussel, *Dreissena polymorpha* (Pallas, 1771), and the Quagga Mussel, *D. bugensis* (Andrusov, 1897), were first introduced to the Great Lakes in the 1980s (Herbert *et al.* 1989; May and Marsden 1992). Whether or not they have become a new component of the Spiny Softshells' diet has not been investigated. The Common Map Turtle, *Graptemys geographica*, and Stinkpot, *Sternotherus odoratus*, feed on dreissenid mussels in Lake Erie at Presque Isle, Pennsylvania (Lindeman 2006; Patterson and Lindeman 2009). Common Map Turtles also feed on dreissenid mussels in Lake Opinicon in Ontario (Bulté and Blouin-Demers 2008) and along the Thames River and in Lake Erie in Ontario (S. Gillingwater, personal communication). Recently, the sister species of the Spiny Softshell, the Smooth Softshell, *Apalone mutica*, was also reported to feed on dreissenid mussels in the upper Mississippi River (Cochran and Peterson 2011).

Turtle trapping has been conducted at Presque Isle since 1999 (Lindeman 2006; Patterson and Lindeman 2009). We had two objectives: a) to examine the relative abundance of Spiny Softshells at Presque Isle, including seasonal changes, and b) to quantify and compare male and female diets with an emphasis on determining the extent to which Spiny Softshells are feeding on Zebra and Quagga Mussels.

Methods

Data were collected at Presque Isle State Park in Erie, Pennsylvania (42°09'40"N, 80°05'26"W). Presque Isle is a sandspit peninsula that juts out into Lake Erie. The park is approximately 1300 ha of stabilized sand with several public beaches and a variety of terrestrial and aquatic wildlife habitats. The study area was located at the eastern (distal) end of the peninsula at Misery Bay and an adjoining lagoon, Graveyard Pond (Figure 1).

We captured turtles in Misery Bay and Graveyard Pond using platform basking traps (MacCulloch and Gordon 1978) and single- and double-ended fykenets (Vogt 1980) with 5- to 15-m lead nets and 0.9-m openings. Fykenets were left overnight and checked once daily, while basking traps were checked for use by turtles throughout the day. We conducted occasional trapping in other habitats on Presque Isle, but greater than 95% of all turtle captures on the peninsula were in Misery Bay and Graveyard Pond. In Misery Bay, where most softshells were caught, the greatest trapping effort and most captures occurred in late August and early September (hereafter late summer). We also trapped in late May, June, and early July (hereafter early summer), when trapping was generally more intense in Graveyard Pond and basking traps were used more than fykenets. We compared the relative abundance of Spiny Softshells from Misery Bay fykenet captures between early and late summer using a 2 × 2 χ^2 contingency table. Trap types and trap nights were recorded consistently beginning in 2002, but only sporadically in prior years, so some earlier data were withheld from analysis. We made additional captures of Spiny Softshells at a nesting site in Thompson Bay and on one occasion in Horseshoe Bay, when hatchlings were captured by hand (Figure 1).

We marked turtles individually by cutting combinations of 1–3 triangular notches in the posterior half of the rim of the carapace through 2011 (Plummer 2008)

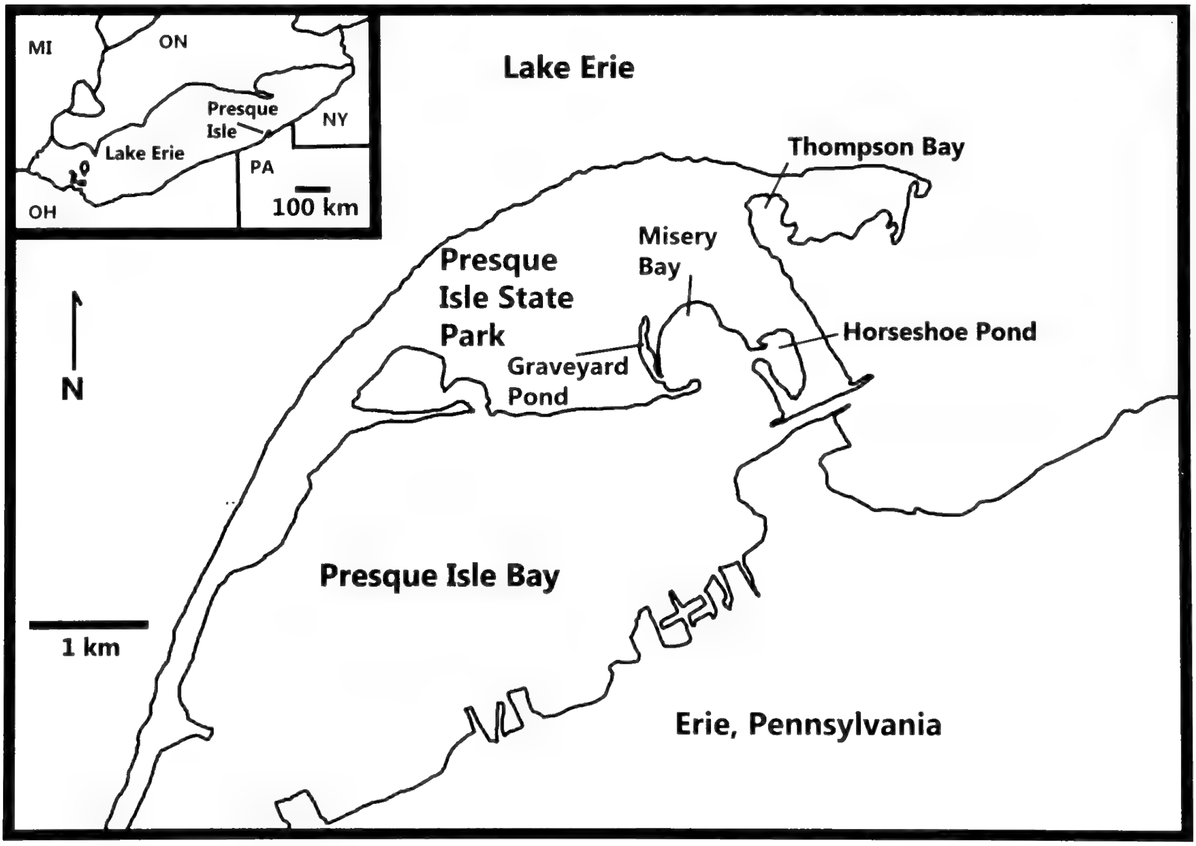

FIGURE 1. Presque Isle State Park on Lake Erie in Erie, Pennsylvania, showing the primary turtle trapping locations in Misery Bay and Graveyard Pond. The locations of Thompson Bay and Horseshoe Pond, where opportunistic captures of Spiny Softshells (*Apalone spinifera*) occurred, are also shown.

and thereafter by applying three-digit numbers with a tattoo gun (Weber *et al.* 2012). Straight-line carapace length (SCL) was measured to the nearest mm with forestry calipers and body mass (BM) was determined to the nearest 1 g, 10 g, or 100 g using 100-g, 1000-g, and 5-kg spring scales, respectively (models pes20100, pes41000, and pes80005, respectively; Pesola Scales, Kapuskasing, Ontario). We determined sex based on diameter of the base of the tail, which is larger relative to overall body size in males, and the more mottled pattern of the carapace in females.

From 2005–2013, we confined Spiny Softshells for 48 hr indoors in plastic bins containing a few centimeters of water. We collected fecal samples by passing the water through a sieve. Samples were preserved in 70% ethanol. Turtles were re-released where they had been captured.

Prey remains in the feces were sorted to the lowest taxonomic category possible under a dissecting microscope (7–30×). Most insects were not identifiable to taxonomic order due to fragmentation, except for caddisfly larvae, whose cases were passed intact, allowing them to be categorized separately from other insects. We calculated the volume of each prey type using volumetric displacement. If a prey type made no noticeable displacement, it was estimated to constitute either 0.01 or 0.05 mL based on size. Each prey category was ranked using an Index of Relative Importance (IRI) based on average volume of feces by type multiplied by the frequency at which each type occurred in feces, divided by the total of the products for all taxa. The IRI values sum to 100 (Hyslop 1980, as modified by Bjorndal *et al.* 1997). We separated IRI sample calculations by sex.

Results

Over 17 years, 73 Spiny Softshells were captured a total of 77 times at Misery Bay (n = 68; 67 fykenet captures and one hand-captured hatchling), Graveyard Pond (n = 4; two fykenet captures, one basking trap capture, and one hand-captured hatchling), Thompson Bay (n = 3; females encountered while nesting), and Horseshoe Pond (n = 2; hand-captured hatchlings). Spiny Softshells accounted for 2% of the total catch of 3749 turtles and were the fifth most common of six species captured overall in trapping on Presque Isle (Table 1).

Relative abundance in Misery Bay fykenet captures rose significantly in the late summer. There were 53 Spiny Softshells of 1027 turtles caught in late summer (5% of all turtles) compared to only 12 Spiny Softshells of 454 turtles caught in early summer (3% of all turtles; $\chi^2_1 = 4.75$, $P = 0.029$; Figure 2). From May to July, Spiny Softshells averaged 0.05 captures per trap-night (one capture per 22 trap-nights), while from August to September, Spiny Softshells averaged 0.33 captures per trap-night (one capture per 3 trap-nights). The total catch of turtles in fykenets set in Misery Bay was higher in late summer (1.70 turtles per trap-night) compared to early summer (0.33 turtles per trap-night). This was due to an increased late-summer catch of Spiny Softshells, Common Map Turtles, and Stinkpots, countering a seasonal decline in the capture rate of the Common Snapping Turtle, *Chelydra serpentina*, while the capture rate of Painted Turtles, *Chrysemys picta*, remained low in both periods (Figure 3). The Spiny Softshell recapture rate (5%) was very low compared to recapture rates for the four other most commonly captured species (range 17–36%; Table 1).

TABLE 1. Turtle catch statistics at Presque Isle State Park for all capture methods, 1999–2015.

Species	New captures	Recaptures	Total	% of total captures	% new captures
Graptemys geographica	1571	814	2385	64	66
Chrysemys picta	207	44	251	7	82
Sternotherus odoratus	385	78	463	12	83
Chelydra serpentina	364	207	571	15	64
Apalone spinifera	73	4	77	2	95
Emydoidea blandingii	2	0	2	0.0005	100
Total	2602	1147	3749		69

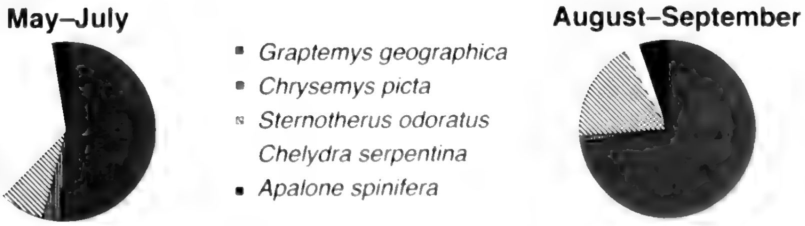

FIGURE 2. Proportions of all turtles captured by species using fykenets set in Misery Bay for early summer (May–July, n = 454) versus late summer (August–September, n = 1027) for 2003–2015 and dates from the period 1999–2002 when trap type was recorded.

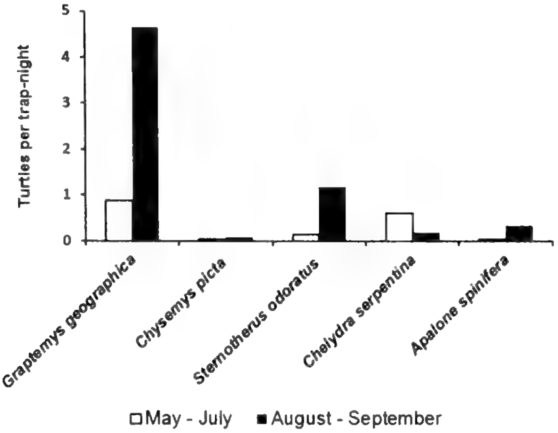

FIGURE 3. Average number of turtles captured per fykenet trap-night by species for early summer (May–July) versus late summer (August–September) for 1999–2015.

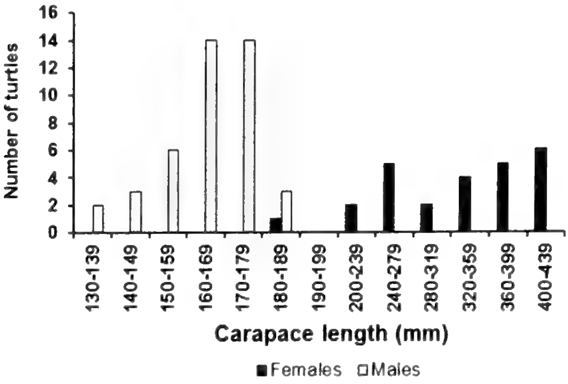

FIGURE 4. Distribution of straight-line carapace length for female and male Spiny Softshells (*Apalone spinifera*) at Presque Isle State Park.

We found almost no overlap in body size between male Spiny Softshells (n = 42; from 133 to 183 mm SCL, mean 164.9 mm SCL; from 192 to 591 g BM, mean 426.4 g BM) and female Spiny Softshells (n = 25; from 188 to 422 mm SCL, mean 327.5 mm SCL; from 522 to 6400 g BM, mean 3401.3 g BM; Figure 4).

Fecal samples were collected from 31 individuals between 2005 and 2013, with 26 samples from males and five samples from females. Eight prey categories were found: fish, caddisfly larvae, crayfish, insect fragments, *Dreissena* spp. mussels, sphaeriid clams, algal stalks, and leaf fragments (Table 2). Among males, insect fragments had the highest IRI value, followed by algal stalks and caddisfly larvae. Among females, algal stalks had the highest IRI value, followed by crayfish and fish. Samples from three females were predominantly algal stalks and fish, while samples from the other two females were predominantly crayfish. *Dreissena* shell fragments were present in two samples, from a male measuring 133 mm SCL, at 43% of sample volume, and a female measuring 393 mm SCL, at 5% of sample volume.

Discussion

Trapping data indicated a low relative abundance for Spiny Softshells in the Presque Isle turtle assemblage, although this value doubled during late summer in Misery Bay. There was however a paradox with respect to the species' relative abundance versus its recapture rate. We recorded a 5% recapture rate. This was much lower than the recapture rates of the four other, more abundant species. In the absence of the relative abundance data we collected, the low recapture rate might be interpreted as being consistent with high abundance of Spiny Softshells. However, the fact that Spiny Softshells were only 4% of turtles caught in fykenets in Misery Bay, by far the most successful trapping method and trapping site for the species, suggests they are relatively rare at Presque Isle rather than abundant.

Movement habits and trap avoidance may provide alternative explanations for the low recapture rate of Spiny Softshells at Presque Isle. The results of a telemetry study by Galois *et al.* (2002) on Spiny Softshell movement patterns in Lake Champlain may explain the seemingly contradictory catch statistics at Presque Isle. Female average home range size was 32.1 km^2 and male average home range size was 2.8 km^2. Females and males were recorded to move minimum distances

TABLE 2. Dietary data for Spiny Softshells (*Apalone spinifera*) at Presque Isle State Park, with percent frequency of occurrence (%F), mean percent volume (%V), and index of relative importance (IRI).

	Males (n = 26)			Females (n = 5)		
Prey taxon	%F	%V	IRI	%F	%V	IRI
Crayfish	4	3.0	0.20	40	36.0	22.00
Caddisfly larvae	35	9.0	4.00	40	0.3	0.10
Insect fragments	100	49.0	59.00	80	3.0	4.00
Zebra and Quagga Mussels	4	2.0	0.08	20	0.9	0.30
Sphaeriid clams	0	0.0	0.00	20	0.9	0.30
Fish	15	7.0	1.30	60	22.0	19.00
Algal stalks	100	29.0	35.00	100	36.0	54.00
Leaf fragments	8	2.0	0.20	20	0.1	0.03

of up to 25.0 and 6.3 km, respectively. It may be that the recapture rate of Spiny Softshells at Presque Isle was low because they are such capable swimmers and are more transient in Misery Bay and Graveyard Pond than the other resident turtle species. It is also possible that marked Spiny Softshells exhibit a greater ability than the other turtle species in Presque Isle to learn to avoid fykenets following capture and release. Trap shyness comparisons among co-occurring turtle species have not been investigated. A low recapture rate of marked Spiny Softshells has also been recorded in the Thames River in Ontario (S. Gillingwater, personal communication). A study of this phenomenon, if indeed it is a general attribute of the species, should be the focus of future research.

The reasons for the seasonal increase in Spiny Softshell captures in Misery Bay in late summer are unknown. Similar increases occurred for two other species, Common Map Turtles and Stinkpots, while Common Snapping Turtle captures declined in the same months. These changes probably relate to seasonal shifts in habitat use, as they were predictably encountered throughout the 17 years of study (P. Lindeman, unpublished data).

The most important prey of Spiny Softshells at Presque Isle were insects, crayfish, fish, and algae. Previous dietary studies of Spiny Softshells have found insects and crayfish to be important prey (Lagler 1943; Williams and Christiansen 1981; Cochran and McConville 1983). Fish and algae (the latter as part of poorly defined vegetative categories) have variously been reported as relatively important (Williams and Christiansen 1981; Cochran and McConville 1983) or nearly absent from the diet (Lagler 1943).

Notwithstanding the fact that female fecal sample size was low (many females held over one to two nights did not defecate), dietary differences between the sexes were relatively pronounced. While both sexes fed moderately heavily on stalked algae (the only taxon present in every sample), males fed most heavily on insects, while females ate less insects and all five passed relatively large amounts of either crayfish or fish. Both fish and crayfish were of low importance (IRI less than two) in male diets. Surprisingly, this widespread, frequently abundant, and strongly size-dimorphic species has not been studied for dietary differences between the sexes. The three most detailed dietary studies of Spiny Softshells have reported pooled samples from males and females (Lagler 1943; Williams and Christiansen 1981; Cochran and McConville 1983), although in the last of these studies, males were reported to eat more dragonfly naiads and females more fish, with similar amounts of crayfish eaten by both sexes. In a similarly size-dimorphic congener, the Smooth Softshell, dietary differences between the sexes were reported by Plummer and Farrar (1981): males fed more on terrestrial food sources, including various insect taxa, fruits, and seeds. Females fed more on aquatic food sources, in particular caddisfly larvae, fish, and crayfish, partly mirroring the results presented here. In many Map Turtle and Sawback species of the diverse emydid turtle genus *Graptemys*, strongly divergent diets typify the small males and much larger females (Lindeman 2013). Further studies of dietary differences between the sexes in the two widespread North American Softshell species are clearly warranted.

While dreissenid mussels were found in only two samples and in low mean percent volume, at least two other species of turtles feed heavily on these invasive molluscs in Misery Bay and Graveyard Pond. Adult female Common Map Turtles consumed primarily dreissenid mussels, with an IRI score of 98; IRI scores declined sharply in smaller juvenile females and both small-bodied adult males and unsexed juveniles had IRI scores less than two (Lindeman 2006). Stinkpots of both sexes also fed heavily on dreissenid mussels, with IRI values of 62 for males and 60 for females (Patterson and Lindeman 2009). Mussels increased in importance in the diets of larger turtles in both species.

Mussels and other hard-shelled molluscs have not been reported to be important prey of Spiny Softshells (Lagler 1943; Williams and Christiansen 1981; Cochran and McConville 1983). Nevertheless, it is possible that the low number of dietary samples from large females (n = 5) obscured the dietary importance of invasive dreissenid mussels in our study. In the only previous report of a species of *Apalone* in North America eating dreissenids, Cochran and Peterson (2011) found that five of 17 female Smooth Softshells caught in a Mississippi River side channel in Wisconsin contained dreissenids (volumetric percentages were not reported). Spiny and Smooth Softshells, along with the Map Turtles and Sawbacks, are among the world's most size-dimorphic turtle species, with adult females in all of these species being greater than 50% longer than adult males in shell length (Gibbons and Lovich 1990). Given the much greater proclivity for mollusc consumption among large adult females than in the smaller conspecific males in many species of Map Turtles and Sawbacks (Lindeman 2013), further study of the possible use of dreissenid mussels by Spiny Softshells should concentrate on the diets of large adult females. Gulf Coast populations of Spiny Softshells have enlarged heads and jaws and may be significant mollusc predators (Lindeman 2000), but the degree to which females in northern populations have the jaw strength and alveolar structure necessary to crush and consume molluscs, particularly the relatively thin shells of dreissenid mussels, is not yet clear.

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Excavation of Red Squirrel (*Tamiasciurus hudsonicus*) Middens by Bears (*Ursus* spp.) in Limber Pine (*Pinus flexilis*) Habitat in Banff National Park, Alberta

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Bears (*Ursus* spp.) in North America eat the seeds of several pines (*Pinus* spp.), including Limber Pine (*P. flexilis* E. James). Information on use of Limber Pine in Canada is limited to a report of three bear scats containing pine seeds found in Limber Pine stands of southwestern Alberta. After my preliminary fieldwork in Banff National Park revealed that bears were eating seeds of Limber Pine there, I conducted a field study in 2014–2015 to assess this use. Because bears typically obtain pine seeds from cone caches (middens) made by Red Squirrels (*Tamiasciurus hudsonicus*), I described the abundance, habitat characteristics, and use by bears of Red Squirrel middens in and adjacent to Limber Pine stands at six study sites. On Bow River escarpments, I found abundant Limber Pines (basal area 1–9 m^2/ha) and middens (0.8 middens/ha, standard deviation [SD] 0.2). Of 24 middens, 13 (54%) had been excavated by bears, and three bear scats composed of pine seeds were found beside middens. Although Limber Pines occurred on steep, xeric, windswept slopes (mean 28°, SD 3), middens occurred on moderate slopes (mean 12°, SD 3) in escarpment gullies and at the toe of slopes in forests of other species, particularly Douglas-fir (*Pseudotsuga menziesii*). At the five other study sites, I found little or no use of Limber Pine seeds by bears, suggesting that Limber Pine habitat may be little used by bears unless the pines are interspersed with (non-Limber Pine) habitat with greater forest cover and less-steep slopes where squirrels establish middens. These observations provide managers with an additional piece of information regarding potential drivers of bear activity in the human-dominated landscape of Banff National Park's lower Bow Valley.

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

Introduction

Seeds of the genus *Pinus* (Pinaceae) are eaten by Asiatic Black Bears (*Ursus thibetanus*), American Black Bears (*U. americanus*), and Grizzly-Brown Bears (*U. arctos*; Mattson and Jonkel 1990). Pine seeds range in weight from < 5 mg for Jack Pine (*P. banksiana* Lambert) and Lodgepole Pine (*P. contorta* Douglas ex Loudon) to the 900-mg seed of Torrey Pine (*P. torreyana* Parry ex Carrière; Tomback and Linhart 1990). However, only large pine seeds (≥ 90 mg) are known to be eaten by bears. In North America, bears eat the 240-mg seeds of Colorado Pinyon (*P. edulis* (Engelm.); Costello *et al.* 2001, 2003), the 175-mg seeds of Whitebark Pine (*P. albicaulis* (Engelm.); Kendall 1983), the 170-mg seeds of Southwestern White Pine (*P. strobiformis* (Engelm.); Mattson and Arundel 2013), the 120-mg seeds of Jeffrey Pine (*P. jeffreyi* (Balf.); Kuhn and Vander Wall 2007), and the 90-mg seeds of Limber Pine (*P. flexilis* E. James; McCutchen 1996; seed sizes from Tomback and Linhart 1990). Of these, only Whitebark Pine and Limber Pine extend into the northern United States and Canada; the other three species occur in the southwestern United States.

In the Yellowstone ecosystem, bears obtain Whitebark Pine seeds from caches of cones (middens) made by Red Squirrels (*Tamiasciurus hudsonicus*; Kendall 1983; Schwartz *et al.* 2006; Fortin *et al.* 2013). As stated by Mattson and Reinhart (1997: 926), when Whitebark Pine seeds are abundant, Grizzly Bears in Yellowstone "eat virtually nothing else". Whitebark Pine seeds are nutrient and energy rich, containing approximately 21% protein, 21% carbohydrate, and 52% lipids, exclusive of the seed coat (Tomback *et al.* 2001).

Limber Pines are also common in the Yellowstone ecosystem, but Kendall (1983) did not find evidence that Yellowstone bears ate their seeds. Limber Pine stands appeared to support few if any Red Squirrels, and Kendall found neither claw marks nor broken branches on Limber Pine trees to suggest that bears were harvesting cones directly from trees. However, McCutchen (1996) found that some American Black Bears, in some years, fed intensively on Limber Pine seeds obtained from Red Squirrel middens in Rocky Mountain National Park, Colorado.

In Alberta, a Limber Pine survey during 1995–1996 recorded three bear scats containing pine seeds in Limber Pine stands: two in Waterton Lakes National Park and the third in the Porcupine Hills, roughly 50 km north of Waterton Lakes National Park (United States Department of the Interior and United States Geological Survey 2012). Many Limber Pines at these locations were short enough that bears could have obtained cones

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directly from trees. The species of bear was unknown; this was a brief survey as part of a study on pine stand health.

In Banff National Park, both American Black Bears and Grizzly Bears are known to eat Whitebark Pine seeds (Raine and Kansas 1990; Hamer and Pengelly 2015). However, to my knowledge, there are no records of bears eating the seeds of Limber Pine in Banff National Park. During preliminary fieldwork in 2014, I determined that bears were eating Limber Pine seeds and I therefore studied Limber Pine in and near Banff National Park during 2014–2015 to assess this use and describe the habitat where bears obtain Limber Pine seeds. Limber Pines in Banff National Park are tall, upright trees, and I assumed that if bears fed on their seeds, they likely would obtain them from Red Squirrel cone caches, as reported in Rocky Mountain National Park (McCutchen 1996) and as reported for Whitebark Pine (Mattson and Reinhart 1997; Hamer and Pengelly 2015). Thus, my principal objective was to record the abundance, habitat characteristics, and use by bears of Red Squirrel middens in and adjacent to Limber Pine stands.

Study Area

Banff National Park extends eastward from the Continental Divide and, thus, is in a rain shadow with respect to the prevailing westerly winds (Holland *et al.* 1982). The park includes Main Range and Front Range habitat of the Rocky Mountains, but does not extend eastward into the Alberta Foothills. Warm, drying adiabatic winds (Chinooks) frequently descend the east slopes of the Rocky Mountains. These winds contribute to the rain shadow effect and to the development of xeric, non-forested balds and open-forest communities below the tree line on south- and west-facing slopes (Achuff 1982; Hamer 1996).

Limber Pine grows on dry, windswept sites, often in shallow soils, and on steep, rocky sites and within cliff bands (Steele 1990; Alberta Whitebark and Limber Pine Recovery Team 2014). Limber Pine is relatively shade intolerant (Steele 1990) and is commonly found in low-density, open forests. In Banff National Park, Limber Pine occurs in the montane and lower subalpine, from valley bottom to about 2000 m elevation, in the eastern, more xeric portions of the park. It typically grows on steep, south- and west-facing slopes with high exposure to the warming, drying influence of Chinook wind and solar radiation.

In Banff, Limber Pine is often found in open forests with Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), a species that also tolerates warm, dry sites (Vyse *et al.* 2006). Limber Pine is also found with White Spruce (*Picea glauca* (Moench) Voss) at lower elevations, Interior Spruce (*P. engelmannii* Parry ex Engelmann var. *engelmannii* × *P. glauca*) in the subalpine, and Lodgepole Pine (*Pinus contorta* Douglas ex Loudon). Limber Pine occasionally grows in close proximity to Whitebark Pine in upper-elevation, windswept sites in the park. However, Limber Pine extends farther east into portions of the Front Ranges where Whitebark Pine is absent.

Corns and Achuff (1982: 105) described a specific Limber Pine–Douglas-fir/Juniper (*Juniperus* spp.)/ Common Bearberry (*Arctostaphylos uva-ursi*) open-forest vegetation type (type O2) in Banff National Park. It is found on rapidly drained, moderately to steeply sloped, south-facing erosional escarpments along the lower Bow and North Saskatchewan rivers, in habitat that is among the warmest and driest in the park. These escarpments are composed of glacial till, unconsolidated material that is frequently eroded, resulting in exposed till and substantial gullying.

Methods

I searched Limber Pine habitat to determine the density and use by bears of Red Squirrel middens, i.e., locations where squirrels cache large numbers of conifer cones, shred these cones to obtain seeds, and create conspicuous deposits of organic material (Gurnell 1984). I also examined Limber Pine trees for broken branches, claw marks, or crushed cones on the ground that could indicate that bears were obtaining cones directly from trees.

I established six study sites based on local knowledge of Limber Pine stands. Four (A, B, D, E) were in Banff National Park: three (A, D, E) in the main Bow Valley between the east park boundary and the beginning of the Bow Valley Parkway and one (B) near the Icefields Parkway crossing of the North Saskatchewan River. The Red Deer River site (C) was less than 1 km east of the park boundary; and F was 21 km east of the park in a narrow portion of the Bow Valley that is subject to strong Chinook wind. Some Limber Pine trees at site F were wind stunted and had cones within 0–2 m of the ground.

Methods differed among the six sites (Table 1). On river escarpments (sites A and B, Table 1), Limber Pines occurred in confined bands above the rivers. Thus, I established 5–12 ha blocks in this linear habitat and made total searches for Red Squirrel middens by walking on elevational contours at regular intervals within these blocks, such that my sightlines overlapped. When the topography was complex, I used the tracks function of a handheld Global Positioning System (GPS) unit to ensure complete visual coverage.

On the Bow River escarpment, I established four blocks of habitat where Limber Pines were abundant (site A.1, Table 1). I fixed the four corners of each block on a handheld GPS unit. The two upper corners were on the escarpment rim, separated by 300 m or 500 m (horizontal map distances); the two lower corners were located at the toe of the slope, similarly separated by 300 m or 500 m. Thus, block boundaries from rim to toe of slope were straight lines of variable length, whereas upper and lower boundaries were fixed hori-

TABLE 1. Limber Pine (*Pinus flexilis*) study sites in and near Banff National Park, Alberta, 2014–2015.

Site	Watershed	Topography	Range of elevation, m	(Co-)dominant tree species	(Co-)dominant indicator species	Field method
A.1	Bow	River escarpment	1360–1470	Douglas-fir	Juniper	Four 5–10-ha blocks, total search
A.2	Bow	Adjacent upland forest	1440–1460	White Spruce, Lodgepole Pine	feathermoss	Three 1.8-ha blocks, total search
B	North Saskatchewan	River escarpment	1400–1440	White Spruce	Bearberry	One 12-ha block, total search
C	Red Deer	Alluvial fan	1670–1800	Limber Pine, White Spruce	Bearberry	7-ha area surveyed in 5 h
D	Bow	Mountain side	1520–1690	Douglas-fir	Juniper	6 ha of belt transects
E	Bow	Mountain side	1460–1600	Douglas-fir, Lodgepole Pine	Juniper, Bearberry	6 ha of belt transects
F	Bow	Mountain side	1380–1570	Douglas-fir, Limber Pine	Juniper, Bearberry	6 ha of belt transects

zontal map distances, but followed the rim and toe of slope, respectively, and, hence, were irregular in shape. Blocks covered 5.2–9.7 ha. The mean horizontal distance from rim to toe of slope was 226 m (standard deviation [SD] 7, $n = 4$ blocks).

I established a 500-m long block where Limber Pines were most abundant. I then established three additional blocks, each 300 m long, two downstream and one upstream of the 500-m long block. Each block was separated by 300 m of unsampled habitat. Blocks were numbered consecutively from upstream to downstream. Limber Pine had low density beyond these blocks and was not sampled.

I recorded coordinates for all Red Squirrel middens in each block with a handheld GPS unit to accurately locate middens near boundaries. In addition, I recorded the presence of Limber Pine cones or cone scales, slope aspect and steepness, and basal area of trees using a 2 m^2/ha prism, following the methods described by Hamer and Pengelly (2015). I examined middens for evidence of excavation by bears. Because Limber Pine cones were 25 times more abundant in 2015 than 2014 (15 cones/tree in 2015 versus 0.6 cones/tree in 2014 on 10 permanently identified trees in site A.1), I re-examined all middens in late September 2015 for evidence of excavation by bears.

Location of middens was facilitated by their large size (mean 39 m^2, range 11–92 m^2; Figure 1). All midden excavations were attributed to bears. Although few scats were found at middens in this study, those found were from bears. In addition, excavations did not differ in appearance from those found in Whitebark Pine habitat, where abundant bear scats and radio-locations from collared bears were positively linked to excavated middens (Hamer and Pengelly 2015). Thus, there appears to be no plausible alternative to bears being the source of these excavations (Figure 1). This contention is further supported by observation that middens in habitat lacking nearby Whitebark Pine or Limber Pine were not dug, including the 15 undug middens of upland site A.2 and an additional nine middens (all undug) in a block 300 m upstream of site A.1. This latter block was excluded from this report because no Limber Pines were recorded at either middens or systematic plots.

Because 79% of site A.1 middens occurred in gullies, I obtained additional information on gully characteristics. I used trigonometry to calculate gully size at the midden by measuring slope distance with a steel tape and slope angle with a clinometer, from gully bottom to crest of gully side, at right angles to the run of the gully at the midden. I averaged the heights of left and right sides to obtain gully depth.

To compare habitat characteristics at middens to characteristics in the site as a whole, I recorded habitat characteristics at 65-m intervals along linear transects on fixed elevational contours within each block (systematic plots). In each block, I ran three parallel transects spaced by 50 m of elevation. I varied starting

FIGURE 1. Red Squirrel (*Tamiasciurus hudsonicus*) cone cache or midden excavated by bears at site A.1 of the Bow River escarpment, adjacent to Limber Pine (*Pinus flexilis*) habitat, Banff National Park, Alberta, 2015. Photo: D. Hamer (10-second timer).

distances on each transect so that systematic plots would not lie directly upslope or downslope from each other.

Because site A.1 was used intensively by bears, I also obtained comparative data from the gently sloping, upland forest at the top of the escarpment (site A.2, Table 1) by establishing 300-m by 60-m irregularly shaped plots (i.e., following the lie of the escarpment rim), adjoining blocks 2–4. Middens were recorded if they were within 60 m of the rim. Upland forest plots were not established at block 1 nor along 200 m of the 500 m length of block 2 because human activity had removed or highly modified the forest at those locations.

At the North Saskatchewan River escarpment (site B, Table 1), the distance from escarpment rim to river bottom was less than half that at the Bow River escarpment, and there was little gullying. Therefore, I searched one 1300-m long, 12-ha block where Limber Pines occurred, following the procedures described for site A. Because of time constraints, I established systematic plots along only 650 m of the 1300-m block length, where Limber Pines were more abundant.

The Red Deer River site was an active alluvial fan created by a stream discharging into the valley bottom of the main Red Deer River Valley (site C, Table 1). I spent 5 h surveying 7 ha of this alluvial fan during a helicopter-assisted field day. This survey was facilitated by the gentle slope and open, immature forest of this disturbed site, which provided easy travel and high visibility. However, because time was limited, I did not collect all data at middens, and I could not confidently state that I had completed a total search. Systematic plots were established at 80-m intervals along a linear transect running through the alluvial fan.

I established three mountain sites in the Bow Valley where Limber Pines occurred on steep slopes with abundant rock outcrops (sites D–F, Table 1). These sites were too extensive for total searches, as used on the confined river banks of sites A and B and the alluvial fan of site C; thus, I sampled them by running 20-m wide belt transects following procedures described by Hamer and Pengelly (2015). I ran transects on elevational contours; 30-m belts were used in open habitat with higher visibility. I used a handheld GPS unit to locate transects at regular vertical intervals on the slopes and to measure transect lengths. I located and described all Red Squirrel middens that fell inside belt transects (Hamer and Pengelly 2015). I also established comparative systematic plots at 65–m intervals along the transects as described for escarpment blocks.

Results

Bow River escarpment (site A)

The mean basal area of Limber Pine in systematic plots at the Bow River site was 9 m²/ha in block 2 and 1–2 m²/ha in the remaining three blocks. Of the 24 Red Squirrel middens examined in 2014 at this site (Table 2), bears had excavated 10 (42%). Bear scats composed almost entirely of pine seed coats were found at three middens. Re-examination in 2015 revealed that bears had excavated 11 of the 24 middens (46%). Two that had been recorded as excavated during 2014 field work were not excavated in 2015, but three other middens were. Hence, 13 different middens (54% of 24 middens) were excavated when 2014 and 2015 observations are combined.

Five of the 24 middens (21%) were at the toe of the slope; one had been excavated by bears. The remaining 19 middens were at the bottoms of gullies (mean gully width 42 m [SD 15, *n* = 4]; mean depth 7 m [SD 3, *n* = 4]). Mean slope steepness at the middens was less than half that at the systematic plots (Table 2).

Only one of the 24 midden sites contained Limber Pine, resulting in a mean basal area at middens of only 0.06 m²/ha. However, mean basal areas of Douglas-fir, White Spruce, and Lodgepole Pine were 23 (SD 11), 11 (SD 4), and 8 (SD 6, *n* = 4) m²/ha at the middens. The total basal area for all conifers at the middens was more than double that in the systematic plots (Table 2).

Sixteen middens were located in upland White Spruce–feathermoss (e.g., *Hylocomium splendens* (Hedw.) Schimp. in B.S.G., *Pleurozium schreberi* (Brid.) Mitt.) forest on the gently sloping bench land adjacent to the escarpment (site A.2, Table 2). None was excavated by bears in 2014, but one was excavated in 2015. Eleven of the upland middens (69%) contained Limber Pine cones or cone scales. The nearest Limber Pines occurred on the rim of the escarpment.

North Saskatchewan River escarpment (site B)

The basal area of Limber Pine was 5 m²/ha in the systematic plots on the North Saskatchewan escarpment (Table 2). One midden occurred on the open slopes of the escarpment. Two were in the single gully that dissected the block, in White Spruce–feathermoss forest (total 0.2 middens/ha). Four middens were within 60 m of the escarpment rim in adjacent upland White Spruce–Lodgepole Pine forest (0.9 middens/ha). All seven middens contained Limber Pine cones or cone scales; none was excavated by bears.

Red Deer alluvial fan (site C)

In the Red Deer site, basal areas of Limber Pine, White Spruce, and Lodgepole Pine were 7, 6, and 5 m²/ha, respectively, at systematic plots placed in the active portion of the fan. No middens were located in this Limber Pine habitat. Four middens were located on the eastern edge of the fan in an alluvially inactive zone where successionally mature White Spruce–feathermoss forest has developed; all contained Limber Pine

TABLE 2. Habitat characteristics at Red Squirrel (*Tamiasciurus hudsonicus*) midden plots and at systematically placed plots in Limber Pine (*Pinus flexilis*) habitat at six study sites in and near Banff National Park, Alberta, 2014–2015.

Site	No. middens	Mean midden density, no./ha (SD)	Mean slope aspect, ° (SD)		Mean slope steepness, ° (SD)		Mean basal area of Limber Pine, m²/ha (SD)		Mean basal area of all conifers, m²/ha (SD)		No. middens excavated by bears
			Midden	Systematic	Midden	Systematic	Midden	Systematic	Midden	Systematic	
A.1	24	0.8 (0.2)	230 (13)	212 (21)	12 (3)	28 (3)	0.1 (0.1)	3.0 (4.0)	44 (8)	17 (5)	13
A.2	16	3.0 (0.9)	17 (55)	25 (43)	5 (1)	6 (3)	0.2 (0.3)	0.0	44 (2)	45 (12)	1
B	3	0.2	153 (65)	147 (15)	10 (4)	29 (6)	0.0	5.0 (4.0)	27 (7)	7 (4)	0
C	4	0.6		122 (9)		8 (1)	0.0	7.0 (4.0)		17 (4)	0
D	1	0.2	213	233 (21)	16	25 (6)	0.0	0.4 (0.7)	66	28 (8)	0
E	4	0.7	146 (23)	155 (21)	21 (5)	31 (9)	2.0 (4.0)	2.0 (4.0)	36 (19)	17 (14)	2
F	2	0.3	144	185 (30)	14	25 (8)	0.0	3.0 (5.0)	48	10 (8)	1

cones or cone scales but none was excavated by bears. The mean distance from these middens to the nearest Limber Pine was 75 m (range 46–95 m).

Mountain sites (sites D-F)

Sites D–F had low Limber Pine basal area and low midden density (Table 2). Mean slope steepness at the middens was less than that at the systematic plots (Table 2). All middens contained Limber Pine cones or cone scales; two middens in site E and one midden in site F had been excavated by bears.

(Note added in proof: One excavated midden containing 48 Limber Pine cones and 57 Whitebark Pine cones on its surface was discovered on 13 September 2016. It was located 6 m from a 16 October 2013 GPS location of a collared adult female Grizzly Bear. This midden was less than 2 km from site E, at 2120 m elevation, adjacent to a rocky ridge crest where both Limber Pine and Whitebark Pine are abundant [D. Hamer, 2016 field observations]).

Discussion

My observations at the Bow River escarpment of Red Squirrel middens excavated by bears and three bear scats composed of pine seed coats are, to my knowledge, the first record of bears in Banff National Park eating Limber Pine seeds. The species of bear responsible for these field signs could not be determined, as both Grizzly and American Black Bears are common in this portion of the park. Species identification could likely be achieved by DNA or remote camera sampling. However, only three pine seed scats were located during this study and were unsuitable for DNA analysis because of age; and use of cameras was precluded.

The steep, windswept, open escarpment at the Bow River site was not used by Red Squirrels as midden locations. Rather, all 24 middens were either in gullies or at the toe of the slope, adjacent to steeper slopes where Limber Pine trees occurred. Middens were on slopes that were less than half as steep and contained more than twice the conifer basal area as slopes where Limber Pines occurred. Limber Pines were similarly absent from midden sites elsewhere in the study area. Eighteen of the 20 middens in sites B–F were in White Spruce, Lodgepole Pine, and/or Douglas-fir forests, where Limber Pine measured zero in basal area. Kendall (1983) found a similar pattern in Yellowstone National Park: no Red Squirrel middens occurred within her three Limber Pine study areas. It appears that Limber Pine stands, typically, are not Red Squirrel habitat and, hence, are less likely to be sites where bears obtain pine seeds. On the Bow River escarpment, however, frequent small gullies provide Red Squirrel habitat in close (< 100 m) proximity to Limber Pine stands, and my observations in 2014 and 2015 suggest that bears regularly eat the seeds of Limber Pine at this location.

Observations from the North Saskatchewan River escarpment and Red Deer River alluvial fan provided further evidence that Limber Pine stands do not, in themselves, support bear use of Limber Pine seeds. These two sites had the highest basal areas of Limber Pine of all sites, but I recorded only one midden and no evidence of use of Limber Pine seeds by bears. Hence I conclude that Limber Pine habitat tends to show minimal or no use by bears – unless the pines are interspersed with (non–Limber Pine) habitat with higher forest cover and lesser slope steepness where squirrels can establish middens, such as found at the Bow River escarpments.

The Red Deer alluvial fan differed from other sites in having gentle slopes of less than 10° steepness. The coarse, rocky alluvium found at the surface of the active portion of this fan may have prevented squirrels from burying and caching cones, and thus may have had an effect analogous to steep slope.

Gurnell (1984) found that Red Squirrels moved Lodgepole Pine cones as far as 185 m. However, I assume that the abundance of Limber Pine cones in middens will decrease with increasing distance from Limber Pine trees, and at some distance a lower number of Limber Pine cones and seeds presumably will not attract bears. For instance, none of the 16 middens in the upland White Spruce forest above the Bow River escarpment but within 60 m of the escarpment rim was excavated by bears in 2014, although eleven of these middens contained Limber Pine cones or cone scales. The abundance of Limber Pine cones may also explain why some middens at the Bow River escarpments were excavated while others were not. For example, Limber Pine was abundant in block 2 of this site (mean basal area at systematic plots, 9 m^2/ha), and all eight middens in this block were excavated in 2015. In contrast, Limber Pine was less abundant in the other three blocks (1–2 m^2/ha), and only three of the 16 middens at these other locations were excavated in 2015.

Although the North Saskatchewan site was identified as a Limber Pine–Douglas-fir type by Corns and Achuff (1982), I did not find Douglas-fir at this site. Elevation was the same as at the Bow River escarpment (1400 m, Table 1), but the North Saskatchewan is farther north in a glaciated region of the park that includes the Wilson Icefield 5 km north of my study area. At the North Saskatchewan site, the lack of Douglas-fir and the presence of only one forested gully to provide suitable food and shelter for Red Squirrels in close proximity to Limber Pine trees may explain why midden density was only a quarter of that found at the Bow escarpments and also why bears apparently did not eat Limber Pine seeds at the North Saskatchewan escarpment.

No field signs were found to indicate that bears were harvesting cones directly from Limber Pine trees. Although Banff National Park is subject to frequent Chinook winds, the trees are not stunted as they are in Waterton Lakes National Park or the Porcupine Hills of southwestern Alberta, where Alberta's strongest Chinook winds occur (Vickers *et al.* 2001). Thus, cones were not within reach of bears on the ground except at site F, which also lacked evidence that bears had harvested cones from trees.

The Bow River Valley has been described as one of the most human-dominated landscapes where Grizzly Bears still survive (Gibeau *et al.* 2001). Hebblewhite *et al.* (2003) found that 82% of American Black Bear mortality in the Bow Valley is caused by humans. The Bow Valley escarpment, where I observed substantial use of Limber Pine seeds by bears, is within 3 km of a town of roughly 10 000 people, the four-lane Trans-Canada Highway, the Canadian Pacific Railway main line, and an 800-unit campground. The escarpment is also traversed by a network of walking and bicycling trails and undesignated paths.

Managers should consider use of Limber Pine seeds by bears in the Bow River escarpment if they choose to mitigate soil erosion and other impact from the profusion of paths that currently dissect the unique and fragile habitat of the Bow River escarpment. Continued evaluation of bear use of Limber Pine seeds may also benefit management of Limber Pine throughout Alberta, where this tree species is listed as endangered (Alberta Whitebark and Limber Pine Recovery Team 2014).

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Exploring the Adaptive Significance of Five Types of Puma (*Puma concolor*) Vocalizations

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Communication is a central component of animal behaviour, yet communicative behaviours are poorly studied due to their complexity and varied functions. Pumas (*Puma concolor*) are wide-ranging, solitary felids that primarily use indirect cues (e.g., scent marking) for communication. Because these cryptic carnivores are rarely observed directly, little is known about their vocalizations in the wild. We recorded a variety of Puma vocalizations among females and family groups using motion-triggered video cameras and then attempted to understand the function of each vocalization. We found two categories of vocalizations: 1) attention-attracting (caterwauling and mewing), and 2) calls (contact, agitated, and alarm). Vocalizations to attract attention ranged across broad frequencies. Contact, agitated, and alarm calls are narrow-frequency vocalizations that varied in intensity and were used to communicate with nearby conspecifics. Vocal communication entails risk, and while some Puma vocalizations may provide benefits that outweigh their risk, others are structured to limit detection and risk. These observations highlight the importance of the structure of vocalizations used during different behaviours to understand their adaptive significance.

Key Words: Alarm call; communication; family groups; *Puma concolor*; vocalizations; remote camera

Introduction

Communication to convey information between individuals or groups is a central component of animal behaviour (Davies *et al.* 2012). All behavioural interactions between individuals, from courtship and mate selection to territorial defense, are conducted through signals or displays (Bradbury and Vehrencamp 1998; Davies *et al.* 2012). Felid species, being primarily solitary, conduct most of their communication using a variety of indirect signals (Seidensticker *et al.* 1973; Smith *et al.* 1989; Peters and Tonkin-Leyhausen 1999; Logan and Sweanor 2001; Allen *et al.* 2016), including visual, olfactory, auditory, and tactile cues (Bailey 1974; Verberne and Leyhausen 1976; Logan and Sweanor 2010). Such communicative behaviours require study, especially for cryptic species, due to their complexity and varied functions (Bradbury and Vehrencamp 1998; Davies *et al.* 2012). By better understanding acoustic communications, we can shed light on the evolutionary basis of these calls as well as provide a more complete picture of animal behaviour.

Pumas, *Puma concolor* (Linnaeus, 1771) are large, solitary felids that range widely across North and South America. Intraspecific communication between Pumas is dominated by indirect cues via scent marking, with the most common form being scraping (Logan and Sweanor 2001; Allen *et al.* 2014, 2015). Vocal communication is generally limited to family groups (i.e., between mothers and kittens) and to mating pairs (Rabb 1959; Currier 1983; Logan and Sweanor 2001). Male and female Pumas have different life histories with males occupying much larger home ranges and more frequently creating scent marks (Logan and Sweanor 2001; Allen *et al.* 2014, 2015), and only female Pumas exhibiting parental care (Logan and Sweanor 2001). Females give birth to 1–4 kittens in each litter and raise them for 12–24 months before the kittens disperse (Logan and Sweanor 2001). Vocalizations may be an important aspect of communication between adult females and their young prior to dispersal.

Due to the difficulty of observing wild Pumas, there is little known about their vocalizations, and most information on their vocalizations has been based on captive animals (e.g., Rabb 1959; Potter 2002). However, captivity often alters an animal's behaviours or creates new ones (Mallapur and Chellam 2002; Quirke *et al.* 2012), making it important to collect observations of Puma vocalizations in the wild. Logan and Sweanor (2001) described observing several different types of vocalizations by wild Pumas but, due to the limitations of field observations, they were not always able to visually identify both the sender and receiver of the communications and their associated body language. Other researchers have tested Puma reactions to recorded vocalizations (Macarrao *et al.* 2012) or described Puma vocalizations during a hunt (Smallwood 1993), but these instances were either not recorded or were responses to unnatural situations. Recent advances in the technology of motion-triggered video cameras now enable researchers to remotely record intimate behaviours in Pumas and other cryptic species (e.g., Macarrao *et al.* 2012; Allen and Taylor 2013). Thus, although vocalizations have been observed in the wild by researchers, we can now use motion-triggered cameras with sound recording capabilities to document Puma communications under natural conditions.

The structure of Puma vocalizations likely reflects adaptations to their specific function and behaviour. For example, vocal exchanges between females and kittens potentially attract the attentions of male Pumas and other large predators that are a major source of mortality for Puma kittens (Logan and Sweanor 2001). Thus, acoustic characteristics of each of these vocalizations have likely been optimized through natural selection to communicate most effectively at different distances (short-, medium-, and long-range) while minimizing exposure to predation risks (Peters and Tonkin-Leyhausen 1999). In this study, we compared and categorized five different types of Puma vocalizations to better understand how these acoustic communications contribute to and illuminate different behaviours.

Study Area

We studied Pumas living in a 1700 km^2 area of the Santa Cruz Mountains of California (36°58'26.82"N, 122°1'50.87"W). Pumas live throughout in this region and are not hunted, although much of their mortality is nevertheless due to anthropogenic causes (e.g., killed for livestock depredations or by vehicle collisions; C. C. W., unpublished data). The Pacific Ocean, cities of San Francisco and San Jose, and Highway 101 bound the western, northern, and eastern edges of the study area, respectively. The study area has a Mediterranean climate with the majority of rainfall occurring from November to April. Elevations range across a gradient from sea level to 1155 m (Wilmers *et al.* 2013).

Methods

As part of a larger study on Puma ecology we captured 42 Pumas from 2010–2013 (see Wilmers *et al.* 2013 and Allen *et al.* 2014 for study overview and Puma capture information). We monitored the Pumas using Global Positioning System (GPS)-telemetry collars (Model GPS Plus 1D, Vectronics Aerospace, Berlin, Germany) and opportunistically deployed motion-triggered video cameras with microphones (Bushnell TrophyCam IR 6 mp, Overland Park, Kansas, USA) at sites of interest. These sites included community scrapes (n = 45, scent marking locations regularly used by Pumas e.g., Allen *et al.* 2014), a nursery (n = 1), and baiting sites (n = not recorded) where we placed road-killed deer carcasses. We located these sites (except for baiting sites) using GPS information collected by the collars we placed on the wild Pumas. At each location, we placed one motion-triggered video camera, set to record 60 s of audio and video each time motion was detected with a 1 s delay before triggering again.

Studies of wild felid vocalizations have limited sample sizes due to the elusive nature of the research subjects (Peters and Tonkin-Leyhausen 1999), but the frequency and harmonics of vocalizations are generally stereotypical having been selected for over many generations (Peters and Peters 2010). In addition, although we placed numerous cameras at sites, we were not prioritizing acoustic data and thus our recordings were of variable quality and distances from the signal producer. Therefore, instead of reporting mean results from multiple recordings of similar behaviours, we used the videos with the highest quality sound recording to ensure the integrity of the recording and accurate characterizations of vocalizations. For each recording, we used the package Seewave (Sueur *et al.* 2008) in the program R (R Development Core Team 2013) to create spectrograms and measure the structure of the vocalization, including the dominant frequency, frequency range, and duration (defined as the duration for one vocalization, not the series).

Results

Attention-attracting vocalizations

On 17 May 2013, a camera we placed at a community scrape recorded an uncollared female Puma caterwauling (Video S1). The female Puma made a series of caterwauls for 14 s. The caterwauling vocalization was loud, long, and covered a large frequency range. It ranged from 0.1–5.0 kHz and had the longest duration of all vocalizations (caterwauling call = 1.9 s; Figure 1).

A camera set at the site of a nursery of Puma female 23F (Video S2) captured 23F interacting with three neonatal kittens on 23 May 2012. The kittens do not vocalize in a prior video before their mother's return and do not make any vocalizations when their mother arrives at the nursery, possibly because they are sleeping. While nursing, the kittens do not initially vocalize but then begin mewing as they shift their nursing positions. The mewing by kittens had the largest frequency range of all Puma vocalizations (2.1–14.7 kHz, duration = 0.4 s; Figure 2), over twice as large as those of caterwauling, but the vocalizations were much shorter in duration.

Call vocalizations

We placed many cameras at community scrape sites, which were regularly used for communication by Pumas. On 31 August 2012, one of these cameras recorded a female Puma walking through the community scrape with her kittens (Video S3). The group leaves the area covered by the camera and 11 s later the mother Puma begins giving a high whistling call. After 23 s, a third straggling kitten is then seen walking past the camera to catch up with the rest of the family group. The structure of the contact call exhibits a sweeping frequency pattern (i.e., progressing from one frequency to another and then back to the original again), with the dominant frequency near the top of their range. The contact call ranged from 2.2–4.5 kHz (duration = 0.4 s; Figure 3), with a dominant frequency of 4.3 kHz.

At a camera set at another community scrape site on 6 September 2013, we recorded a young kitten (5–7 months old) alone investigating the site (Video S4). The mother was not visible when the kitten began to give an agitated call and no response from any of its family members was recorded. The call ranged from 0.4–4.1 kHz (duration = 0.5 s; Figure 4).

On 25 January 2012, we recorded the alarm call of 33M, a 13-month-old un-collared male kitten of 19F, when he was trapped by a foot-hold snare. We set a camera and a foot-hold snare at this location in an attempt to video a recapture of collared female 19F near one of her kill sites (Video S5). 33M triggered the foot-hold snare instead of his mother. He was visibly startled immediately upon capture, and he vocalized a series of short whistles 15 s later. His mother was in the immediate vicinity based on her GPS location data. The alarm call of 33M had a large range, from 0.9–5.2 kHz (duration = 0.3 s; Figure 5), with the dominant frequency of 2.9 in the middle of the range.

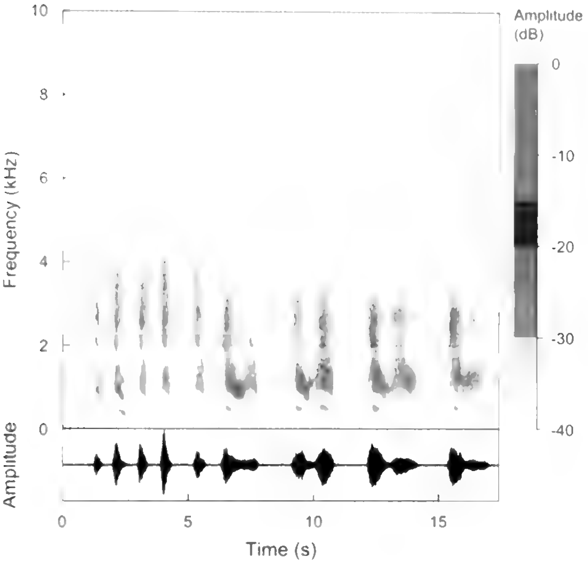

Figure 1. A spectrogram of a Puma (*Puma concolor*) caterwauling (from Video S1).

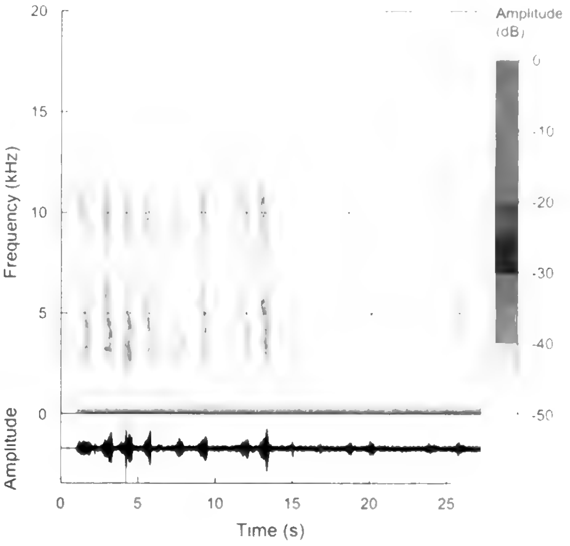

Figure 2. A spectrogram of a Puma (*Puma concolor*) mewing (from Video S2).

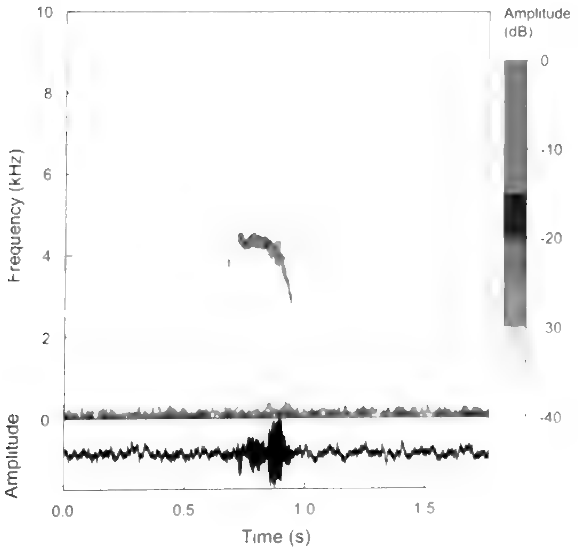

FIGURE 3. A spectrogram of a Puma (*Puma concolor*) contact call (from Video S3).

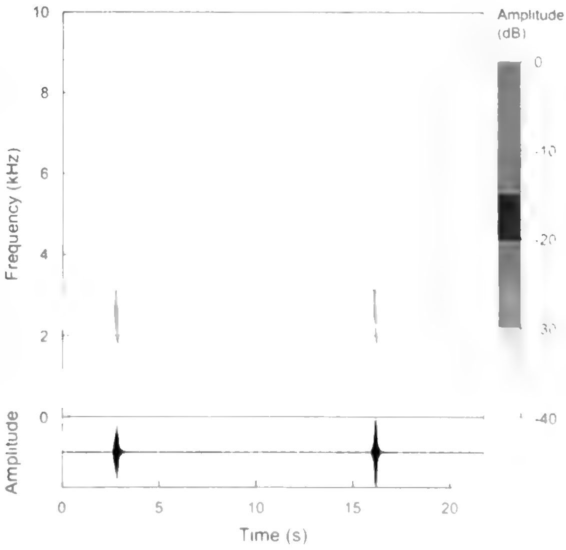

FIGURE 4. A spectrogram of a Puma (*Puma concolor*) agitated call (from Video S4).

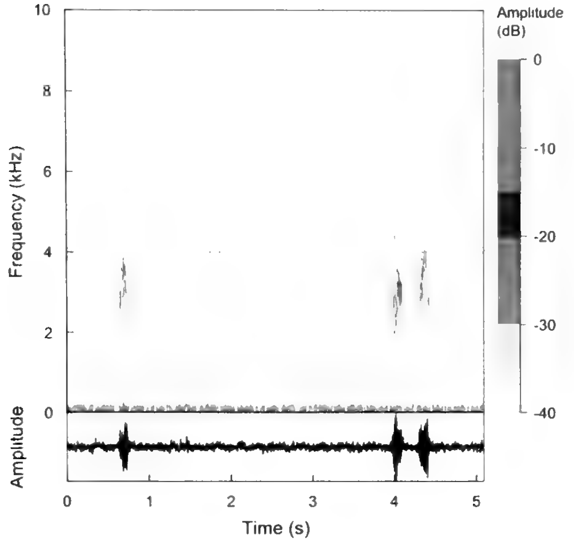

FIGURE 5. A spectrogram of a Puma (*Puma concolor*) alarm call (from Video S5).

Discussion

These are among the first published recordings of vocalizations from wild Pumas, and provide new insight into the structure and possible adaptive significance of Puma vocalizations. Vocal communication entails risk, as it can attract the attention of predators or competitors and increase the risk of injury or mortality for both the sender and receiver of communications (Hughes *et al.* 2012). Our findings suggest that our recorded vocalizations fall into two types: 1) vocalizations that are used to attract attention of conspecifics with little regard to cost, and 2) contact and alarm calls which are short calls that vary in intensity and are used to communicate with nearby conspecifics.

Vocalizations designed to attract attention (caterwauling and mewing) were characterized by broad frequencies and modulations, or changes in frequency (Vencl 1977; Redondo and deReyna 1988), and caterwauling was characterized by long durations. Caterwauling is presumed to be used to attract mates from a distance (Logan and Sweanor 2001) and is primarily used by females (Logan and Sweanor 2001; Allen *et al.* 2014). The range of frequencies used likely enables the vocalizations to carry long distances to attract all possible mates in the vicinity. Similarly, mewing is a vocalization aimed at gaining attention, despite the danger clearly posed to young animals. An experiment conducted with ground-nesting birds found that begging increased predation risk, which suggests that the immediate reward of food greatly outweighs any observed risks (Haskell 1994). Young animals in a single litter or brood compete with each other, and the more insistent individuals often obtain more nutrition (e.g., Redondo and De Reyna 1988), allowing them to be larger and out-compete other individuals, and increase their chances of survival. The direct benefits of attracting a mate or caregiver apparently outweigh any potential risks posed by predators.

Contact calls are vocalizations that are theoretically used for communication while limiting danger, and are characterized by pure tones and high pitches that are difficult to localize and attenuate over short distances (Vencl 1977). This allows for immediate communication, but limits the ability of predators to easily locate the sender or receiver of vocalizations. It is the nature of Puma family groups to travel large distances, and they appear to use vocalizations to stay together. After kittens reach three months of age, they are capable of traveling distances greater than1 km to kill sites with their mothers, and regularly accompany their mothers after they reach six months of age (Logan and Sweanor 2001). With multiple kittens there are always opportunities for one to lag behind or stray while in transit that could increase their risk of injury or mortality. Therefore, contact and alarm call vocalizations between family groups could serve to reduce this risk. Puma vocalizations may be structured to limit detection risk from larger predators (e.g., Gray Wolves (*Canis lupus*), bears (*Ursus* sp.), humans) while allowing close-range communications.

Agitated and alarm calls were superficially similar to contact calls in that they were short but they contrasted in that they incorporated broad frequencies and were harsher. Similar patterns, in which calls signifying higher urgency and danger tend to be noisier and harsher, have been found in other species as diverse as Baboons (*Papio cynocephalus ursinus*) and Mongoose (*Suricata suricatta*; Seyfarth and Cheney 2003). The broader frequencies likely made the sender more immediately locatable than contact calls (Redondo and De Reyna 1988), but the increased risk of these calls might be acceptable because these calls were produced in response to a perceived immediate threat or danger. For example, defensive calls by birds and small mammals may recruit conspecifics to help mob a predator (Vencl 1977; Maier *et al.* 1983), and defensive calls by Puma kittens may serve a similar function by eliciting protective behaviour by their mother.

The structure of Puma vocalizations informs our understanding of their adaptive significance. Pumas are large mammals capable of producing deep and guttural calls; that they instead sometimes use birdlike calls to communicate likely reflects the adaptive significance of those call structures. Although the volume, or amplitude, of calls is also an important factor to consider, we could not compare absolute amplitudes because calls were recorded at different distances from the microphones. The use of vocalizations by Pumas demonstrates that acoustic communications may provide benefits that outweigh their risks and highlights the importance of the structure of vocalizations used during different behaviours. Based on our video recordings that support and enhance the field observations of Smallwood (1993) and Logan and Sweanor (2001), Pumas vocally communicate in numerous circumstances, including at nurseries, to maintain contact between family groups while travelling or in distress, and when trying to locate mates. The use of motion-triggered video cameras with sound-recording capabilities can create new avenues of scientific research, including cataloguing the full range of Puma vocalizations, understanding intraspecific communication for breeding, intra-familial behaviours exhibited at nurseries, and interspecific interactions including predation and competition.

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SUPPLEMENTARY MATERIAL:

VIDEO S1. A video of a female Puma (*Puma concolor*) caterwauling. https://youtu.be/U3o3x6T-bmI
VIDEO S2. A video of Puma (*Puma concolor*) kittens mewing at their nursery. https://youtu.be/rv6KzyQ7BeA
VIDEO S3. A video of a Puma (*Puma concolor*) giving a contact call. https://youtu.be/seXH_kqM_KM
VIDEO S4. A video of a Puma (*Puma concolor*) giving an agitated call. https://youtu.be/fCadngkBreA
VIDEO S5. A video of a Puma (*Puma concolor*) giving an alarm call. https://youtu.be/uToKCSQJa8M

Note

Application of Oxygen During Medetomidine and Ketamine Immobilization of Wolverines (*Gulo gulo*)

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Chemical immobilization involves risks for study animals. Research indicates that anesthetized Wolverines (*Gulo gulo*) can develop hypoxemia due to drug-induced physiological changes and altitude. We administered supplemental oxygen intranasally at flow rates between 0.5 and 1.5 L/min to Wolverines immobilized by medetomidine and ketamine between ~2110–2880 m in the Rocky Mountains. Following capture in log box traps, we measured hemoglobin oxygen saturation (SpO_2) and rectal temperature before and after application of oxygen using a pulse oximeter and digital thermometer. We determined oxygen flow rates based on the volume required to reach a SpO_2 reading over 90%. We observed initial hemoglobin oxygen saturation below 75%, indicating hypoxemia, for all Wolverines handled. Supplemental oxygen reversed the hypoxemia, increasing hemoglobin oxygen saturation to over 90% within 13 min in all cases. We recommend that supplemental oxygen be provided to immobilized Wolverines anesthetized using medetomidine and ketamine to guard against hypoxemia.

Key Words: Altitude; anesthesia; chemical immobilization; elevation; *Gulo gulo*; ketamine; medetomidine; oxygen; Wolverine

Introduction

Chemical immobilization is critical to many wildlife studies to restrain animals for procedures such as radio-marking or biological sampling. Physiological changes caused by chemical immobilization drugs can carry risks for animals under anesthesia. Wolverines, *Gulo gulo* (Linnaeus, 1758) have been immobilized using several drug combinations including telazol (Golden *et al.* 2002), ketamine and xylazine (Copeland 1996), and medetomidine and ketamine (Quigley 2000; Fahlman *et al.* 2008). Of these, medetomidine is a potent alpha-2 sedative that can cause bradycardia (Virtanen 1989) and decreased partial pressure of arterial oxygen (Caulkett *et al.* 1999). Arterial oxygen saturation (SpO_2) during immobilization of free-ranging Wolverines can decrease due to drug-related physiological changes or due to high altitude. Fahlman *et al.* (2008) presented data indicating that reduced oxygen saturation in Wolverines immobilized using medetomidine and ketamine at their study site in Scandinavia at altitudes of 500–1300 m was partially attributable to drug-induced intrapulmonary changes (70%), and partially due to altitude (30%). Decreased air pressure at higher altitudes can result in decreased oxygen concentration in the lungs leading to lower oxygen saturation in the blood. Generally, arterial hemoglobin oxygen saturation under 90% is considered unfavourable, is indicative of impaired cardiopulmonary performance (McDonnell and Kerr 2007), and can lead to impaired brain function. Researchers and wildlife professionals immobilizing wildlife should also be mindful of the possibility that pulse oximetry may overestimate SpO_2 and miss cases of hypoxemia (Fahlman *et al.* 2010). Administering oxygen to chemically immobilized wildlife will increase oxygen saturation in uncompromised animals and treat or prevent hypoxemia (Fahlman 2014).

The altitude at our study site (2400–3100 m) is significantly higher than the highest immobilization sites in Scandinavia. Thus, in addition to the data presented by Fahlman *et al.* (2008), we hypothesized that Wolverines immobilized with medetomidine and ketamine at our study site would have reduced oxygen saturation and that oxygen saturation could be improved with oxygen from a portable oxygen cylinder. We tested this hypothesis by using a pulse oximeter to record an estimate of SpO_2 of Wolverines immobilized with medetomidine and ketamine before and after intranasal oxygen supplementation.

Methods

As part of a larger study of Wolverine ecology (Inman *et al.* 2012), we captured and anesthetized Wolverines during the spring of 2008 and winter of 2008–2009. Our study area included the Rocky Mountains of Idaho, Montana, and Wyoming (45°N, 111°W). Temperatures during winter captures generally ranged between -20°C and 0°C. During spring, capture temperatures could reach 15°C. Capture altitudes ranged from ~2110–2880 m. We captured adult and subadult Wolverines using log box traps (Copeland *et al.* 1995; Lofroth *et al.* 2008) equipped with trap-transmitters (Telonics, TBT-500, Mesa, Arizona, USA). We also captured juvenile

Wolverines by hand at den or rendezvous sites (Persson *et al.* 2006). We used a variable-powered CO_2 pistol (CO_2 PI, Dan-Inject, Knoxville, Tennessee, USA) or a hand syringe to deliver a dose of ketamine and medetomidine. We injected adult and subadult Wolverines in variable locations (usually in a large mass of muscles towards the rear of the animal) with ~0.34 mg/kg medetomidine + 10.1 mg/kg ketamine (3 mg medetomidine + 100 mg ketamine total dose per animal) and juveniles with ~0.11 mg/kg medetomidine + 3.3 mg/kg ketamine (0.3 mg medetomidine + 10 mg ketamine total dose per animal). When it was safe to handle the Wolverines we examined them, applying eye lubricant and a blindfold fashioned from a section of sock, before recording body temperature, pulse, and respiration rate. We placed Wolverines in synthetic sleeping bags modified to fit a Wolverine with a 1.9 L rubber latex water bottle filled with hot water to retain body heat. We surgically implanted all Wolverines with an intra-peritoneal VHF radio-transmitter (Advanced Telemetry Systems M1255B, M1250B, M1245B, Isanti, Minnesota, USA). We followed handling procedures approved by the Institutional Animal Care and Use Committee, Montana Department of Fish, Wildlife and Parks (IACUC 1-2006, FWP2-2010) as permitted by US Department of Agriculture, Animal and Plant Health Inspection Service (Permits 81-R-0015 and 81-R-0018). Based on age at reproductive maturity for female Wolverines (Persson *et al.* 2006) and the age through which dispersal movements occur, we classified Wolverines of three years or older as adults, Wolverines between one and three years of age as subadults, and Wolverines in their first year of life as juveniles. We estimated adult and subadult Wolverine age by assessing tooth wear and eruption. Juveniles were identified by their body size and presence at den or rendezvous sites.

We delivered compressed, medical grade oxygen using an M6 aluminum oxygen cylinder tank, a CGA 870 0–8 L/min oxygen regulator, and a human neonate size nasal cannulae. We inserted the double cannula fully (~1 cm) into both nostrils of the Wolverines. The cannula was held in place by the blindfold. We administered oxygen intranasally at flow rates between 0.5 and 1.5 L/min. We modified flow rates based on the SpO_2 readings while Wolverines were under anesthesia until SpO_2 readings were greater than 90%. We used an N-20 PA pulse oximeter (Nellcor, Boulder, Colorado, USA) with the probe clipped to the tongue to measure SpO_2. We recorded initial SpO_2 of anesthetized Wolverines as soon as they were safe to handle. We then began oxygen administration and continued recording SpO_2 throughout handling. After initiating oxygen administration, we recorded the time elapsed before reaching a SpO_2 reading over 90%. We continued administering oxygen at flow rates between 0.5 and 1.5 L/min for the duration of handling. We used a continuous read DataTherm II (Geratherm Medical AG, Geschwenda, Germany) digital thermometer to measure rectal temperature and record temperatures at 1 min intervals. Combined, the oxygen cylinder, regulator, hoses, cannula, pulse oximeter, and thermometer weighed 3.2 kg. At such low weights, including these items in capture kits did not impair travel to remote, backcountry capture sites.

Results

We recorded SpO_2 and rectal temperatures during anesthesia using ketamine and medetomidine for two juvenile, two subadult, and one adult Wolverine (Table 1). The initial SpO_2 readings, taken as soon as possible upon handling for all five Wolverines ranged from 49% –74% (mean = 64%). SpO_2 readings rose to over 90% within 2–13 min (mean = 7 min) after administration of intranasal oxygen. After reaching an SpO_2 reading over 90%, readings generally stabilized between 93% and 97%. All rectal temperatures were considered normal, ranging from 36.5–39.2 °C.

Discussion

Wildlife professionals using chemical immobilization have a responsibility to minimize the adverse effects that the capture methods and immobilizing

TABLE 1. Arterial oxygen saturation (SpO_2) and rectal temperatures of Wolverines (*Gulo gulo*) during anesthesia by ketamine and medetomidine.

		Dosage (mg/kg)		Air	SpO_2 (%)[§]		Min.to SpO_2	Rectal
Sex	Age[*]	Med.[†]	Ket.[‡]	(°C)	Initial	First >90%	>90%[‖]	Temp. (°C)
F	JV	0.11	3.2	13	74	91	<13	37.4–38.3
M	JV	0.11	3.4	13	61	95	<2	37.9–39.2
M	SA	0.28	8.3	-12	67	93	<5	36.5–37.5
M	SA	0.34	10.2	-9	68	–	<9	38.0–38.3
F	AD	0.39	11.7	-9	49	96	<4	37.7–37.9

* Age classes JV (juvenile), SA (subadult), and AD (adult).

† Medetomidine.

‡ Ketamine.

§ SpO_2: measure of hemoglobin oxygen saturation in the blood by pulse oximetry.

‖ Minutes between first administering oxygen and SpO_2 exceeding 90%.

drugs may have on study animals. Our results suggest that oxygen supplementation for Wolverines immobilized with ketamine and medetomidine at high altitudes can reverse hypoxemia. Each of the five Wolverines we immobilized had initial SpO_2 readings much lower than 90%, indicating severe hypoxemia. All Wolverines in our study had SpO_2 readings equal to or lower than Wolverines at lower altitudes in Scandinavia (Fahlman *et al.* 2008).

The SpO_2 increased after we applied supplemental oxygen to above 90% within 13 min for all Wolverines immobilized. However, we anticipate SpO_2 levels will exceed 90% more quickly when supplemental oxygen flow rates are optimized. The Wolverine that took just under 13 min to reach an SpO_2 reading of 90% (12 min 20 s) was the first to be given supplemental oxygen during our study before we had experimented with different flow rates. Originally, we were concerned that application of compressed oxygen could be problematic at cool temperatures during captures. This is because compressed air cools as it expands, potentially putting Wolverines at risk of low body temperatures. Captures during our study occurred mostly during winter in log box traps where temperatures were frequently below freezing. Given the small body size of Wolverines, we were concerned with the possibility of hypothermia (Fahlman *et al.* 2008). However, after taking steps to retain body heat during immobilization with sleeping bags and hot water bottles, we observed normal rectal temperatures for all five Wolverines treated.

From our experience, we strongly recommend that researchers and wildlife professionals immobilizing Wolverines with medetomidine and ketamine administer oxygen throughout handling. Supplemental oxygen is used to treat or prevent hypoxemia for many wildlife species under anesthesia (Fahlman 2014). If logistics and flight restrictions limit the use of oxygen cylinders in the field, a portable battery-driven oxygen concentrator is another useful source for oxygen that can be used for wildlife immobilization (Fahlman *et al.* 2012). More research is advisable to verify the findings of our study by blood gas analysis, using other drug combinations, and to evaluate minimum effective oxygen flow rates that can maintain SpO2 above 90% consistently. However, our results suggest that Wolverines immobilized at higher altitudes are at risk of hypoxemia. Because medetomidine and ketamine can lead to hypoxemia at any altitude, we recommend intranasal oxygen supplementation for all Wolverines immobilized using these drugs.

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Note

Predation of a Western Water Shrew (*Sorex navigator*) by a Belted Kingfisher (*Megaceryle alcyon*)

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Jung, Thomas S. 2016. Predation of a Western Water Shrew (*Sorex navigator*) by a Belted Kingfisher (*Megaceryle alcyon*). Canadian Field-Naturalist 130(4): 299–301.

Belted Kingfishers (*Megaceryle alcyon*) are highly piscivorous and rarely take prey other than fish. Here, I report an observation of a male Belted Kingfisher preying on a Western Water Shrew (*Sorex navigator*) in a small boreal stream in southwestern Yukon. This observation provides further evidence that Belted Kingfishers will occasionally prey on riparian small mammals when the opportunity arises and points to piscivorous birds as apparently novel predators of shrews.

Key Words: Belted Kingfisher; *Megaceryle alcyon*; predation; *Sorex navigator*; Western Water Shrew; Yukon

Predation of *Sorex* shrews is rarely observed, and most species appear to have few predators, despite their diminutive size. Although mammalian carnivores appear to find shrews unpalatable, likely because of their pungent, musky odour, Red Foxes (*Vulpes vulpes*), Ermine (*Mustela erminea*), and other species do occasionally prey on shrews as indicated by diet analyses (Nagorsen 1996). In contrast, shrew skulls are often found in the pellets of various birds of prey, particularly owls, which appear to prey on them regularly (Nagorsen 1996).

Belted Kingfishers (*Megaceryle alcyon*) are highly piscivorous, and observations of non-fish prey are rare (Kelly *et al.* 2009). However, they are known to consume crustaceans and frogs occasionally. With respect to small mammals, Cairns (1998) reported an Eastern Water Shrew (*Sorex albibarbis*) consumed by a Belted Kingfisher, and Jung (2013) reported another kingfisher attempting to prey on a diurnally active Spotted Bat (*Euderma maculatum*). No other instances of small mammals as prey of kingfishers have been reported in the literature. Here, I record an observation of a Belted Kingfisher preying on a shrew.

At approximately 0830 Pacific Daylight Time on 12 July 2015, a male Belted Kingfisher was observed and photographed in a dead tree with a small mammal in its beak (Figure 1). The tree was adjacent to McIntyre Creek, a small tributary of the Yukon River, located immediately northwest of Whitehorse, Yukon, Canada (60.7°N, 135.1°W).

The size and morphology of the small mammal, particularly the shape of the snout, indicated that it was a shrew. I identified the species based on the estimated tail length. ImageJ software was used to measure the culmen length of the kingfisher and the tail length of the shrew in the digital photograph (Figure 1). Kelly *et al.* (2009) provide a range of culmen lengths of 48–63 mm (*n* = 130) for Belted Kingfishers, so I applied a midpoint value of 55 mm for the culmen length of the photographed Belted Kingfisher. I then used the estimated culmen length as a scale to estimate the tail length of the shrew as 92 mm.

Nagorsen (1996) reported varying shrew tail lengths: 29–49 mm (*n* = 137) for Common Shrews (*S. cinereus*), 22–34 (*n* = 50) for American Pygmy Shrews (*S. hoyi*), 35–68 (*n* = 436) for Montane Shrews (*S. monticolus*), and 62–88 (*n* = 177) for Western Water Shrews — the only shrew species known from southcentral Yukon (Slough and Jung 2007). Thus, the only shrew in the region with a tail length ≥ 68 mm is the Western Water Shrew, which is present in McIntyre Creek, based on a targeted live-trapping study of them (M. Leung, unpublished data, 2007).

The shrew had a bloody abdomen, presumably from the kingfisher "piercing" or "pounding" it to stun and subdue it—the common method kingfishers use to kill fish prey (White 1953)—suggesting that the kingfisher had killed the shrew, rather than finding it already dead. It is not known whether the kingfisher consumed the shrew.

Nagorsen (1996) reported the total length of Western Water Shrews as 133–179 mm (*n* = 179); if the mean tail length (75 mm) is subtracted, their body length is about 58–104 mm. The length of fish consumed by kingfishers is ≤ 127 mm (Salyer and Lagler 1946); hence, water shrews are likely approaching the upper limit of the size of prey that a kingfisher can consume.

The main scientific value of this observation is that it further demonstrates that Belted Kingfishers will occasionally prey on small mammals, despite their highly piscivorous diet, corroborating Cairns (1998) and Jung (2013). Bantock (2008) reported a Common Kingfisher (*Alcedo atthis*) in England killing a Eurasian Pygmy Shrew (*S. minutus*) and attempting to consume it. If

FIGURE 1. A male Belted Kingfisher (*Megaceryle alcyon*) with a Western Water Shrew (*Sorex navigator*) that it had likely captured and killed. Photograph taken on 12 July 2015 near Whitehorse, Yukon, Canada. Photo: Ed Lepp.

Belted Kingfishers can swallow prey as large as water shrews then they likely gain a substantial amount of energy for the effort and should do so as opportunity allows. Such opportunism is similar to reports of shrews (*Sorex* spp.) being occasionally consumed by fish that normally eat much smaller prey (i.e., Arctic Grayling [*Thymallus arcticus*; Moore and Kenagy 2004; Jung *et al.* 2011] and Rainbow Trout [*Oncorhynchus mykiss*; Lisi *et al.* 2014]). In addition, predators of water shrews are not well reported (Beneski and Stinson 1987; Nagorsen 1996; Powell *et al.* 2007), and this observation confirms the Belted Kingfisher as a predator of water shrews. Finally, this observation adds to others (e.g., Cochran and Cochran 1999; Moore and Kegany 2004; Jung *et al.* 2011; Lisi *et al.* 2014; Jung 2016) who report small mammals being susceptible to predation by apparently novel predators while in the water.

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Note

First Record of Pacific Angel Shark (*Squatina californica*) in Canadian Pacific Waters

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King, Jackie R., and A. Maria Surry. 2016. First record of Pacific Angel Shark (*Squatina californica*) in Canadian Pacific waters. Canadian Field-Naturalist 130(4): 302–303.

We report the first verified record of a Pacific Angel Shark (*Squatina californica*) from British Columbia, Canada. A Pacific Angel Shark, 1.1–1.2 m in total length, was observed on 30 April 2016 in approximately 12 m of water, 30 m from the tip of Clover Point, Vancouver Island, British Columbia (48°24'10"N, 123°20'56"W).

Key Words: Pacific Angel Shark; *Squatina californica*; British Columbia; first record

The Pacific Angel Shark (*Squatina californica*) is a distinctive chondrichthyan in appearance, with a flattened body and large pectoral fins (Ebert 2003). The flattened body along with dorsally placed eyes make this species easy to distinguish from other sharks. The large pectoral fins are clearly separated from the head, and the gill slits are partly lateral to the head (Ebert 2003) making it easy to distinguish from skates and rays. The dorsal body surface ranges in colour from grayish brown to reddish with speckled dark spots; the ventral body surface is white (Ebert 2003). The Pacific Angel Shark has a large, terminal mouth with conical nasal barbels on the anterior margin (Compagno *et al.* 2005).

This species is endemic to the eastern Pacific and is found in temperate waters on the continental shelf (Ebert 2003). It usually occupies depths less than 100 m but has been observed at 183 m (Ebert 2003). The Pacific Angel Shark is demersal, typically found on sandy or muddy flat bottoms near rocky reefs or kelp forests (Ebert 2003). It is an ambush predator, remaining motionless in one location, partly covered by sand, waiting to strike quickly at bony fishes that swim close to its head (Fouts and Nelson 1999).

In the eastern North Pacific, the Pacific Angel Shark has been reported from southeastern Alaska to the Gulf of California (Evermann and Goldsborough 1907). However, the northern extent of this distribution is drawn from a single record from 1903 in southeastern Alaska (Evermann and Goldsborough 1907), which was problematic even when first reported (Mecklenburg *et al.* 2002). The exact locality for this specimen was not available, but the designation in southeastern Alaska in Evermann and Goldsborough (1907) places it somewhere between Dixon Entrance and Portland Canal to Yakatut Bay. The next most northerly record is a single specimen captured in October 1931 near Seattle in Puget Sound, Washington (Schultz *et al.* 1932; Mecklenburg *et al.* 2002).

In contrast, the Pacific Angel Shark is common throughout California and Mexico (Cailliet 2005). In California, a commercial fishery for this species operated out of Santa Barbara from the late-1970s through the 1980s until 1990 when drift net fishing was banned by the State of California (Richards 2001). A commercial fishery for Pacific Angel Shark exists in Mexico, both along the Pacific coast and in the Gulf of California (Richards 2001; Cailliet 2005).

Despite a published distribution range that extends northward to Alaska, to date there has been no record of a Pacific Angel Shark from Canadian Pacific waters. On 30 April 2016 at approximately 1600 Pacific Standard Time, a Pacific Angel Shark was observed and photographed (Figure 1) by an underwater diver in approximately 12 m of water, 30 m from the tip of Clover Point, Vancouver Island, British Columbia (48°24'10"N, 123°20'56"W). The diver estimated the shark to be 1.1–1.2 m in total length. It was resting, motionless, on the rocky bottom. The occurrence was reported to the Pacific Shark Sightings Network of Fisheries and Oceans Canada (www.pac.dfo-mpo.gc.ca/SharkSightings).

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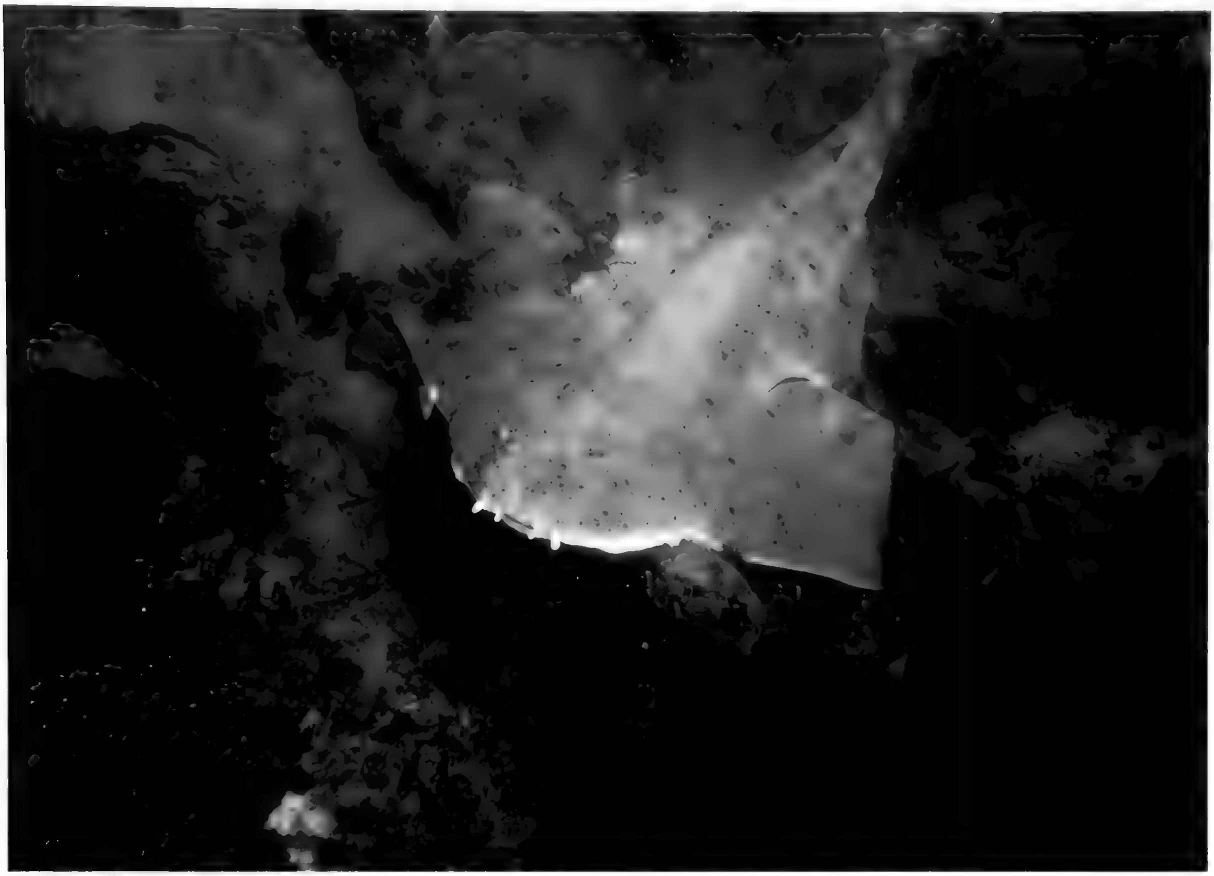

Figure 1. First record of a Pacific Angel Shark (*Squatina californica*) approximately 1.1–1.2 m in total length, photographed at Clover Point, Vancouver Island, British Columbia, on 30 April 2016. Photo: Mark Cantwell.

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Note

There and Back Again: One Caribou's (*Rangifer tarandus*) Migratory Behaviour Hints at Genetic Exchange between Designatable Units

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Watters, Megan, and Craig DeMars. 2016. There and back again: one Caribou's (*Rangifer tarandus*) migratory behaviour hints at genetic exchange between designatable units. Canadian Field-Naturalist 130(4): 304–307.

Spatial overlap periodically occurs between Boreal Caribou designatable unit (DU) 6 and Northern Mountain Caribou DU7, although overlaps are thought to occur primarily in winter when the likelihood of genetic exchange is low. In May 2013, a Caribou migrated from the Parker Boreal Caribou range (DU6) to calve in the alpine area of the Muskwa Northern Mountain Caribou range (DU7). This individual calved in the Parker range in 2014, but in 2015, she repeated her 2013 migration, travelling into the Muskwa range to calve within 700 m of her 2013 calving location. This individual's behaviour points to possible genetic exchange between the two DUs.

Key Words: Caribou; *Rangifer tarandus*; Boreal Caribou; Northern Mountain Caribou; designatable unit; genetic exchange; calving behaviour

For species that are geographically widespread, conservation strategies frequently rely on classifying and prioritizing populations as evolutionary significant units, defined as populations with unique evolutionary histories and adaptive distinctiveness (Crandall *et al.* 2000). In Canada, this approach has been applied to Caribou (*Rangifer tarandus*) with populations classified into 12 "designatable units" (DUs; COSEWIC 2011). The development of Caribou DUs incorporated multiple lines of evidence, including phylogenetics; genetic diversity and structure; morphology; movements, behaviour, and life history; and distribution. It was based on Committee on the Status of Endangered Wildlife in Canada (COSEWIC) guidelines, first approved in 2009 (COSEWIC 2015), where DUs must satisfy a variety of criteria that show both discreteness and evolutionary significance.

Boreal Caribou, classified as DU6, have a widespread distribution in Canada (COSEWIC 2011). Behaviourally, Boreal Caribou also have a unique spatial strategy when calving, with females dispersing widely to calve in isolation (Bergerud and Page 1987; Ferguson and Elkie 2004). However, these pre-calving movements occur primarily within a herd's annual range and are considerably shorter than the long-distance migrations of other DUs, such as Barren-ground Caribou (DU3). Many individuals show relatively high fidelity to calving areas, a behaviour similar to females in other DUs (Schaefer *et al.* 2001; Wittmer *et al.* 2006).

In British Columbia, Boreal Caribou (DU6) are restricted to the northeast corner of the province, where their distribution is adjacent to Northern Mountain Caribou (DU7; COSEWIC 2011). Northern Mountain Caribou are phylogenetically divergent from Boreal Caribou (COSEWIC 2011; Serrouya *et al.* 2012; Weckworth *et al.* 2012), are morphologically distinct (Kuzyk *et al.* 1999), and follow elevational migration at calving (Gustine *et al.* 2006). Overlaps between DU6 and DU7 are believed to be restricted to the winter months suggesting that little genetic exchange occurs between the two units (COSEWIC 2011; Serrouya *et al.* 2012; Weckworth *et al.* 2012). Here, however, we report plasticity in calving behaviour of one Caribou considered to be a member of the boreal population, pointing to possible genetic exchange between DU6 and DU7.

Our focal area encompasses the Parker Boreal Caribou range (58°45'N, 123°5'W) and the Muskwa Northern Mountain Caribou range (58°4'N, 124°25'W) in northeastern British Columbia, Canada. The Parker range is located within the Taiga Plains ecoprovince (Demarchi 2011) and is a mosaic of low-lying peatlands, deciduous and mixedwood uplands, and riparian areas (DeLong *et al.* 1991). Peatlands are dominated by Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) and Tamarack (*Larix laricina* (Du Roi) K. Koch), whereas uplands are characterized by White Spruce (*Picea glauca* (Moench) Voss), Lodgepole Pine (*Pinus contorta* Douglas ex Loudon), Trembling Aspen (*Populus tremuloides* Michaux), and Paper Birch (*Betula papyrifera* Marshall).

The Muskwa range (Figure 1) is located in the Northern Boreal Mountain ecoprovince, and has a rugged mountainous landscape. Alpine areas typically lack vegetation or are characterized by low shrubs, herbs, bryophytes, and lichens, whereas the subalpine zone is typified by White Spruce and Subalpine Fir (*Abies*

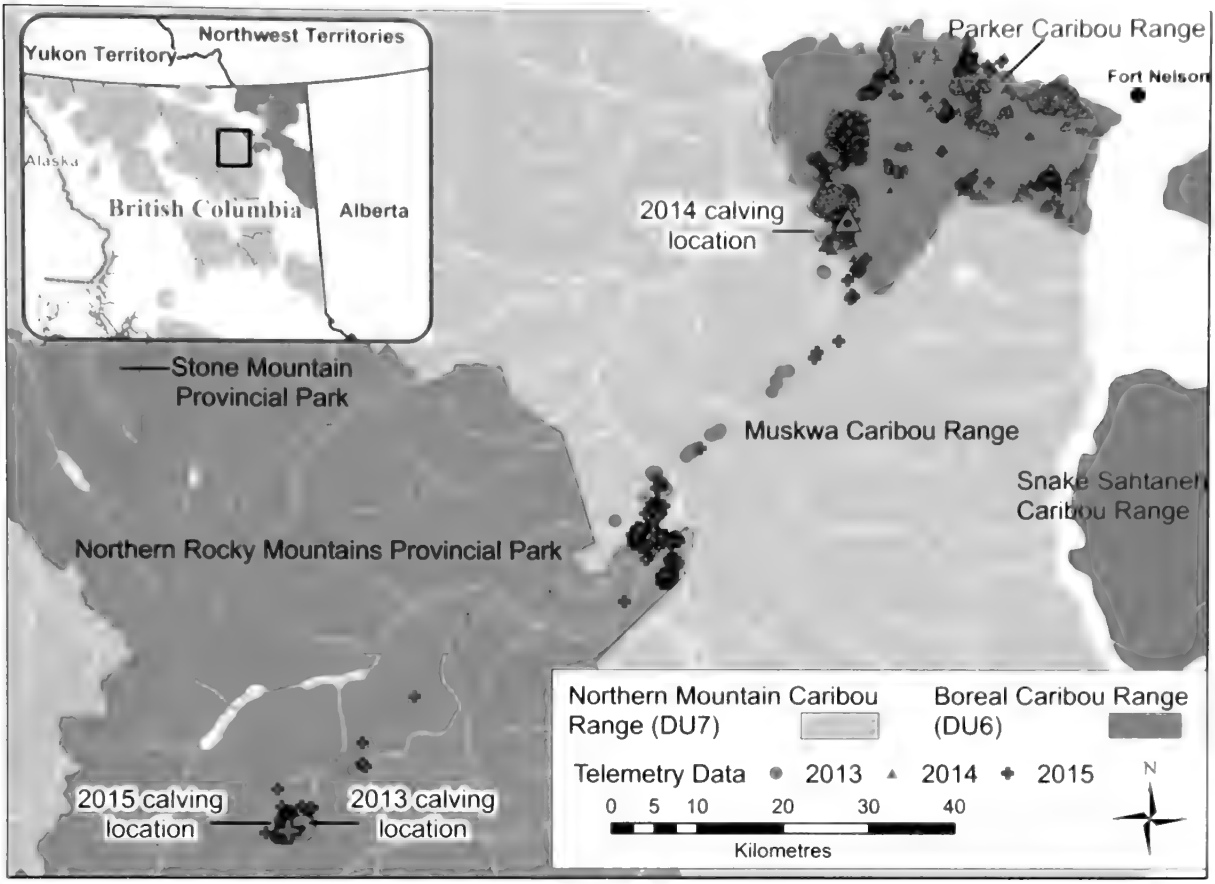

FIGURE 1. Movement of Caribou 14 in northeast British Columbia, 2013–2015. In 2013 (circles) and 2015 (crosses), this female migrated from the Parker Boreal Caribou range to calve in a high alpine area within the Muskwa Northern Mountain Caribou range; in 2014 (triangles), she remained in the Parker range. Designatable unit boundaries according to COSEWIC (2011).

lasiocarpa (Hooker) Nuttall) at lower elevations and tall Scrub Birch (*Betula glandulosa* Michaux) and willow (*Salix* spp.) shrubs at upper elevations (DeLong *et al.* 1991).

As part of a monitoring program initiated collaboratively between government and industry (BC MOE 2015), Global Positioning System (GPS) radio-collars (model 2110E; Advanced Telemetry Systems, Isanti, Minnesota, USA) were deployed on 30 female Caribou across British Columbia's Boreal Caribou range during the winter of 2012–2013. Collars were programmed for a fix rate of every 4 h during the calving season and every 8 h otherwise. In February 2015, Caribou with failing collars were recaptured and fitted with new ones (model GPS Plus Vertex Survey-1, Globalstar; GmbH Vectronics Aerospace, Keswick, Ontario, Canada) programmed for a fix rate of every 13 h. On capture, blood samples were extracted from all females to estimate pregnancy status via blood-serum progesterone testing (in pregnancy, progesterone ≥ 2.0 ng/mL; Prairie Diagnostic Services, Saskatoon, Saskatchewan, Canada). All Caribou were captured by net-gunning from a helicopter and were physically restrained during handling. All capture and handling procedures complied with approved government animal care protocols (Resources Inventory Committee 1998; British Columbia Wildlife Act permit FJ12-83091).

For each collared female, we predicted parturition based on movement patterns during the 2013–2015 calving seasons. In northeast British Columbia, peak calving occurs in mid-May (Culling *et al.* 2006; DeMars and Boutin 2014). For the 2013 and 2014 calving seasons, we predicted parturition events using a movement-based method (MBM) outlined in DeMars *et al.* (2013). This method estimates parturition status (calved/did not calve) using *a priori* thresholds of 3-day average movement rates (TDAMs; m/h). For each female, we used GPS location data and predicted that a female had calved when TDAMs dropped below 15.3 m/h. In 2015, we could not use the MBM because collar fix rates were too infrequent; therefore, we predicted parturition visually by plotting daily movement rates.

In 2013, a radio-collared female in the Parker range initiated an unusual pre-calving migration pattern. This female, estimated to be 4–6 years of age, was captured on 7 January 2013 within the Parker range and was determined to be pregnant. This individual, hereafter known as Caribou 14, remained within the Parker range until 27 May 2013, when she embarked on a journey of approximately 100 km into the Muskwa range where she calved in the alpine area on Mount Shawcross on 1 June 2013 (Figure 1). Caribou 14 remained in the alpine and subalpine areas until 30 June 2013 when she retraced her migratory path, arriving back in the Parker range two weeks later.

The following year, Caribou 14 remained in the Parker range, where she calved on 30 May 2014 and remained for the rest of the year (Figure 1). On 21 February 2015, she was recaptured in the Parker range, fitted with a new collar, and determined to be pregnant. On 14 May 2015, she once again left the Parker range and travelled into the Muskwa range, following a similar route as in 2013. She calved on 27 May 2015 within 700 m of her 2013 calving location. She remained in the alpine area until 1 August 2015 then travelled approximately 34 km in a 24-h period to a peatland complex on the eastern side of the Muskwa range. This rapid movement suggests pursuit by a predator and potential loss of her calf (DeMars *et al.* 2013). Caribou 14 remained in this area of the Muskwa range until she was killed by a wolf pack on 21 November 2015 (DES 2015).

Of the 30 female Boreal Caribou monitored during the course of our study, Caribou 14 was the only individual to demonstrate this atypical calving behaviour. In fact, among the 156 adult female Caribou collared in British Columbia boreal ranges between 2012 and 2015 (Culling and Culling 2015), Caribou 14 was the only animal to exhibit this unusual calving strategy.

The long distance pre-calving migratory movements of Caribou 14 and fidelity to an alpine calving site are characteristics consistent with Northern Mountain Caribou (DU7). Yet, this individual also displayed characteristics of DU6 Caribou by also calving and overwintering in the Boreal Caribou range. It is currently unknown whether calving behaviours are fixed in Caribou; nonetheless, unique calving behaviour is a key criterion for differentiating ecotypes (Bergerud 1996) and is among the multiple lines of evidence differentiating DUs (COSEWIC 2011), suggesting that plasticity in calving behaviour is rare. Although previous studies have documented movement of Boreal Caribou between ranges in Quebec and Labrador (Brown *et al.* 1986), and spatial overlap of mountain and northern ecotypes of Caribou in all seasons in central British Columbia (Jones 2007), to our knowledge, ours is the first documented case of a Caribou switching between calving behaviour characteristic of Boreal Caribou (DU6) and calving behaviour associated with Northern Mountain Caribou (DU7).

If such behaviours are genetically hard-wired (Berthold and Pulido 1994; but see Serrouya *et al.* 2012, who suggested that genetic structure does not consistently correspond with ecotype), the long distance migration and parturition in the Muskwa range by Caribou 14 suggest that genetic exchange between these two DUs may be occurring. Such exchange would have to take place during the rut and, in this respect, Caribou 14 showed spatial variation during this period, being in the Parker range for the 2013 and 2014 ruts and in the Muskwa range for 2015.

The potential intermixing of Northern Mountain and Boreal Caribou has direct implications for conserving Caribou within this range, where the population is estimated to be less than 50 and in sustained decline (Environment Canada 2012; Culling and Culling 2015). Such intermixing, for example, may reduce the vulnerability of a small, isolated population to negative genetic effects, such as inbreeding depression (Ingvarsson 2001). However, we caution that our observation is restricted to a single animal and, therefore, conclusions may be limited. Nevertheless, our results suggest further investigation may be warranted to understand rates of potential movements between these two adjacent populations and would help resolve the current DU boundaries.

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White-tailed Deer (*Odocoileus virginianus*) Subsidize Gray Wolves (*Canis lupus*) During a Moose (*Alces americanus*) Decline: A Case of Apparent Competition?

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Moose (*Alces americanus*) in northeastern Minnesota have declined by 55% since 2006. Although the cause is unresolved, some studies have suggested that Gray Wolves (*Canis lupus*) contributed to the decline. After the Moose decline, wolves could either decline or switch prey. To determine which occurred in our study area, we compared winter wolf counts and summer diet before and after the Moose decline. While wolf numbers in our study area nearly doubled from 23 in winter 2002 to an average of 41 during winters 2011–2013, calf:cow ratios (the number of calves per cow observed during winter surveys) in the wider Moose range more than halved from 0.93 in 2002 to an average of 0.31 during 2011–2013. Compared to summer 2002, wolves in summers 2011–2013 consumed fewer Moose and more White-tailed Deer (*Odocoileus virginianus*). While deer densities were similar during each period, average vulnerability, as reflected by winter severity, was greater during 2011–2013 than 2002, probably explaining the wolf increase. During the wolf increase Moose calves remained a summer food item. These findings suggest that in part of the Moose range, deer subsidized wolf numbers while wolves also preyed on Moose calves. This contributed to a Moose decline and is a possible case of apparent competition and inverse-density-dependent predation.

Key Words: *Alces americanus*; apparent competition; *Canis lupus;* diet; Gray Wolf; inverse-density-dependent predation; Minnesota; Moose; *Odocoileus virginianus*; scat; White-tailed Deer

Introduction

Gray Wolf (*Canis lupus*) diet in Minnesota generally consists of White-tailed Deer (*Odocoileus virginianus*), Moose (*Alces americanus)*, and Beavers (*Castor canadensis*; Frenzel 1974; Van Ballenberghe *et al.* 1975; Fritts and Mech 1981; Kunkel 1992; Paul 2002). In multiple-prey systems, wolf diet may be influenced by "changes in species abundance, prey switching, vegetation supply, and climatic conditions" (Forbes and Theberge 1996:1512). Wolves respond to declines in primary prey by switching to secondary, "buffer" prey (Pimlott *et al.* 1969; Van Ballenberghe *et al.* 1975; Messier and Crête 1985; Forbes and Theberge 1996).

Moose in northeastern Minnesota declined 55% (to varying degrees in various areas) from a point estimate of 8840 in 2006 to 4020 in 2016 (DelGiudice 2016). Wolves were implicated in this decline based on an inverse relation between their numbers in the northeastern part of Moose range and the calf:cow ratio (the number of calves per cow observed during winter surveys; Mech and Fieberg 2014). Wolves may contribute to limiting Moose populations (Peterson *et al.* 1984; Larsen *et al.* 1989) by predation on calves (Testa *et al.* 2000; Bertram and Vivion 2002) and were a major source of calf mortality in northeastern Minnesota (Severud *et al.* 2015). Following the decline in Moose, wolves could either decline or broaden their diet (increase consumption of an alternate prey) to include deer. Wolves subsidized by deer could continue to kill Moose (even at low Moose densities) potentially resulting in an inverse-density-dependent predation rate and apparent competition (Holt 1977; Holt *et al.* 1994; Wittmer *et al.* 2005; Hebblewhite and Smith 2010), furthering the Moose decline. An inverse-density-dependent predation rate occurs when the predation rate on prey increases while the density of the prey decreases because the predator is subsidized by an alternate prey species (Wittmer *et al.* 2005; Hebblewhite and Smith 2010). Apparent competition occurs when two prey species indirectly, negatively interact through the sharing of a common predator. In such cases the increasing abundance of one prey species indirectly results in the decreasing abundance of the other prey through the numerical response of the shared predator (Holt 1977; Holt *et al.* 1994; Chaneton and Bonsall 2000). Apparent competition has been hypothesized and demonstrated in various, sympatric ungulate populations including Moose, Elk (*Cervus canadensis*), and Woodland Caribou

(*Rangifer tarandus caribou*) living in areas with wolves (Seip 1991, 1992; Hurd 1999; Wittmer *et al.* 2005). Because interactions in large-mammal terrestrial systems are particularly complex and because the data required to conclude apparent competition are difficult to acquire, apparent competition is often difficult to distinguish in natural food webs from indirect amensalism (i.e., when two prey share a common predator, and prey species "A" is negatively indirectly affected by prey species "B", but prey species "B" is not indirectly affected by prey species "A"; Chaneton and Bonsall 2000).

To determine whether wolf abundance declined following the Moose decline or whether wolves increased consumption of an alternate prey (i.e., prey switched) in our study area of northeastern Minnesota (the southwestern part of the Mech and Fieberg [2014] study area), we compared wolf numbers and diet in that area before and after the Moose decline.

Methods

Our study area ("scat study area"; Figure 1) was approximately the southwestern third of a 2060 km², long-term wolf study area (Mech 2009) in the east-central Superior National Forest (47.8806°N, 91.4162°W, approximate centre of our long-term study area) of northeastern Minnesota, USA (see Nelson and Mech [1981] for a detailed description).

White-tailed Deer are more abundant in the scat study area, whereas Moose, although they inhabit our scat study area, are more abundant to the northeast in the larger wolf study area (Frenzel 1974; Mech 2009; Mech and Fieberg 2014) where Moose may reach densities of greater than or equal to 0.2 moose/km² (e.g., ≥ 8 moose/34.7 km² survey plot) in some locations (DelGiudice 2016). Pre-fawning deer densities (i.e., densities of deer before fawns are born each year) during 2011–2013 were approximately 1.5–2.0 deer/km² (Grund 2014).

During 2011–2013, we collected wolf scats greater than or equal to 25 mm wide (to minimize collecting scats from smaller sympatric canids such as Coyotes [*Canis latrans*; Weaver and Fritts 1979]) along logging roads and trails while conducting other field work that occurred primarily during June–August, but sometimes during the fall and winter (Figure 1), in generally the same area as Paul (2002). We collected 38 scats in 2011, 27 in 2012, and 57 in 2013. A portion of some scats were used to bait traps, and scats were frozen in preparation for analysis. Scats were placed in individual nylon stockings, boiled, rinsed, and then spread out on a plate and allowed to air dry (Ibrahim 2015).

We analyzed scat contents macro- and microscopically for deer, Moose, Beaver, Snowshoe Hare (*Lepus americanus*), and small mammal remains. The entire scat contents were examined macroscopically and bones, teeth, claws, feathers, trash, vegetation, soil/rocks, etc. were recorded. We randomly selected 25 hairs from each scat using a grid overlain on the spread-out, dried scat (Ciucci *et al.* 2004; Ibrahim 2015) and examined

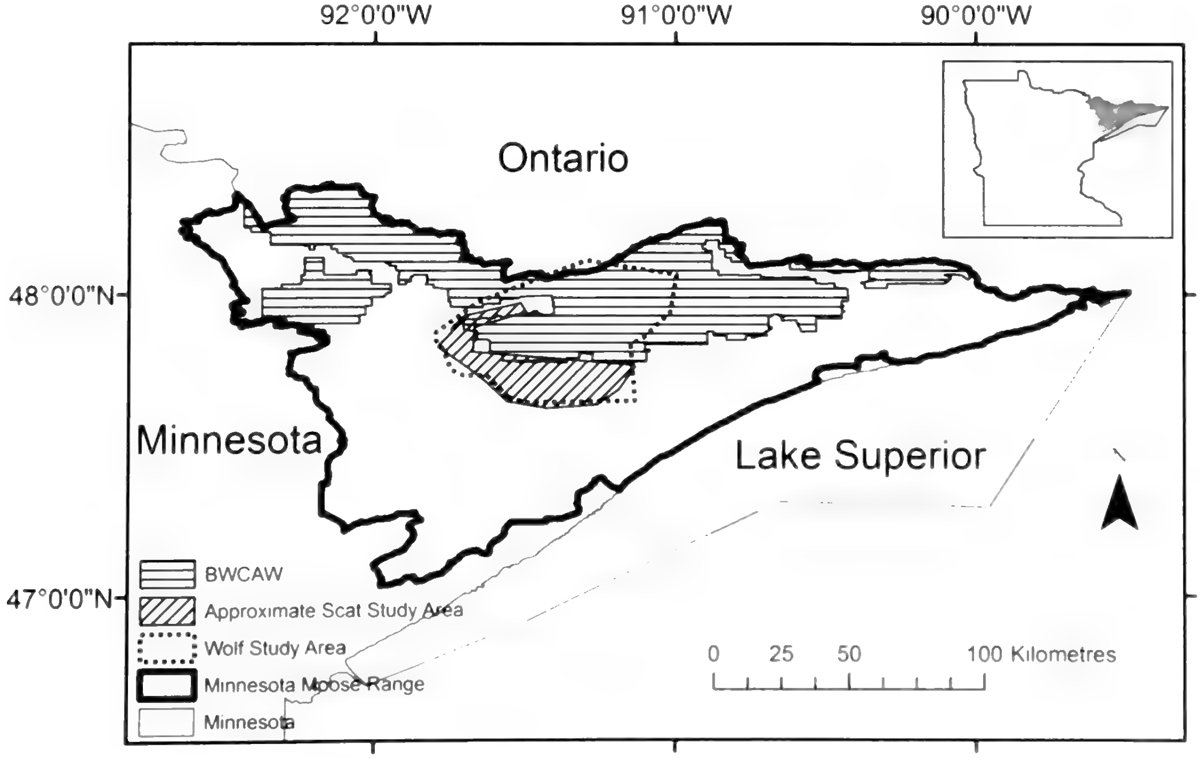

FIGURE 1. Study area for Gray Wolf (*Canis lupus*) scat collection (Approximate Scat Study Area) during 2011–2013, the long-term wolf study area, the Boundary Waters Canoe Area Wilderness (BWCAW), and Moose (*Alces americanus*) range in northeastern Minnesota, USA. Inset shows the state of Minnesota (including Minnesota's Lake Superior territory) with the main map area of interest shaded.

them with a dissecting scope (Swift® Tri-power, San Jose, CA) at 1–4 magnification. At least one hair representative of each species (and age class in ungulates) of the 25 hairs was examined (and occasionally negative impressions of the hairs; Kennedy and Carbyn 1981) with a compound microscope (Swift® M3500D, San Jose, CA) at four or 10 magnification. We used hair colour, texture, shape, length, diameter, medulla pattern, and scale pattern to identify the prey species, and age class in ungulates (i.e., fawn or calf versus adult; Adorjan and Kolenosky 1969; Kennedy and Carbyn 1981; Carrlee and Horelick 2011; Ibrahim 2015). It was generally harder to determine ungulate age class as summer progressed and adult coats were emerging. Thus, greater uncertainty exists in August than in our June age-determinations. Nevertheless, we are reasonably confident in our age-class designations because we used many features to identify them (i.e., characteristics listed in the previous sentence). When the weight of evidence was equal for more than one age class, we coded age class as "unknown". We did not try to differentiate juveniles after August.

We calculated frequency of occurrence of prey categories and calculated biomass consumed (kg) using prey weights (Table 1) as given by Kunkel (1992) and Weaver's (1993) modification of Floyd *et al.*'s (1978)

TABLE 1. Gray Wolf (*Canis lupus*) scat contents and estimated prey consumption[*] in the Superior National Forest, Minnesota, USA (2011–2013).

Prey	Prey weight (kg)	Prey weight (kg) / scat	# of scats containing the prey item	Frequency of occurrence	Kg consumed	% of kg consumed	# of individuals consumed	Relative % individuals consumed
JUNE (POOLED YEARS), *n* scats = 51								
Adult deer	58.00	0.9030	14.0	27.5	12.6	40.9	0.2	7.2
Fawn deer	6.30	0.4894	35.0	68.6	17.1	55.4	2.7	90.3
Calf Moose	23.40	0.6262	1.0	2.0	0.6	2.0	0.0	0.9
Beaver	11.25	0.5290	1.0	2.0	0.5	1.7	0.1	1.6
JULY–AUGUST (POOLED YEARS), *n* scats = 55								
Adult deer	58.00	0.9030	7.0	10.9	6.3	18.2	0.1	6.3
Fawn deer	13.95	0.5506	30.0	50.0	16.5	47.4	1.2	68.7
Calf Moose	53.10	0.8638	10.5	18.8	9.1	26.1	0.2	9.9
Beaver	11.25	0.5290	5.5	10.9	2.9	8.4	0.3	15.0
2011 (POOLED SEASONS), *n* scats = 38								
Adult deer	58.00	0.9030	11.0	25.0	9.9	40.6	0.2	12.2
Fawn deer	11.40	0.5302	22.0	52.3	11.7	47.6	1.0	73.1
Calf Moose	43.20	0.7846	1.0	2.3	0.8	3.2	0.0	1.3
Beaver	11.25	0.5290	4.0	11.4	2.1	8.6	0.2	13.4
2012 (POOLED SEASONS), *n* scats = 27								
Adult deer	58.00	0.9030	6.0	20.7	5.4	32.5	0.1	8.8
Fawn deer	11.40	0.5302	17.5	62.1	9.3	55.6	0.8	77.0
Calf Moose	43.20	0.7846	0.5	3.5	0.4	2.4	0.0	0.9
Beaver	11.25	0.5290	3.0	10.3	1.6	9.5	0.1	13.3
2013 (POOLED SEASONS), *n* scats = 57								
Adult deer	58.00	0.9030	17.0	28.8	15.4	40.1	0.3	14.9
Fawn deer	11.40	0.5302	25.0	44.1	13.3	34.6	1.2	65.6
Calf Moose	43.20	0.7846	10.0	18.6	7.9	20.5	0.2	10.2
Beaver	.. 11.25	0.5290	3.5	6.8	1.9	4.8	0.2	9.3
ALL YEARS, ALL SEASONS[†], *n* scats = 122								
Adult deer	58.00	0.9030	34.0	25.8	30.7	38.5	0.5	12.4
Fawn deer	11.40	0.5302	65.0	50.8	34.5	43.2	3.0	71.1
Calf Moose	43.20	0.7846	11.5	9.9	9.0	11.3	0.2	4.9
Beaver	11.25	0.5290	10.5	9.1	5.6	7.0	0.5	11.6

[*] Prey weights as used by Kunkel (1992), prey weight per scat (kg) calculated from Weaver's (1993) equation, # of scats that contained the prey item, frequency of occurrence = # of detections of particular prey item/total prey item detections in all scats (e.g., this included 10 scats that contained two prey items so the total items detected [132] was greater than the total number of scats collected [122]), kg consumed = number of scats × prey weight/scat, number of individuals consumed = kg consumed/average prey weight, and relative percent of individuals consumed = number of individuals consumed of one prey type/the sum of all individuals of all prey types consumed as reflected by the scat contents. In five scats with two primary prey, we considered these as ½ scat for each prey for biomass–consumed calculations. Although we did not consider small mammals as primary prey (four were detected during July–August 2001 and one during July–August 2012), we included them in frequency of occurrence calculations as well as a deer of unknown age class (132 total prey item detections).

[†] All seasons included 17 scats we collected during September–March (13 adult deer and four Beavers).

biomass equation. For scats that contained two primary (i.e., not small mammal) prey (5/122 scats or 4%), we assumed they contained equal amounts of biomass consumed (Ciucci *et al.* 1996) because interior soft tissue (e.g., muscle and organs) and hairless portions (e.g., Beaver tails and feet) would not be represented by the proportion of hair. To better understand the influence of wolf diet on prey populations, we also calculated the number of individuals eaten (kg consumed/average prey weight), and the relative percent of individuals consumed (number of individuals consumed of one prey item/the sum of all individuals of all prey items consumed) as reflected by scat contents by prey type. To compare our results to those from a previous study in our area (Paul 2002) that used different prey weights, we re-calculated Paul's (2002) biomasses using prey weights given in Kunkel (1992) and Weaver's (1993) biomass equation. Chi-square tests were used to assess differences in the summer counts of prey items between the studies (i.e., June–August 2002 and June–August 2011–2013; Paul 2002) in Statistix v. 10 (2015).

As part of a long-term research project (Mech 2009), wolves were captured and radio-collared (Institutional Animal Care and Use Committee 2015). We located wolves approximately weekly via aerial radio-telemetry and calculated winter pack counts for the larger study area as the maximum pack size observed during weekly locations from December–March each year (Mech 2009). We calculated winter wolf populations using only the packs residing in the scat study area (Figure 1).

Results

Winter wolf counts in our scat study area showed an increase from 23 wolves during 2001–2002 to 45 in 2010–2011, at least 42 during 2011–2012, and a minimum (poor survey conditions) of 37 in 2012–2013.

Of 38 scats collected in 2011, 27 in 2012, and 57 in 2013, none contained adult Moose or Snowshoe Hare: deer were the most common prey (adult 34/122 scats, fawn 67/122), then calf Moose (13/122) and Beaver (12/122; Table 1). Only five of 122 (4%) scats included two primary prey (two fawn deer and Beavers, two fawn deer and calf Moose, and one Beaver and calf Moose). Five others (4%) included both fawn deer and small mammal. In one scat, small mammal was the only prey.

Deer fawns were most frequently detected (51%) and represented the most biomass (43%) and individuals consumed (71%; Table 1). Adult deer were the second most detected, percent of biomass, and relative individuals consumed (Table 1). Although Beavers and calf Moose occurred about equally in our scat contents, because Beavers are smaller, more individuals were consumed than calf Moose (Table 1).

More deer and fewer calf Moose and Beavers were detected during June–August 2011–2013 than in June–August 2002 ($\chi^2 = 19.87$, df = 3, $P = 0.0002$; Tables 1 and 2). Because we did not detect any adult Moose, we could not compare that category (although Paul [2002] reported seven scats containing adult Moose during June 2002 and two during July–August 2002).

TABLE 2. Recalculation of prey contents in wolf (*Canis lupus*) scats* for June and July–August 2002 (see Table 4 in Paul [2002]) in part of the Superior National Forest, Minnesota, USA.

Prey	Prey weight (kg)	Prey weight (kg) / scat	# of scats containing the prey item	Kg consumed	% of kg consumed	# of individuals consumed	Relative % individuals consumed
JUNE (2002)†							
Adult deer	58.00	0.90300	9	8.1	16.3	0.1	4.8
Fawn deer	6.30	0.48940	25	12.2	24.6	1.9	66.3
Adult Moose	227.00	2.25500	7	15.8	31.7	0.1	2.4
Calf Moose	23.40	0.62620	15	9.4	18.9	0.4	13.7
Beaver	11.25	0.52900	8	4.2	8.5	0.4	12.8
Snowshoe Hare	1.08	0.44764	0	0.0	0.0	0.0	0.0
JULY–AUGUST (2002)†							
Adult deer	58.00	0.90300	3	2.7	7.8	0.1	3.4
Fawn deer	13.95	0.55060	18	9.9	28.5	0.7	52.0
Adult Moose	232.00	2.29500	2	4.6	13.2	0.0	1.5
Calf Moose	53.10	0.86380	16	13.8	39.8	0.3	19.1
Beaver	11.25	0.52900	7	3.7	10.7	0.3	24.1
Snowshoe Hare	1.08	0.44764	0	0.0	0.0	0.0	0.0

*Prey weights as used by Kunkel (1992), prey weight per scat (kg) calculated from Weaver's (1993) equation, # of scats containing the prey item, kg consumed = number of scats × prey weight/scat, number of individuals consumed = kg consumed/average weight of prey, and relative percent of individuals consumed = number of individuals consumed of one prey type/the sum of all individuals of all prey types consumed as reflected by the scat contents.

†During June, two deer were not identifiable to age class and during July–August, two deer and one Moose were not identifiable to age class, so these detections were not included in this comparison analysis.

Discussion

The wolf population nearly doubled in our scat study area from winter 2002 to 2011, while Moose calf:cow ratios in northeastern Minnesota more than halved from 0.93 in winter 2002 to 0.24 in 2011, 0.36 in 2012, and 0.33 in 2013 (DelGiudice 2016). Although wolf summer diet in 2011–2013 consisted of fewer Moose and more deer than summer 2002 prior to the Moose decline (Paul 2002), Moose calves remained a summer food item during 2011–2013. We suspect that wolves did not decline initially following the Moose decline because they were subsidized, at least temporarily, by deer.

Deer densities were low in 2002 and 2011–2013 (i.e., ≤ 2 deer/km^2; Grund 2014), but differences in winter severity indices (WSI; number of days with minimum temperature less than or equal to −17.8°C plus number of days with greater than or equal to 38 cm snow on the ground: < 100 = mild, 100–180 = moderate, > 180 = severe; Kohn 1975) among those periods suggest differences in deer vulnerability to wolf predation (Mech *et al.* 1971; DelGiudice *et al.* 2006). The winter before Paul's (2002) study was mild (WSI approximately 51–79; MN DNR 2015). Winters 2010–2011, 2011–2012, and 2012–2013 included just one mild winter (WSI = 120–180+, 51–79, and 120–159, respectively; MN DNR 2015). Furthermore, the one "moderate" winter (2012–2013) during our scat study was atypical because the 38 cm snow depth threshold for daily point accumulation in WSI calculations was not exceeded until mid-February (Tom Rusch, personal communication). Despite the less than "severe" WSI, a local wildlife manager reported that "winter (2012–2013) exceeded both 1995–1996 and 2013–2014 in deer mortality" (Tom Rusch, personal communication; 1995–1996 and 2013–2014 both exceeded WSI of 200 and were considered "severe"). Thus, although deer densities have remained relatively low between 2002 and 2011–2013, deer were, on average, likely more vulnerable to wolf predation during our scat study compared to 2002.

Wolves typically prey on more vulnerable prey (Mech *et al.* 1971). When a prey species is more vulnerable (e.g., deep snow would typically hinder deer more than Moose; Mech *et al.* 1971), wolves that were more numerous due to an alternate prey subsidy could then take advantage of a new vulnerability in either species. As well, the average vulnerability of a prey population changes during the biological year and subsidized wolf numbers would have a greater negative impact on Moose calf and deer fawn recruitment than if there were fewer wolves overall.

Our findings suggest that, in at least part of the Moose range, wolves prey-switched and consumed more deer. At the same time, wolves continued to prey on Moose calves, contributing to the Moose decline and resulting in a possible case of apparent competition and inverse-density-dependent predation (Wittmer *et al.* 2005; Hebblewhite and Smith 2010). We cannot definitively conclude that apparent competition and inverse-density-dependent predation of Moose calves occurred. We do not have precise information on changing prey densities in our scat study area and we did not evaluate predation rates. We measured wolf diet as reflected by scat contents. But we think apparent competition and inverse-density-dependent predation likely because 1) wolf populations nearly doubled in our study area between the two scat studies presumably increasing predation pressure, 2) calf:cow ratios in the wider Moose range more than halved between the two studies, and 3) Moose calves remained a summer food item for wolves in the later scat study. Because both Moose and deer can be negatively, indirectly affected through a shared wolf predator, we do not think this is a case of indirect amensalism (i.e., where only one of the two prey species is negatively, indirectly affected through sharing a common predator; Chaneton and Bonsall 2000).

Although our results cannot be generalized to the entire northeastern Minnesota Moose range, wolves and deer inhabit most of that range. Our findings might help explain the role of wolves and deer in the range-wide Moose decline and offer the apparent competition /inverse-density-dependent predation hypothesis to be tested further.

Another factor (not mutually exclusive) in the Moose decline is that deer in our study area could have resulted in increased incidence of brain worm (*Parelaphostrongylus tenuis*) in Moose. This would further alter Moose vulnerability as well as lead to direct Moose mortality from the parasite (Karns 1967; Lankester 2010). Because our study focused mainly on summer wolf diet (when adult Moose are rarely killed by wolves), we cannot evaluate whether *P. tenuis* was a factor influencing increased wolf predation on Moose. Additional research regarding the importance of health-related factors in the Moose decline and in predisposing Moose to wolf predation is needed and is ongoing by the Minnesota Department of Natural Resources (M. Carstensen, personal communication).

Subsequent to our wolf diet study, wolf populations in our study area declined (L.D.M. and S.M.B-M., unpublished data). Thus, we suspect that the local deer population declined following increased wolf predation. Ultimately, it appears that the wolf population eventually tracked the declining Moose population (L.D.M. and S.M.B-M., unpublished data), with a lag due to increased deer vulnerability.

We collected scats opportunistically along trails and logging roads. Our results may have differed if we had collected scats near kills (Potvin *et al.* 1988) or homesites (where adults provision pups). Another regional study that examined 1000 wolf scats and included a more complex suite of prey (i.e., also adult Moose, Black Bear [*Ursus americanus*], Snowshoe Hare, and various small mammals) determined that wolf dietary diversity could be determined with as few as 15–50 scats (Ibrahim 2015). Because we considered a more reduced suite of primary prey our sample likely reflects average summer wolf diet breadth in our scat study area. Although we did not detect Snowshoe Hare and adult Moose in wolf scats during our study, we expect that wolves did consume them but at such low rates that summer wolf predation would not negatively affect their populations in our study area.

Scat studies cannot differentiate scavenging and predation, and their effect on prey populations might differ among large ungulate prey species (Forbes and Theberge 1992, 1996). Although biomass calculations are less biased than frequency of occurrence (Ciucci *et al.* 1996), they do not account for prey condition (poorer prey would weigh less), caching, nor incomplete carcass consumption (e.g., bones), and food lost to scavengers (Peterson and Ciucci 2003).

Additional data on seasonal prey densities and seasonal wolf diet would improve future research. Collecting more scats in the Boundary Waters Canoe Area Wilderness (i.e., northeast of our sampling area; Figure 1), would improve our understanding of wolf diet in an area with fewer (almost no) deer (Nelson and Mech 2006) and more Beavers (S.M.B-M. and L.D.M., unpublished data).

Examining location clusters from GPS-collared wolves (Demma *et al.* 2007) should be used to more precisely determine the influence of wolf predation on Moose and the importance of Moose to the wolf diet. To best determine the influence of wolf predation on Moose, radio-tagged adult and calf Moose should be studied for cause-specific mortality (Severud *et al.* 2015). We recommend continued multi-faceted research (e.g., use of thermal refugia, habitat use with respect to deer, etc.) of both radio-tagged adult and calf Moose to best determine the causes for the recent decline in Moose.

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Behavioural Changes in Belugas (*Delphinapterus leucas*) During a Killer Whale (*Orcinus orca*) Attack in Southwest Hudson Bay

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Killer Whales (*Orcinus orca*) were observed on 4 August 2012 attacking Belugas (*Delphinapterus leucas*) at high tide near the mouth of the Seal River (59°9'19"N, 94°45'28"W) in southwest Hudson Bay, near the location where six Belugas had been fitted with satellite transmitters three weeks earlier. The distribution of Belugas was analyzed before, during, and after the attack. In the presence of Killer Whales, the six Belugas altered their behaviour by reducing their combined range size from 285 km^2 four days before the attack to 172 km^2 on the day of the attack. Their range more than tripled, to 655 km^2, in the days immediately following the attack before returning to the pre-attack size. Following the attack, the tagged Belugas expanded their range northward, going from a mean pre-attack distance of 9.4 km from the attack site to a maximum of 23.5 km. Visual observations of Belugas clumping together and moving toward shore corroborated satellite data. This evasive behaviour by Belugas was different from that reported for Narwhals (*Monodon monoceros*) suggesting that the two monodontid species may have evolved different survival strategies related to the risk of Killer Whale predation. With predicted changes to Arctic sea ice, the summering habitat of Belugas will be available to their main predator for longer periods. A better understanding of Beluga behaviour and risk of predation is required for Beluga conservation and stock management.

Key Words: Beluga Whale; *Delphinapterus leucas*; home range; Hudson Bay; Killer Whale; *Orcinus orca*; Orca; predation; sea ice

Introduction

Over the last 30 years, Hudson Bay has experienced a dramatic loss in sea ice. Spring sea ice concentration (percentage of sea ice cover) has decreased 15.1–20.4% per decade in western and southwestern Hudson Bay (Hochheim *et al.* 2011), with spring break up advancing 15–40 days between 1971 and 2003 in James Bay and southern and western Hudson Bay (Gagnon and Gough 2005). For an ice-associated species, such as the Beluga Whale (*Delphinapterus leucas*), less sea ice and longer periods of open water mean that more habitat is available to previously seasonally excluded top predators, such as Killer Whales (*Orcinus orca*). The presence of Killer Whales in the eastern Canadian Arctic, and specifically in Hudson Bay, is increasing (Higdon and Ferguson 2009; Higdon *et al.* 2012) and this trend is expected to continue as sea ice diminishes. Killer Whales in the eastern Canadian Arctic prey on marine mammals and are known to kill and consume Bowhead Whales (*Balaena mysticetus*), Narwhals (*Monodon monoceros*), seals, Walruses (*Odobenus rosmarus*), and Belugas; however, their dietary intake and their effect on prey populations in the Arctic are largely unknown (Ferguson *et al.* 2012).

On 4 August 2012, Killer Whales were observed and photographed attacking Belugas at high tide near the mouth of the Seal River (59°9'19"N, 94°45'28"W). Three weeks before this event, six Belugas in this area had been caught and fitted with satellite transmitters for a larger study on their habitat and estuary use in Manitoba. We took this opportunity to analyze behaviour that may elucidate more generally how Belugas respond to a relatively new predator. We tested dispersal of tagged Beluga Whales in the days immediately following the Killer Whale attack and the distance of Belugas from the attack site before and after the event.

Methods

In July 2012, six Belugas near the Seal River in northern Manitoba were fitted with satellite transmitters with the support of the Hunters and Trappers Association of the closest Inuit community, Arviat (Table 1). All whales, male and female adults and mature juveniles, were caught using the hoop net technique described by Orr *et al.* (2001) between 11 and 16 July and fitted with SPLASH satellite-linked transmitters (Wildlife Computers, Redmond, Washington, USA). The transmitters were attached near the dorsal ridge of each

TABLE 1. Characteristics of Belugas (*Delphinapterus leucas*) fitted with satellite-linked transmitters in 2012 near the Seal River estuary, Hudson Bay, Canada.

Tag no.	Tagging date, day-month-year	Sex	Body length, cm	Fluke width, cm
118957	11-07-2012	M	326	79
118958	11-07-2012	F	323	72
118955	13-07-2012	M	402	106
118956	15-07-2012	M	380	92
118960	15-07-2012	F	298	68
118959	16-07-2012	M	375	94

animal using nylon pins and washers; they were configured to transmit location and dive information up to 400 times daily.

Location data were filtered using Jonsen's state-space model (Jonsen *et al.* 2005) and estimated locations generated by the model (in a 4-h time step) were plotted in ArcGIS 10.4 (Esri, Redlands, California, USA). Beluga Whale home range and distance from the attack site were compared for the days leading up to, the day of, and the days following the Killer Whale attack. Distance metrics and kernel density estimates were calculated using ArcGIS 10.4. The number of days included in analysis on either side of the attack was determined by availability of data from each of the six tagged animals. For the purposes of this analysis, four days on either side of the attack were used.

Observations

Tourists and experienced guides (who were in communication with a local pilot flying the area) were interviewed (August 2012) and their observations of the Killer Whale attack were summarized. They confirmed that Killer Whales were not seen in the area immediately before or after the attack. The attack began on 4 August at 0930, almost exactly at high tide, and ended at 1045. There were 10–12 Killer Whales in two groups (seven and four or five) that included three large males. Most of the time, they were offshore in about 150 m of water, but, at some point, four Killer Whales came close to shore, chasing Belugas. The whales engaged in some breaching activity, pushing Belugas out of the water, and it was clear that they were hunting the Belugas although no direct observations of kills were seen.

During the attack, Belugas were observed moving quickly, porpoising, thrashing in the water, and clumping together close to shore in < 2 m of water (Figure 1) as they moved southward along the coast. On the day following the attack, few Belugas were observed near the southern outflow of the Seal River, a location where they are typically seen in high numbers at this time of

FIGURE 1. A Polar Bear (*Ursus maritimus*) looks on as Belugas (*Delphinapterus leucas*) clump together near shore in less than 2 m of water during a Killer Whale (*Orcinus orca*) attack near the mouth of the Seal River, Hudson Bay. Photo: Andy Morley.

year, and Killer Whales were spotted further south in the bay, near Churchill.

Results

Leading up to the day of the attack, the tagged Belugas consistently used the waters immediate adjacent to the mouth of the Seal River, staying within 10 km of the attack site. In the presence of Killer Whales, the six Belugas altered their behaviour by reducing their combined range size from 285 km^2 four days before the attack to 172 km^2 on the day of the attack. Following the attack, the Belugas expanded their range northward, from a mean distance of 9.4 km over the four days before the attack to a highest mean distance of 23.5 km two days after the attack (Figure 2), and increasing their 75th percentile kernel density area from 172 km^2 on the day of the attack to 655 km^2 two days later (Figure 3). This area and mean distance from the attack site then declined, returning to levels similar to those observed before the attack by the fourth day. Data from before the attack also indicate that the Beluga home ranges decreased before and on the day of the Killer Whale attack. Visual observations were consistent with the satellite data.

Discussion

Satellite telemetry results from this research have provided the first detailed insight into the movements of Belugas in the presence of marine mammal-eating Killer Whales. Here, Belugas clumped together during a predation event and dispersed after it. This clear change in behaviour, both visually observed and remotely recorded via satellite-tracked movements, indicates that Belugas differ from Narwhals under similar circumstances. As reported by Laidre *et al.* (2006), Narwhals exhibit slow quiet movements and increase their home range during attack, indicating a different strategy to reduce risk of attack that may be linked to the characteristics of their preferred summering habitat. Whereas the western Hudson Bay Belugas prefer the shallow estuaries of Manitoba (Richard 2004) in summer, high Arctic Narwhals prefer deep fiords of northern Baffin Island (Richard *et al.* 1994). Tidal flats are broad in this area and extend up to 10 km offshore. Belugas may restrict their movements to these flats where Killer Whales are too large to enter without risk of at least temporary stranding.

As the Arctic sea ice has changed and the summering grounds of Belugas have become free of sea ice for longer periods, Killer Whale predation on Belugas has likely increased. In a traditional knowledge study on Killer Whales in Hudson Bay and around Baffin Island in Nunavut (Westdal *et al.* 2013), some of the hunters and elders interviewed in three communities suggested that Killer Whale numbers were causing a decline in the availability of locally harvested species, such as Beluga Whales. Conversely, other hunters in the same study proposed that Killer Whale predation was not

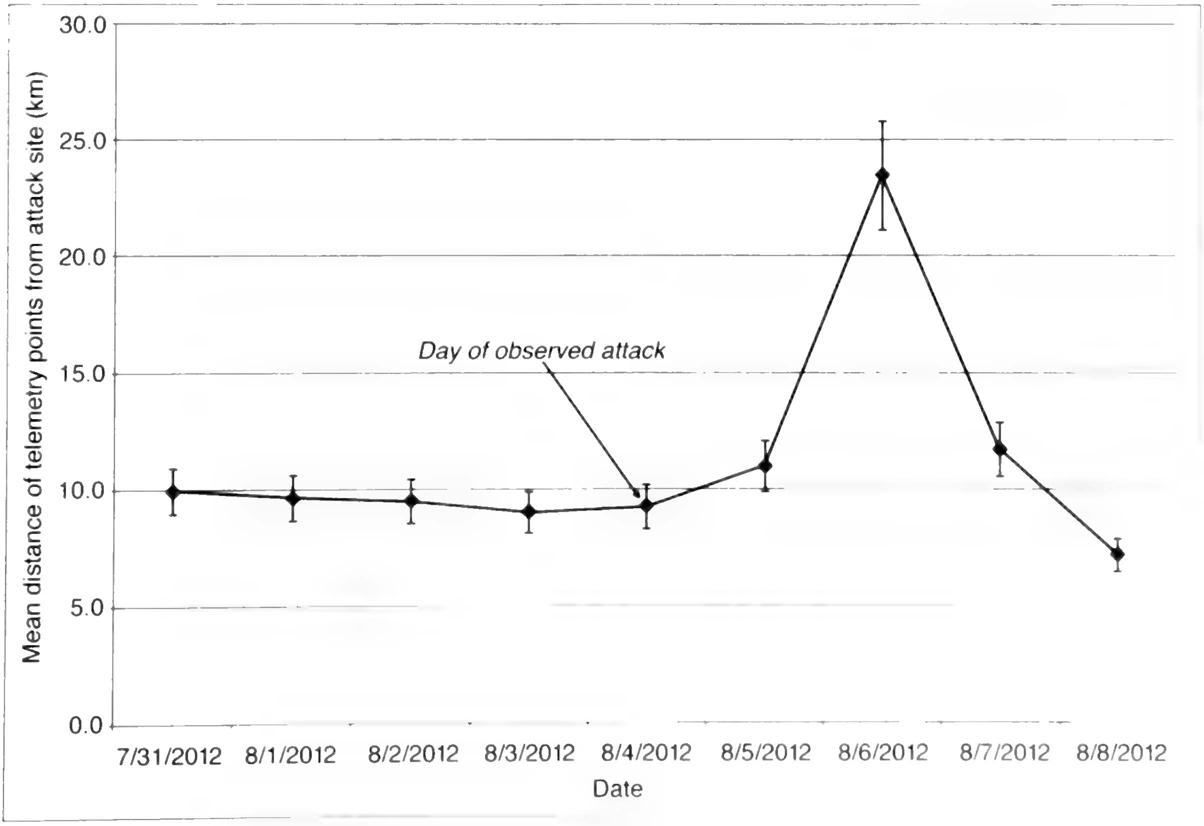

FIGURE 2. Mean distance of all tagged Belugas (*Delphinapterus leucas*; ± 10% standard error) from site of attack by Killer Whales (*Orcinus orca*) before and after the attack near the Seal River estuary, Hudson Bay.

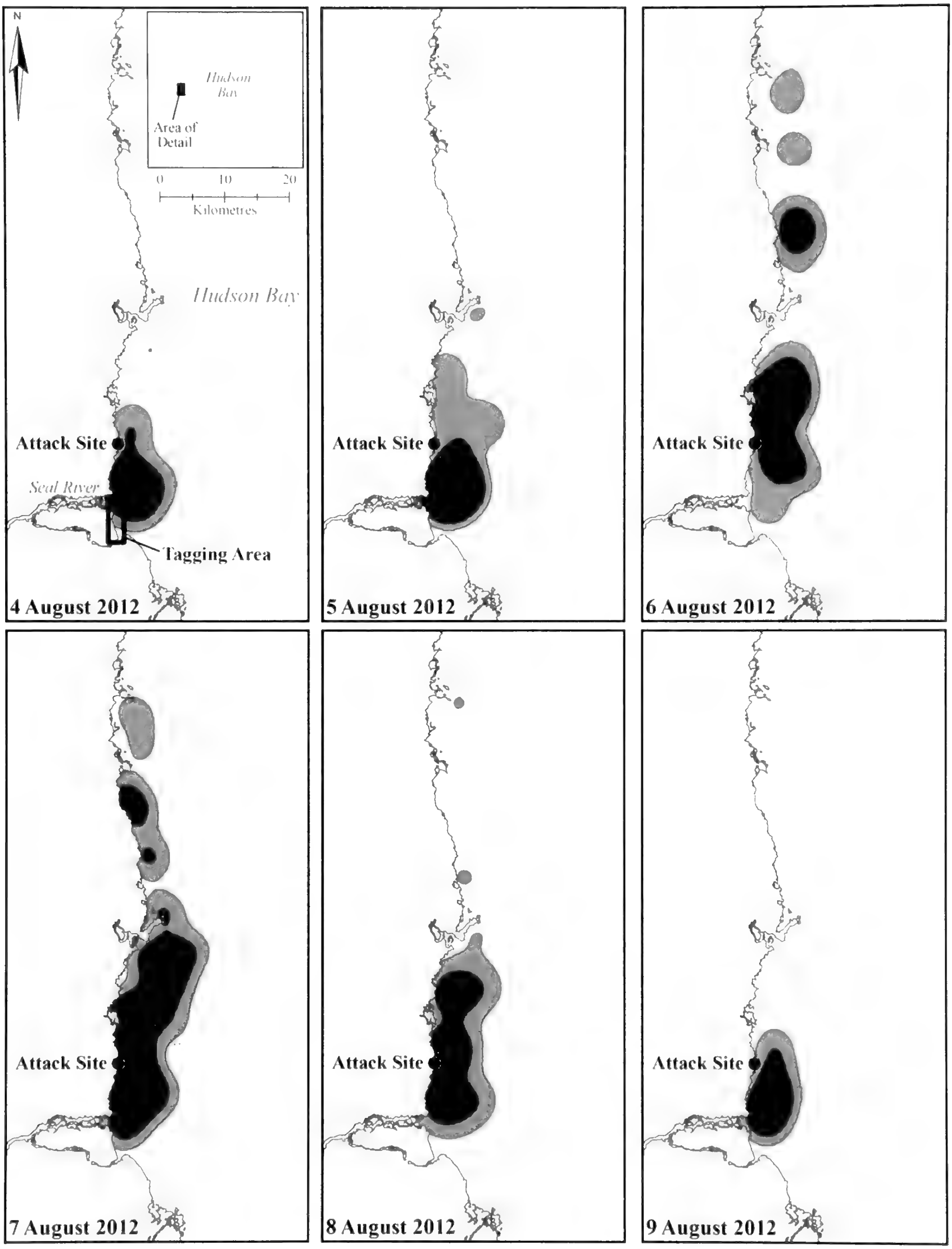

FIGURE 3. Kernel density of tagged Belugas (*Delphinapterus leucas*) showing their dispersal in the days immediately following a Killer Whale (*Orcinus orca*) attack on 4 August 2012 and their eventual return to the pre-attack area near the Seal River estuary, Hudson Bay. Dark grey shading indicates 50th percentile; lighter grey shows 75th percentile.

extensive enough to cause a decline of other marine mammals in the region. The impact of Killer Whales on prey such as Belugas in Hudson Bay is difficult to assess scientifically because the size of the Killer Whale population that visits the region is unknown and population trend data for Belugas are lacking (Ferguson *et al.* 2010).

However, non-lethal impacts of predation at the individual or group scale may have consequences. Cetaceans are known to exhibit a range of anti-predator adaptations in response to predation (Ford and Reeves 2008) including living in large groups (Norris and Dohl 1980), which may be the case for Belugas in southwest Hudson Bay. Responses to individual predation events include short-term grouping (Curé *et al.* 2013), a change in vocalizations, and directional swimming away from the threat (Ford and Reeves 2008). Here, short-term changes in distribution were recorded in relation to a predation event. This change, if occurring multiple times during the longer ice-free season, could have significant biological consequences related to energy expenditure and success in calf rearing. Belugas are known to spend summers in the shallows and estuaries of western Hudson Bay and hypotheses for this habitat preference include a dependence on warmer waters for calf rearing. The consequences of short-term but repeated abandonment of this habitat are unknown.

Overall, the lack of knowledge of Killer Whale numbers, predation activity, and possible changes in Beluga distribution and abundance in response to Killer Whale predation results in uncertainty over the future of Hudson Bay Belugas. A better understanding of Beluga behaviour and risk of predation, acquired through telemetry, and continued collection of information on Killer Whale sightings through community-based research are required for conservation and management. Conservation measures directed at Beluga habitat should ensure that more than just core summering areas are protected, as core areas alone are likely to be insufficient in light of the behaviour observed in August 2012.

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Home Ranges and Movements of Elk (*Cervus canadensis*) Restored to Southern Ontario, Canada

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During 2000 and 2001, Elk (*Cervus canadensis*) were restored to the Bancroft, Ontario area. The objective of this study was to determine the home range and movements of six social units of Elk, 5–12 years after restoration, in an area of about 2500 km^2 near Bancroft. Home range and movements were calculated from 40 221 Global Positioning System locations acquired from 56 collared Elk (16 bulls and 40 cows) between 2006 and 2013. Annual home ranges were found to be significantly greater (mean 110.3 km^2, standard error [SE] 11.2) for Elk in areas where winter feeding by humans did not occur compared with those (mean 51.0 km^2, SE 9.0) where winter feeding was prevalent. Elk in winter feeding areas had smaller ranges in winter than other seasons. On a seasonal basis, home range size was larger for Elk in areas where winter feeding did not occur; mean winter home range for Elk in non-feeding areas was 73.4 km^2 (SE 34.0) compared with 8.3 km^2 (SE 2.6) for Elk in areas where winter feeding occurred. The 20 Elk that were monitored for multiple years exhibited home range fidelity among years. The entire range of all radio-collared Elk within the social groups studied covered 1716.4 km^2 during 2006–2013. Average daily movements of Elk in the study area ranged from 1.0 to 2.1 km/day with greatest movements occurring during spring and summer. However, some Elk were capable of moving an average of 5–7 km in a 12-h interval. Movements (about 5 km) to winter range occurred during October to December each year. Cows moved to calving areas in May with mean movements of Elk to spring/summer range about 6 km. Cow/calf groups moved to fall ranges by early September with mean movements of about 4 km. During the rut, mean bull movements of 16.0 km to cow groups over 1–5 days occurred in early September. Hunting of Elk during the fall of 2011 and 2012 did not appear to significantly affect the movements and dispersion of Elk in the study area.

Key Words: *Cervus canadensis*; Elk; home range; movements; population restoration; southern Ontario

Introduction

Elk (*Cervus canadensis*) are fairly mobile animals; they are generally capable of extensive movement and have large home ranges (Irwin 2002; Raedeke *et al.* 2002). For example, in some areas of western North America, home ranges of > 350 km^2 have been documented (Benkobi *et al.* 2005); however, in other jurisdictions such as Manitoba, Elk have extremely small ranges < 20 km^2 (Brook 2010). Although the movement of Elk in established ranges of western North America has been well documented (Irwin 2002; Raedeke *et al.* 2002), only a few studies have reported ranges and movements of restored populations in eastern North America (Larkin *et al.* 2004; Fryxell *et al.* 2008; Haydon *et al.* 2008).

In 1998, Ontario embarked on an Elk restoration program as the species had been extirpated in the province (as well as in the rest of eastern North America) during the late 1800s (Rosatte *et al.* 2002, 2007). During 1998–2001, 443 Elk from Alberta were released in four areas of Ontario (Rosatte *et al.* 2007; Rosatte 2013, 2014). These animals included 120 Elk with very high frequency radio-collars that were released near Bancroft, Ontario in 2000 and 2001 (Rosatte *et al.* 2007). In 2000, the Elk were "hard released" immediately on their arrival in Ontario. Extensive movements by those Elk were documented during the initial years (2000–2004) of the restoration program (Fryxell *et al.* 2008; Haydon *et al.* 2008; Ryckman *et al.* 2010). In fact, during 2000 and 2001, the Elk dispersed over 27 000 km^2 of southern Ontario (Rosatte *et al.* 2007; Yott *et al.* 2011). Eventually, the restored Elk became acclimated to their new habitat, and, by the mid-2000s, their movement became less extensive (Fryxell *et al.* 2008; Haydon *et al.* 2008).

During 2006–2012, 56 of the Bancroft area Elk (progeny of the original restored herd) were captured and fitted with Global Positioning System (GPS) collars. The objective was to determine the home range and movements of six social units in an area of about 2500 km^2 near Bancroft, during 2006–2013, 5–12 years after restoration. A secondary objective was to determine the impact of winter feeding on Elk movements as well as the impact of hunting on Elk dispersion.

Study Area

The study area was centred at 44°58'N, 77°33'W near Bancroft, Ontario. The region is influenced by a temperate continental climate with cold winters and warm summers. The elevation is about 200–400 m above sea level. The study area lies within the Great Lakes–St. Lawrence Forest Region (Chambers *et al.* 1997). The habitat includes mixed deciduous and conifer forests with small pockets of agricultural lands in the northern part of the study area. Dominant forest cover species include Sugar Maple (*Acer saccharum* Marshall), Red Maple (*Acer rubrum* L.), Yellow Birch (*Betula alleghaniensis* Britton), Eastern Hemlock (*Tsuga canadensis* (L.) Carrière), and Eastern White Pine (*Pinus strobus* L.; Chambers *et al.* 1997). Snow accumulation during the winter averages 30–50 cm/month. Additional information on the study area, as well as winter severity data, has been documented by Rosatte (2014).

Methods

The telemetry study was conducted during 2006–2013 and involved six social units of Elk in an area of about 2500 km^2 that was termed the Bancroft area core Elk zone (Figure 1). A social unit of Elk usually consisted of mature cows, immature bulls and cows, and calves. The location of individual social units was determined by telemetry and observation. Because of the small sample sizes of some social units, winter feeding of Elk and White-tailed Deer (*Odocoileus virginianus*) in the Bancroft area, and habitat differences (see Rosatte [2014] for differences), the data were pooled for purposes of analysis into two groups of Elk: Lingham and Bancroft. The Lingham group occupied the southern part of the Elk range in the Bancroft area core Elk zone and included the Mephisto and Lingham social units. The Bancroft group occupied the northern part of the core Elk zone and included the Hartsmere, New Carlow/Boulter, Little Ireland, and Turriff social units.

From March 2006 to February 2012, 56 Elk were fitted with GPS collars (Lotek 3300, Lotek Engineering, Newmarket, Ontario, Canada) and random access satellite sensor link GPS/satellite collars (North Star Science and Technology, King George, Virginia, USA) to allow us to investigate their home range and movements. For the purposes of collaring, Elk were captured either by helicopter using a net gun (Bighorn Helicopters Inc., Cranbrook, British Columbia, Canada; Pathfinder Helicopters, South Woods Cross, Utah, USA; Ontario Ministry of Natural Resources and Forestry [OMNRF] Air Services, Sudbury, Ontario, Canada) or by OMNRF staff stalking Elk on the ground and immobilizing them via a dart gun using a tiletamine-zolazepam/xylazine mixture of drugs in a 5-mL dart (for methods see Rosatte 2007). GPS accuracy was tested before collaring by placing four collars in a variety of habitats and acquiring locations using the collars, as well as a handheld GPS unit and topographic maps to confirm them. Accuracy of collar locations was ± 5 m and, for most of the time, was not affected by habitat as Elk tended to use forest openings with a clear view to the satellites.

Only Elk with a minimum of 300 GPS locations, spaced across all seasons during the tracking period were used for annual (12-month) home range calculations. This exceeds the number of fixes recommended by Seaman *et al.* (1999; $\geq$ 30 locations) and Horne and Garton (2006; $\geq$ 50 locations) for home range estimation. Telemetry locations were assumed to be independent as individual Elk were tracked daily via GPS collars for 10–36 months, with 6–12 h between daily

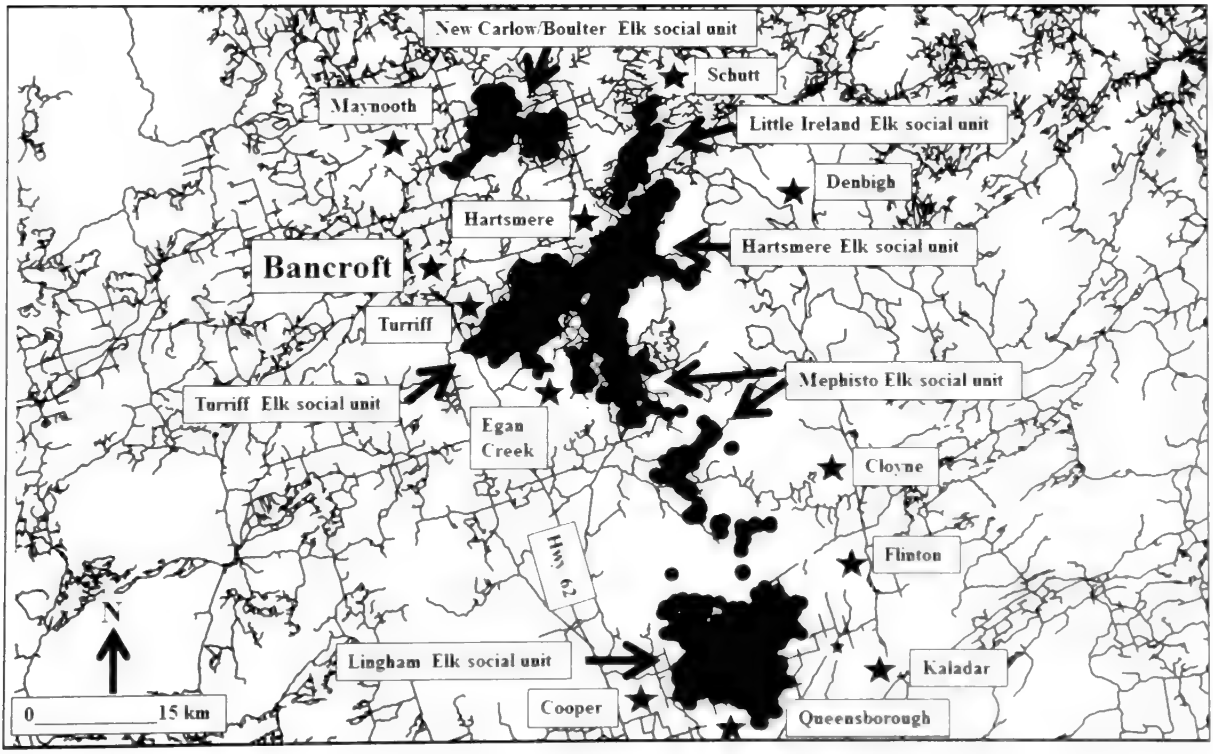

FIGURE 1. Location of Elk (*Cervus canadensis*) social units (based on 39 760 telemetry fixes) within the Bancroft, Ontario, area core Elk zone, 2006–2013. Locations of towns villages (stars) are approximate. Locations of Elk social units are denoted by the black areas of the figure, which represent telemetry fixes.

fixes (White and Garrott 1990). For seasonal home range analyses (3–5 months in duration), only Elk with a minimum of 80 fixes over the season were used for range calculations.

A 100% minimum convex polygon (MCP), created using Hawth's tools (Beyer 2004), was used to estimate total annual, as well as seasonal, range use for each Elk. We used the MCP model, as it is generally the estimator most frequently reported in the literature and allowed comparisons with Elk home ranges in other North American jurisdictions. Seasonal home ranges were determined for each of three periods based on the ecology of Elk in Ontario (Rosatte 2014): spring/summer range, 1 April to 31 August; fall range, 1 September to 30 November; winter range, 1 December to 31 March. The total annual population range for each social unit of Elk was also calculated using locations from all collared Elk in the unit. If more than 75% of among-year annual ranges overlapped, the animal was assumed to exhibit annual range fidelity.

We also used a 95% fixed kernel (Gaussian bivariate normal), determined using Home Range Extension for Arcview (Esri, Redlands, California, USA; Rodgers *et al.* 2005), to calculate annual home ranges for Elk, as this method removes outlying fixes that may result in overestimates. Schoener, Swihat, and Slade indices were calculated to determine the independence of the telemetry data (Rodgers *et al.* 2005). The smoothing factor for the kernel analysis was based on variance of the x and y coordinate data. The data were rescaled, and the bandwidth or smoothing factor for the kernel was selected using a proportion of the reference bandwidth.

The maximum movement distance across seasonal and annual ranges and movement to and from the centre of one seasonal range to the next were calculated using the measuring tool in ArcGIS 9.2 (Esri). Total cumulative movement on a seasonal basis, daily movement, and the greatest distance moved between fixes was calculated using ArcGIS 9.2, ArcMap, and Hawth's tools (Esri). To determine the impact of the September 2011/12 recreational hunt on Elk dispersion, the distance from the centre of their pre-hunt range to the maximum distal movement during the hunt and two weeks post-hunt was calculated using the ArcGIS 9.2 measuring tool. Significant movements followed by a cessation of movements by cow Elk during May and June of any given year indicated the timing of parturition (as per the methods of Allan 2013).

Ranges and movements of GPS-collared Elk within social groups of Elk in the Lingham and Bancroft areas were analyzed separately then compared, as winter feeding by residents in the Bancroft area was expected to have a significant impact on Elk movements. There are also habitat differences between the two areas as noted under Study Area, above, and by Rosatte (2014). Home range and movement data were analyzed using analysis of variance (ANOVA) models in Statistica 6.0 software (Dell, Round Rock, Texas, USA). ANOVAs are robust and not seriously affected by a lack of normality (Zar 1999). However, the data were first screened using Statistica (StatSoft, Tulsa, Oklahoma, USA) to verify the normality assumption and to test for heterogeneity of variances (Levene's test). Where assumptions were not met, i.e., the data were not normally distributed, the data were transformed using a Box-Cox power transformation (maximum likelihood estimation), which transforms the data as close to normality as possible. A repeated measures ANOVA was used for multiple variable comparisons, e.g., sex and age, home range and movements (Zar 1999). A Friedman ANOVA was used for comparisons in an individual sex and age class. Where two variables were being compared and the data met normality assumptions, a one-way ANOVA was used. If a statistical difference was noted, *post hoc* analyses were conducted using a Tukey test (Zar 1999). A Student t test for independent variables was used to compare bull movement to rutting areas in the Lingham and Hartsmere Elk groups, as well as differences in movements of cow and bull Elk during the parturition period. Dispersion of GPS-collared Elk was monitored and analyzed to determine when bull Elk moved to cow groups during the rutting period as well as when bulls left the cow groups after the rut was complete. This was accomplished by using simultaneous GPS locations (± 5 m accuracy) of Elk plotted in Google Earth (Google, Mountainview, California, USA). Sightings of Elk in eastern Ontario by OMNRF biologists and members of the public were tabulated and plotted on a map to depict their occurrence outside the Bancroft area core Elk zone.

Results

Annual and Seasonal Home Ranges of Individual Elk

Between 1 March 2006 and 31 March 2013, 56 GPS-collared adult Elk (40 cows, 16 bulls) were monitored for an average of 345 days (standard deviation [SD] 110) in the Bancroft area core Elk zone. The number of Elk fitted with collars each year was six in 2006, four in 2007, five in 2008, six in 2009, nine in 2010, 20 in 2011, and six in 2012. The total number of locational fixes for all collared Elk was 40 221 and the mean number of fixes per Elk was 731 (SD 596). The GPS collars were successful in transmitting a locational fix 85% of the time (40 221 times in 47 153 attempts).

Mean annual home ranges were significantly greater for Elk in the Lingham group (MCP 110.3 km^2) than in the Bancroft group (51.0 km^2) during 2006–2013 (Table 1, Appendix S1). No differences in mean annual home ranges were found between bulls (94.7 km^2) and cows (116.9 km^2) in the Lingham group (Table 1). Statistical differences were also not detected between bull ranges in the Lingham and Bancroft Elk groups. However, mean annual home ranges for bulls (117.5 km^2) in the Bancroft area were significantly larger than those for cows in that area (33.7 km^2; Table 1). In addition, annual MCP ranges for cows in the Lingham area were significantly larger than those for cows in the Bancroft area (Table 1, Appendix S1). Statistical analysis of the 95% kernel home range data yielded similar results to the MCP analysis (Table 1, Appendix S1).

Seasonal home ranges: For the Bancroft social group, bull and cow ranges during spring/summer and fall were significantly greater than their winter ranges. Bull ranges in Bancroft were also greater than cow ranges during spring, summer, and fall, but not during winter (Table 1, Appendix S2). Bull and cow Elk ranges in the Bancroft area were extremely small (mean 8.3 km^2) during the winter (Table 1).

Seasonal home ranges for the Lingham Elk group (bulls and cows) were significantly larger than ranges for the Bancroft Elk group during spring/summer, fall, and winter (Table 1). In particular, mean Elk ranges during the winter were dramatically larger in the Lingham area (73.4 km^2) than in the Bancroft area (8.3 km^2). Lingham cow ranges were significantly greater than Bancroft cow ranges during all seasons, but only greater than Bancroft bull ranges during the winter. Lingham bull ranges were significantly larger than Bancroft bull ranges only during the winter, but were greater than Bancroft cow ranges during all seasons (Table 1, Appendix S2).

Home range fidelity: Twenty cow Elk were monitored for 2–3 years: eight from the Lingham social unit, four from the Hartsmere unit, and two each from the Turriff, New Carlow, Mephisto, and Little Ireland Elk social units. All 20 exhibited annual range fidelity with > 75% of their among-year ranges occupying the same area as in previous years (2009–2013).

Population range: The entire population range of all radio-collared Elk in the social units and groups that were studied covered 1716.4 km^2 within the 2500-km^2 core Elk zone study area (ranges for individual social units are provided in Appendix S3). This estimate was based on a sample of 46 radio-collared Elk and 39 760 locational fixes during 2006–2013 (Table 2). The entire range of collared Elk in the Bancroft area core Elk zone included an area from Maynooth east to Schutt in the north, south about 82 km to the Queensborough area (Figure 1). The width of the range was approximately 20–30 km in the Bancroft–Harstmere area and about 16 km in the Lingham area. The population range 5–12 years after restoration was significantly smaller (by an order of magnitude; $P < 0.05$) than the range of Elk (> 27 000 km^2) during the restoration phase of the program in 2000 and 2001 (as documented by Yott *et al.* 2011).

Annual and seasonal movements of Elk

Examination of the annual and seasonal movements of the Bancroft and Lingham Elk groups revealed significant interaction. Further testing showed the interaction to be primarily because movements of the Lingham Elk group (mean 1.5 km/day) were significantly greater than those of the Bancroft group (mean 1.0 km/day) during the winter (Table 3, Appendix S4). In the Bancroft Elk group, mean annual bull and cow movements were significantly different: 1.7 km/day versus 1.2 km/day, respectively (Table 3, Appendix S4). In fact daily bull movements in the Bancroft area were greater than cow movements during spring/summer and fall, but not during winter (Table 3). Such differences were not detected in the Lingham Elk group daily movement data, either seasonally or annually (Table 3, Appendix S4). Further analysis of the movement data with respect to between-area and sex comparisons revealed that Lingham cow movements were significantly greater than Bancroft cow movements annually as well as during the winter but not during spring/summer or fall (Table 3, Appendix S4).

Movements between seasonal home ranges: Elk in the Bancroft and Lingham areas exhibited movements

TABLE 1. Annual and seasonal home ranges of social groups of Elk (*Cervus canadensis*) in the Bancroft, Ontario area, 2006–2013, based on 40 211 telemetry fixes.

				Mean home range, km^2 (SE)				
Elk group*	Winter feeding	Age/sex	n†	Annual MCP	Annual 95% kernel	SpSu MCP	Fall MCP	Winter MCP
Bancroft bulls	Yes	AM	6	117.5 (14.0)	92.2 (11.2)	60.9 (10.1)	70.0 (15.7)	3.1 (3.4)
Bancroft cows	Yes	AF	23	33.7 (7.2)	27.9 (5.7)	28.0 (5.5)	17.0 (9.0)	9.5 (1.7)
Bancroft group	Yes	M/F	29	51.0 (9.0)	41.2 (7.5)	35.4 (5.0)	30.2 (8.3)	8.3 (2.6)
Lingham bulls	No	AM	6	94.7 (20.0)	80.1 (18.3)	46.7 (9.8)	53.9 (18.1)	60.7 (11.9)
Lingham cows	No	AF	14	116.9 (13.5)	93.4 (12.0)	48.6 (6.7)	42.7 (9.4)	76.0 (5.3)
Lingham group	No	M/F	20	110.3 (11.2)	89.4 (9.0)	48.0 (6.0)	45.1 (9.3)	73.4 (3.4)

*The Bancroft group consisted of social groups in the Turriff, New Carlow–Boulter, Little Ireland, and Hartsmere areas; the Lingham group consisted of those in the Lingham and Mephisto Lakes areas.

†Sample sizes for annual home ranges only. For seasonal ranges, sample sizes were 6, 24, and 30 for Bancroft bulls, cows, and the group, respectively; sample sizes were 3, 15, and 18 for Lingham bulls, cows, and the group, respectively.

Note: AF = adult female; AM = adult male; M/F = adult males and adult females; MCP = minimum convex polygon; SE = standard error; SpSu = spring/summer.

TABLE 2. Population range of social units and social groups of radio-collared Elk (*Cervus canadensis*) in the greater Bancroft, Ontario area, 2006–2013.

Elk social unit/group	Years	Number collared Elk	Number telemetry fixes*	Population range, km^2	Maximum distance across range, km
Hartsmere unit	2006–2012	17	22 159	607.8	41.0
Turriff unit	2009–2012	4	2 607	39.9	9.4
New Carlow unit	2009–2012	3	2 168	82.6	14.5
Bancroft group	2006–2012	24	26 934	941.9	50.5
Lingham unit	2010–2013	20	11 762	400.5	35.0
Mephisto unit	2011–2012	2	1 064	84.8	17.2
Lingham group	2010–2013	22	12 826	724.3	58.7
All Elk	2006–2013	46	39 760	1716.4	81.6

*One cow from Little Ireland and one bull from Madoc were not included in range calculations.

TABLE 3. Annual and seasonal daily movements of Elk (*Cervus canadensis*) in the Bancroft and Lingham areas, Ontario, 2006–2013, based on 40 221 telemetry fixes.

				Movement, mean km/day (SE)			
Elk group*	Winter feeding	Age/sex	*n*	Annual	SpSu	Fall	Winter
Bancroft bulls	Yes	AM	7	1.7 (0.2)	2.0 (0.2)	2.1 (0.3)	1.2 (0.2)
Bancroft cows	Yes	AF	22	1.2 (0.1)	1.4 (0.1)	1.4 (0.2)	1.0 (0.1)
Bancroft group	Yes	M/F	29	1.3 (0.1)	1.6 (0.1)	1.6 (0.1)	1.0 (0.1)
Lingham bulls	No	AM	6	1.5 (0.1)	1.5 (0.1)	1.6 (0.1)	1.2 (0.2)
Lingham cows	No	AF	16	1.4 (0.1)	1.3 (0.1)	1.3 (0.1)	1.5 (0.1)
Lingham group	No	M/F	22	1.4 (0.1)	1.4 (0.1)	1.4 (0.1)	1.5 (0.1)

*The Bancroft group consisted of social units in the Turriff, New Carlow/Boulter, Little Ireland, and Hartsmere areas; the Lingham group consisted of those in the Lingham and Mephisto Lakes areas.
Note: AF = adult female, AM = adult male, M/F = adult males and adult females, SE = standard error, SpSu = spring summer.

to seasonal ranges during the year. Movements from fall to winter ranges generally occurred during October to December. Movements to spring/summer ranges were less distinct for bulls; however, cows usually moved to their spring/summer range for calving in May. Following calving, cows rejoined their social units in July/August and moved to fall ranges by early September. Bulls joined the social units during early to mid-September, which coincided with the rut on the fall range. Bulls usually left the social group by late October (except in areas where winter feeding occurred).

Elk in the Bancroft area had separate seasonal ranges every year from 2006 to 2012 (see Figure 2 for an example). Bancroft area bull Elk travelled significantly greater distances (mean 13.5 km) from winter range to spring/summer range than adult cow Elk (mean 4.5 km) (Table 4, Appendix S5). Bulls also travelled farther than cows from spring/summer to fall ranges and from fall to winter ranges in the Bancroft area (Table 4). Bancroft area bull movements were significantly greater than Lingham area bull movements from winter to spring range. No differences in movements to seasonal ranges were detected between Lingham and Bancroft area cow Elk or between bull and cow Elk in the Lingham area (Table 4, Appendix S5).

Movement potential of Elk: No differences were detected in mean 12-h movement distances by Elk in spring/summer (5.4 km, SE 0.4), fall (6.0 km, SE 0.6), or winter (6.8 km, SE 0.6; Appendix S5). There were also no differences in mean 12-h movements between bulls (6.1 km, SE 0.6) and cows (5.9 km, SE 0.4; Appendix S5). However, mean movements in a 12-h period were greater for Elk in the Lingham area (6.9 km) than those in the Bancroft area (5.3 km; Table 4, Appendix S5). Among 54 Elk, 25 (48%) had the greatest 12-h movements during the spring/summer, 15 (28%) during the fall, and 13 (24%) during the winter.

Directional movement of Elk: Elk travelled a mean distance of 9.9 km (SD 6.0) from the point of radio-collaring. No significant differences in mean bearing of annual movements were detected between bulls (176.4°, SE 1.6) and cows (173.6°, SE 1.0; $P = 0.14$); however, there was a significant difference between Bancroft area Elk (176.5°, SE 1.0) and Lingham area Elk (171.3°, SE 1.2; $P = 0.001$).

Movements among social groups: Of the 56 Elk that received GPS collars during 2006 and 2012, 16 (29%) moved into the home range of another social unit while they were being monitored. There was very little movement of Elk from the Bancroft area to the Lingham area and vice versa. In fact, only two bulls were documented travelling 10 km and 50 km, from the Hartsmere area south to the Mephisto and Queensborough areas (Lingham Elk social group), respectively, during 2006–

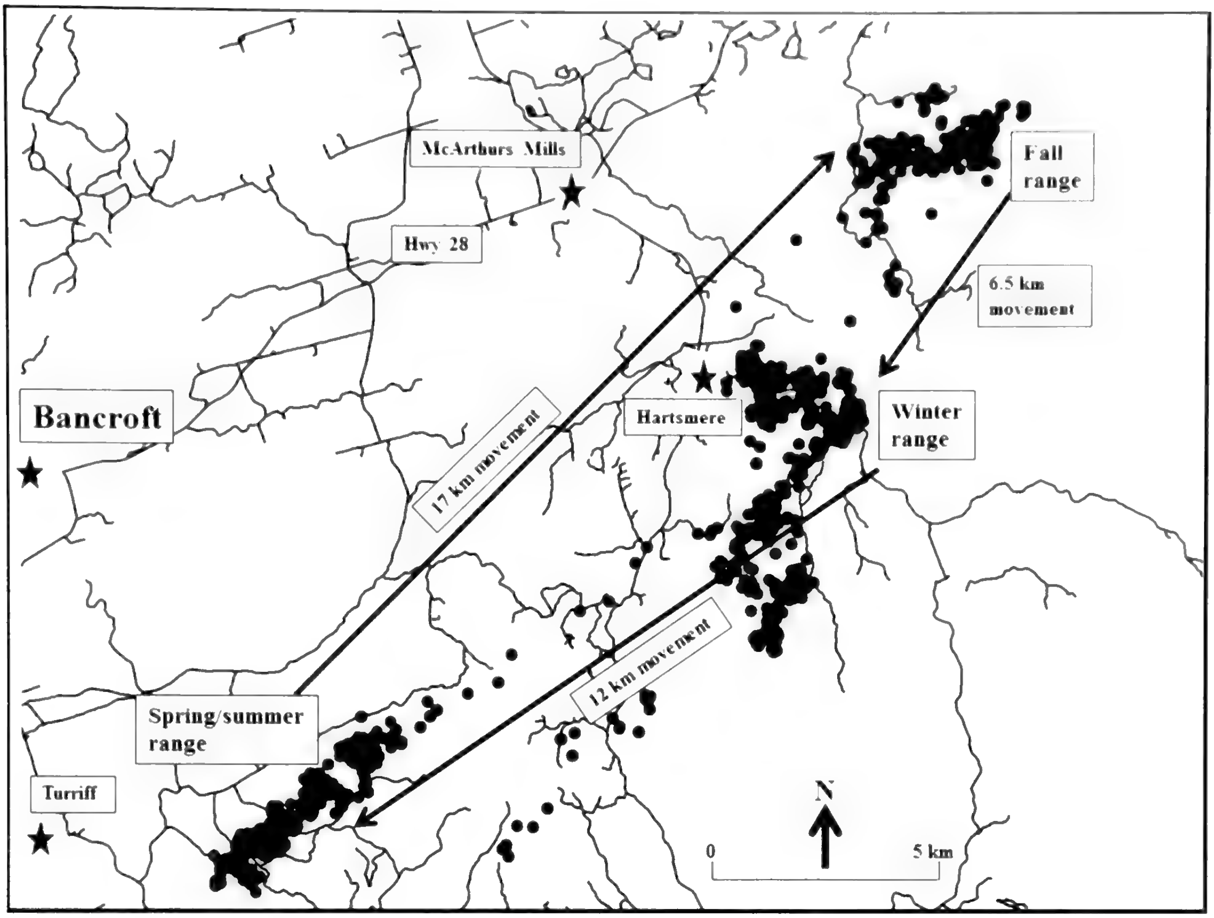

FIGURE 2. An example of the location of spring/summer, fall, and winter ranges (based on 2786 telemetry fixes) of a mature bull Elk (*Cervus canadensis*) in the Bancroft, Ontario area from 1 April 2006 to 31 March 2007.

TABLE 4. Distance moved between seasonal home ranges and maximum distance moved during any 12-h period by Elk (*Cervus canadensis*) in the Bancroft and Lingham areas, Ontario, 2006–2013.

Elk group*	Winter feeding	Age/ sex	*n*	Distance moved, mean km (SE) From winter to SpSu range	From SpSu to fall range	From fall to winter range	Maximum in 12 h during time tracked†
Bancroft bulls	Yes	AM	5	13.5 (1.3)	10.5 (1.2)	10.5 (2.0)	6.8 (0.7)
Bancroft cows	Yes	AF	19	4.5 (0.7)	2.6 (0.6)	3.7 (1.0)	4.8 (0.4)
Bancroft group	Yes	M/F	24	6.4 (1.0)	4.3 (1.0)	5.1 (1.0)	5.3 (0.4)
Lingham bulls	No	AM	2	2.5 (3.6)	5.6 (3.9)	4.7 (1.9)	5.3 (0.9)
Lingham cows	No	AF	15	6.3 (1.2)	4.2 (1.3)	5.2 (0.7)	7.5 (0.6)
Lingham group	No	M/F	17	5.8 (1.2)	4.4 (1.1)	5.1 (1.0)	6.9 (0.5)

*The Bancroft group consisted of social units in the Turriff, New Carlow/Boulter, Little Ireland, and Hartsmere areas; the Lingham group consisted of those in the Lingham and Mephisto Lakes areas.

†For these calculations, sample sizes were 7, 24, 31 for Bancroft bulls, cows, and the group, respectively, and 7, 16, and 23 for Lingham bulls, cows, and the group, respectively.

Note: AF = adult female, AM = adult male, M/F = adult males and adult females, SE = standard error, SpSu = spring/summer

2013. In addition, two cow Elk from the Lingham herd moved 25 km north to the Hartsmere Elk social unit range.

Significant movement of bulls and cows among the various social units of Elk in the Bancroft area was documented. Three Hartsmere bulls moved 23 km to the Turriff social unit range and three other bulls moved 10 km to the Little Ireland social unit range between 2006 and 2012. In addition, four cows moved 10 km from the Hartsmere social unit to the Little Ireland unit, and two Hartsmere cows moved 10 km to the Turriff social unit range between 2006 and 2012 (Figure 1).

Movement of bull Elk to cow groups during the rut: Collared bull Elk ($n = 6$) travelled to cow units for the rut in the Lingham Lake area during 7–15 September 2012 (Figure 3). Travel time averaged 2.1 days (SD 1.43; range 0.5–4 days). Mean movement of six collared bulls to the rutting areas was 6.4 km (SD 0.49, range 6.0–7.1 km). One mature bull was documented travelling 10 km in three days to visit three different social units of cows (which were 5 km apart). Bull Elk ($n = 5$) in the Bancroft area moved to cow social units for breeding during 4–19 September 2006–2009. Mean movement of bulls to rutting areas was 16.0 km (SD 9.08, range 5.2–26.9 km). The average time to travel to rutting areas was 2.2 days (SD 1.79, range 1–5 days). Bull Elk in the Bancroft area travelled significantly greater distances to rutting areas than did bull Elk in the Lingham area ($P = 0.03$).

Impact of the hunt on Elk dispersion: During 2011, 22 cow Elk with functioning GPS collars moved an average of 2.0 km (SD 0.67; range 1.1–3.7) from the centre of their fall pre-hunt range during the two weeks before the hunt (5–18 September 2011). During the hunt (19–25 September 2011), those Elk moved an average of 1.0 km (SD 0.79, range 0.1–3.1) outside their pre-hunt range. Of those Elk, 20 (91%) returned to their pre-hunt range within two weeks of the end of the hunt.

During 2012, 22 Elk (17 cows, five bulls) with functioning GPS collars moved an average of 2.6 km (SD 1.43, range 0.8–5.3) from the centre of their fall pre-hunt range during the two weeks before the hunt (3–16 September 2012). During the hunt (17–30 September 2012), those Elk moved an average of 2.0 km (SD 1.56, range 0.3–6.4) outside their pre-hunt range. Again, 91% returned to their pre-hunt range within two weeks following the end of the hunt.

Elk use of hydro corridors for movement: Elk used hydro corridors for movement as well as for foraging in the Lingham area during 2006–2013. Of 23 Elk collared in the Lingham area, 10 (six cows, four bulls) used hydro corridors based on GPS locations from their collars. One cow moved 9 km along a corridor during calving season (Figure 4). Movements along hydro corridors occurred during all seasons, but use was more frequent (nine of 10 Elk) during spring and summer.

Elk sightings outside the southern Ontario core Elk range

During 2003–2012, 206 Elk sightings (usually accompanied by photographs for verification) were reported to the author by the public and by OMNRF staff. That included individual Elk as well as groups of up to nine Elk. These Elk represent individuals and their progeny that dispersed from the 2500 km^2 core Elk area near Bancroft, Ontario. The locations of the Elk sightings are depicted in Figure 5 and occurred over approximately 50 000 km^2 of southern Ontario.

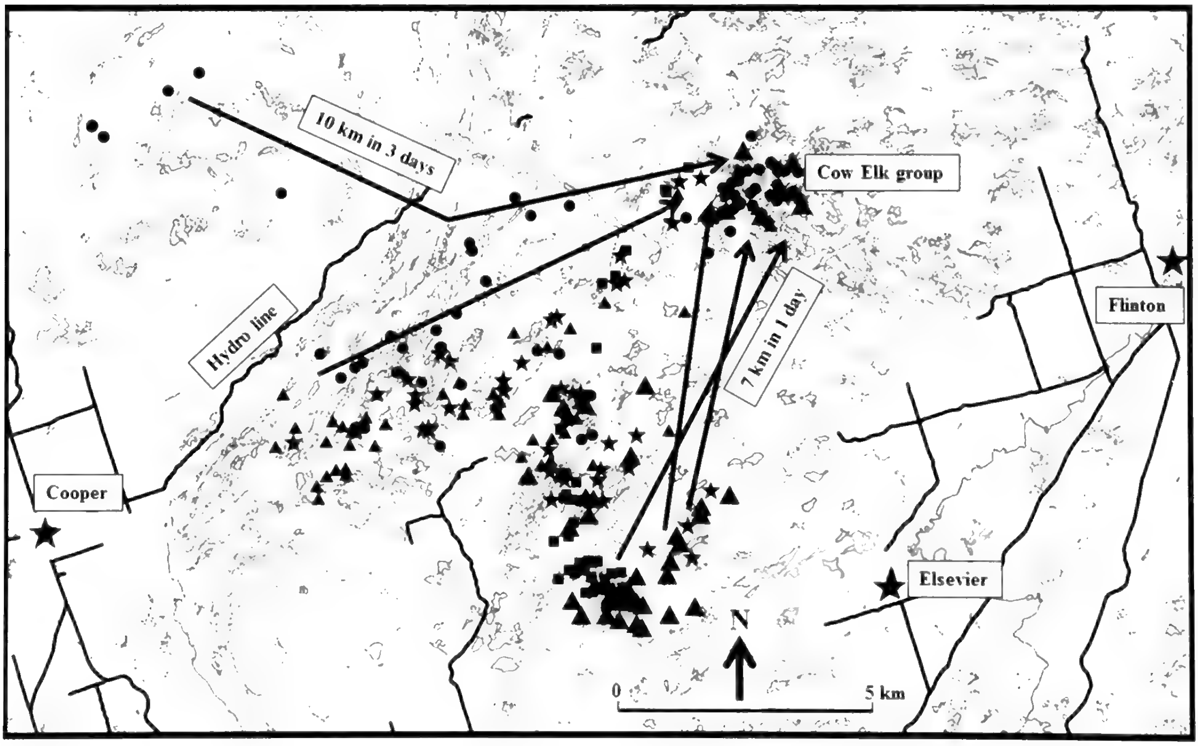

FIGURE 3. Example of movements of five collared bull Elk (*Cervus canadensis*), based on 210 telemetry fixes, toward a large cow Elk social unit before and during the rutting period in the Lingham Lake area, 23 August to 15 September 2012. Movements by bulls of 6–10 km occurred over 0.5–4 days, during 7–15 September 2012. A sixth collared Bull Elk followed the same route to the cow Elk area as one of those depicted but is not shown.

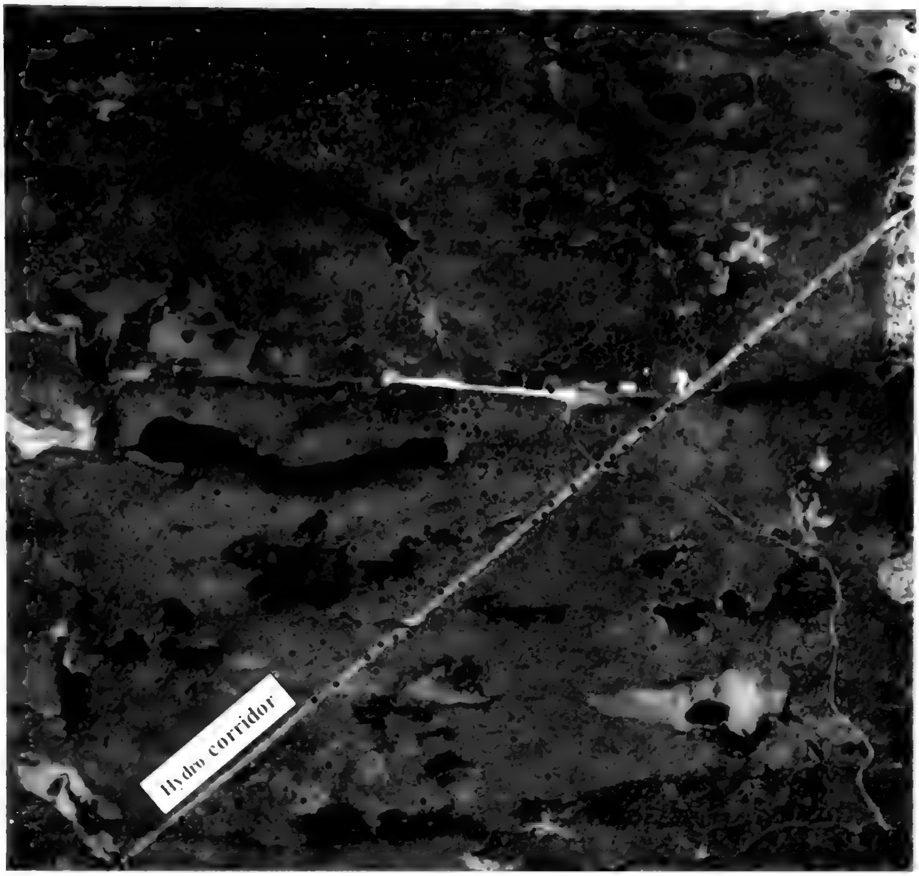

FIGURE 4. Example of a cow Elk (*Cervus canadensis*) using hydro corridors to travel north of Lingham Lake, Ontario, as indicated by telemetry fixes.

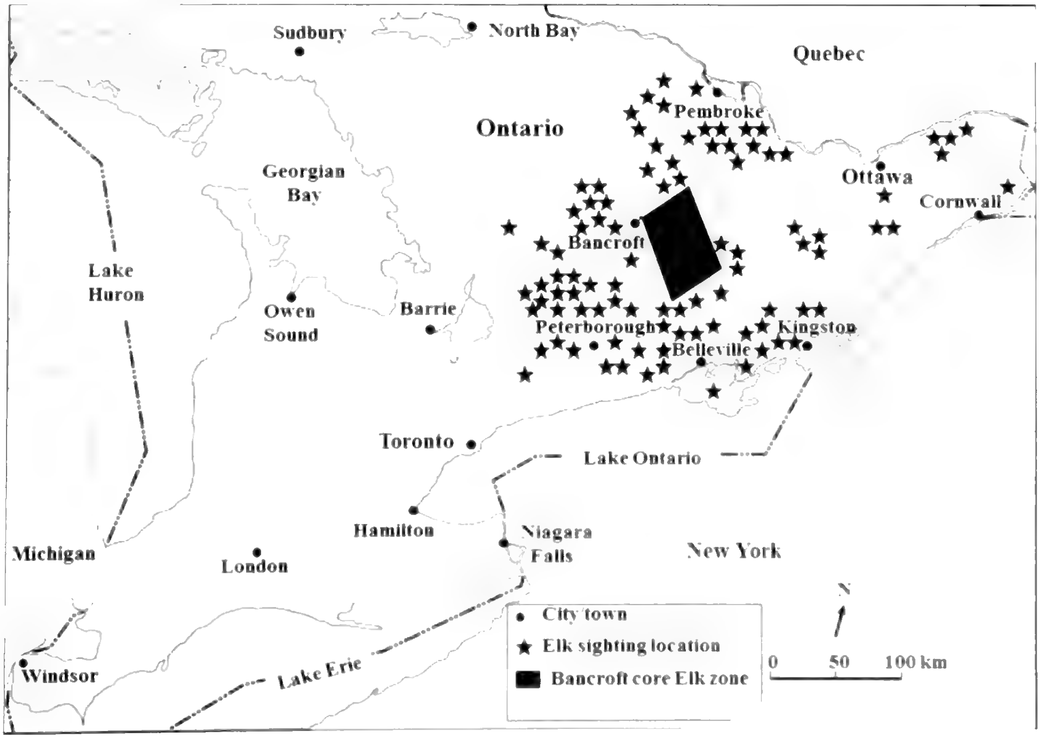

FIGURE 5. County map of southern Ontario, Canada, showing the Bancroft area core Elk zone (the black rectangle) and approximate locations of Elk (*Cervus canadensis*) sightings outside of the core zone, indicating range expansion during 2003–2013.

Discussion

During the late 1800s, Elk were extirpated from eastern North America, including Ontario, because of unregulated hunting, habitat loss resulting from the conversion of land for the production of cattle and crops, and conflicts with humans (Bryant and Maser 1982; Ranta *et al.* 1982; Bosveld 1996; Bellhouse and Rosatte 2005). During the most recent restoration, Elk were acquired from Elk Island National Park, Alberta, and released in four areas of Ontario during 1998–2001 (Rosatte *et al.* 2007; Rosatte 2013). Elk are currently doing exceptionally well in two of the release areas (populations have more than quadrupled), including the Bancroft area in southern Ontario, which was the focus of this study (Rosatte *et al.* 2002, 2007; Rosatte 2013, 2014).

When Elk were released in the Bancroft area in 2000, the herd quickly fragmented and dispersed over a 10 000–27 000 km^2 area (Haydon *et al.* 2008; Yott *et al.* 2011). More than 50% of the animals dispersed more than 40 km from the release site with males and females having annual ranges totalling 15 000 km^2 and 19 000 km^2, respectively (Yott *et al.* 2011). This was a direct result of an unintentional "hard release", i.e., Elk were not held in an enclosure for a recovery or acclimatization period before release as they escaped from the holding pen (Rosatte *et al.* 2007). However, after 2–3 years of a dispersive phase, Elk moved into a home range phase with fewer extensive movements (Fryxell *et al.* 2008). This was confirmed during the current study, as the population range of adult Elk (1716 km^2) 5–12 years after restoration was significantly smaller than the range (> 27 000 km^2) during the restoration phase of the program in 2000 and 2001 (Yott *et al.* 2011). A smaller range is an advantage, as Elk remain in the area where they were intended to be restored.

In this study of the Bancroft and Lingham area Elk groups, average annual home ranges (MCP) for bulls and cows 5–12 years after restoration ranged between 34 km^2 and 118 km^2. Annual kernel ranges (95%) were 79% to 84% that of MCP annual ranges. The kernel ranges are more representative of the core range used by Elk in the Bancroft area, as that analytical method removes outlying telemetry locations that are not part of the core range.

Home range sizes for cow Elk during the 1990s in the Burwash/French River area of Ontario were about 25–50 km^2 with bulls having larger ranges than cows (Hamr and Filion 1996; Bellhouse and Broadfoot 1998). In Manitoba, mean home ranges of cow Elk in forest and agricultural, forested, and farmland areas were 18 km^2, 4.7 km^2, and 4.5 km^2, respectively, in 2002–2005 (Brook 2010). At the other end of the spectrum, cow Elk annual ranges in Colorado and New Mexico were large, averaging 250 km^2 (Webb *et al.* 2011).

The study by Webb *et al.* (2011) also noted a between-year home range overlap of 68%. In the Bancroft study, all cow Elk that were monitored for multiple years exhibited range fidelity. Range fidelity is advantageous for Elk as they have previous knowledge of forage resources and security cover (Webb *et al.* 2011). This is also beneficial from a restoration perspective as Elk remain in an area when released. Range fidelity also facilitates monitoring of Elk populations as survey staff can go to the general areas that Elk have been using for several years.

Home ranges for Elk groups in the Bancroft area core Elk range averaged 30–50 km^2 during spring/summer and fall. However, during winter, ranges in areas where winter feeding occurred averaged only 8 km^2 compared with 73 km^2 in areas where winter feeding did not occur. Although not always the case, Geist (2002) suggests that home ranges in some habitats during winter may be larger than ranges in summer as resources are more restricted in winter making Elk travel farther to meet their energy requirements. In support of this, the home ranges of a migratory herd of Elk in South Dakota averaged 163 km^2 in summer and 355 km^2 in winter (Benkobi *et al.* 2005). Anderson *et al.* (2005) also found an inverse relationship between forage biomass and winter and summer home ranges for Elk in Alberta and Wisconsin. In contrast, ranges in the Bancroft area were smaller in winter, likely because sufficient resources were available as a result of feeding by residents. However, if Elk are confined to a small area in winter, contact among them is increased, which will facilitate the spread of disease and parasites.

Factors other than winter feeding may also affect the size of the winter range. In Yellowstone National Park during the late 1960s, the ranges of cow Elk were 0.3–3.9 km^2 in winter; 1.8–6.2 km^2 in spring; 3.1–16.8 km^2 in summer; and 5.2–16.6 km^2 in fall. In this situation, small winter ranges were a result of movement restriction by deep snow (Craighead *et al.* 1971). Moran (1973) postulated that Elk movements were restricted when snow depth exceeded 46 cm in Michigan. In general, in the current study, snow depth did not appear to affect winter Elk movements in the Lingham area south of Bancroft given the large winter range of those Elk.

In some areas of western North America, Elk migrate from 2.4 km to 150 km between seasonal ranges (Irwin 2002; White *et al.* 2010). Generally, in those areas, spring migrations occur during May/June and fall migrations from September to December (Irwin 2002; White *et al.* 2010). Usually, initiation of migration is stimulated by snow depth (about 20 cm) and snow compaction, which reduces forage availability and increases energy demands (Benkobi *et al.* 2005). The timing of forage green-up can also influence the initiation of spring migration (White *et al.* 2010). The direction of movement may depend on the forage quality and quantity of the habitat and the duration of migration can be 7–43 days in some areas (Benkobi *et al.* 2005; White *et al.* 2010). Elk in the French River area of Ontario migrated about 20 km from summer to winter ranges, whereas Elk at Burwash did not migrate

(Bellhouse and Broadfoot 1998). Similarly, parts of the Yellowstone herds were non-migratory and movements were generally less than 1.6 km in 24 h (Craighead *et al.* 1971). In the current study, Elk groups in the Bancroft area moved about 4–6 km between seasonal ranges. Whether this small distance can be classed as migration depends on one's definition of migration.

With the initiation of the rut during the fall in the Bancroft area, bull Elk moved considerable distances to find groups of cows for breeding. Bull Elk in the Bancroft area moved greater distances to rutting areas than those in the Lingham area. This was probably a function of the dispersion of Elk social groups in the two areas; social units of cows were spatially farther apart in the Bancroft area than in the Lingham area. In the current study, bull Elk in the Bancroft area migrated a mean distance of 11 km between fall and winter ranges and 13 km from winter to spring/summer ranges. Whether this can be classed as migration or simply movement from one part of an annual range to another is debatable. Most movements to winter range occurred during December with the accumulation of snow; however, movement to winter range in the Bancroft area occurred during late October and continued into December because of the initiation of supplementary feeding by some residents.

During an Elk restoration program in Kentucky, Larkin *et al.* (2004) noted that adult and young Elk moved on average 16 km and 9 km, respectively, during the 12 months after release. Ryckman *et al.* (2010) found that, during the early stages of a restoration program in Ontario (including areas other than Bancroft), Elk dispersed 13–22 km, on average, from the point of release. When data from the four release sites in that study were pooled, both adult males and females remained about 20 km from the release sites during 1998–2004 (Ryckman *et al.* 2010). Two years following restoration (2002 and 2003), a cow and a bull Elk dispersed 180 km and 275 km, respectively, from Bancroft, Ontario, into Quebec (R. Rosatte, unpublished data). In the current study, which took place several years post-restoration, there were no significant movements by radio-collared Elk. Most Elk in the Bancroft area core range moved about 10 km from the site where they were radio-collared, travelled about 1–2 km a day, and migrated about 4–6 km from one seasonal range to another. However, it must be noted that this was 5–12 years after restoration and extensive movements would not be expected as Elk had moved from a dispersive phase shortly following restoration to a more encamped, home range phase (Fryxell *et al.* 2008).

In this study, about 30% of collared Elk were documented moving among social units. Houston (1982) noted that Elk in the northern part of Yellowstone National Park also demonstrated movement into the ranges of some of the other nine Elk herds in the park. Smith and Anderson (2001) also found this behaviour in the Jackson Elk herd. Interdemic movement of Elk will ultimately affect the demographics of the social units as well as mortality rates. In fact, Haydon *et al.* (2007) found that the greater the distance Elk moved from their home range in the Bancroft area, the higher the mortality. Smith and Anderson (2001) also found that mortality was higher in Elk that dispersed to new herd segments than in those that did not disperse out of Grand Teton National Park. Interdemic movement may also be an advantageous behaviour, as it will likely decrease the chances of inbreeding depression in a population that is not geographically isolated. Williams *et al.* (2002) warned of the consequences of rapid population growth and the resultant genetic diversity issues including a decrease in heterozygosity, and no unique and few rare alleles, in a re-introduced Elk herd in Pennsylvania. However, this should not be an issue with Elk populations in southern Ontario because of the interdemic movement of Elk among social groups.

In this study, movements of Elk tended to be at a mean bearing of 177° in the Bancroft area. As Yott *et al.* (2011) noted, this may have been because of a tendency to face into the prevailing wind to scent predators. It may also have been a result of the orientation of the landscape and the use of hydro corridors for movement. Kie *et al.* (2005) noted that the directional movements of Elk are affected by topography and Elk tend to move parallel to major drainages. Rivers and streams in the northern part of the Bancroft area core Elk range flow to the east; however, they flow south in the southern part of the core Elk range, similar to the direction that Elk moved. Regardless, resource managers can expect Elk to move southward from the Bancroft area into other areas of southern Ontario (which they have done) where they will need to be managed to prevent conflict with humans.

In some jurisdictions, Elk appear to be sensitive to hunting pressure as evidenced by their movements during the hunting season. During a Montana study in 2007–2009, Cleveland *et al.* (2012) found that movement rates of Elk increased with hunting pressure. In addition, Elk in Montana were reported moving to refuges to avoid hunters (Conner *et al.* 2001; Vieira *et al.* 2003). Conversely, in Ontario, hunting during September 2011 and 2012 had little impact on the dispersion and movements of Elk in the greater Bancroft area. Collared Elk moved < 3 km before and during the hunt (over 3–4 weeks) and most Elk (91%) returned to their fall range after the hunt. Essentially, Elk did not significantly alter their fall range in response to the Elk hunt. This may be explained partly by the fact that the restored Elk in the Bancroft area are used to hunting activity (for other species) during the fall. Before the opening of Elk hunting season in 2011 in the Bancroft area, Elk had been exposed to hunting activity during the one-week Moose (*Alces americanus*) gun hunt (late October), the two-week deer gun hunt (early November), the three-month Black Bear (*Ursus americanus*) hunt (1 September to 30 November), as well as the archery-only seasons for Moose and deer (early October and October–December, respectively). Even though Elk are not being hunted during Moose and deer hunting seasons, they will still be disturbed by hunter activity and the use of all-terrain vehicles and dogs for deer hunting. Minimal movements of Elk during the fall Elk hunt may simply be a reflection of the fact that they are used to disturbances during the fall as hunting has occurred annually in the area since Elk were released in 2000 and 2001. However, movement rates and dispersion of Elk in the Bancroft area could change with an increase in hunting pressure (i.e., more hunters and more tags) or an extension of the season.

Management implications

Several social units of Elk have emerged on the landscape since the restoration of Elk in the greater Bancroft area during 2000 and 2001. These units have established traditional seasonal ranges to which they return annually, and knowledge of these locations will aid in their management. As winter feeding of Elk in some areas near Bancroft, Ontario, has dramatically affected their movements and ranges, feeding should be restricted to severe winters. Hunting pressure currently (2014) does not appear to be affecting Elk movements or dispersion; however, an increase in hunting pressure or season length could influence Elk movements in the Bancroft area. Resource managers will need to remain vigilant as Elk numbers increase and their range expansion in the Bancroft area occurs to the point that is socially unacceptable. In view of this, it is recommended that research and monitoring programs continue, but expand beyond the Bancroft area core Elk zone to include social groups of Elk that have become established in other regions of southern Ontario as was noted in the sighting data.

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Supplementary Material:

Appendix S1. Comparison of annual home ranges of Elk (*Cervus canadensis*) in the Bancroft, Ontario area, 2006–2013.

Appendix S2. Comparison of seasonal homes ranges of Elk (*Cervus canadensis*) in the Bancroft, Ontario area, 2006–2013.

Appendix S3. Home ranges of Elk (*Cervus canadensis*) in individual social units and groups in the Bancroft core Elk zone, 2006–2013.

Appendix S4. Comparison of annual and seasonal movements of Elk (*Cervus canadensis*) in the Bancroft, Ontario area, 2006–2013.

Appendix S5. Comparison of Elk (*Cervus canadensis*) movements between seasonal ranges in the Bancroft, Ontario area, 2006–2013.

Note

Colonization of the Beaufort Coastal Plain by Beaver (*Castor canadensis*): A Response to Shrubification of the Tundra?

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Jung, Thomas S., Jay Frandsen, Danny C. Gordon, Sr., and David H. Mossop. 2016. Colonization of the Beaufort Coastal Plain by Beaver (*Castor canadensis*): a response to shrubification of the tundra? Canadian Field-Naturalist 130(4): 332–335.

A consequence of rapid global warming has been the shrubification (increase in shrub abundance, cover, and biomass) of arctic and alpine tundra ecosystems. Shrubification is likely a key driver of predicted and observed changes in the biodiversity of the Arctic. The American Beaver (*Castor canadensis*) has a vast distributional range, covering most of North America below the tree line; however, it has not been recorded in tundra habitat of the Beaufort Coastal Plain of Yukon and Alaska. In 2015, we observed a beaver dam, lodge, and winter food cache on the Babbage River in Ivvavik National Park, Yukon, Canada. Local Inuvialuit hunters first observed beavers on two rivers immediately east of the Babbage River in 2008 and 2009. Together, these are the first observations of beavers on the Beaufort Coastal Plain and indicate initial attempts at colonization. Colonization of the Beaufort Coastal Plain by beavers may have been facilitated by shrubification of river valleys on the tundra of northern Yukon and adjacent Alaska, which is a consequence of rapid climate warming in the western Arctic.

Key Words: American Beaver; Beaufort Coastal Plain; *Castor canadensis*; climate change impacts; range expansion; shrubification; tundra; Yukon North Slope

The Arctic is undergoing dramatic ecological changes as a result of rapid climate warming (Post *et al.* 2009). One of the most concerning changes is the rapid shrubification (increase in shrub abundance, cover, and biomass) of tundra ecosystems by *Salix* spp., *Betula* spp., and *Alnus* spp. (Sturm *et al.* 2001; Tape *et al.* 2006; Myers-Smith *et al.* 2011a,b). Shrubification can have a substantial impact on soil temperatures, nutrient cycling, biodiversity, and ecological services in arctic and alpine tundra ecosystems (Myers-Smith *et al.* 2011a).

A striking example of climate-induced changes in mammalian biodiversity in the Arctic is the recent colonization by the Snowshoe Hare (*Lepus americanus*) of tundra riparian systems in Alaska, likely as a result of shrubification (Tape *et al.* 2016a). Over longer periods, Moose (*Alces americanus*) have similarly expanded their range onto the tundra of Alaska and northwestern Canada, also likely as a result of shrubification (Coady 1980; Tape *et al.* 2016b). With continued global warming and the concomitant increase in shrubification, other mammals more characteristic of subarctic regions may be expected to colonize the tundra as well, with possible impacts on the biota and ecological functioning of those ecosystems. On the North Slope of Yukon and Alaska (hereafter, Beaufort Coastal Plain), shrubification has been concentrated along river valley corridors (Naito and Cairns 2015; Tape *et al.* 2016a), which may aid in the movement and dispersal of species colonizing the tundra.

The American Beaver (*Castor canadensis*) has an immense distributional range that extends through much of the United States and Canada below the tree line (Jenkins and Busher 1979; Baker and Hill 2003). It has also been successfully introduced in regions of South America and Europe. In North America, beavers may occur at high latitudes, such as in the Mackenzie River Delta, where they occupy forested landscapes (Aleksiuk 1970; Gill 1972); however, Baker and Hill (2003) noted that "they have been unable to colonize Alaskan or Canadian arctic tundra, perhaps because tundra vegetation lacks essentially woody plants for winter food and lodge construction or because thick ice limits surface access in winter." Indeed, observations of beavers on the tundra are uncommon, although they have been incidentally observed immediately east of the Mackenzie River Delta (O. E. Barker, personal communication), where they are relatively close and hydrologically connected to forested areas where ample shrubs are available for forage and lodge construction. Regardless, arctic tundra is atypical habitat for beavers. Here, we report the first observation of a beaver on the Beaufort Coastal Plain of Yukon and Alaska, an ecological region that is not hydrologically connected to forested watersheds (Craig and McCart 1975) or previously known to be inhabited by beavers (Baker and Hill 2003).

On 22 July 2015, we observed a beaver dam on the Babbage River (68.95430°N, 138.53500°W), about 26 km south of the coast of the Beaufort Sea, in Ivvavik

National Park, Yukon, Canada, and about 210 km northwest of Inuvik, Northwest Territories. We found the dam while conducting an aerial survey of cliff-dwelling raptors from a helicopter flying approximately 30 m above the ground. The dam was in a small side channel to the west of the main stem of the river at an elevation of about 60 m above sea level. On 22 September 2015, while en route to conduct other work, we returned by helicopter and located and photographed the dam, along with a beaver lodge and winter food cache (Figure 1). The presence of a newly constructed food cache demonstrated that the site was occupied by beavers. The food cache was composed of shrubs, and the dam and lodge were built of mud and woody material from shrubs. As our aerial survey was focussed on cliff habitats, we were unable to survey the extent of the Babbage River or adjacent rivers to search for other signs (e.g., dams, lodges) of beaver occupancy.

Based on accounts of mammal distribution in the region (e.g., Youngman 1975; Slough and Jung 2007; MacDonald and Cook 2009), distribution maps in detailed species accounts of beavers (Jenkins and Busher 1979; Baker and Hill 2003), online museum records (e.g., ARCTOS), and personal communication with Yukon biologists and park wardens (see Acknowledgements) and local Inuvialuit hunters and trappers who have had extensive experience on the Beaufort Coastal Plain in the past > 40 years, beavers are not known from the Beaufort Coastal Plain in Yukon. Indeed, when describing the northern extent of beaver, Baker and Hill (2003) commented that "they were widespread in Alaska, except along the Arctic Slope from Point Hope east to the Canadian border".

Local Inuvialuit hunters had first observed evidence (i.e., dam and house) of a single colony on the Blow River in 2008 and the Running River in 2009 (D.C.G., personal observation), which are about 60–65 km and 50 km east of the Babbage River, respectively. Thus, our observation on the Babbage River in 2015, coupled with earlier observations by Inuvialuit hunters on adjacent rivers in 2008 and 2009, apparently constitute the first evidence of beavers on the Beaufort Coastal Plain.

We do not know how beavers reached the Beaufort Coastal Plain, but they would have had to cross a mountain range or swim in the sea, both of which are likely significant barriers to dispersal. All rivers on the Beaufort Coastal Plain flow north to the Beaufort Sea and are not hydrologically connected to any forested subarctic watershed (Craig and McCart 1975). The continental divide between the watersheds on the Beaufort Coastal Plain and those to the south are separated by rugged mountains. Moreover, for beavers to have moved from the Mackenize River Delta, where they occur, to rivers on the Beaufort Coastal Plain would

FIGURE 1. Photographs of an American Beaver (*Castor canadensis*) winter food cache (A) and dam (B) on the Babbage River, Ivvavik National Park, Yukon, Canada, 22 September 2015. Insets show details of the lodge and winter food cache (A) and the dam (B). Photos: J. Frandsen.

require travelling west along the coast of the Beaufort Sea. Dispersal of beavers from the Mackenzie Delta may be a response to increased beaver density there in recent years as observed by local Inuvialuit hunters (D.C.G., personal observation).

Jarema *et al.* (2009) demonstrated that beaver respond strongly to climate warming, both by expanding its range and by increasing its abundance at the core of its range. In terms of range expansion, beavers are similar to Moose (Tape *et al.* 2016b) and Snowshoe Hare (Tape *et al.* 2016a) in that they would be expected to benefit from shrubification of tundra environments because they can forage extensively on shrubs (Aleksiuk 1970; Busher 1996), and they also use shrubs as building materials for their lodges and dams (Jung and Staniforth 2010). Given that shrubification of the Beaufort Coastal Plain is underway (Myers-Smith *et al.* 2011b; Naito and Cairns 2015; Tape *et al.* 2016a) and has likely increased habitat suitability for beavers, it is plausible that they could colonize waterbodies there, once barriers to colonization (i.e., mountain passes or the ocean) were successfully crossed.

Beaver occupancy of the Beaufort Coastal Plain is of interest from at least three perspectives. First, coupled with other recent reports (Jung and Staniforth 2010; Elsey *et al.* 2015), our observation points to the remarkable adaptability of beaver to colonize atypical habitats. Second, it further demonstrates the changes in mammalian communities that are occurring in the Arctic as a result of climate-induced shrubification of riparian areas, similar to those pointed out by Tape *et al.* (2016 a,b). Finally, because beaver are a keystone species that modifies ecosystems (reviewed by Rosell *et al.* 2005), their colonization of the Beaufort Coastal Plain may induce changes in the local landscape and hydrology, with concomitant impacts on the biodiversity of riverine and riparian ecosystems (e.g., riparian birds [Cooke and Zack 2008] and anadromous fish [Malison *et al.* 2014]). Thus, it would be prudent to monitor for changes in beaver abundance and distribution on the Beaufort Coastal Plain and ecological changes that may be a result of their colonization.

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Evidence for Freshwater Residualism in Coho Salmon, *Oncorhynchus kisutch*, From a Watershed on the North Coast of British Columbia

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The Coho Salmon, *Oncorhynchus kisutch*, is one of seven species of Pacific salmon and trout native to northeastern Pacific Ocean watersheds. The species is typically anadromous; adults reproduce in fresh water where juveniles reside for 1–2 years before seaward migration after which the majority of growth occurs in the ocean before maturation at 2–4 years old when adults return to fresh water to spawn. Here, we report maturation of Coho Salmon in two freshwater lakes on the north coast of British Columbia apparently without their being to sea. A total of 15 mature fish (11 males and four females) were collected in two lakes across two years. The mature fish were all at least 29 cm in total length and ranged in age from three to five years old. The occurrence of Coho Salmon that have matured in fresh water without first going to sea is exceedingly rare in their natural range, especially for females. Such mature Coho Salmon may represent residual and distinct breeding populations from those in adjacent streams. Alternatively, they may result from the ephemeral restriction in the opportunity to migrate seaward owing to low water levels in the spring when Coho Salmon typically migrate to sea after 1–2 years in fresh water. Regardless of their origin, the ability to mature in fresh water without seaward migration may represent important adaptive life history plasticity in response to variable environments.

Key Words: Life-history; Coho Salmon; morphology; genetic identification; sexual maturation; plasticity

Introduction

Pacific salmon and trout (Salmonidae: *Oncorhynchus*) comprise a complex of up to 12 species found from central Taiwan in the western Pacific, north and east through Japan, Russia, Alaska and south to northwestern Mexico (Groot and Margolis 1991; Behnke 1992). Across this range, *Oncorhynchus* species are renowned for their cultural, recreational, commercial, and scientific significance (Hendry and Stearns 2004; Lackey *et al.* 2006). The broad significance of Pacific salmon and trout has made them one of the best studied fishes with special attention on their life history (Groot and Margolis 1991; Quinn 2011).

Many species of salmon and trout are diadromous fishes, i.e., the life history of the group, to varying degrees, encompasses periods of time spent both in freshwater and marine environments (McDowell 1987). Specifically, Pacific salmon and trout are either permanent residents of fresh water (e.g., many species and sub-species of interior trout and kokanee) or anadromous, i.e., fish are born in fresh water, spend variable amounts of time there, migrate to sea to grow and mature, and return to fresh water to spawn (Pacific salmon and anadromous trout). In Pacific salmon and trout, a general evolutionary trend has been towards a lesser amount of time spent in fresh water. For instance, Pink Salmon, *O. gorbuscha*, that migrate to sea soon after emergence from their gravel nests and mature at two years old, occupy a more derived position in the evolutionary tree of *Oncorhynchus* than various species of Pacific basin trout that may be permanent residents of fresh water (Smith and Stearley 1989; Crête-Lafrenière *et al.* 2012). Notwithstanding this broad evolutionary pattern, many species show considerable variability in their expression of anadromy. Perhaps the best natural examples of such variability involve Sockeye Salmon and Kokanee, the anadromous and freshwater-resident forms of *O. nerka* (Ricker 1940) or Steelhead Trout and Rainbow Trout, the anadromous and non-anadromous forms of *O. mykiss* (Behnke 2002; Quinn 2011). In addition, Pink Salmon, Coho Salmon (*O. kisutch*), and Chinook Salmon (*O. tshawytscha*) have all established non-anadromous, but migratory, populations after introduction from their native range in the Pacific basin to the Great Lakes basin and, in the case of some Chinook Salmon, when introduced to New Zealand (McDowell 1990). In the case of Chinook Salmon, occasional reports of precocial maturation of male salmon, i.e., before migration to the sea, have been reported both in experimental and natural Pacific basin populations (Gebhards 1960; Taylor 1989). There have also been a few scattered reports of "residual" Coho Salmon (i.e., fish derived from anadromous parents that do not migrate to sea) in North America (e.g., Foerster and Ricker

1953; Rousenfell 1958) and Asia (Berg 1948; Schmidt 1950). These residuals matured at varying rates and included both males and females, but no self-sustaining freshwater-resident populations in the native range of Coho Salmon are known. The phenomenon, however, appears to be very rare given that in British Columbia alone Coho Salmon are thought to comprise over 1300 populations spawning in about 300 streams (McPhail 2007; Quinn 2011).

In this paper, we report the occurrence of an apparently robust population of freshwater-resident Coho Salmon including both males and females and describe aspects of their life history inferred from analysis of growth patterns in scales and diets. The occurrence of freshwater-resident life history types of Coho Salmon adds further complexity to the design of conservation strategies to best represent biodiversity within this important species (e.g., Allendorf *et al.* 1997; Irvine and Fraser 2008; Taylor *et al.* 2011).

Study Area

Fishes were collected from a total of six lakes in west central British Columbia (Table 1) as part of a comprehensive biological and limnological sampling program to assess possible environmental impacts of the modernizing of a nearby aluminum smelter and associated increased sulphur dioxide emissions (ESSA Technologies Ltd. 2015). All the lakes were small, ranging from 2.3 to 10.3 ha in surface area (Table 1). Lak034 is just north of Terrace, British Columbia, while all other lakes are south of Terrace (Figure 1). All lakes have intermittent outlets that drain ultimately to the Skeena River drainage. End Lake and West Lake have no inlets and most inflow to the lakes likely comes from groundwater sources. End Lake was connected to Little End Lake by a common outlet channel that was 1 m deep and 2 m wide and edged with floating bog over its entire length. Water exchange between the two lakes is probably minimal, but fish can move between the lakes.

Methods

Fish sampling occurred during 7–11 October 2013 and 5–8 October 2015 when surface water temperature was in the range of 9.7–11.5°C and 8.3–11.2°C, respectively. This was close to the optimal temperature for gill netting as estimated by Ward *et al.* (2012). Four nets were used in each lake; two were sinking Resource Inventory Committee (RIC) standard gill nets (RIC 1997), 91.2 m long and 2.4 m deep with six panels of different mesh sizes (25, 89, 51, 76, 38, and 64 mm stretched mesh). The other two were sinking fine mesh gill nets, 12.4 m long and 1.8 m deep with four equal length panels of different mesh sizes (12.5, 19, 16, 25 mm stretched mesh). The fine mesh was uncoloured monofilament, <0.13 mm for the three smallest meshes and 0.18 mm for the largest mesh size. The fine mesh nets were used to target small fishes and the RIC nets were used to target larger fishes. All nets were installed in late afternoon and recovered the following morning in littoral areas 1.5–6 m deep. The characteristics of each net set were recorded on a field form at the time of sampling (lake, unique set code, date, start and end time, geo-coordinates). Each fish captured was identified with lake number, date, unique set code, mesh size where the capture occurred, unique fish code, species code, and scale number. Each fish was also

TABLE 1. Lake names and characteristics sampled in 2013 and 2015. Also shown are the fork lengths, ages, and maturity status of Coho Salmon (*Oncorhynchus kisutch*) captured in five of the lakes. Maturity represents the presence ("Yes") or absence ("No") of mature fish within that age class. The "+" accompanying the age in years indicates that the fish is of an age somewhat older than the year listed. For instance, a 0+ fish is in its first year of life and a 1+ fish is estimated to be in its second year of life.

Lake	Area (ha)	Latitude, °N	Longitude, °W	Age (years)	*n*	Fork length (cm, SD)	Maturity
West	6.77	54.3170	128.6503	1+	2	20.3 (1.4)	No
				2+	15	22.5 (2.2)	No
				3+	10	25.8 (3.0)	No
				4+	10	32.6 (2.1)	Yes
				5+	5	31.4 (2.3)	Yes
Little End	2.30	54.3365	128.6287	0+	2	12.0 (0.1)	No
				1+	11	19.3 (1.6)	No
				2+	8	23.2 (3.0)	No
				3+	1	31.0 (NA)	No
End	10.25	54.3332	128.6285	0+	1	12.1 (NA)	No
				1+	8	17.6 (3.3)	No
				2+	2	20.0 (0.6)	No
				3+	1	26.5 (NA)	No
Lak007	2.62	54.3093	128.5578	0+	1	8.2 (NA)	No
				1+	5	11.7 (0.9)	No
Lak016	2.58	54.3115	128.6411	3+	2	34.8 (1.0)	Yes
				4+	1	35.5 (NA)	Yes
Lak034	8.62	54.5931	128.6071	NA	NA	NA	No

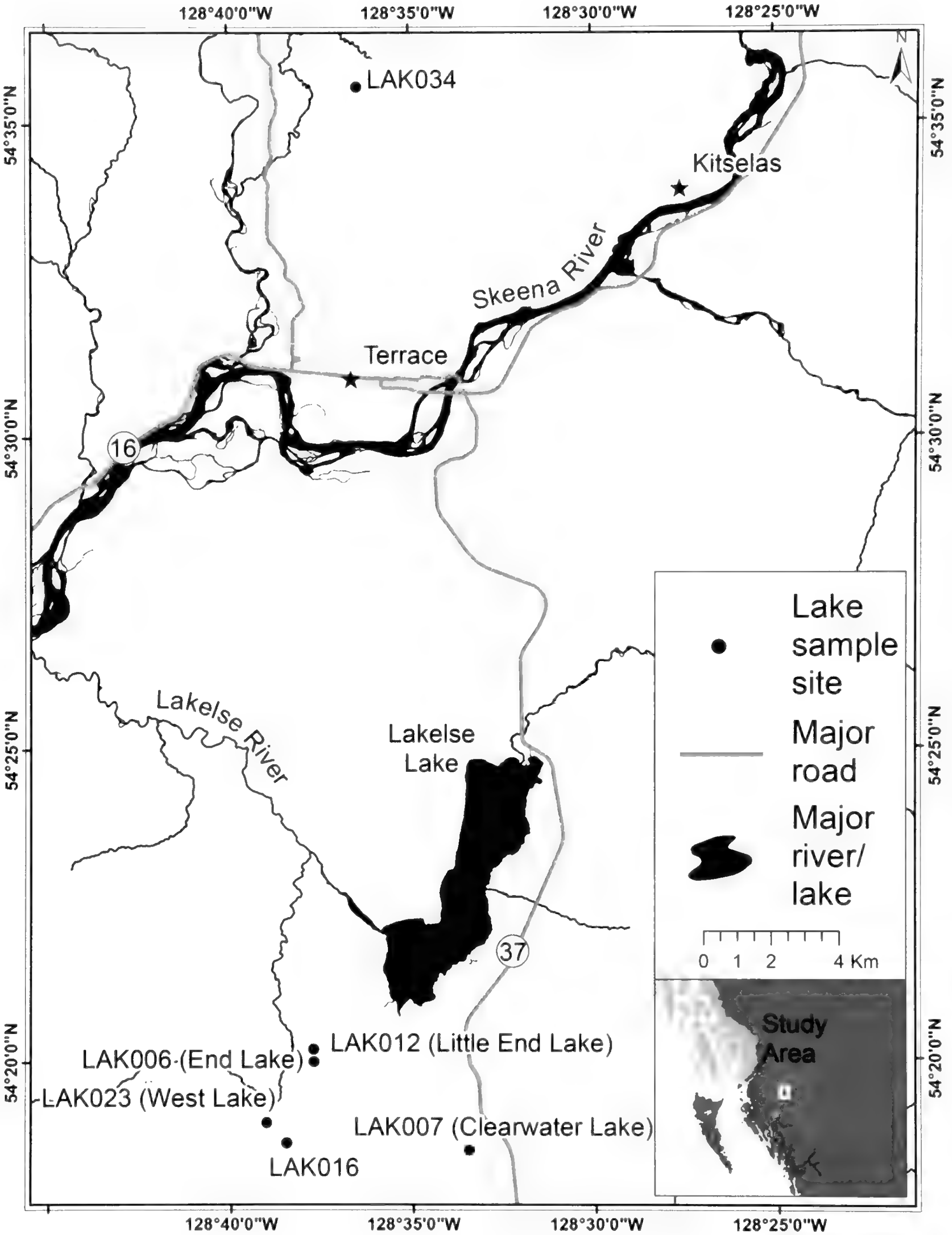

FIGURE 1. Locations of lakes sampled for fishes. The inset shows the study area within British Columbia, Canada.

measured to the nearest 0.1 cm (fork length), and weighed to the nearest g on an Ohaus Scout Pro SP4001 (Dundas, Ontario, Canada) top loading balance. Otoliths were removed from the head of each fish and scales were removed from a location between the posterior end of the dorsal fin and the lateral line. Both were stored in labeled envelopes for later aging using the methodology of Ward and Slaney (1988). For the

Coho Salmon collected, maturity status was assessed after dissection and visual inspection of the abdominal cavity.

Each fish was identified to species in the field using the dichotomous field keys (Trautman 1973; Phillips 1977; McPhail 2007). Fish collected in 2013 and putatively identified in the field as *Oncorhynchus* spp. using the dichotomous keys above ($n = 42$) were also subject to DNA analysis to confirm identification. Here, four or five scales were taken and DNA was extracted using the Qiagen Blood and Tissue DNeasy extraction kits (Hilden, Germany) and kept at 4°C until analysis. The DNA was used in polymerase chain reaction (PCR) assays of variation at two loci that are diagnostic for differences among Coho and Chinook Salmon and Rainbow Trout (Greig *et al.* 2002; Ward *et al.* 2005). The first test is for a difference in the Growth Hormone-2 (GH-2) intron and each species DNA fragment is a different size. Coho Salmon have GH-2 alleles that are less than 120 base pairs (bp) and typically 112–114 bp in size, while Chinook Salmon and Rainbow Trout (*O. mykiss*) are characterized by 120 and 124 base pair alleles, respectively (Greig *et al.* 2002). Differences among species in GH-2 were resolved using electrophoresis (DNA fragment size fractionation) and laser detection after PCR with fluorescently-labelled primers using the methodology outlined by Greig *et al.* (2002). These differences are reported as fragments of different size (in base pairs) after electrophoresis on a Beckman-Coulter CEQ 8000 automated genotyper (Brea, California, USA). The species-specific differences have been verified by assaying *Oncorhynchus* from across the Pacific basin, including British Columbia (Greig *et al.* 2002).

The second test was conducted on only a subset of fish ($n = 9$) and assayed sequence differences in the mitochondrial DNA cytochrome oxidase I (CO1) gene that is the standard animal "barcoding" gene (Ward *et al.* 2005). A portion of the CO1 gene (~650 base pairs in length) was amplified from genomic DNA extracts using PCR and the materials and methodology described by Blanchfield *et al.* (2014). The amplified fragment was sequenced at the Nucleic Acid and Protein Service at the University of British Columbia. To identify the sequences taxonomically, the 'Identification' module of Barcode of Life Database Systems (BOLD-SYSTEMS, http://www.boldsystems.org/, Ratnasingham and Hebert 2007) was used to calculate Kimura 2 parameter (K2P) genetic distances and clustered these by Neighbor-joining (NJ) tree analysis and provide a visual representation sequence identity against BOLD databases (Hubert *et al.* 2008). The sequence was also submitted to the BLASTn search engine of GenBank using the "nucleotide blast" program against the nucleotide collection (nr/nt) database (http://www.ncbi.nlm.nih.gov/BLAST). For all sequences, genetic identity scores (GIS) and E-values are reported. The GIS is the percentage of aligned nucleotide sites that are the same between the unknown sample and the genetic database samples. The E-value describes the number of different sequence alignments with matching scores equal to or greater than that observed and that is expected to occur in a database search by chance; the lower the E-value (to a minimum of 0), the more significant is the observed match.

Results

In 2013, four species were found in the West, End, and Little End lakes. Both Little End Lake and End Lake had Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*), Coho Salmon, and Dolly Varden char (*Salvelinus malma*) whereas West Lake only had fish putatively identified as Coho Salmon and Threespine Stickleback (*Gasterosteus aculeatus*). Smaller salmonids resembled typical Coho Salmon with obvious parr marks and falcate (sickle-shaped) anal fins with black and sometimes white trailing edges (McPhail 2007). Larger individuals (up to 36.0 cm fork length) had anal fins that were longer than the fin ray base indicating that these unknown *Oncorhynchus* were not Coastal Cutthroat Trout or Rainbow Trout. In fact, they superficially resembled Kokanee (non-anadromous Sockeye Salmon, *O. nerka*); they were "silvery" in overall colouration and had clear anal fins, deciduous scales, no visible parr marks, and only very faint spotting on tails (McPhail 2007). Their generally stout and small number (~16–26) of gill rakers, however, strongly suggested that they were not Kokanee/Sockeye Salmon (gill raker counts generally >30). The branchiostegal ray counts (~11–15) also suggested that these fish were not Chinook Salmon (13–19) and, in fact, were morphologically similar to Coho Salmon.

After molecular analyses, all 42 *Oncorhynchus* were positively identified as Coho Salmon, *O. kisutch*, as they all had the GH-2 alleles that were less than 120 base pairs (bp) and most were 112–114 bp in size. Chinook Salmon and Rainbow Trout are characterized by 120 and 124 bp alleles, respectively. The first nine fish (nos. 1–9) were also assayed at the CO1 gene and all sequences were positively identified as Coho Salmon using the GENBANK database (% identity = 92–99%, E-values all zero) as well as the BOLD identification engine with 100% placement accuracy.

The Coho Salmon sampled in 2013 ranged in fork length from 11.9 to 36.2 cm across the three lakes, and were generally larger and older in West Lake than in End Lake and Little End Lake (Table 1). A few age-0 and age-1 Coho Salmon were captured but, in general, smaller and younger salmonids were not present in the samples from any of the lakes. Thirteen of the fish were maturing as indicated by enlarged gonads (Figure 2) and all were from West Lake; there were 12 males and one female. All mature fish from West Lake were at least 29.0 cm in fork length and were aged four and five years old, compared to average fork lengths of 26.7 cm (± 5.0 cm and 3.0+ yr (range 1+ to 5+), respectively in the lake. Coho Salmon from Little End and End lakes were smaller (mean ± SD = 20.6 ± 4.5 cm, $n = 22$, and 18.3 ± 4.2 cm, $n = 12$, respectively) and younger (1.4 yr +, range 0+ to 3+, and 1.3 yr +, range 0+ to 3+) than those of West Lake.

In 2015, six fish species were collected in Lak007, three in Lak016, and two in Lak034. Using the morphological characters that were validated with genetic analysis in 2013, Coastal Cutthroat Trout were found in all three lakes, while Lak007 and Lak016 also had Coho Salmon and Dolly Varden char, but Lak034 had only Coastal Cutthroat Trout and Threespine Stickleback. Chinook Salmon, Rainbow Trout, and Prickly Sculpin (*Cottus asper*) were also found in Lak007. The three Coho Salmon captured from Lak016 in 2015 were also large, all exceeded 34.0 cm fork length (mean = 35.0 ± 8.0 cm, were 3+ to 4+ in age, and all were mature females (Table 1). Coho Salmon captured in Lak007 were smaller (mean = 18.8 ± 2.0 cm, $n = 7$) and younger (all ages were 0+ to 1+, $n = 6$) than those in Lak016 and all were immature (Table 1).

Discussion

The presence of large, mature fish that have not migrated to the ocean is a very uncommon observation for Coho Salmon in their native range, especially for females. We did not have the opportunity to examine the otoliths of the mature fish that we encountered to see if microchemistry signals in these otoliths indicated a lack of migration to the sea (e.g., see Zimmerman 2005) and future studies should endeavour to seek such confirmation. It is, however, highly unlikely that the mature Coho Salmon we found had ever been to sea. First, only End Lake had any perceptible outlet draining the lake during the normal anadromous migration time of Coho Salmon. The area downstream of the lakes is flat relief marsh habitat with no defined stream channels. Salmon, therefore, likely only have opportunistic access to the lakes from the anadromous portions of the Skeena River drainage (i.e., during high water events). Although End Lake has a defined outlet, it quickly transforms into marsh-like habitat within forest cover and no clear stream channel downstream of the outlet. Second, while Coho Salmon may mature as precocial "jack" males after only approximately six months at sea, these fish are typically 2+ in total age (e.g., Foerster and Ricker 1953; Sandercock 1991) whereas the mature fish we found were 3+ to 5+ years old. Finally, "jack" Coho Salmon are exclusively male (Sandercock 1991), yet we observed four mature female Coho Salmon in the two lakes.

Coho Salmon rearing in lakes as age-0+ fish is relatively common, but their size in the autumn of their first year is rarely greater than 100 mm and most emigrate to the ocean as age-1+ smolts at sizes of less than 200 mm (Sandercock 1991; Irvine and Johnston 1992). The age-0+ Coho Salmon in the lakes that we sampled appear to resemble other lake-dwelling Coho Salmon, i.e., that have duller fin colours and less falcate anal fins than their stream-dwelling counterparts (Swain and Holtby 1989). Lake-dwelling Coho Salmon were also found to be less aggressive than stream-dwelling Coho Salmon, which is likely a result of decreased territorial and station-holding behaviour in lake environments (Swain and Holtby 1989).

The mature Coho Salmon captured in 2013 were all from West Lake and only one of these fish was a female. The three mature fish captured from Lake016 in 2015 were all female. The differences between lakes in the apparent sex ratio of mature Coho Salmon is likely a result of low sample sizes and not any kind of sex-bias in freshwater maturation as reported in other salmonids (e.g., Myers *et al.* 1986; Taylor 1989). In the latter species, precocial maturation of largely male fish has been suggested to result from sex-related differences in the tradeoffs between the benefits of seaward migration to exploit higher growth opportunities in marine environments and its relationship to increased fecundity in females versus the presumably much lower relative benefit for sperm production in males (Hendry *et al.* 2004). By contrast, the mature Coho Salmon that we observed apparently had no opportunity to migrate to sea during the period 2013–2015.

Non-anadromous Coho Salmon populations are common in the Great Lakes, where they were first introduced in the 1960s (Sandercock 1991; Rand and Stewart 1998), which indicates that there is no physiological reason that Coho Salmon must migrate to the ocean to mature. Maturation of non-andromous Chinook Salmon males across their native range is common (e.g., Gebhards 1960; Taylor 1989; Foote *et al.* 1991; Johnson *et al.* 2012), but observations of non-anadromous Coho Salmon maturation within their native range are rare (Foerster and Ricker 1953). The observation of mature male and female Coho Salmon in two lakes is interesting because it suggests that coastal populations may include some individuals that do not migrate to sea and may mature and reproduce in fresh water. The degree to which such freshwater-resident forms may be reproductively-isolated from sympatric anadromous forms is a question that has been addressed in several other species of salmonid fishes (e.g., Foote *et al.* 1989; Verspoor and Cole 1989). The existence of sympatric and reproductively-isolated populations within a taxon is increasingly recognized as an important component of conservation planning (Taylor 1999; Wood *et al.* 2008). Alternatively, the mature Coho Salmon may simply have been a response to an ephemeral restriction in the opportunity to migrate seaward owing to low water levels in the spring when Coho Salmon typically migrate to sea after 1–2 years in fresh water (Sandercock 1991). For instance, plasticity in the timing of migration to the sea by smolts as a response to minor freshets has been noted in some populations (Irvine and Ward 1989).

Interestingly, we detected very few age-0+ Coho Salmon in the lakes that we sampled despite using fine

FIGURE 2. Image of (a) mature male and female Coho Salmon (*Oncorhynchus kisutch*), and (b) a single mature female Coho Salmon from West Lake, British Columbia, Canada. In the top image the middle fish is a mature male, the top and the bottom fishes are immature females. The measuring board is 30 cm long. Photos: Eric A. Parkinson

mesh nest that have been shown to capture juvenile Rainbow Trout of similar age/size (Askey *et al.* 2007). Consequently, we should have detected more young Coho Salmon if they were common. The absence of age 0+ Coho Salmon in the lakes raises two possibilities. First, if Coho Salmon do spawn as freshwater residents in these systems (e.g., on submerged beaches), perhaps survival of lake-spawned fish is very low or they enter tributary streams for a year or more before re-entering the lakes. Alternatively, perhaps young Coho Salmon result from spawning in tributary streams and they spend the first year or two of life in these streams before entering the lakes. These lakes, however, are at the edge of a flat gravel plateau and examination of air photos and the 1:20000 provincial watershed atlas suggests that inlet tributary streams are rare and although all lakes have outlet streams and some have second order tributary that enter these outlets, access to these lakes may be limited by drought or beaver dams from time to time. On balance, therefore, it appears most likely that it is intermittent access to lakes from tributary streams that results in episodic occurrence of mature Coho Salmon in the lakes.

Regardless of the unknown aspects of the reproductive juvenile ecology of the lake-dwelling Coho Salmon that we have observed, the reproductive plasticity that it represents may be an important aspect of the life history repertoire of Coho Salmon that promotes their persistence in variable and unpredictable environments (Hutchings 2004; Chevin *et al.* 2010).

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Long-term Changes in the Fish Assemblage in Sandybeach Lake, Northern Ontario, Following the Introduction of Rainbow Smelt (*Osmerus mordax*)

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Rainbow Smelt (*Osmerus mordax*, Mitchill, 1814) has been widely introduced into lakes across North America and are reported to have an adverse effect on native fishes. In this study, we investigated the long-term changes to the pelagic fish assemblage in a northwestern Ontario lake (Sandybeach Lake) after Rainbow Smelt were introduced in the 1980s. We repeated an earlier summer, pelagic gill-netting survey of Sandybeach Lake and a nearby reference lake (Little Vermillion Lake) that does not contain Rainbow Smelt. Fishes throughout the water column were sampled with overnight sets of 5.2-m-deep, multi-mesh horizontal gill-nets. Compared with 1990 pelagic sampling, native fishes were significantly less abundant, less diverse, and largely absent from the deeper parts of Sandybeach Lake in 2012. Cisco (*Coregonus artedi*, Lesueur, 1818), Emerald Shiner (*Notropis atherinoides* Rafinesque, 1818), and Lake Whitefish (*Coregonus clupeaformis*, Mitchill, 1814) were notably absent in 2012. In contrast, Rainbow Smelt remained abundant at all depths sampled. A small number of ciscoes — including Shortjaw Cisco (*Coregonus zenithicus* (Jordan and Evermann, 1909)) — and Lake Whitefish were captured from benthic gill-nets. Based on the lack of ciscoes in pelagic gill-nets, the very old ages (mean 30 years) of the few individuals captured in benthic gill-nets, and a severely skewed sex ratio, it is highly likely that ciscoes will be extirpated from Sandybeach Lake. Although the composition of the pelagic fish assemblage differed between years, Cisco was still abundant in Little Vermillion Lake with the presence of young individuals indicating ongoing recruitment.

Key Words: Lake; invasive species; introduction; impact; Cisco; *Coregonus artedi*; Lake Whitefish; *Coregonus clupeaformis*; Rainbow Smelt; *Osmerus mordax*

Introduction

The Rainbow Smelt (*Osmerus mordax*, Mitchill, 1814) is a small (up to 20 cm long), elongate, and laterally compressed anadromous fish that was historically limited to the Atlantic coastal drainage of eastern North America (Scott and Crossman 1973). As a result of human transfers and natural dispersal, the species' distribution in Canada has expanded to include the Laurentian Great Lakes and inland lakes in Manitoba and Ontario (Franzin *et al.* 1994). Model-based forecasts indicate the potential for Rainbow Smelt to spread into thousands more inland Ontario lakes, almost all of which support fish species known to be adversely affected by Rainbow Smelt (Mercado-Silva *et al.* 2006). Once introduced, Rainbow Smelt often establish large populations and can have a negative effect on native fishes through competition for zooplankton and predation of larval fish (Loftus and Hulsman 1986; Evans and Loftus 1987; Myers *et al.* 2009). Cisco (*Coregonus artedi*, Lesueur, 1818) and Lake Whitefish (*Coregonus clupeaformis*, Mitchill, 1814) are two inland lake species that have shown rapid declines following Rainbow Smelt establishment in small, northern temperate lakes (Evans and Loftus 1987; Hrabik *et al.* 1998).

Following the 1989 confirmation of Rainbow Smelt in Sandybeach Lake (also known as Big Sandy Lake), Wain (1993) undertook a study of their initial impacts on oligotrophic lake fishes. Conducted within several years of colonization, a high degree of diet and habitat overlap between Rainbow Smelt and ciscoes and corresponding negative demographic impacts on Cisco were reported. Shifts in the spatial distribution of Yellow Perch (*Perca flavescens* (Mitchill, 1814)) from pelagic to littoral habitats were also inferred. The study also provided the first record of Shortjaw Cisco (*Coregonus zenithicus* (Jordan and Evermann, 1909)) from Sandybeach Lake.

A member of the formerly diverse Great Lakes cisco flock, the Shortjaw Cisco has been assessed as threatened in Ontario (MNRF 2016) and Canada (COSEWIC 2015). Invasive species are considered a significant threat affecting Canadian freshwater fishes at risk (Dextrase and Mandrak 2006). Rainbow Smelt has been introduced into most of the lakes in Ontario and Manitoba that are known to support Shortjaw Cisco (SCRT

2005). Etnier and Skelton (2003) have suggested that Rainbow Smelt may be responsible for Shortjaw Cisco declines in Lake Saganaga and for a more poorly differentiated present-day cisco fauna in Lake Nipigon than described in the early 1900s. However, direct effects are not well understood, but may include predation, competition, and food web disruption (SCRT 2005). An improved understanding of the risk to Shortjaw Cisco associated with Rainbow Smelt invasions is important for recovery efforts and future status assessments.

In 2012 and 2013, we completed a summer, gill-net survey of Sandybeach Lake in northwestern Ontario and a nearby reference lake without Rainbow Smelt (Little Vermillion Lake) to confirm the presence of Shortjaw Cisco in Sandybeach Lake and characterize the long-term (> 20 years) impact of Rainbow Smelt on ciscoes and other native fishes.

Study Site

Our research was done in two oligotrophic lakes near Dryden, Ontario. Sandybeach Lake (49°49'N, 92°21'W) has a surface area of 3803 ha, a mean depth of 20.3 m, and a maximum depth of 41.0 m; it is 35 km east of Dryden. Little Vermillion Lake (50°00'N, 92°11'W) has a surface area of 2292 ha, a mean depth of 9.6 m, and a maximum depth of 26.0 m; it is 45 km northeast of Dryden. Both lakes are located in headwater areas of the English River drainage and support similar fish assemblages, including Cisco, Emerald Shiner (*Notropis atherinoides* Rafinesque, 1818), Lake Whitefish, Lake Trout (*Salvelinus namaycush* (Walbaum, 1792)), Ninespine Stickleback (*Pungitius pungitius* (L., 1758)), Spottail Shiner (*Notropis hudsonius* (Clinton, 1824)), White Sucker (*Catostomus commersonii* (Lacepède, 1803)), and Yellow Perch. Rainbow Smelt are not present in Little Vermillion Lake. The first report of Rainbow Smelt from lakes in the Dryden area was in 1962 (Campbell *et al.* 1991).

Methods

Fish Sampling

We sampled Sandybeach Lake on 14–19 August 2012 and Little Vermillion Lake on 9–13 August 2013. Sampling occurred four and two weeks later in the calendar year, respectively, than in 1990 (Wain 1993). At the time of sampling, thermoclines were well established in both lakes: in Sandybeach Lake, at a depth of 11–13 m from the water surface; in Little Vermillion Lake, 8–9 m. Above the thermocline (i.e., the epilimnion), water temperatures were 18–21°C in Sandybeach Lake and 17–19°C in Little Vermillion Lake. Below the thermocline (i.e., the hypolimnion), mean water temperature was 7.7°C in Sandybeach Lake and 7.0°C in Little Vermillion Lake.

We used the same net design and randomized depth-stratified sampling approach as Wain (1993). We sampled fishes in the pelagic zone of both lakes with 5.2-m-deep pelagic horizontal gill-nets consisting of 6-m panels of 6.25-, 8-, 10-, 12.5-, and 16-mm mesh (total net length 30 m). In both lakes, nets were suspended in the water column at the following four depth strata: 0.9–6.1 m; 6.1–11.3 m; 11.3–16.5 m; and 16.5–21.7 m. For all depth strata, six nets were set at locations where the lake was 22 m deep. In Sandybeach Lake, six additional nets were set at each of the two upper depth strata where the lake was 12 m deep and at a depth stratum of 32–37.2 m where the lake was 39 m deep. The total number of overnight gill-net sets was 42 in Sandybeach Lake and 24 in Little Vermillion Lake.

At both lakes, overnight net sets were in place longer than in 1990. At Sandybeach Lake, the mean duration of net sets was 13.1 h (9.1 h in 1990). The mean duration of net sets at Little Vermillion Lake was 15.2 h (9.0 h in 1990).

To improve Shortjaw Cisco detection, we also sampled Sandybeach Lake with overnight sets of 1.83-m-deep, benthic gill-nets consisting of 15-m panels of 25-, 38-, and 51-mm mesh (total net length 45 m). Thirty-one net sets were placed between 9 and 24 August 2012 at a range of water depths (24–41 m, mean 36 m).

We froze ciscoes for later processing in the laboratory. To interpret whether Sandybeach Lake ciscoes were Cisco or Shortjaw Cisco, we counted gill rakers and examined jaw morphology (Hubbs *et al.* 2004). For fish from both lakes, we examined gonads to determine whether individual cisco were female or male. Using otoliths, we interpreted the ages of all Sandybeach Lake cisco ($n = 33$) and a sub-sample ($n = 47$) of Little Vermillion Lake cisco. Annuli from transverse sections of otoliths were interpreted using a compound microscope with reflected light (Muir *et al.* 2008).

Data Analysis

Before analysis, we standardized gill-net catch data by duration (hours) of each net set (catch-per-unit effort, CPUE). Catch was standardized by duration of each set because gill-net sets in Sandybeach Lake were 30% longer in 2012 than in 1990 and 40% longer in Little Vermillion Lake in 2013 than in 1990. For each lake, we tested for differences between years in terms of native fish CPUE (number of individuals captured per hour) and native species richness (number of species captured per hour) using the non-parametric Mann-Whitney test (Sokal and Rohlf 1995). In addition, for each lake, we tested whether the structure of the native fish assemblage differed between years using the non-parametric multivariate test, analysis of similarity (ANOSIM; Clarke 1993). ANOSIM was done with sample-by-species matrices of log-transformed abundance data and the Bray-Curtis dissimilarity measure. Catch data from all depth strata were pooled for these statistical tests. To examine whether between-year differences varied with depth sampled, we calculated native fish CPUE and species diversity (Shannon-Weiner index) for each depth stratum. We used 95% confidence intervals to identify significant differences between years. The between-year similarity of fish assemblages within depth strata was characterized using the Bray-Curtis dissimilarity measure (Legendre and Legendre 1998), which is bounded by zero and one, where zero indicates samples share all the same species and one indicates samples do not share any species. For all analysis, we excluded Rainbow Smelt from datasets.

Statistical analysis was completed using PAST version 1.94 (Hammer *et al.* 2001).

Results

Sandybeach Lake

In 2012 using pelagic gill-nets, we captured 3821 fish representing nine species. Mean native species CPUE (81% less) and richness (52% less) were significantly lower in 2012 than 1990 (Mann-Whitney test: CPUE $U = 378$, $P < 0.001$; richness $U = 444$, $P < 0.001$; Figure 1). The structure of the fish assemblage also differed between years (ANOSIM: $R = 0.38$, $P < 0.001$). Five of the nine species found in 1990 were not collected in 2012, including previously abundant Cisco and Emerald Shiner (Table 1). Smallmouth Bass (*Micropterus dolomieu* (Lacepède, 1802)) and Ninespine Stickleback, which were not captured in 1990, were moderately abundant in 2012. Compared with 1990, Rainbow Smelt CPUE declined by 56%; however, this species still represented 94% of fishes collected in 2012 and it was found in all gill-net sets. During both years, the largest numbers of Rainbow Smelt were captured from the 6.1–11.3 m depth stratum (Figure 2).

Across all depth strata, mean CPUE of native fishes was lower in 2012 than 1990 (Table 2). However, only differences at the shallowest and deepest depths were considered significant. Differences were a result of the absence, in 2012, of previously abundant Emerald Shiner from the upper depth stratum and Cisco from the deepest stratum (Figure 2). At all depths, native fish assemblages from 1990 and 2012 were dissimilar (Table 2). Compared with 1990, substantive declines in native species diversity (and number of species detected) were evident at the deepest stratum sampled in 2012. In 1990, the mean number of native species caught in pelagic nets set at 32.0–37.2 m was 1.5 species. No native species were caught in 2012 at this depth.

We captured 33 ciscoes with the larger-mesh, benthic gill-nets. Other fishes captured included Rainbow Smelt ($n = 261$), Lake Whitefish ($n = 47$), Mottled Sculpin (*Cottus bairdii* Girard, 1850; $n = 22$), White Sucker ($n = 9$), Lake Trout ($n = 3$), and Burbot (*Lota lota* (L., 1758); $n = 2$). For 13 of the ciscoes collected, low gill raker counts ($n = 37–39$) and short lower jaws were consistent with descriptions of Shortjaw Cisco (Hubbs *et al.* 2004). Gill raker counts of other ciscoes were higher ($n = 40–43$) and lower jaws were either terminal or extended. In 2012, the mean age of ciscoes was 30.4 years (range 19–35 years) and mean total length was 300.1 mm (range 222–345 mm). The sex ratio of ciscoes was severely skewed (27 female: 2 male). Ciscoes netted in 1990 were smaller, with total lengths between 97 and 251 mm (Wain 1993). Mean total length of Lake Whitefish captured in 2012 was 538 mm (range 477–618 mm).

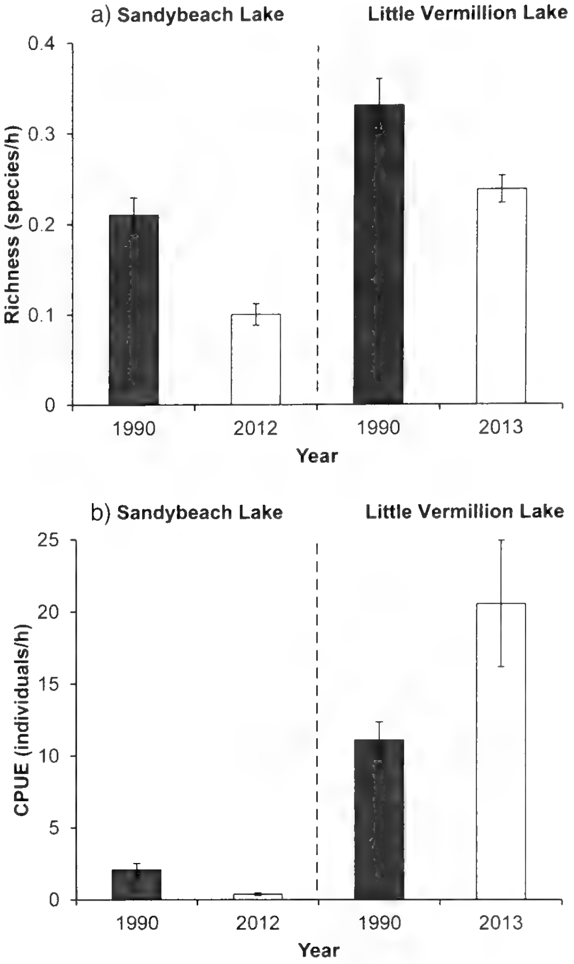

FIGURE 1. Between-year differences in native fish species richness (a) and catch-per-unit effort (CPUE; b) based on catches from summer, pelagic gill-net sets in Sandybeach Lake, where Rainbow Smelt (*Osmerus mordax*) were present, and Little Vermillion Lake, without Rainbow Smelt. Mean values and standard errors (SE) are presented.

Little Vermillion Lake

In 2013, we captured 7026 fish representing eight species. The mean native species richness at Little Vermillion Lake was significantly lower (28% less) in 2013 than 1990 (Mann-Whitney test: $U = 156$, $P < 0.001$; Figure 1). The structure of the Little Vermillion Lake fish assemblage also differed between years (ANOSIM: $R = 0.18$, $P < 0.001$). Two of the nine species detected in 1990 were not collected in 2013, including Bluntnose Minnow (*Pimephales notatus* (Rafinesque, 1820)) and Emerald Shiner (Table 1). Mean CPUE increased by 85.4% from 1990 to 2013, reflecting the greater abundance of Cisco and Yellow Perch. However, the dif-

TABLE 1. Between-year comparison of the composition and mean catch-per-unit effort (CPUE, number/h) of species captured in pelagic gill-nets in Sandybeach Lake where Rainbow Smelt (*Osmerus mordax*) were present and Little Vermillion Lake where they were absent, northern Ontario.*

	Composition, %		CPUE, mean (SE)	
Species	1990	2012	1990	2012
SANDYBEACH LAKE				
Burbot (*Lota lota*)	< 0.1	0.0	< 0.10	0.00
Cisco (*Coregonus artedi*)	2.6	0.0	0.56 (0.09)	0.00
Deepwater Sculpin (*Myoxocephalus thompsonii*)	< 0.1	0.0	< 0.10	0.00
Emerald Shiner (*Notropis atherinoides*)	5.8	0.0	1.06 (0.29)	0.00
Lake Trout (*Salvelinus namaycush*)	< 0.1	0.2	< 0.10	< 0.10
Mottled Sculpin (*Cottus bairdii*)	< 0.1	0.0	< 0.10	0.00
Ninespine Stickleback (*Pungitius pungitius*)	0.0	1.5	0.00	< 0.10
Northern Pike (*Esox lucius*)	< 0.1	0.2	< 0.10	< 0.10
Rainbow Smelt (*Osmerus mordax*)	88.4	94.3	15.50 (3.34)	6.80 (0.93)
Smallmouth Bass (*Micropterus dolomieu*)	0.0	0.5	0.00	< 0.10
Spottail Shiner (*Notropis hudsonius*)	2.9	2.6	0.60 (0.48)	0.17 (0.063)
Troutperch (*Percopsis omiscmaycus*)	< 0.1	0.6	< 0.10	< 0.10
Walleye (*Sander vitreus*)	0.0	< 0.1	0.00	< 0.10
Yellow Perch (*Perca flavescens*)	0.0	< 0.1	0.00	< 0.10
Species	1990	2013	1990	2013
LITTLE VERMILLION LAKE				
Bluntnose Minnow (*Pimephales notatus*)	< 0.1	0.0	< 0.10	0.00
Cisco (*Coregonus artedi*)	62.5	38.7	6.60 (1.13)	7.37 (1.23)
Emerald Shiner (*Notropis atherinoides*)	7.4	0.0	0.89 (0.41)	0.00
Lake Trout (*Salvelinus namaycush*)	< 0.1	0.4	< 0.10	< 0.10
Lake Whitefish (*Coregonus clupeaformis*)	1.2	0.3	0.13 (0.08)	< 0.10
Ninespine Stickleback (*Pungitius pungitius*)	3.7	0.1	0.44 (0.41)	< 0.10
Northern Pike (*Esox lucius*)	< 0.1	< 0.1	< 0.10	< 0.10
Smallmouth Bass (*Micropterus dolomieu*)	0.0	< 0.1	0.00	< 0.10
Spottail Shiner (*Notropis hudsonius*)	1.4	< 0.1	0.17 (0.13)	< 0.10
Yellow Perch (*Perca flavescens*)	23.6	60.4	2.80 (1.01)	12.96 (4.51)

*Total number of fishes captured: Sandybeach Lake, 1990 = 2315, 2012 = 3821; Little Vermillion Lake, 1990 = 6791, 2013 = 7026.
Note: SE = standard error.

ference between years was not significant (Mann-Whitney test: $P = 0.38$). In both years, Cisco ($n = 2716$) and Yellow Perch ($n = 4244$) represented more than 94% of the pelagic gill-net catch (Table 1). Cisco was collected from all gill-net sets, and Yellow Perch was collected from 83% of gill-net sets. Most Yellow Perch were collected from the upper depth stratum, while most Cisco were collected from the intermediate depth strata (Figure 2). Compared with 1990, there was a large increase in the number of gill-nets that captured Lake Trout (16 nets in 2013 versus one net in 1990).

Significantly more fish were collected from the two upper depth strata in 2013 than 1990. Fewer fish were collected from the deepest level sampled (Table 2). At all depths, native fish assemblages from 1990 and 2013 were substantially more similar than observed at Sandybeach Lake (Table 2). Differences in species composition between years were most evident at the top depth stratum (0.9–6.0 m) where, in 2013, formerly abundant Emerald Shiner was absent (Figure 2) and 85% fewer Spottail Shiner were captured. Compared with 1990, large increases in native species diversity were evident at the two deepest strata sampled in 2013: 11.3–16.5 m and 16.5–21.7 m. Although the total number of species detected at these depths was similar, species were more frequently detected by each gill-net in 2013 (mean 3.25 species per net) than 1990 (mean 2.25 species per net). The largest changes in abundance were associated with Lake Whitefish (two individuals in 1990 versus 15 in 2013) and Lake Trout (one in 1990 versus 17 in 2013).

In 2013, the mean age of Little Vermillion Lake Cisco was 1.8 years (range 0–7 years), and mean total length was 112 mm (range 54–173 mm). Cisco sex ratio was 192 female: 99 male. Ciscoes netted in 1990 were similar in size, with total lengths between 49 and 195 mm (Wain 1993).

Discussion

Our study indicates that a long-term decline in the abundance and diversity of native fishes in the pelagic zone of Sandybeach Lake has occurred since Rainbow Smelt were introduced. The most notable change from 1990 to 2012 was the absence of Cisco and Emerald Shiner in 2012. Based on the lack of ciscoes in pelagic gill-nets, the small number of old individuals in benthic

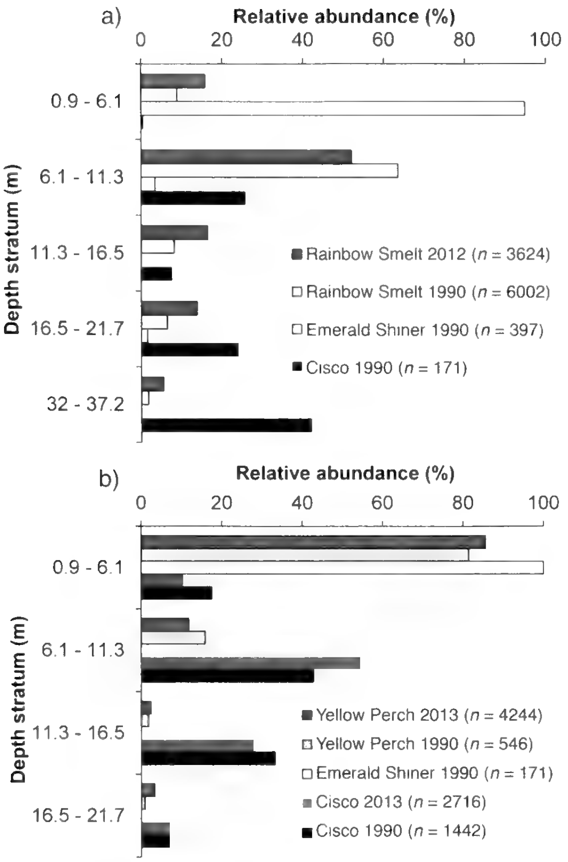

FIGURE 2. Between-year and among-depth-strata variation in the relative abundance (% caught at each stratum) of four fishes captured in pelagic gill-nets set in Sandybeach Lake (a), where Rainbow Smelt (*Osmerus mordax*) were present, and Little Vermillion Lake (b), without Rainbow Smelt, northern Ontario. The number of each species captured is given in parentheses.

gill-nets, and a severely skewed sex ratio, we expect ciscoes will be extirpated from Sandybeach Lake. In contrast, Cisco was still abundant in Little Vermillion Lake, with the presence of young individuals indicating ongoing recruitment. The severe, long-term decline of ciscoes in Sandybeach Lake is consistent with observations from smaller lakes in Wisconsin (Hrabik *et al.* 1998).

Although the Laurentian Great Lakes and other large lakes provide sufficient habitat and resource heterogeneity to reduce competition between Rainbow Smelt and native fishes, small lakes provide less opportunity for niche segregation (Rooney and Paterson 2009; Olynuk 2013). Wain (1993) found that Sandybeach Lake ciscoes have a narrower habitat niche (in the presence of abundant Rainbow Smelt) than Cisco in Little Vermillion Lake. Although widely distributed at all depths of Little Vermillion Lake, Cisco was most prevalent in the deep, hypolimnetic waters of Sandybeach Lake. Shifts in the expected vertical distribution of Cisco in the presence of Rainbow Smelt have been observed in other inland lakes (Rudstam and Magnuson 1985). Also, both ciscoes and Rainbow Smelt in Sandybeach Lake primarily fed on the same zooplankton prey, calanoid copepods (*Calanoida* spp.; Wain 1993). Compared with Little Vermillion Lake, zooplankton abundance in Sandybeach Lake was much lower, especially in the epilimnion and metalimnion where Rainbow Smelt were most abundant (Wain 1993). Therefore, in addition to the substantial potential for larval consumption (Loftus and Hulsman 1986; Myers *et al.* 2009), Rainbow Smelt likely had a negative impact on Sandybeach Lake ciscoes through competition.

Emerald Shiner was previously abundant in the epilimnion of Sandybeach Lake, but absent in 2012. In the

TABLE 2. Variation in the abundance (CPUE), richness, diversity (Shannon-Weiner index), and dissimilarity (Bray-Curtis measure) of native fish species caught in pelagic gill-nets between years and by depth strata in Sandybeach Lake where Rainbow Smelt (*Osmerus mordax*) were present and Little Vermillion Lake where they were absent, northern Ontario.

Lake	Depth, m	Year	CPUE, mean (95% CI)	Richness	Species diversity index (95% CI)	Dissimilarity
Sandybeach	0.9–6.1	1990	4.11 (3.06–5.08)	5	0.51 (0.41–0.56)	0.83
		2012	0.71 (0.51–0.91)	6	0.68 (0.47–0.85)	
	6.1–11.3	1990	1.90 (0.00–2.22)	6	0.83 (0.70–0.94)	0.94
		2012	0.35 (0.23–0.48)	5	1.40 (1.20–1.51)	
	11.3–16.5	1990	0.23 (0.11–0.36)	1	0.00	1.00
		2012	0.17 (0.09–0.25)	4	0.93 (0.76–1.22)	
	16.5–21.7	1990	0.85 (0.31–1.30)	4	0.62 (0.32–0.86)	0.98
		2012	0.46 (0.24–0.68)	3	0.51 (0.28–0.78)	
	32.0–37.2	1990	1.44 (0.79–2.15)	4	0.26 (0.07–0.45)	1.00
		2012	0.00	0	—	
Little Vermillion	0.9–6.1	1990	17.20 (15.70–18.70)	6	1.27 (1.22–1.33)	0.63
		2013	49.20 (39.70–58.70)	8	0.29 (0.27–0.32)	
	6.1–11.3	1990	11.40 (8.80–14.00)	4	0.62 (0.55–0.69)	0.32
		2013	20.60 (17.70–23.50)	6	0.62 (0.59–0.65)	
	11.3–16.5	1990	11.10 (9.00–13.20)	3	0.09 (0.05–0.14)	0.18
		2013	9.80 (8.40–11.10)	4	0.43 (0.37–0.48)	
	16.5–21.7	1990	4.50 (3.80–5.20)	5	0.25 (0.15–0.36)	0.36
		2013	2.50 (2.00–3.00)	5	0.67 (0.52–0.80)	

Note: CI = confidence interval, CPUE = catch-per-unit effort, individuals/h.

Laurentian Great Lakes, Emerald Shiner populations declined after the invasion and proliferation of invasive Alewife (*Alosa pseudoharengus* (Wilson, 1811)) and Rainbow Smelt, likely resulting from competition and predation (Crowder 1980). The pelagic eggs and larvae of Emerald Shiner are vulnerable to predation (Rooney and Paterson 2009), and adults have been found to comprise a substantial component of the diet of Rainbow Smelt in inland lakes (MacCrimmon and Pugsley 1979; Evans and Loftus 1987). However, in this study, a strong link between Rainbow Smelt and the absence of Emerald Shiner cannot be made, as Emerald Shiner was also absent from Little Vermillion Lake in 2013. Factors responsible for the species' absence from Little Vermillion Lake are unknown.

Based on the lack of juvenile whitefish in 1990, Wain (1993) suggested that recruitment failure was occurring in Sandybeach Lake. Rainbow Smelt introductions can negatively affect Lake Whitefish recruitment through predation on larval whitefish (Loftus and Hulsman 1986). In contrast to our experience at Little Vermillion Lake, we did not capture any Lake Whitefish from the pelagic zone of Sandybeach Lake. Lake Whitefish captured with benthic gill-nets in 2012 were larger (total length 477–618 mm) than whitefish captured in 1990 (total length 402–497 mm). These observations indicate that whitefish recruitment remains poor.

Differences in gill-raker count and jaw morphology provide evidence that both Cisco and the threatened Shortjaw Cisco are present in Sandybeach Lake. However, recent genetic-based research indicates that Shortjaw Cisco in inland Canadian lakes should be interpreted as a divergent morph of the ancestral Cisco, rather than a separate species (Turgeon *et al.* 2016). Accordingly, the authors recommend a lake-specific conservation approach that considers local diversity of cisco morphs. For Sandybeach Lake, the long-term consequence of the Rainbow Smelt introduction appears to be imminent extirpation of both morphs. Based on the results of this study and Hrabik *et al.* (1998), any future introduction of Rainbow Smelt into small, deep Ontario lakes with multiple cisco morphs (e.g., Loonhaunt Lake in northwestern Ontario and White Partridge Lake in Algonquin Provincial Park) would likely have similar impacts. Where already established, Rainbow Smelt may disrupt the ecological conditions that maintain reproductive isolation between sympatric cisco morphs. In Norway, the introduction of Vendace (*Coregonus albula* (L., 1758)) — an efficient zooplanktivore resulted in the rapid collapse of a genetically isolated, European Whitefish species-pair (*Coregonus lavaretus* (L., 1758)) into a single population (Bhat *et al.* 2014). Considering the presence of Rainbow Smelt in most lakes with multiple cisco morphs, future research on the risk of "speciation in reverse" would help to assess the long-term prospects for this component of Canadian aquatic biodiversity.

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Note

Observation of an Eastern Wolf (*Canis* sp. cf. *lycaon*) Caching Food in a *Sphagnum* Bog in Algonquin Provincial Park, Ontario

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Moldowan, Patrick D., and Hugo Kitching. 2016. Observation of an Eastern Wolf (*Canis* sp. cf. *lycaon*) caching food in a *Sphagnum* bog in Algonquin Provincial Park, Ontario. Canadian Field-Naturalist 130(4): 351–354.

We report summer caching of a partial carcass of a White-tailed Deer (*Odocoileus virginianus*) fawn by an Eastern Wolf (*Canis* sp. cf. *lycaon*) in a *Sphagnum* bog in Algonquin Provincial Park, Ontario, Canada. The microhabitat conditions in bogs (i.e., low temperature, acidity, and organochemical compounds) likely inhibit food spoilage, making bogs potentially important sites for food caching. Wolves in Algonquin Park experience low summer food availability and high pup mortality from starvation. Caches likely serve as necessary reserve food stores for adults and pups. Recent research has shown that wetland habitats are important den and rendezvous sites for Algonquin Eastern Wolves based on prey availability and, we suggest, perhaps for food storage and accessibility. This caching behaviour was recorded on video. We recommend that future research investigate Eastern Wolf selection of food-caching sites, as a complement to other spatial ecology studies.

Key Words: Bog; *Canis lycaon*; *Canis* sp. cf. *lycaon*; Eastern Wolf; food cache; *Odocoileus virginianus*; prey; *Sphagnum*; White-tailed Deer

Food caching is an important strategy used by animals to overcome periods of food scarcity. Food-caching behaviour has been observed in multiple canid species, including Gray Wolves (*Canis lupus*; Murie 1944; Mech 1970; Adams *et al.* 1995; Mech and Adams 1999; Schultz 2010; Nelson 2011; Nelson and Mech 2011), Coyote (*C. latrans*; Knowlton *et al.* 1999; Way and Cabral 2009), Red Fox (*Vulpes vulpes*; Mech 1967, 1970; Macdonald 1976; Maccarone and Montevecchi 1981), Arctic Fox (*V. lagopus*; Maccarone and Montevecchi 1981, citing personal communication with D. Macdonald), and Gray Fox (*Urocyon cinereoargenteus*; Fox 1971). Canids cache a wide variety of food items in a diversity of microhabitats (Vander Wall 1990) and are known to do so as pups and adults (Phillips *et al.* 1990b, as cited by Packard 2003). Eggs of ground-nesting birds (Maccarone and Montevecchi 1981), partly consumed prey, regurgitated food (Mech and Adams 1999; Mech *et al.* 1999), and/or inanimate objects (Nelson and Mech 2011) may be buried in snow (Murie 1944; Cowan 1947; Mech 1970; Adams *et al.* 1995; Schultz 2010; Nelson 2011; Nelson and Mech 2011), underground in shallow surface pits or dens, rock crevices, mud, leaf litter, or rotting logs (Young 1944; Cowan 1947; Mech 1988; Mech *et al.* 1998; Nelson and Mech 2011), at bed sites (Nelson and Mech 2011), or remain *in situ* with individuals revisiting the site to continue feeding (Mech 1970). However, most records of prey caching among wolves are limited to caching in snow (e.g., Adams *et al.* 1995; Mech *et al.* 1998; Nelson 2011; Nelson and Mech 2011). Reports describing caching in seasons other than winter tend to be vague about the local cache environment (e.g., Cowan 1947; Macdonald 1976; Nelson and Mech 2011), which limits inference about the characteristics of food-cache sites. Here, we document an observation of an Eastern Wolf (*Canis* sp. cf. *lycaon*) caching the partial carcass of a White-tailed Deer (*Odocoileus virginianus*) fawn in a *Sphagnum* bog, a little documented environment for canid food caching with relevance to food preservation and the species' spatial ecology.

Eastern Wolves are largely restricted to Algonquin Provincial Park and the surrounding area of central Ontario and Quebec, forming a genetically distinct population (Rutledge *et al.* 2010, 2012; Benson *et al.* 2012). The species is threatened in Canada (COSEWIC 2015) and Ontario (COSSARO 2016). Recent genetic and morphological evidence has demonstrated Eastern Wolf hybridization with Coyotes (*C. latrans*) and Gray Wolves (*C. lupus*) in Algonquin Park and adjacent regions (Rutledge *et al.* 2010; Benson *et al.* 2012; COSEWIC 2015; COSSARO 2016).

Our observation took place at Broadwing Lake (45.59806°N, 78.52806°W, WGS84) in the Wildlife Research Area of western Algonquin Park. The region is characterized by upland hardwood forest dominated by Sugar Maple (*Acer saccharum* Marshall), Yellow Birch (*Betula alleghaniensis* Britton), and Eastern Hemlock (*Tsuga canadensis* (L.) Carrière) atop the Precambrian shield of the Algonquin dome (Forbes and Theberge 1993). Broadwing Lake is approximately 5.8 ha in open water area with an additional 1.9 ha of riparian, floating

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bog characterized by *Sphagnum* moss, Leatherleaf (*Chamaedaphne calyculata* (L.) Moench), and Large Cranberry (*Vaccinium macrocarpon* Aiton). The lake is surrounded by Black Spruce (*Picea mariana* (Miller) Britton, Stems & Poggenburgh) and hardwood forest.

On 5 June 2013 at about 0945 Eastern Daylight Time, a single Eastern Wolf was observed exiting the forest and crossing the *Sphagnum* bog area on the western side of Broadwing Lake. Carrying an unidentified prey item in its mouth, the wolf proceeded to the centre of the bog before dropping the prey. Over the course of 2–3 minutes the wolf dug at the bog mat with its forefeet, deposited the prey item in the depression, and covered the cavity with forward strokes of its downturned muzzle, packing with the forelimbs and muzzle (Video S1). After the prey was buried, the wolf retreated back to the forest.

When the wolf had left the vicinity, one of us (H.K.) visited the site and uncovered the food cache. The partial carcass of a White-tailed Deer fawn was buried at a depth of approximately 10–15 cm in saturated *Sphagnum* moss. The carcass consisted of the anterior half of the fawn, including the head, neck, two forelimbs, and thoracic cavity with ribcage. The fawn was eviscerated. Fresh blood was present on the carcass indicating that the predation was recent. The fawn carcass was not weighed or measured. No additional monitoring of the cache site was conducted.

To our knowledge, this is one of the first descriptions of the use of a bog site for food caching by a canid and the first record of food caching by an Eastern Wolf. The observed caching behaviour was similar to that described for Gray Wolves (Murie 1944), Arctic Grey Wolves (*C. lupus arctos*; Mech 1988), Coyotes (Phillips *et al.* 1990b, 1991; Knowlton *et al.* 1999), and Red Foxes (Macdonald 1976). This caching sequence, including forelimb digging and substrate scooping and tamping with the snout, is highly stereotyped in canids (Phillips *et al.* 1990a,b, 1991). Although we have characterized the observed canid as a putative Eastern Wolf, we recognize that the animal could have been admixed with a combination of ancestry derived from Eastern Wolf, Coyote, and/or Gray Wolf (which could only be affirmed through genetic analysis; Rutledge *et al.* 2010; Benson *et al.* 2012).

Bogs provide a unique set of environmental traits that may promote food preservation (Hoppe 1977, cited in Elgmork 1982; Verhoeven and Liefveld 1997). First, sub-surface temperatures in bogs remain cool during mid-summer providing natural refrigeration of the cache. For instance, at a depth of 10–15 cm, temperatures among the saturated *Sphagnum* moss measure 4–6°C, approximately 20°C cooler than the ambient daytime air temperature during midsummer in Algonquin Park (P.D.M., unpublished data). In addition, the low pH of *Sphagnum* bogs (typically 4.0–4.8; Gorham and Janseens 1992) may inhibit spoilage of the cache. Organochemical compounds found in *Sphagnum*, such as phenolic acids, exhibit bactericide and fungicide properties, thereby suppressing decomposition (Hoppe 1977, cited in Elgmork 1982; Verhoeven and Liefveld 1997).

Mech (1970) speculated that wolves lose a large portion of cached food to scavengers. Domestic Dogs (*C. lupus familiaris*) are adept at finding wolf food caches (Cowan 1947) and scavengers frequenting wolf kill sites, such as Red Foxes, Black Bears (*Ursus americanus*), Ravens (*Corvus corax*), and insects, are capable of locating and exploiting food caches (Murie 1944; Peterson and Ciucci 2003). Food cached in bogs may be difficult to detect because of the delayed onset of spoilage and, thus, may be less likely to be lost to scavengers. Gray Wolves in Denali National Park, Alaska, have been reported caching a Caribou (*Rangifer tarandus*) calf in the muddy substrate of a flowing stream, and several cached calves have been found submerged along the edge of spruce bogs (Mech *et al.* 1998). According to Egmork (1982), half of the caching sites used by Brown Bear (*Ursus arctos*) in Norway were *Sphagnum* bogs.

The diet of wolves in Algonquin Park consists largely of American Beaver (*Castor canadensis*), Moose (*Alces americanus*), and White-tailed Deer (Kolenosky 1972; Voigt *et al.* 1976; Forbes and Theberge 1996; Benson and Patterson 2013). Young animals are particularly vulnerable to wolf predation (Pimlott 1975; Voigt *et al.* 1976; Mech and Petersen 2003; Mech *et al.* 2015). Based on the relative size of the fawn carcass and date of the caching observation, the prey fawn was likely < 1 month old (in Algonquin Park, White-tailed Deer fawning begins in late May; Voigt 1976). Birth weight of White-tailed Deer fawns ranges from 1.8 to 3.8 kg (Smith 1991; Geist 1998). Food consumption rates have been estimated at 0.10 kg/kg wolf/day (2.9 kg/wolf/day) in Algonquin Park (Kolenosky 1972) and 0.14 kg/kg wolf/day (5.4 kg/wolf/day) based on a review of studies across North America (Peterson and Ciucci 2003). Thus, given the consumption rates of wolves, the deer fawn was likely killed and partly consumed by the single wolf. If multiple wolves had been involved, the small carcass would likely have been consumed in its entirety. This conclusion is supported by findings from Benson and Paterson (2015) that wolves in western Algonquin Park spend most of their time apart from packmates and, presumably, hunting alone during non-winter months. Furthermore, wolves are more likely to cache food in the absence of conspecifics (Townsend 1996).

Caches serve as reserve food sources in the event that a hunt is unsuccessful, and they are especially important in providing a regular food supply for pups (Mech 1988; Mech *et al.* 1998). In western Algonquin Park, infrequent predation of Moose and low deer abundance in summer (Forbes and Theberge 1996; Theberge *et al.* 1996; Benson *et al.* 2015), as well as low American Beaver densities (Benson *et al.* 2013), contribute to food limitation for wolves. This food limitation appears to pose a serious risk for pup survival (Benson *et al.* 2013, 2015). High pup mortality in western Algonquin Park resulting from starvation (Benson *et al.* 2013) illustrates the importance of cached food stores during summer, particularly when adult wolves are hunting and leave pups at dens or bog rendezvous sites (Benson *et al.* 2015). Recent research in Algonquin Park has demonstrated that wolf packs that had lost pups to starvation selected dens and rendezvous sites closer to wetlands than other packs (Benson *et al.* 2015). Thus, home-sites close to bog habitats may confer advantages not only for hunting (Benson *et al.* 2015), but also for food storage and accessibility.

Sphagnum bog habitats, given their spoilage-inhibiting environmental conditions, seem to be suitable caching sites for a diversity of food-caching species in northern regions. However, the importance of bogs as food-caching sites remains to be studied. Cryptic caching behaviour and location of caches (Mech *et al.* 1998) make study difficult. We recommend that future reports of food caching in the wild be accompanied by detailed descriptions of behaviour and/or the local cache environment (e.g., Elgmork 1982) so that inferences can be made about cache structure and conditions, which may, in turn, inform aspects of species' biology (e.g., interspecific interactions, habitat use). Future research may investigate the potential relation between den and rendezvous site selection in Eastern Wolves related to the spatial distribution of cache sites.

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SUPPLEMENTARY MATERIAL:

VIDEO S1. Eastern Wolf (*Canis* sp. cf. *lycaon*) demonstrating food-caching behaviour in a *Sphagnum* bog, Algonquin Provincial Park, Ontario, Canada. Video by Hugo Kitching. https://youtu.be/Pj5hKJTMD5U.

A Tribute to William Burton Preston, 1937–2013

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Wrigley, Robert E., Terry D. Galloway, James R. Duncan, and Francis R. Cook. 2016. A tribute to William Burton Preston, 1937–2013. Canadian Field-Naturalist 130(4): 355–358.

William Burton Preston (Figure 1), 76, passed away at St. Boniface Hospital in Winnipeg, Manitoba, 11 October 2013 after an extended struggle with kidney failure which necessitated regular dialysis. He was born in Penticton, British Columbia, on 6 March 1937, to Earl and Kathleen Preston.

Bill was an outstanding example of a dedicated naturalist who effectively combined academic credentials with his field experience and communication skills to reach out and share his own fascination with nature with the public. As pointed out in in an earlier tribute (2014, which has contributed large portions of the text here, see Acknowledgments), Bill grew up happily exploring the desert, grassland, and forests of the Okanagan Valley, and there developed his love of nature and interest in rattlesnakes and the insect fauna.

He obtained a B.Sc. and M.Sc. at the University of British Columbia in wildlife management. His M.Sc. thesis was a study of the facial pits of the Northern Pacific Rattlesnake (*Crotalus viridis oreganus*). After graduating, Bill married Willetta, and the couple moved south to Norman, Oklahoma for Bill to do a Ph.D. in Zoology comparing the ecology of two species of water snakes. They also studied the rich insect fauna of the region and in addition, explored many parts of the southern United States, Mexico, and St. Lucia.

Returning to Canada in 1969, Bill accepted the position of Curator of Reptiles, Amphibians and Fishes at the newly opened Manitoba Museum of Man and Nature in Winnipeg, where he remained for 28 years. His outstanding *Amphibians and Reptiles of Manitoba* was published in 1982 by the Museum. Bill loved field work and was elated to discover the first Manitoba records of the Great Plains Toad (*Bufo cognatus*) and a species of ant. His interest in amphibians and reptiles never waned but was eventually secondary to entomology for which he amassed an extensive insect collection from the time he was a boy. He co-authored *The Butterflies of Manitoba* and contributed to the *Encyclopedia of Manitoba*, as well as numerous journal articles.

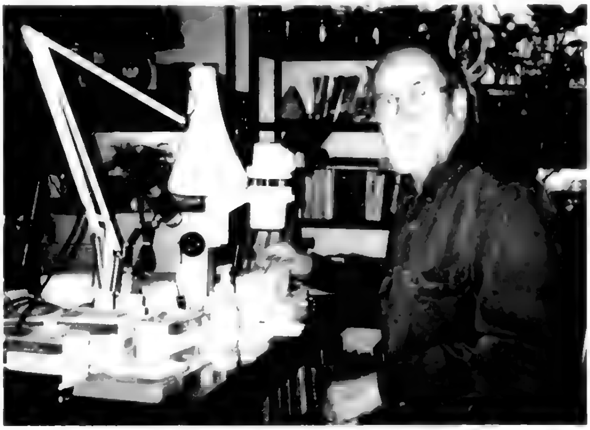

FIGURE 1. Bill in the Preston Winnipeg home – the insects tended to take over the house – taken in the late 1990s soon after he had retired and was coming to terms with his medical issues. Photo: Willetta Preston.

F.R.C. first met Bill in 1963 at the Annual Meeting of American Ichthyologists and Herpetologists in Vancouver, on Bill and Willetta's return from their honeymoon in San Francisco. Bill had just finished the research for his M.Sc. and, after the meetings, offered to be a guide to see habitats and species of amphibians and reptiles in the Okanagan region. A friendship was forged that lasted a lifetime. In 1971, they both attended the American Society of Ichthyologists and Herpetologists meetings at Los Angeles and on a memorable field trip to the desert areas to the east, Bill demonstrated the proper handling of poisonous snakes in collecting a sidewinder at night on the road. Years later when F.R.C.'s wife, Joyce, discovered her calling in entomology, Bill never failed to mention when he had seen one of her papers whenever they met. He gained examples of spiders collected on a visit to F.R.C.'s farm on a stopover in Ottawa years ago, as Bill never missed an opportunity to add to his collections.

Willetta has provided F.R.C. with some reflections (personal communications, 12 and 13 November 2016):

> "I do remember the Los Angeles meeting field trip… catching the snake and big water beetles on our night drive. The snake returned to Canada in his suitcase tied in a snake bag inside one of his cigar boxes he used for insects. Before the days of x-raying everything. We went to Ichs and Herps meeting in Costa Rica in the early 70's and while he was interested in all the herps he also collected insects which were much more common than the herps. Ken Stewart and Pat Gregory were there too and we ate at McD's not for the food as much as for the insects that came to the lights. He would walk along the streets picking up things or taking them off store windows. He took his net into an open air bar and picked a large insect off the wall above the bar with the bartenders ok after much miming and net waving. Earlier that day the bus had dropped us out of town a bit and we walked back collecting along the way. The recent earthquake there had taken out the power in most of the town and volcanic bombs had destroyed the church windows. We found a store that sold flashlights and they soon had a run on them when the rest of the group saw them. There was much interest from the locals in our activities and heard "gringos" and "ranas" mentioned . Likely as well our Spanish was spotty. He always had an insect net with him and I was asked by one of the women in the group why an entomologist was on the I and H trip. His version of multitasking. … We went to Australia to spider meetings stopping at Fiji on our way back, to Trinidad and Tobago for spider meetings, to Barbados, Haiti and Hawaii and he went to the Dominican Republic and Colorado on butterfly trips. We both went to Ecuador on a butterfly trip where we went into a remote field camp by dugout canoes. … We enjoyed our travels but the Okanagan was always home and we owned the family farm for 20 years after his dad died intending to retire there. It was a very difficult decision to sell it but didn't make sense to move there for family and medical reasons and the fact the bulk of his professional life had been here [Winnipeg]. When we went there to ready the house for sale we went to his master's research collecting area on the mountain and he climbed up to the top using all his energy. Again I worried and wondered but he yelled down all pleased with himself from the top. Guess you have to live not just exist. We went near there again but no more talk of climbing. He was very upset with the encroachment of the vineyards in the valley he roamed as a boy and in some ways made the decision to sell easier for him. He refused to drink Okanagan wine and many a server got a lecture on why. The family still mentions it when we order wine when we are out. My uncle owned a pool at his home in Westbank near Kelowna and Bill was always willing to skim the pool not just to help but he fished some great specimens out if it. He would wander on the hill above the pool in uncle's orchard with his camera and bug net usually followed by whatever kids were there at the time.
>
> We did do a tour of Spain and Morocco in 2003 (Africa was one of the items on his bucket list) which we thoroughly enjoyed but by then his energy levels were limited so he wasn't able to do much collecting. However he did take lots of film and edited a nice movie from it … In Australia we went to the butterfly garden in Kuranda where they toured him through the breeding areas – a beautiful place. He loved Australia and was fascinated with all the new species of everything. We also went to the open air market where he bought a didgeridoo. The seller gave him a lesson and he got pretty good on it. On our way to Fiji we had a day's layover in Brisbane so we stored our luggage in airport lockers and went into town. It was too big to fit the lockers so went to town with us. We dropped off his insects at the Queensland museum where they would arrange to send them to him and revisited a neat bookstore he had found when we were there earlier at the meetings. He walked up to a salesman and asked what they had in sheet music for the didgeridoo. He looked a little taken aback and then said they didn't have much call for it. They both had a good laugh. One of a kind for sure. I made the best decision of my life when we were married and have enjoyed a very rich life with him."

In Winnipeg, Bill walked frequently down to the Red River behind the Manitoba Museum during his lunch break and faithfully recorded notes on the appearance and habits of butterflies. At the Museum in the 1970s (Figure 2), Bill contributed to a number of permanent-gallery exhibits on insects, amphibians, reptiles and fishes, and participated in a nationally travelling exhibit on "Collecting Manitoba's Natural Heritage". His giant model of a female mosquito is a masterpiece, exact is every detail.

He never lost his "little boy" excitement about learning new things regarding the natural world, and he just had to discuss these observations with his Museum colleagues. In fact, it was impossible to walk past the open door of his office without being invited in for a lengthy conversation. Bill was also notorious for his quirky sense of humour, and often he could barely complete a joke without losing his voice as he broke out in laughter. He loved showing youngsters the many critters in his laboratory, ranging from a Hognose Snake (*Heterodon nasicus*) to a giant, one-eyed Snapping Turtle (*Chelydra serpentina*) he had rescued from the Assiniboine River. Bill had the well-earned respect of his many friends and colleagues due to his broad knowledge, developed over his career at the Museum. Bill was always generous with his time and expertise, and often helped friends and students with troublesome identifications of the species he knew best.

Bill was an active participant in the Entomological Society of Manitoba Youth Encouragement and Public Education Committee, when it was revamped under the president-ship of Ron Sinha in 1973. The group organized numerous field trips and workshops in the ensuing years, to La Barrière Park, Sandilands Provincial Forest, and to the newly developing outdoor education facility at Fort Whyte.

For a number of consecutive years, the Youth Encouragement Committee conducted a week-long display on insects at Polo Park Shopping Mall, and later at the

FIGURE 2. Bill in his lab at the museum in 1972. Image ©The Manitoba Museum, Winnipeg, Manitoba. Photo: Robert Taylor.

newly opened St. Vital Mall. There were all manners of insects, alive and dead on offer to the public. Bill was the only person who always attended all day every day of the exhibit. He loved to talk about insects, and there was hardly a better opportunity for non-stop conversation than at the entomology display. He could never understand the concern of the Polo Park manager when someone had placed a drinking straw to breach the petroleum jelly barrier that was meant to contain the Thatching Ant (*Formica obscuripes*) colony. Many of the ants had gone walkabout in the night and were found by disgruntled shop keepers the next morning. Bill just couldn't see the problem: to him they were harmless ants.

Bill belonged to a number of associations including the Entomological Society of Canada, The Entomological Society of Manitoba, Manitoba Naturalists, Winnipeg Amateur Movie Makers, and the Rock and Mineral Society. T.D.G. commented that he didn't think he could emphasize enough Bill's contributions to the Youth Encouragement and Public Education Committee of the Entomological Society of Manitoba (ESM), notably in the early to the mid-1970s. The President of the ESM essentially turned over responsibility for this committee's activities to the graduate students in the Department of Entomology. T.D.G. was the first student to chair the committee in 1973–1974. Bill was the one 'adult' member of the ESM who was very enthusiastic about activities of the committee, and he served in official and unofficial capacities on it for all the years T.D.G. was a member.

ESM hosted many field trips to La Barrière Park, Sandilands Provincial Forest, and Fort Whyte Centre, to name a few, and Bill shared in knowledge and expertise with one and all. At one point, the Youth Encouragement Committee had a mailing list of more than 100 kids who were contacted for each event. The participants even chose a name for their group, "The ESM Young Entomologists", and produced a logo and pin. Bill was part and parcel of all of this.

His photography expertise was also something highly valued by his entomological colleagues. Bill's photos have been widely published, and he gave many talks to the public and to arthropod enthusiasts. He was always generous with his knowledge about photographic techniques, and he encouraged many aspiring macrophotographers. He also organized the photo salon for the Entomological Society of Canada. This was a tremendous amount of work, but he loved receiving and going through all the entries.

He was a member of several government committees such as the Manitoba Endangered Species Advisory Committee from 24 June 1988 to the time of his death, and attended meetings regarding the snake pits at Narcisse. During these years, he was instrumental in providing advice to the Minister on the listing of species as Endangered or Threatened under the *Manitoba Endangered Species Act*. Bill also helped us with the assessment of the NatureServe conservation S-Ranks for various invertebrate taxa (mussels, butterflies, tiger beetles, etc.) in the formative years of the Manitoba Conservation Data Centre, and more recently for the federal-provincial-territorial General Status Ranks of Wild Species program. J.R.D. stressed that he generously assisted the province of Manitoba in better understanding the conservation status of a large slice of the diversity of wild animals and plants on both informal and formal (legislative) programs. He also made considerable contributions to the Manitoba volunteer dragonfly surveys which documented 11 species new to Manitoba. No matter the occasion, Bill always worked very hard while also infusing the efforts with a sense of humour despite the many personal health challenges he faced. His contagious enthusiasm and passion for wild species and nature will be greatly missed.

Bill twice received the West Kootenay Rod and Gun Club Bursary Award while attending the University of British Columbia; later he received the Criddle Award for excellence in amateur entomology, presented by the Entomological Society of Canada in 1994 and Blue Racer Award presented by the Canadian Amphibian and Reptile Conservation Network for long-standing contributions to the research and conservation of amphibians and reptiles in Canada in 2002. Upon his death, Bill was added to the list of Memorable Manitobans by the Manitoba Historical Society for 2013.

In later years, Bill's health deteriorated to the point where he could no longer participate in field activities but, with the loving support of Willetta, he maintained a positive attitude about life and his passion for nature to the end of his days.

At the time of his death, Bill was working on projects about tiger beetles, ants, the Okanagan Valley (Figure 3), and an autobiography for his family. He had a pretty well completed manuscript on Manitoba tiger beetles and was working on one on ants and another on the Okanagan of his youth compared to the changes now. After his death, his entomology collection of 24,364

FIGURE 3. Bill collecting in the Okanagan in 1974, his version of Eden was roaming those hills. Photo: Willetta Preston.

specimens was donated by his estate to the B. Wallis/R. E. Roughley Museum of Entomology at the University of Manitoba. T.D.G. and technician Dave Holder filled the back of a half-ton truck with it from the Preston home to transport it to the university one cold, wintry Winnipeg afternoon.

Bill is survived by his wife of 50 years, Willetta; his son David (Jill), their children Jessica and Declan of Calgary; his daughter Kathi (Rob) their children Jordan (Jessica), Steven (Crystal), and Trevor; and daughter Carmen (Dave), their children Shayla and Evan as well as four great-grandchildren Stormii, Konnor, Steven, and Kailee; his brother Tom, sisters Marilyn (Fred) and Joanne (Mark); sisters-in-law Gwen (Mike) and Gretta; as well as a number of nieces, nephews, cousins.

Acknowledgements

Primary information at Bill's passing appeared in the Winnipeg Free Press 19 October 2013. Bill's wife, Willetta, and daughter Carmen, provided this and other records, including photographs, from Bill's files. And we are indebted to both for personal recollections which included Carmen's on what it was like growing up in a herpetologist/entomologists home. Thanks are due for comments from Randy Mooi and to Nancy Anderson for help with granting permission for one of the photographs, both at The Manitoba Museum. Much of the text here is drawn from the earlier tribute by R. Wrigley and T. Galloway; William Burton Preston (1937–2013 2014) — One of a Kind. The Entomological Society of Manitoba Newsletter. 40(2): 4–5 (Fall/Winter 2013–2014) and Bulletin of the Entomological Society of Canada 46(1): 38–39 (2014) with supplementary additions by the authors.

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A Tribute to Dr. Edward Lloyd Bousfield, 1926–2016

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Conlan, Kathleen E., Marjorie A. Bousfield, Ed A. Hendrycks, Eric L. Mills, Francis R. Cook, and Charles G. Gruchy. 2016. A tribute to Dr. Edward Lloyd Bousfield, 1926–2016. Canadian Field-Naturalist 130(4): 359–372.

Canadian scientist Edward Lloyd Bousfield died in Mississauga, Ontario on 7 September 2016 at age 90 (Figure 1). Ed was a world authority on the systematics of amphipod crustaceans. He discovered and described over 300 new species and has 18 species and two genera named in his honour with another to come (Table 1).

Ed joined the National Museum of Canada (with the natural sciences now in the Canadian Museum of Nature, CMN) in 1950 after obtaining his B.A. and M.A. degrees at the University of Toronto (1948 and 1949), and deciding on a career as a biologist, rather than a musician. He then earned a Ph.D. at Harvard University (1954) and, on the recommendation of John Dymond (1887–1964), Head of Zoology at the University of Toronto, applied to and was hired by CMN as Invertebrate Zoologist (1950–1963). Expecting to work for federal Fisheries or as a university professor, Ed considered that this move had a monumental impact on his career path. Ed said later, "It was a good thing I took the job. Thank heavens I did. I can't imagine a job that's given me more pleasure than this job. The director says, here's the money, here's the car, here's the staff, go do your job and turn in the report at the end of the year. I think that philosophy yields far better results than standing over somebody every five minutes".

In 1964, Ed was promoted to Chief Zoologist and in 1974 he became Senior Scientist. During his 36 years at CMN, Ed influenced the museum's outlook in many ways. Canadian Museum of Nature herpetologist Francis Cook says, "I am indebted to him for supporting my two-year educational leave for my Ph.D. though his patience with me wore out before I finally submitted my thesis and obtained the degree. But when I submitted the manuscript for museum publication, Ed served as in-house reviewer and recommended the museum publish it, backing up the positive comments of an outside reviewer".

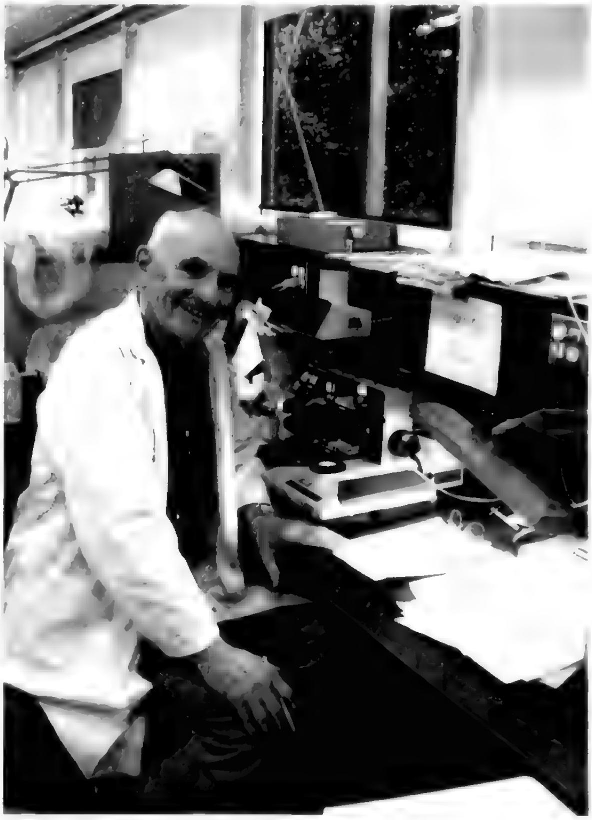

FIGURE 1. Ed reviewing illustrations in the Canadian Museum of Nature's new laboratories in the Natural Heritage Campus, Gatineau, Quebec. Photo: Ed Hendrycks (2010).

Ed's first years at CMN were spent in the Victoria Memorial Museum Building (VMMB) in downtown Ottawa, which also housed the National Art Gallery and the Geological Survey of Canada. After these organizations moved to new quarters in 1960, the VMMB became the headquarters for Nature and Man. Eventually, the nature collections became too large for the VMMB.

TABLE 1. Species and genera named in honour of E. L. Bousfield, grouped by Order and Family. In brackets are the common name or description used by Ed. Classification follows the World Register of Marine Species (http://www.marinespecies.org/index.php).

I. Decapoda		
	Alpheidae:	
		Synalpheus bousfieldi Chace, 1972 (Yucatan snapping shrimp)
II. Annelida		
	Spionidae:	
		Scolelepis (Parascolelepis) bousfieldi Pettibone, 1963
III. Amphipoda		
	Stegocephalidae:	
		Bouscephalus Berge and Vader, 2001
		Bouscephalus mamillidacta (Moore, 1992)
	Bateidae:	
		Batea bousfieldi (Ortiz, 1991) (West Floridian single-cusped bateid)
	Pontogeneiidae:	
		Paramoera bousfieldi Staude, 1995 (North Pacific shore shrimp)
	Haustoriidae:	
		Acanthohaustorius bousfieldi Frame, 1980 (Western Atlantic sand shrimp)
		Protohaustorius bousfieldi Robertson and Shelton, 1978 (Gulf States sand shrimp)
	Stenothoidae:	
		Metopella bousfieldi Tzvetkova and Golikov, 1990 (Laptev Sea)
	Liljeborgiidae:	
		Liljeborgia bousfieldi McKinney, 1979 (Gulf worm-tube commensal)
	Colomastigidae:	
		Colomastix bousfieldi LeCroy, 1995 (West Floridian sponge commensal)
	Crangonyctidae:	
		Crangonyx bousfieldi Zhang and Holsinger, 2003
	Talitridae:	
		Bousfieldia Chou and Lee, 1996 (Type: Taiwanese landhopper)
		Bousfieldia omoto Morino, 2014
		Bousfieldia phoenixae Chou and Lee, 1996
		Microrchestia bousfieldi Lowry and Peart, 2010
		Platorchestia bousfieldi Hou and Li, 2003 (Chinese coastal landhopper)
	Hadziidae:	
		Metaniphargus (Caribdzia) bousfieldi Stock, 1977 (Puerto Rican cave shrimp)
	Maeridae:	
		Quadrivisio bousfieldi Karaman and Barnard, 1979 (Indo-Pacific 4-eyed scud)
		Maera bousfieldi Krapp-Schickel and Jarrett, 2000
	Melitidae:	
		Melita bousfieldi Garcia-Madrigal, 2010
	Ischyroceridae:	
		Microjassa bousfieldi Conlan, 1995 (Northeastern Pacific thumb shrimp)
		Pseudericthonius bousfieldi Souza-Filho and Serejo, 2014

These, along with the science, exhibits, and administrative staff were gradually moved to 13 buildings around Ottawa, which resulted in an unhappily fragmented institution. While the invertebrate, bird, and mammal collections were in South Ottawa at Holly Lane, the library was down the road, botany, herpetology, ichthyology, and mineralogy were in West Ottawa, and paleobiology was in East Ottawa. Finally, in 1996, CMN was able to consolidate its labs and collections at its present-day Natural Heritage Campus in Gatineau, Quebec. Ed enjoyed this new setup even though he was by then retired, as it gave new opportunities to meet museum staff, reunite with colleagues, and enjoy some dynamic conversations at coffee breaks. Despite this massive move of over 10 million specimens, all of Ed's collections, photographs, and drawings were carefully preserved there and his collection information is now being digitized and will be online for public access.

Although Ed's doctoral work was on barnacles, he shifted to amphipods in the early 1950s on the advice of his University of Toronto professor A.G. Huntsman (1883–1973), who felt that this group would open many research opportunities. This was sage advice as Ed subsequently spent most of his career studying amphipods, publishing papers from 1951 to 2012, although he also forayed into molluscs, publishing the useful *Canadian Atlantic Seashells* in 1960 followed by the French version in 1964 (Bousfield 1960, 1964). After his official retirement in November 1986, Ed continued his studies as Research Associate and Curator Emeritus at CMN, the Royal Ontario Museum in Toronto, and the Royal British Columbia Museum in Victoria.

Ed was pivotal to the twentieth-century growth of the CMN invertebrate collections through his widespread fieldwork and follow-up lab studies (Figure 2). Jean-Marc Gagnon, current Curator of Invertebrates at CMN, estimates that CMN has about 48 000 lots (single or group of specimens collected at one location) thanks to Ed's work. Not all of these are amphipods; his collections cover all sorts of invertebrates as well as four lots of birds, 57 herptiles, and more than 1000 fish. The large fish collection attributed to Ed came as a result of an extensive field trip in 1963 along the Alaskan coast with CMN ichthyologist Don McAllister (1934–2001; Coad 2010; Cook *et al.* 2010). This was a mutually useful collaboration as while Ed helped with the fish catch, the fish generated collections of amphipod prey from their gut contents and amphipod parasites from their skin and gills.

Immediately upon being hired by CMN, Ed was given a museum car and budget and told to get out into the field. For the next 30 years he embraced this work plan whole-heartedly, involving students, colleagues, and family in his program. In the two summers following their marriage in June 1953, Ed and his wife, Barbara (née Schwartz, d. 1983), a former technician for museum botanist Erling Porsild (1901–1977), worked together in the field (Figure 3). Beginning in 1958, Ed

FIGURE 2. Ed collecting near Shippagan, N.B. (1947). Photographer unknown.

FIGURE 3. Barbara Bousfield as Ed's field assistant. Photo: Ed Bousfield (1953 or 1954)

and Barbara's children (Marjorie, Kathy, Mary, and later, Ken) joined in the North American collecting expeditions, with the family living in a tiny rented Shasta trailer that Ed hauled on and off ferries, through steep mountain passes, and across seemingly endless prairies (Figure 4). Ed shared his love of this work with his children by having them take turns acting as his field assistants, once they reached school age or so. Getting out of bed in the dark coolness of an early morning to catch the low tide was not always something they wished to do, but once up, they enjoyed interesting adventures. "How many little kids could pronounce *Dogielinotus*, and know what it looked like, and the kind of beach on which it was to be found (along with the red "worms")?" laughed Ed. The remembered joy of this field work inspired daughter Marjorie to become a field biologist herself. In the last half hour of his life, Ed referred to these as "fun times".

Ed mentored over 40 students at 14 universities in Canada, 11 in the U. S. and internationally in Russia, Kuwait, France, Australia, and New Zealand. In a letter to CMN colleague Charles Gruchy, Ed said, "Hard to believe a government scientist could have broad university impact, but I lucked in with amphipods as a virtually unstudied but readily collectible aquatic invertebrate group, thanks mainly to A.G. Huntsman at U. of T.". Ed also maintained a key role in the Canadian Society of Zoologists, of which he was a 54-year member and President in 1979–1980. Other society involvements included the Crustacean Society, the Estuarine Research Federation, The Ottawa Field-Naturalists' Club, and The Brodie Club of Toronto. On his final presentation at The Brodie Club in April 2014, Ed made a detailed freehand drawing of an amphipod from memory.

Ed enjoyed reaching out to the general public and being involved in exhibits at the VMMB. Exhibit designer Asoka Weerasinghe wrote in condolence, "Dr. Bousfield, I was saddened to hear that you have left us. Thanks for your wisdom that you shared with me when putting together the Animal Life 3 and 4 Halls in the early 1970s at the Victoria Memorial Museum in Ottawa. It was a joy to have had the opportunity to work with you and come to know you as a special human being".

Ed's enthusiasm for natural history spread beyond museum doors to the children's Macoun Field Club and the parent The Ottawa Field-Naturalists' Club, where he held various executive positions. He would often lead dip-netting excursions to Ottawa-area rivers and lakes

FIGURE 4. Ed and his younger children taking a break from early morning collecting while the elder two children may be continuing the search for amphipods. Photo: Barbara Bousfield (about 1964).

(Figure 5). A former Macouner, Alice Smeathers, wrote that "we children were always so impressed by the fact that scientists would give up their Saturday mornings to spend with us. The club led me to a life-long interest in natural science. I used my interest in teaching Elementary School and as a Girl Guide leader and now with my grandchildren. Bless you Dr. B.". Professor Emeritus Eric Mills of Dalhousie University met Ed through the Macoun Field Club, and became his field assistant. He writes that "the two summers, 1955 and 1957, that I spent with Ed in B.C. (and some points south) would make an essay in themselves, showing how the young Bousfield operated, and the kind of effect that could have on a 19-year-old just graduated from high school". This shows "…in just one example how important The Club was in encouraging young naturalists into scientific careers". Macoun-graduate Susan Laurie-Bourque became Ed's artist for many of his publications, later illustrating for numerous other scientists at CMN and abroad.

Ed's interests were also artistic. As a young teen, Ed had written and illustrated fictional nature stories for a young-naturalists' publication in Toronto. His artistic ability continued through his working life in collaboration with Susan and earlier artists Floy Zitten, Ruth von Arx, and Charles Douglas (1923–2004; Bousfield and Cook 2012). Ed was adept at arranging music and playing musical instruments. He played trumpet into his seventies and guitar until 2014. He played in swing bands as a youth and the Salvation Army band as a near-senior and sang Barbershop in between. In his later years, he was a member of the "Aged in Harmony" senior men's musical group of Ottawa, the "Songsters" group at Somerset House in Victoria, B.C., and co-founder of the "Victoria Melody Makers" swing orchestra. Ed was also a great sports fan, particularly of ping-pong where his noon games at CMN with ornithologist Earl Godfrey (1910–2002) were legendary. Outside the museum, he was a five-pin bowler, curler (Figure 6), and lawn bowler.

From 1963 to 1970, Ed published a valuable series of taxonomic treatments of Atlantic coast amphipods. He collaborated with Groupe interuniversitaire de recherches océanographiques du Québec, making collections in the St. Lawrence estuary, and he was a Senior Visiting Investigator at the Woods Hole Marine Biological Laboratory on Cape Cod. This culminated in the book *Shallow-water Gammaridean Amphipoda of New England* (Bousfield 1973). Despite the regional title, this treatise covered amphipods that spanned the length of the U.S. and Canadian Atlantic coasts, making it of immense value to taxonomists and ecologists world-wide.

FIGURE 5. Ed dip-netting with children from the Macoun Field Club. Photo: Barbara Bousfield (1959)

FIGURE 6. A special presentation to Ed from artist Floy Zitten, noting Ed's prowess with curling. The title of the award refers to scientist Georg Sars (1837–1927), whose skilled drawings and keen observations produced treatises that every amphipod taxonomist relies on today. Photo: Marjorie Bousfield (2016).

Following the success of his Atlantic coast research, Ed turned his attention fully to the Pacific and soon realized that this was a much more diverse coast, with numerous undescribed species. Ed's collecting expeditions extended from Alaska to northern California with Marjorie Bousfield, Kathy Conlan, John Dickinson, Peter Frank, Norma Jarrett, Ron Long, Eric Mills, and Fahmida Rafi (1933–2008) as assistants (Figure 7). When his family was in tow, Ed worked without an official assistant. Ed was open to bringing women along on field trips. CMN colleague Jacqueline Madill recalls, "When I applied for a position to work at the former National Museum of Natural Sciences he challenged me during the job interview, concerned that I was too petite and feminine to lift heavy objects and participate in field work. This was in an era when only male scientists had been allowed to participate in field work at our Museum and research in laboratories was dominated by male colleagues. After I described activities that I had participated in to illustrate what I could do, he listened not only politely but in an open and inviting manner. When I was hired, I have been forever grateful that Ed was able to allow for change".

Ed took advantage of his western trips to visit marine labs such as Friday Harbor Laboratories and Bamfield Marine Science Centre and give field courses and lectures. He also conducted workshops through the Southern California Association of Marine Invertebrate Taxonomists and pioneered the use of common names for amphipods (McLaughlin *et al.* 1995).

An unexpected result of the Pacific coast research was a delving into the Russian language by Ed, and much later, Marjorie. This was necessitated by the common distribution of many North Pacific amphipods on Russian, Alaskan, and British Columbian coasts. The works of Russian amphipodologists Yevpraxiva Fyodorovna Gurjanova (1902–1981) and Nina Liver'evna Tzvetkova (1932–2010) were essential to interpreting amphipod biogeography and taxonomy in the North Pacific, and so Ed took several Russian courses in the early 1960s. It was while cutting and pasting sections of Gurjanova for Ed in the mid-1970s that Marjorie first became interested in the Russian language. Subsequently, she too studied Russian, and translated for Ed many taxonomic descriptions. Despite the constraints of travel to the U.S.S.R., Ed was able to collaborate with Tzvetkova, resulting in a taxonomic treatment in Russian (Bousfield and Tzvetkova 1982).

Ed's focus on the Pacific Northwest influenced the career paths of many collaborators. His first field assistant, Eric Mills, was converted from ornithology to marine biology by Ed, and spent some years at Queen's and Dalhousie as an amphipod taxonomist. While Mills worked in the Museum laboratory in 1959–1960 as Ed's assistant, Ed encouraged him to work up some of the B.C. species from 1955 and 1957, publishing as sole author (Mills 1961, 1962), as well as his bird observations (Mills 1960a,b). Not only did he become a prolific amphipod expert and ecologist, Mills also published on the history of science, especially marine science, a subject dear to Ed's heart. Assistant Fahmida Rafi sorted and catalogued numerous collections for Ed and then moved within CMN to the challenge of isopod taxonomy (e.g., Rafi 1985; Rafi and Laubitz 1990).

FIGURE 7. Ed's "Amphipod Unit" in Summer 1986. Left to right, Ed Hendrycks, Susan Laurie-Bourque, Karen Hahn, Kathy Conlan, Elemae Lashley, Marjorie Bousfield (visitor), Norma Jarrett, and Ed Bousfield. Photographer unknown; permission granted from Canadian Museum of Nature.

Norma Jarrett, who began as a CMN Volunteer, spent over two decades with Ed and became a competent amphipod taxonomist and co-author (Jarrett and Bousfield 1982, 1994a,b, 1996). CMN colleague Diana Laubitz became an authority on caprellid and podocerid amphipods (e.g., Laubitz 1979, 1993). John Dickinson came to Ed as a two-year post-doc and worked up the Pacific coast ampeliscids (Dickinson 1982, 1983). Hiroshi Morino came from Japan as a visiting scientist to further trans-Pacific studies (Bousfield and Morino 1992). Later, Ed was honoured with the dedication of a new species by Morino (Table 1).

Despite such an intensive focus on the Pacific Northwest, Ed's hoped-for book never materialized. The extraordinary diversity of the amphipods on this coast required more resources and time than anyone could have expected. However, there were fortunate outcomes of the Pacific coast project. Ed, with the help of CMN executives Charles Gruchy and Steven Cumbaa, launched the careers of Ed Hendrycks and Kathy Conlan at CMN, where they still work today.

Hendrycks helped move the Pacific coast project forward with taxonomic treatments on talitrids, pleustids, and eusirids (Bousfield and Hendrycks 1994 a,b, 1995 a,b, 1997, 2002; Hendrycks and Bousfield 2001, 2004). Hendrycks considers Ed "an amphipod legend, one of the BIG GUNS so to speak". Hendrycks recounts: "I remember vividly the day in 1983 that I met Ed. I was terrified, nervous but also excited at meeting a famous government scientist and entered his office at 2378 Holly Lane in Ottawa. He was seated behind his large desk, surrounded by reprint boxes and books. He was an intimidating man, but very quickly made me feel comfortable. He explained his research to me, showed me some amphipods and asked whether I could draw well. I said I think I can and showed him some pencil drawings I had done of beetles. Apparently this satisfied him, as within a few days I was hired on a contract! That was the start of my career as an amphipodologist at the museum. Ed had very set methods in which he conducted particular aspects of his amphipod research and one of them in particular stuck with me. While most taxonomists made multiple slide mounts from their dissected specimens (some more than 10 per amphipod), Ed was adamant that he preferred only one! The slide was made the same way each time, with the appendages in the same orientation. In this way, he could rapidly "compare" two slides by stacking one on top of the other under the stereoscope, as the appendages would be close to the same position. I have continued to adopt Ed's technique to this day! I will forever be grateful to Ed for hiring me that day and launching my career. He was larger than life and I will miss him always".

Kathy Conlan's contribution to the Pacific coast project was taxonomic review of amphithoids, aorids, isaeids, and ischyrocerids (Conlan 1982, 1983, 1988, 1990; Conlan and Bousfield 1982 a,b). Ed's broad understanding of the evolution and behaviour of amphipods helped her understand the effect of sexual selection and how sexually selected characters could be unreliable taxonomic traits (Conlan 1989, 1991). Conlan attributes Ed's deep love of discovery and his immense breadth of knowledge of crustacean phylogeny, behaviour, physiology, and ecology to be her inspiration to look beyond morphology to functionality.

Ed was patient with his assistants and generous with his time. When Conlan was first learning amphipod morphology, she asked Ed in frustration how she could recognize when a specimen was a juvenile of one species rather than an adult of some other, small-bodied species. "Oh," said Ed (with a smile), "juveniles just have that baby-faced look". That was a puzzling answer, but in time, Conlan could see what he meant and went on to use the same cryptic descriptor with her students.

Ed was also generous with his authorships. Colleague Jim Carlton, now Emeritus Professor of Marine Sciences at Williams College in Massachusetts, recalls vividly his correspondence with Ed, 50 years ago in 1966. At the behest of Jerry Barnard, Jim sent specimens of a talitrid from San Francisco Bay to Ed for identification; given Ed's deep familiarity with this group from the California coast, Ed immediately recognized it as something special ("To say that this material is interesting would be an understatement", Ed wrote to Jim that fall). Ed deduced it was likely a non-native but undescribed species, and wrote the paper and prepared the figures. Jim contributed, in the form of letters, information on other exotic species in the Bay, and habitat data. Most scientists would have simply put Jim in the acknowledgements — instead, Jim writes, "Ed, the gentleman and scholar that he was, very generously made me a co-author on what was to be my first peer-reviewed paper!" (Bousfield and Carlton 1967). It was to be years later that Ed learned that Jim was 18 years old at the time — but that would have made no difference to Ed.

Many studies by Ed and collaborators were published in-house. When this unit was closed after an extensive re-organization at CMN in 1991, Ed found that there were no other publishers of large taxonomic treatments. This situation could have been the death knell for Ed's goal of a Pacific coast guidebook, but, undaunted, Ed put forward his personal funds to develop the journal *Amphipacifica*. This ran from 1994 to 2004 and became the vehicle for both himself and his colleagues to get new species descriptions, taxonomic revisions, and reviews of biogeography and evolution into the scientific literature.

Besides his intensive focus on the Atlantic and Pacific coasts of North America, Ed collected amphipods in the Caribbean, Australia, and South America. One of his more memorable findings was of hypogean talitrid amphipods in a lava tube on the island of Kauai (Hawaii; Bousfield and Howarth 1979). Another spectacular find occurred on a boat cruise on Lake Baikal (Russia) where he was invited to bring back to CMN a beautiful sponge covered in spiny amphipods. Perhaps his most memorable expedition was the historic circumnavigation of the Americas by CSS *Hudson* in 1969–1970. Ed participated in the leg of the voyage from Buenos Aires to Santiago. With an assistant and small boat, Ed worked along famous Beagle Channel, making collections that included what was described in the press as the amphipod equivalent of a dinosaur.

Ed was proud of his discovery of a credible basis for organizing amphipod taxa into superfamilies (Bousfield 1977, 1978), a re-classification that has stood the test of time. He became particularly interested in the use of specialized organelles, such as calceoli, presumed vibration sensors that form on the antennae of species that tend to mate freely in the water column. Ed's broad understanding of the evolution of the Amphipoda extended to the Crustacea as a whole, both extant and fossil. He had a keen interest in the curious crustaceans of the Burgess Shale (Bousfield 1995) and had many good discussions on crustacean evolution with colleagues Waldo Schmitt (1887–1977; U.S. National Museum) and Frederick Schram (the Universiteit van Amsterdam, the Netherlands).

Not afraid of conflict, Ed viewed amphipod relationships through a different lens than contemporary-amphipodologist Jerry Barnard (1928–1991) at the U.S. National Museum. This made conference attendance entertaining for colleagues of the two, and no doubt spurred both scientists to greater heights. Ed and colleague Craig Staude wrote a special tribute to Barnard in Ed's first issue of *Amphipacifica* after Barnard's early death (Bousfield and Staude 1994). Colleague Wim Vader of the University Museum of the University of Tromsø in Norway feels that "Ed's death really signifies the end of an era in amphipod taxonomy, and not only in Canada, but everywhere. Ed had a very sharp eye for both differences and relationships among the amphipods; it was often possible to disagree with him, although not easy, as Ed was especially thin-skinned-to criticism; but his opinions were always well worth listening to and studying, and were only neglected at your peril".

Ed's interests broadened even further after 1992 when he moved to Victoria and married his third wife, Joyce Burton (née Bradley, d. 2009) following a brief marriage to Margaret Tuer (neé Ainslie) in the mid-1980s. Living not far from Cadboro Bay, Ed became interested in the elusive mega-serpent, *Cadborosaurus*.

With Paul LeBlond of the University of British Columbia, Ed formalized it as a new genus and species, *Cadborosaurus willsi* (Bousfield and LeBlond 1995), and wrote a popular book about it (LeBlond and Bousfield 1995). Ed was convinced that "Caddy" existed, rueing the misinterpretation of the type specimen as whale offal and its long-ago disposal, leaving only grainy photographic evidence. CMN colleague Francis Cook, who reviewed their book (Cook 1995), says, "I always admired Ed for his ingenuity in blending so many anecdotal reports into a life history of the beast, but always maintained the need for a fresh specimen and not dependence on fuzzy photographs of a discard if recognition of its existence was to be validated and generally accepted". Ed enjoyed the scepticism and enthusiasm he received along with the numerous requests for talks and interviews. He was, as CryptoNews stated, "a daring zoologist" for even considering a subject that most scientists simply dismissed.

In 1999, Ed and Joyce returned to Ottawa and then the Toronto area, where they could be closer to Joyce's family. This return to Ontario also brought about a closer relationship with CMN, enabling Ed to launch new amphipod projects. Ed's ultimate goal was to produce a book, *The Amphipods of Canada*, which would comprise over 1000 species, he estimated. With that in mind he launched into a taxonomic treatment of holarctic pontoporeiids. As with other North American amphipod groups, Ed discovered that a group seemingly consisting of fewer than 10 species actually comprised many more, in this case 40+ species in eight genera, mostly new to science. The unending mushrooming of the group prevented Ed from publishing his revision before he became too ill to continue the work. Ed quipped that "only about half a dozen amphipod people…have tackled this group seriously during the past 170+ years. The others were apparently too smart to get involved!".

In 1978, Ed was elected Fellow of the Royal Society of Canada and, in 1985, he received the Government of Canada's Outstanding Achievement Award. In 1986, he was made Honorary Member of the Ottawa Field Naturalists' Club and in 1992, Honorary Member of the Canadian Society of Zoologists. Never interested in full retirement, Ed remained an active Emeritus Scientist at CMN. In an interview in 2016, Ed said, "One thing I can't believe is the amount of international recognition you get. Even now, at age 90…I am still getting emails from people who are interested in what I did!" and "My best life-long friends were scientists, because they had the same aims in life as I had".

When colleague Eric Mills gave Ed a copy of his latest book in Ottawa not all that long ago, he wrote inside "To Ed Bousfield, mentor and friend". "I know that Ed was touched by this", said Eric. "And now I can see clearly that the same thing could have been written by so many of the people that he worked with". Colleague Wim Vader says that he "… was always struck about how eager Ed still was to learn more and to understand the taxonomy and relationships, as well as the functional morphology, of his beloved animals". "Those amphipods." Ed would say, "You can never beat them into submission. There's always another new species around the corner, just when you think you're done". Ed Bousfield leaves us an immense collection full of many more species to discover and an incomparable legacy of encouragement to others.

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Book Reviews

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

ZOOLOGY

Being a Bird in North America, North of Mexico, Volume 1: Waterfowl to Shorebirds

By Robert Alvo. 2015. Robert Alvo, Ottawa, ON, Canada, http://babina.ca/. 255 pages, 41.99 CAD, Cloth.

As a birder and young ecologist, it goes without saying that I have a lot of books based around conservation, birding, and field guides. With my bookshelves full, when thinking about adding a new book to my collection, there has to be something unique about it. Most bird-related books that I own typically fall under one of three categories: birding field guides, natural history, or autobiography. *Being a Bird in North America* is not a field guide; however, its blend of humour, natural history, and conservation science makes this book both informative and original.

Each species' account contained a global map of its range, along with the species' Nature Serve status. Accounts include traditional photos that you might find in a field guide or online account, plus a unique cartoon for the species. These cartoons were drawn by 15 cartoonists and resemble something unique about the species' biology, behaviour, or conservation.

I found myself quickly looking up species I was familiar with to see if I could guess what the cartoon would depict. I was pleasantly surprised to correctly guess what the illustration would be for a number of species; for others, the meaning could easily be found within the subtext of the species' account.

Species accounts are easy to read and include very little jargon. This makes it a book that can be enjoyed not only by experienced birders, but also inexperienced birders or children who have an interest in natural history. No two species accounts are alike, with topics ranging from behaviour, such as feeding or breeding, population threats, conservation management, and personal accounts or experiences with the species. While this can sometimes feel a bit unsystematic, it also brings a certain charm to it and it is nice to have such a variety of topics.

Many conservation programs and projects are mentioned in these accounts, bringing to light the vast amount of research and conservation effort being put in place for different species. Science communication is a growing field within the scientific community, especially within the environmental sector. Providing a stronger understanding of what research is being conducted, what conservation techniques are being implemented and their relevance to other species helps to build further support for conservation efforts. By placing these efforts into an easy, enjoyable, and educational read, *Being a Bird in North America* helps to communicate these facts to an audience greater than what may be normally targeted.

This book acts as a great supplement to a field guide, when you want to learn more about the natural history of a species, or as a stand-alone book. Throwing in some humour and popular culture references made the reading more delightful, pairing perfectly with the thoughtful and witty cartoons. *Being a Bird in North America* is a great addition to one's coffee table or bedside table. I can't wait to see what the next edition has in store!

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Peterson Field Guide to Reptiles and Amphibians of Eastern and Central North America. Fourth Edition

By Robert Powell, Roger Conant, and Joseph T. Collins. 2016. Houghton Mifflin Harcourt, 125 High Street, Boston, MA, USA, 02110. 512 pages, 21.00 USD, Paper.

The Peterson field guide series began in 1934 with jacket pocket coverage of eastern North American birds, which progressed through successive revisions to a sixth edition in 2010. Its approach was used for other vertebrates, invertebrates, plants, minerals, and astronomy and these have become the "Gold Standard" among field guides. In 1958, the addition of reptiles and amphibians of eastern North America was an instant success and greatly accelerated their accurate field identification. In 1975, the second edition expanded coverage to include the central portion of the continent; it was a companion to the 1966 guide to western species, filling a geographic gap in coverage between the two earlier guides.

Roger Conant wrote the first two editions and his wife, Isabelle Hunt Conant, illustrated them with photographs she took of living specimens posed in similar positions for ease and accuracy of comparison and coloured by hand from the same living specimens. A third edition in 1991 added Joseph T. Collins to update the text and artist Tom R. Johnson to illustrate the added species. Featured was Collins's attempt to unilaterally accomplish what he regarded as a modernization of the scientific nomenclature, but this did not meet with universal support from herpetologists (see Cook 1991). An expansion of this edition in 1998 did not include any text revision (see Cook 2001).

The Conants and Collins have since died but finally a new group led by Dr. Robert Powell, a professor of biology at Avila University in Kansas City, Missouri, has taken up the daunting challenge of updating the text. A decision to build on past editions assures that the fourth is still a great field guide, with its scrapbook of previous illustrations interspaced with the new photographs. Its nomenclature follows the 2012 committee-generated list published by The Society for the Study of Amphibians and Reptiles which is now used by all major herpetological societies for North America.

The number of species included in the new edition of the field guide has increased since 1991 from 379 to 501, adding those uncovered since the earlier editions, particularly through widespread molecular analysis, and the continued or new establishment of 60 intentionally or accidentally introduced exotic species.

The maps have been updated by Travis W. Taggert with consultation of an impressive list of United States herpetologists but very few Canadians. Throughout, Taggert's novel innovation is his careful attempt to more accurately depict in these maps the distributions, particularly of aquatic and semi-aquatic species, as following a dendroidal pattern within watersheds, and by attention to the fragmented edges of most ranges. A few Canadian ranges appear exaggerated in northern regions due to the map projection chosen. On others, records are difficult to detect because of the small map size and because those judged to be disjuncts are indicated by a miniscule "x". Inclusion of provincial atlas reports may have included occasional unverified localities.

In contrast to the early editions, sections on capture and keeping amphibians and reptiles in captivity have been reduced or eliminated, as well as the treatment of poisonous snakebites, as these topics are now treated in greater depth and modern relevance in other publications. Throughout, the emphasis in a changing world is on conservation of populations and habitats and knowledge of provincial, state, and federal regulations.

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Reptile Ecology and Conservation: A Handbook of Techniques

Edited by C. Kenneth Dodd, Jr. 2016. Oxford University Press, Great Clarendon Street, Oxford, UK, OX2 6DP. 490 pages, 79.95 CAD, Paper, 58.99 CAD, E-book.

Methods in reptile ecology and conservation have evolved greatly over the past few decades. Satellites can now track the movement of sea turtles and water samples can be used to detect the species present in a wetland using environmental DNA. *Reptile Ecology and Conservation* brings together 30 papers written by 57 experts on a variety of new and standard techniques. While most of the authors are from the USA, there are authors from South America, Europe, Africa, and Asia, giving the book a global perspective.

The book is divided into six parts. Part one, Introduction, consists of three chapters covering reptile diversity and life history, setting research objectives, and data collection. Part two, The Individual, consists of six chapters on marking and measuring individuals, digital identification, preserving specimens, reproduction, diet, and movement patterns. Part three, Sampling Reptiles, is composed of seven chapters on locating or capturing different groups of reptiles. Two preliminary chapters summarize basic methods for surface-dwelling reptiles and arboreal or fossorial reptiles, while the other chapters focus on different reptile groups: sea snakes, freshwater turtles, terrestrial turtles, sea turtles, and crocodilians. Part four, Reptiles in the Community, consists of six chapters on plot and transect censuses, rapid assessments of species diversity, measuring microhabitats, water quality and toxicology, species richness and diversity, and landscape ecology. Part five, Experimental Applications, Physiological Ecology, and Genetics, is composed of three chapters on experimental design, thermal ecology, and the role of genetics. Part six, Trends Analysis and Conservation Options, consists of four chapters on occupancy models, estimating abundance, biological sampling for disease monitoring, and conservation management.

Entire books have been written on many of these topics, so these chapters only provide a basic introduction and high-level review of the concepts and issues. As such, the chapters can lack detail. For example, the section on cover board surveys does not even discuss the effect of different types of cover objects on the species detected. Although chapters had to be kept short to limit the physical size of the book, inserting additional references would not have significantly increased the length of the book.

The chapter on data collection took a novel approach. Rather than just present his own perspective, the author surveyed 28 experienced herpetologists to get a broad range of opinions and experiences. Although the trusty field book is the most commonly used method for data collection, a compelling argument is made that tablet computers have many advantages over field books, particularly when coupled with back-up cloud storage to prevent data loss and the ability to consult years of data in the field.

Reptile Ecology and Conservation is similar to another recent book, *Reptile Biodiversity: Standard Methods for Inventory and Monitoring* (edited by McDiarmid *et al.* 2012, University of California Press). For example, Richard Vogt wrote the section on sampling freshwater turtles for both books. Which book is better will depend upon a reader's particular interest. Dodd's book has chapters on toxicology and biological sampling for disease, which are not covered in the McDiarmid book. Examine both books carefully before deciding which one to purchase. *Reptile Ecology and Conservation* is an excellent book both for established researchers looking for new ideas and graduate students just beginning their research careers.

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The Beaver: Its Life and Impact. Second Edition

By Dietland Müller-Schwarze. 2011. Cornell University Press, Sage House, 512 East State Street, Ithaca, New York, NY, USA, 14850. 228 pages, 39.95 USD, Cloth.

Beavers are the second largest rodents in the world. Two extant species comprise the beaver genus *Castor*. The Eurasian Beaver (*Castor fiber*) was once widespread in Eurasia until uncontrolled hunting (for its fur and castoreum) nearly wiped out the species (concerted reintroduction programs throughout much of its former range have re-established many populations). The North American Beaver (*Castor canadensis*) is one of North America's most iconic mammals, having played a significant role in the human colonization of the continent.

Author Dietland Müller-Schwarze correctly refers to the beaver by its many descriptors – ecosystem/wetlands engineer, keystone species, and invasive species. Perhaps no other Holarctic mammal (with the exception of man) can influence its environment as profoundly as beavers. Admired for their determination and ingenuity, beavers are also sometimes shunned by those that find their natural behaviour in altering landscapes to be destructive and a nuisance. Given their ecological and economic importance, mammologists know much about the life history of beavers. Yet, despite knowing much about their biology, few compiled works exist. This up-to-date and inclusive book, in its second edition, is an attempt by Müller-Schwarze to fill that void.

The book is effectively organized into five parts, each one covering a different aspect of beaver life history and human interactions: I. The Organism; II. Behavior; III. Populations; IV. Ecology; and V. Beaver and People: Conservation, Use, and Management. Each part is comprised of several chapters which present comprehensive information on a specific aspect of beaver biology, ranging from specific topics that include morphology (form and function), physiology (e.g., diving and thermoregulation) and behaviour (e.g., communication) to broader subject matters that encompass population biology, ecology (e.g., diseases; predators), and wildlife management.

Much of the information presented is data rich; many past, classical scientific studies on beavers (e.g., intra- and interspecific interactions; summer versus winter metabolic rates) are cited in the text. Though the prose is largely scientific, the writing style is clear and concise which facilitates quick understanding for those relatively familiar with biological terms and jargon. Colour and black-and-white photographs interspersed throughout the text illustrate the various aspects of beaver life history, highlighting anatomical features (skull, castor sacs), beaver infrastructure (dams, lodges, trails, and canals), and the species' importance and impact on human culture (e.g., fur trade).

Altogether, Müller-Schwarze has done a commendable job, compiling almost all the pertinent studies on beavers into an easily accessible resource. This is a book which should find a place on the library shelf of every bibliophile who has an interest in wildlife and landscape management. Readers who are particularly interested in learning more about the biology and historical significance of one of the world's most charismatic rodents will be pleased with this excellent contribution.

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OTHER

Field Notes on Science and Nature

Edited by Michael R. Canfield. 2011. Harvard University Press, Kittredge Hall, 79 Garden Street, Cambridge, MA, USA, 02138. 297 pages, 27.95 USD, Paper.

Recently, one of my colleagues dropped by and asked me to look up some information from field research we'd done about twenty years ago. Should be straightforward, I thought. I dug out my field notebook and attempted to interpret my notes. That's when I realized that my note-taking wasn't as good as it should have been. Clearly, the notes made sense to me at the time, but decades later not so much. Yet field notes, just like specimen records, should be a permanent record of work done. And if I can't figure out what my own field notes mean, then how can they be useful to anyone else following up on the same project or field area after I am gone? How do you take field notes that remain comprehensible years later?

So I opened this book with great anticipation, interested to see how other field scientists take records. Some have clearly had the same difficulty: "Few things are more frustrating than not being able to understand your own notes from several seasons ago". Well, yes, I would agree! "Write so that the picture is clear for an external audience, and it will be clearer to you as well." So advise John Perrine and James Patton in their account of resurveying wildlife in areas of California originally studied by teams coordinated by Joseph Grinnell, director of the Museum of Vertebrate Zoology, in the early twentieth century. The notes taken at that time were so good that the modern teams were able to go back to the same sites to resample. Now that is good field recording!

Biologist Michael Canfield has gathered articles about field note taking by thirteen eminent scientists from different fields of bioscience, geoscience, and ecology. Besides Perrine and Patton, the contributors include George Schaller, Bernd Heinrich, Kenn Kaufman, Roger Kitching, Anna Behrensmeyer, Karen Kramer, Jonathan Kingdon, Jenny Keller, James Reveal, Piotr Naskrecki, and Erick Greene. There are many different styles of note-taking represented here, from narratives with sketches, to detailed drawings and sketch maps, to predefined forms to be filled in, to an entirely digital database. All these accomplish the same task: that of keeping an accurate (and understandable) record of what was seen, collected, or experienced in the field. It is interesting to see that there isn't a standard way to keep notes; each field scientist has developed their own style, which is customized according to their research focus and field methods.

The book is fascinating to read and beautifully produced. Chapters are copiously illustrated. All include sample pages from notebooks or records, showing exactly how different observers approach recording field information. Often, notetaking techniques have evolved over the course of a lifetime or a career. Both Bernd Heinrich and Anna Behrensmeyer show examples of notes taken early in their career as comparisons with more recent notebooks. Behrensmeyer points out that an early field site drawing lacks a scale, something that would have been helpful when returning to the study later. Heinrich describes how he started taking field notes – records of plants and animals that he encountered while he was out running – when he was a child and young teenager. The lesson is clear. Note taking is a skill that develops over a lifetime, and the earlier it is started, the better.

Why keep a field notebook? A good question, to which Erick Greene and other contributors give cogent answers. Perrine and Patton describe field notes as "letters to the future". Many contributors maintain that a field notebook is not just for projects. Greene makes an eloquent case that a field notebook should be like an everyday journal – a place for recording observations and thoughts about the natural world. George Schaller shares that he keeps two notebooks: one to record his scientific observations, the second as a personal journal, "a daily record of impressions, ideas, concerns, and complaints".

Anthropologist Karen Kramer indicates that her personal field journal helped her "to maintain normalcy under circumstances that at the time seemed far removed from my cultural frame of reference". Greene emphasizes the value of notebooks as "an incredibly fertile incubator for your ideas and observations", noting that "one of the hardest parts of science is coming up with new questions". He describes an exercise in which he asked university students in an ecology class "to pick one 'thing' and observe it carefully over the entire semester". Many students were extremely resistant to doing this, although some became enthusiastic converts to field observation and note taking. I thought it was rather sad that students in university had not already been exposed to the discipline of note taking and field observation. There is clearly still a place for natural history clubs in developing these skills, as Roger Kitching acknowledges in his account of his childhood years in Hull, Yorkshire.

Sketching and drawing often supplement notetaking. In other cases, sketches are the main form of recording, as Jonathan Kingdon shows with sample pages of his observations on Caracal cat and guenon monkey behaviour. Kingdon is an immensely talented and justly famous wildlife artist, as well as a respected scientist. His pages are both beautiful and informative. Scientific illustrator Jenny Keller provides some hints on making accurate field sketches and recording colour. She works primarily on marine lifeforms. Colour records are especially important for these because specimens' colours can change dramatically and quickly when they are out of water or dead.

Besides a notebook, a camera is an essential piece of field equipment. Perrine and Patton show examples of "then and now" photographs, with images of Emerald Lake taken in 1924 and retaken in 2006. The comparison of vegetation composition and density is instructive to document landscape change. Their examples show why images are such an important part of field records. Beginning in the mid-1960s, Polaroid photography was a useful adjunct to field record keeping. Images could be annotated right in the field and taped into the notebook. Behrensmeyer shows several examples of this. Nowadays, digital photography is the norm, and images can be added to electronic records and annotated, as Naskrecki shows. His digital records also include sound recordings and sonograms of the katydids he studies, examples of the expanding data types that can now be captured and processed directly in the field. Digital imagery allows an instant assessment of record quality. This is a far cry from earlier times when there was much anxious waiting to get photographs or slides developed after returning from the field, hoping that they would turn out well and provide good visual documentation.

An especially important aspect of fieldwork is knowing exactly where you are when you collect a specimen or record an observation. The field notes show different ways of documenting location. In 1961, botanist James Reveal recorded the location of a specimen of *Polygala* by using a legal land description, the familiar section-township-range system. In October 1975, he recorded another collecting location with reference to distance along a major highway from a specific junction. Today, most contributors mention using a Global Positioning System (GPS) unit to record location and elevation information. Both descriptive and instrumental locational data are valuable because they capture different aspects of location. GPS coordinates give a precise point on the landscape, whereas descriptive accounts usually tell you how to get there.

In his introduction, Canfield situates modern field notetaking in the tradition of great naturalists of the past, including Gilbert White, Henry David Thoreau, and Charles Darwin. Their field notes formed the basis for classic natural history works – *The Natural History of Selborne*, *Walden*, and *The Voyage of the Beagle*. The published accounts may be polished for literary effect but the field notes provide the straightforward record of what happened. Several contributors to this volume have also drawn on field notes for popular works. Notable among these are Schaller's *Stones of Silence*, Heinrich's *Winter World*, as well as many books by preface-writer Edward Wilson. Indeed, all contributors are accomplished writers as well as scientists, and their words are worth reading, re-reading, and savouring. With this well-chosen and thoughtful suite of essays, Canfield has achieved his objective "to encourage more rigorous and long-lasting documentation of our natural world".

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Time and A Place: An Environmental History of Prince Edward Island

Edited by Edward MacDonald, Joshua MacFayden, and Irene Novaczek. 2016. McGill-Queen's University Press, 1010 Sherbrooke West, Suite 1720, Montreal, QC, Canada, H3A 2R7 Douglas Library Building, 93 University Avenue, Kingston, ON, Canada K7L 5C4, and Island Studies Press, Room 204, Main Building at UPEI, 550 University Avenue, Charlottetown, PEI, Canada, C1A 4P3. 442 pages, 34.95 CAD, Paper.

Time and A Place enjoys the dual distinction of being the first environmental history of Prince Edward Island (PEI) and, indeed, "Canada's first provincial environmental history" (p. 10). PEI is unique in several ways among Canada's provinces and territories, in addition to being the only island. It is Canada's smallest province, at once its "most densely populated" (p. 7), lowest in absolute population numbers, and most rural, with about 53% of its people living in the country; its geology differs from that of the rest of Canada, built as it is on sandstone-covered ancient silt; and its human past dates from its emergence as a land mass 5000 years ago. Thus, its environment has been shaped and reshaped by human actions for millennia. As the editors explain in their helpful introduction, environmental history is about environments, not nature, for these millennia of human activity have left "little that resembles wilderness or untouched nature on Prince Edward Island" (p. 7). Are field naturalists able to play a role in understanding this place, and receive benefits from the attempt?

Environmental history is a relatively new field in the broader discipline of Canadian history. Doing environmental history requires drawing contexts from several disciplines, such as bioregionalism, natural history, ecology, and nissology, the study of islands. This book flowed from the *Time and A Place* conference that did just that, drawing some "60 local, national, and international participants" to UPEI's L. M. Montgomery Institute on June 13–18, 2010 [http://www.lmmontgomery.ca/content/2010-time-and-place-conference-june-13-18]. The papers gathered here are more than conference proceedings, however, having been expanded for this book, a recent addition to the McGill-Queen's Rural, Wildland, and Resource Studies Series.

Time and A Place is an ambitious work: it attempts to cover all aspects of the environmental history of PEI, from its geological formation to the several phases of use and occupation by Aboriginal peoples, already present in the Maritime region for 13 millennia, to the impacts flowing from the relatively late settlement by European peoples after 1720. The book opens with an introduction providing theoretical context and overviews of the 11 main chapters, organized in three sections. It concludes with a thoughtful epilogue that brings out the themes of the book. An appendix lists two centuries of provincial legislation, primarily regulations relating to forestry, hunting, fishing, and agriculture from 1770–1970, a pre-conservation period characterized by protection of resources for continuing use. An extensive bibliography and notes on contributors round out the book. The black-and-white illustrations are not a strong point, unfortunately, the small maps in particular being generally difficult to decipher.

A theoretical framework for approaching the study of islands is provided in the two papers comprising the first section. The generally accepted view is that islands are simply chunks of land surrounded by water. Not so simple, asserts Gillis, as he introduces the concept of the ecotone, or boundary zone, that introduces us to islands as "terraqueous" areas (p. 35). The geographer Wynne expands on this in his critique of the notion that islands, being self-contained, are ideal museums or laboratories for research. To understand islands, one needs to study both land and water and how each, separately and together, shape an island's history, economy, and culture.

The rest of the book demonstrates the point. The four chapters in Section II, Shaping Abegweit, focus on people and the environment; the five chapters in Section III examine development and the environment. The distinction is impossibly neat, of course, for people and development figure in most chapters.

Archaeologists Keenleyside and Kristmanson begin the analysis of people and the environment by recounting the long arc of Aboriginal use and occupation of the Island over some 5000 years. The difficulties inherent in estimating pre-contact numbers of Aboriginal people mean it is also difficult to assess their imprint on the land, which appears to have been extensive yet sustainable. This shifted as the increasing numbers of European newcomers quickly disrupted the ancient balance (pp. 77–79). The European settlers came initially from France after 1720 and Britain some 50 years later, changing the Island landscape forever. As environmental biologist (and published CFN author) Sobey shows, forests provided them with resources at many levels, from personal to industrial. Early settlers were farmers and farming meant clearing forested lands. Two-thirds of the original forest cover had disappeared by 1900, 77% by 1910 (p. 107). Surprisingly, Sobey's is the first attempt to provide a complete overview of the history of forest use on the Island (p. 82). While the need to conserve the forest was recognized as early as 1902 (p. 108), conservation for environmental reasons rather than as a guarantee of continuing use did not become a movement until much later, a topic demonstrated in the regulations contained in the appendix and informing the next chapter, Curley's exploration of public attitudes toward wildlife and habitat.

As with several of the authors, biologist Curley begins with the long view, touching on Aboriginal resource use before quickly moving to the impacts of early settlers' commercial exploitation of wildlife. These included the extinction of several species and the pollution and degradation of waterways through agricultural activities. Curley explores the slowly changing attitudes of citizens to these impacts and offers cautious hope that efforts such as the creation of parks and other protected areas, engagement through citizen science, and better-informed government action will make a positive difference. This chapter and Novaczek's study of marine species, which covers similar themes, are perhaps of most interest to field naturalists. That said, the histories of land use help us understand that PEI nature is now couched in centuries of human activities. To understand it, having some appreciation of those histories is useful.

The third section shifts the focus to development, although people cannot be left out. Agriculture is analysed extensively in two papers that differ in approach and style. McFayden's treatment of the 1869–1971 period attempts to critique if not dispel several of the 'normal' concepts of agriculture using a wide variety of sources, including social accounts. Bringing the discussion up to 2014, former provincial director of forestry Arsenault presents a fact-based account, heavily dependent on government studies and reports, that mixes in observations of failure to act with some notes of tentative progress and hope for the future.

But an island includes its waters, and MacDonald and Becke offer a fascinating account of the changing nature of Island fisheries. The focus shifts from species to species – mussels, oysters, lobster – but the human element is also changing, a result of continually advancing technologies and expanding market economies. Villages that coalesced along shorelines when all the work was muscle-powered disappeared under the effects of improved roads and transportation, industrial technologies, and the ability to reach far-away markets.

These changes contribute to new perceptions of the shoreline and nostalgia for a romanticized past. The historian MacEachern explores the resulting tension in his analysis of tourism guides, published annually by the PEI government for over 60 years. His study reveals shifting perceptions of both the beauty of nature and the nature of beauty, with resulting changes of emphasis and description of PEI's natural attributes, such as its forests, no longer wilderness as Sobey demonstrated, and its beaches, no longer sites of fisheries, now spots for tourists to enjoy.

I can vouch for the Island's beauty, having visited every summer for the past 25 years, but evidences of the modern industrial world are increasing everywhere. One omission from this discussion is the impact of the Confederation Bridge, a divisive issue for Islanders at the time that receives only occasional and passing reference. Perhaps it's simply too soon to assess its impact.

These industrial changes are not all negative; for example, reforestation is increasing, as elsewhere in the world, as farmland is abandoned. And, as Stuart notes in her optimistic look at energy, an island with no oil or capacity for hydro-electric production has had to learn early on to innovate if it wants to stay warm and get work done. Stuart asserts that this necessitates a ready, pragmatic acceptance of new energy technologies. The result is higher than average use of 'green power', firsts in Canada in such initiatives as household waste management, and experience with alternative energy sources such as wind power.

Evidence is accumulating that Islanders are generally, though not yet universally, coming around to the view that protection of the environment and its biodiversity is increasingly urgent and essential. As noted above, that biodiversity has been understudied, even compared to other Maritime provinces. It is here that field naturalists can no doubt make their greatest contributions. Hopefully, *Time and a Place* will inspire just such an outcome.

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Crossing Home Ground: A Grassland Odyssey through Southern Interior British Columbia

By David Pitt-Brooke. 2016. Harbour Publishing Co. Ltd., P.O. Box 219, Madeira Park, BC, Canada, V0N 2H0. 310 pages, 32.95 CAD, Cloth.

Resettling the Range: Animals, Ecologies, and Human Communities in British Columbia

By John Thistle. 2015. University of British Columbia Press, 2029 West Mall, Vancouver, BC, Canada, V6T 1Z2. 218 pages, 29.95 CAD, Paper.

The two books reviewed here form a "literary cartography of place" – in this case, the dry grasslands of British Columbia's interior valleys. For most travellers, our only exposure to these grasslands is through our car window as we drive the Trans Canada Highway along the Thompson River Valley through Kamloops or south from there through Merritt on the Coquihalla Highway. Heat waves in the summer sun, wind-drifted snow in the winter. The two books could not be more different. *Crossing Home Ground* takes the form of daily diary entries, ruminations, and reflections of David Pitt-Brooke's 75-day pilgrimage from near the USA border north and west to Williams Lake in the Chilcotin country. He wanted to experience that dry interior intimately, and over two years he walked over a thousand kilometres, one foot in front of the other. On the other hand, John Thistle's book, *Resettling the Range*, is an academic treatise, laden with over 40 pages of notes and references, that explores the ecology and history (human and non-human) of the same grasslands through the lens of attempted eradication of "wild" horses and grasshoppers in the late nineteenth and early twentieth centuries. But they are complementary.

Each of the seven chapters in *Crossing Home Ground* covers a geographical area or length of time or season on Pitt-Brooke's journey. Many of his daily entries dwell on the logistics of finding a route and somewhere to camp that was relatively flat and had potable water, preferably on public land, in areas where there are no hiking guidebooks. At times he suffered from mild dehydration because of a shortage of water in the hot, dry climate. He sprinkles in lessons on the natural history of the bunchgrass meadows and Ponderosa Pine-Douglas-fir parklands that he hikes through and camps in. Long hours and days alone lead to reminiscences of growing up in the Okanagan, ruminations and reflections on what it means to love a landscape, to understand the intricacies of its ecology, and anger over desecration by all-terrain vehicles (ATVs), mines, cattle, and rampant housing development. He wonders "what if we started to see land not as a possession but as a cherished responsibility, like a child or a spouse or an ageing parent?".

The first third of Pitt-Brooke's journey was spent linking together remnants of native grasslands, pockets of bunchgrass that were often on steep slopes too rugged for logging or livestock. Many of these were legally protected, although some were still suffering abuse, particularly from ATVs. He felt like an urban backpacker, seeking out "little corridors of greenery through the concrete and asphalt", as many of these remnants were surrounded by decades of development, subdivisions, malls, vineyards – the "uglification" of paradise. He likened this to reverse alchemy, changing gold into lead.

But as Pitt-Brooke bushwhacked his way west from Vernon, he rose up onto the high plateau that lies between the Columbia and Fraser river valleys, where there are still vast valleys of native grassland. This isn't to say that these are all healthy ecosystems. As Thistle details in *Resettling the Range*, the Nicola Valley grasslands and those along the Thompson River between Kamloops and Ashcroft and the Fraser River between Lillooet and Williams Lake (nearly 500 000 ha or 1.2 million ac), have been heavily impacted by grazing and associated activities since the 1858 Fraser River gold rush brought thousands of head of cattle, sheep, mules, and horses to the area. Prior to that there were no large herds of grazing animals. Bison never made it to these grasslands and, while horses evolved in North America, they died out 11 000 – 13 000 years ago and were only reintroduced in the 15th and 16th centuries by the Spanish invaders. By the time settlers arrived, First Nations peoples had been using horses for travel, hunting, warfare, trade, and profit for several hundred years. While not branded like settler horses, most of these animals were owned, although there were horses that became feral when their owners died in the 1862 smallpox epidemic. And settlers themselves often let their horses roam and graze freely on Crown (provincial) land.

By the turn of the 19th century, most of the available grasslands were owned, or leased from the provincial government, by three large corporate ranches (Gang Ranch, Douglas Lake Cattle Company, and the BC Cattle Company) and numerous smaller family ranches. Meanwhile, starting in 1861, First Nations groups were being squeezed onto smaller and smaller reserves. One of the big problems was that settler lands included lowlands where they could grow forage (often irrigated) to winter their livestock, while the reserves were usually in uplands (meadows interspersed with forest) where neither winter forage nor water was available – the "biogeography of dispossession". Settlers considered First Nations' horses as "useless" (not part of the capitalist economy) and competing for grass with their cattle. Thus started a war on wild horses, which included hiring shooters to kill horses found on Crown land between January and May, which Thistle describes as being "little more than a proxy war on Aboriginal people". His contention is supported by many excerpts from letters and reports, showing at a minimum paternalistic viewpoints and often outright racism. During the period 1924–1955, over 13 000 horses were killed, the vast majority of which belonged to First Nations people.

Through much of this same period the government was also waging a war on grasshoppers. Major irruptions occurred in 1898, 1907, 1914, and 1922. Even decades later entomologists struggle to understand what triggered the large outbreaks, but their abundance and distribution was a response to a range of environmental variables: weather (hot, dry conditions in early spring and fall), predation, parasitism, and disease. By the early 1900s, some range managers were starting to sound the alarm about overgrazing of Crown lands, which exacerbated the other variables and made the outbreaks more destructive. But rather than tackle the thorny issues of land allocation and range monopoly, and the need to reduce herd sizes to something resembling carrying capacity, the government took the politically expedient route and started poisoning grasshoppers, first using arsenic and later DDT. Neither eliminated the grasshoppers but did wreak havoc on the grasslands, impacting not only wildlife, but also the health of livestock and people.

After the grasshopper war (the use of military terminology was good psychology for bringing people onside) there were new enemies for settlers to battle: fire suppression was allowing tree encroachment into grasslands, while bark beetles killed swathes of forest that impacted fences and travel to far pastures. By the late 1960s, refrigeration and easier transportation gave rise to factory feedlot systems, to which large corporate ranches had the resources to adapt, while smaller family ranches and First Nations ranchers did not.

As Pitt-Brooke said, "Falsifying the past destroys any value it might have had as a guide to the future". While *Resettling the Range* is not an easy read, Thistle has done an admirable job of sifting through the details of early settler history to document how we arrived at the state of our present-day grasslands. But read *Crossing Home Ground* for its message of hope. As Pitt-Brooke observes, "given half a chance they [grasslands] do come back. And it doesn't take centuries … Protection and lots of time. That's the key".

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NEW TITLES

Prepared by Barry Cottam

† Available for review * Assigned

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

ZOOLOGY

Pacific Reef and Shore – A Photo Guide to Northwest Marine Life. By Rick Harbo. 2017. Harbour Publishing, P.O. Box 219, Madeira Park, BC, Canada, V0N 2H0. 96 Pages, 12.95 CAD, Paper.

*** Ecology of Salmonids in Estuaries around the World: Adaptations, Habitats, and Conservation**. By Colin D. Levings. 2016. University of British Columbia Press, 2029 West Mall, Vancouver, BC, Canada, V6T 1Z2. 388 pages, 75.00 CAD, Cloth.

Peterson Reference Guide to Woodpeckers of North America. By Stephen Shunk. 2016. Houghton Mifflin Harcourt, 125 High Street, Boston, MA, USA, 02110. 320 pages, 40.00 USD, Cloth, 35.00, E-book.

Peterson Reference Guide to Owls of North America and the Caribbean. By Scott Weidensaul. 2015. Houghton Mifflin Harcourt, 125 High Street, Boston, MA, USA, 02110. 352 pages, 40.00 USD, Cloth.

One Wild Bird at a Time: Portraits of Individual Lives. By Bernd Heinrich. 2016. Houghton Mifflin Harcourt, 125 High Street, Boston, MA, USA, 02110. 224 pages, 28.00 USD, Cloth.

Handbook of Larval Amphibians of the United States and Canada. By Ronald Altig, and Roy W. McDiarmid. 2015. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 368 pages, 75.00 USD, Cloth.

Slugs and Snails. By Robert Cameron. 2017. HarperCollins Canada, 2 Bloor Street East, 20th Floor, Toronto, ON, Canada, M4W 1A8. 528 pages, 135.00 CAD, Cloth, 66.99 CAD, Paper, 49.99 CAD, E-book.

Eco-evolutionary Dynamics. By Andrew P. Hendry. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 336 pages, 65.00 USD, Cloth.

Freshwater Dinoflagellates of North America. By Susan Carty. 2014. Cornell University Press, Sage House, 512 East State Street, Ithaca, NY, USA, 14850. 272 pages, 95.00 USD, Cloth.

Listening to a Continent Sing: Birdsong by Bicycle from the Atlantic to the Pacific. By Donald Kroodsma. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 336 pages, 29.95 USD, Cloth.

Coyote America: A Natural and Supernatural History. By Dan Flores. 2016. Basic Books, 1290 Avenue of the Americas, New York, NY, USA, 10104. 288 pages, 35.99 CAD, Cloth.

Birds of British Columbia and the Pacific Northwest: A Complete Guide. By Richard Cannings, Tom Aversa, and Hal Opperman. 2016. Heritage House Publishing Co. Ltd, 103 - 1075 Pendergast Street, Victoria, BC, Canada, V8V 0A1. 464 pages, 29.95 CAD, Paper.

At Sea with the Marine Birds of the Raincoast. By Caroline Fox. 2016. Rocky Mountain Books, 103 - 1075 Pendergast Street, Victoria, BC, Canada, V8V 0A1. 272 pages, 25.00 CAD, Paper.

The Book of Frogs: A Lifesize Guide to Six Hundred Species from Around the World. By Tim Halliday. 2016. University of Chicago Press, 1427 East 60th Street, Chicago, IL, USA, 60637. 656 pages and 1230 colour plates, 55.00 USD, Cloth, 33.00 USD, E-book.

ENTOMOLOGY

The Bees In Your Backyard: A Guide to North American's Bees. By Joseph S. Wilson, and Olivia Messinger Carril. 2016. Princeton University Press, 41 William Street, Princeton, NJ, USA, 08540-5237. 288 pages, 29.95 USD, Paper.

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Vascular Plants of Alberta, Part 1: Ferns, Fern Allies, Gymnosperms, and Monocots. By John Packer, and A. Joyce Gould. 2017. University of Calgary Press. 300 pages, 34.95 CAD, 41.95 USD, Paper. Drawn from the 30-volume *Flora of North America*.

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Animal Metropolis: Histories of Human-Animal Relations in Canada. Edited by Joanna Dean, Darcy Ingram, and Christabelle Sethna. 2017. University of Calgary Press, 2500 University Drive NW, Calgary, AB, Canada, T2N 1N4. 336 pages, 34.95 CAD, Paper.

Galapagos: Preserving Darwin's Legacy, Second Edition. By Tui de Roy. 2016. Bloomsbury Publishing Inc., 1385 Broadway, 5th Floor, New York, NY, USA, 10018. 240 pages, 50.00 USD, Cloth.

Secrets of the Seas: A Journey into the Heart of the Oceans. By Callum Roberts. Photographs by Alex Mustard. 2016. Bloomsbury Publishing Inc., 1385 Broadway, 5th Floor, New York, NY, USA, 10018. 240 pages, 40.00 USD, Cloth.

Wildlife, Land, and People: A Century of Change in Prairie Canada. By Donald G. Wetherell. 2016. McGill-Queen's University Press, Douglas Library Building, 93 University Avenue, Kingston, ON, Canada, K7L 5C4. Carleton Library Series Number 238. 640 pages, 49.95 CAD, Cloth or E-book.

The Complete Naturalist. By Nick Baker. 2015. Bloomsbury Publishing Inc., 1385 Broadway, 5th Floor, New York, NY, USA, 10018. 352 pages, 34.00 USD, Paper.

Why Ecology Matters. By C. Krebs. 2016. The University of Chicago Press, 1427 East 60th Street, Chicago, IL, USA, 60637. 208 pages, 75.00 USD, Cloth, 25.00 USD, Paper.

News and Comment

Upcoming Meetings and Workshops

Pacific Branch of the Entomological Society of America Annual Meeting

The 101st annual meeting of the Pacific Branch of the Entomological Society of America to be held 2–5 April 2017 at DoubleTree by Hilton Portland, Portland, Oregon. Registration is currently open. More information is available at http://www.entsoc.org/pacific/2017-pacific-branch-annual-meeting.

Northeast Fish & Wildlife Conference

The 73rd annual Northeast Fish & Wildlife Conference, hosted by the Virginia Department of Game and Inland Fisheries, to be held 9–11 April 2017 at the Norfolk Waterside Marriott, Norfolk, Virginia. Registration is currently open. More information is available at http://www.neafwa.org/annual-conference.html.

Biodiversity Without Boundaries 2017

Biodiversity Without Boundaries 2017, hosted by NatureServe Canada, to be held 9–13 April 2017 in Ottawa, Ontario. The theme of the conference is: 'Managing Natural Resources and Biodiversity in a Rapidly Changing World'. Registration is currently open. More information is available at http://www.natureserve.org/news-events/events/biodiversity-without-boundaries-2017.

Southwestern Branch of the Entomological Society of America Annual Meeting

The 65th annual meeting of the Southwestern Branch of the Entomological Society of America to be held 9–13 April 2017 at the Wyndham Garden Hotel Austin, Austin, Texas. Registration is currently open. More information is available at http://www.entsoc.org/southwestern/2017-southwestern-branch-annual-meeting.

US Regional Association of the International Association for Landscape Ecology Annual Meeting

The annual meeting of the US Regional Association of the International Association for Landscape Ecology to be held 9–13 April 2017 at the Hyatt Regency Inner Harbor, Baltimore, Maryland. The theme of the conference is: 'People, Places, Patterns: Linking Landscape Heterogeneity and Socio-Environmental Systems'. Registration is currently open. More information is available at http://usiale.org/baltimore2017/#2017.

The Washington-British Columbia Chapter of the American Fisheries Society Annual General Meeting

The Washington-British Columbia Chapter of the American Fisheries Society Annual General Meeting to be held 10–13 April 2017 in Spokane, Washington. The theme of the conference is: 'Fisheries Collaborations: Tipping the Scales Toward Success'. Registration is currently open. More information is available at http://agm.wabc-afs.org/.

Northeast Natural History Conference

The 2017 Northeast Natural History Conference to be held 21–23 April 2017 at the Radisson Hotel, Cromwell, Connecticut. Registration is currently open. More information is available at https://www.eaglehill.us/NENHC_2017/NENHC2017.shtml.

Canadian Society for Ecology & Evolution Meeting

The 2017 Canadian Society for Ecology & Evolution Meeting, hosted by the University of Victoria, to be held 7–11 May 2017 at the Victoria Conference Centre and The Royal BC Museum, Victoria, British Columbia. Registration is currently open. More information is available at http://www.csee2017.ca/?lang=en.

2017 International Conference on Ecology & Transportation

The 9th biennial International Conference on Ecology & Transportation conference, co-hosted by the Utah and Wyoming Departments of Transportation, with support from the US DOT Federal Highway Administration, to be held 14–18 May 2017 at the Salt Place Convention Center, Salt Lake City, Utah. Registration is currently open. More information is available at http://www.icoet.net/ICOET_2017/index.asp.

Annual Meeting of the Canadian Society of Zoologists

The 56th annual meeting of the Canadian Society of Zoologists to be held 15–19 May 2017 at the University of Manitoba, Winnipeg, Manitoba. Registration is currently open. More information is available at http://www.csz-scz2017.com/.

Annual Conference on Great Lakes Research

The International Association for Great Lakes Research's 60th Annual Conference on Great Lakes Research to be held 15–19 May 2017 in Detroit, Michigan. More information is available at http://iaglr.org/conference/about.php.

OE3C 2017 Ontario Ecology, Ethology and Evolution Colloquium

OE3C 2017 Ontario Ecology, Ethology and Evolution Colloquium to be held 18–20 May 2017 at Queen's University, Kingston, Ontario. Registration is currently open. More information is available at http://www.queensu.ca/oe3c17/.

International Urban Wildlife Conference 2017

The 2017 International Urban Wildlife Conference, hosted by the San Diego State University and the Wildlife Society's Urban Wildlife Working Group, to be held 4–7 June 2017 in San Diego, California. More information is available at http://www.urban-wildlife.org/index.html.

Society for Freshwater Science Annual Meeting

The Society for Freshwater Science Annual Meeting to be held 4–8 June 2017 at the Raleigh Convention Center, Raleigh, North Carolina. Registration is currently open. More information is available at http://sfsannualmeeting.org/.

Phycological Society of America Annual Meeting

The annual meeting of the Phycological Society of America to be held 4–8 June 2017 at the Embassy Suites by Hilton Monterey Bay Seaside, Seaside, California. Registration is currently open. More information is available at http://www.psaalgae.org/meetings/2017/6/4/psa-2017-annual-meeting.

Animal Behavior Society Annual Conference

The 54th annual conference of the Animal Behavior Society to be held 12–16 June 2017 at the University of Toronto's Scarborough Campus, Scarborough, Ontario. More information is available at http://www.animalbehaviorsociety.org/2017-sd/.

Francis Cook steps down after long and distinguished service with the Ottawa Field-Naturalists' Club and the *Canadian Field-Naturalist*

When Francis Cook stepped down as associate editor in 2016 he completed a staggering 48 years of service[1] to the *Canadian Field-Naturalist* (a journal of field biology and ecology with global recognition). He was Editor-in-Chief[2] for 34 years (Figure 1). Francis' influence on the Ottawa Field-Naturalists' Club, the *Canadian Field-Naturalist*, and field biology in temperate and arctic North America was not just long in duration, it was immense.

The *Canadian Field-Naturalist* (1919 onwards) and its predecessors, *Transactions of the Ottawa Field-Naturalists' Club* (1887–1918) and *The Ottawa Naturalist* (1879–1887), have had 29 Editors-in-Chief. Only four of these have served for 10 or more years (Brunton 1986): James Fletcher (10 years), Arthur Gibson (12 ¾ years), Douglas Leechman (11 years), and Harold Senn (13 ¼ years). Thus the editorial contribution of Francis Cook is three times that of any other editor over the 136-year period of publication. The total number of volumes, issues, and pages Francis edited is 35, 137, and 19 275! This does not include the editorial work done on papers that were submitted to the journal and reviewed but ultimately not published. The amount of editorial work on manuscripts and communication with authors, Associate Editors, printers, Copy Editors, and business managers represented by these figures consumed an enormous amount of time over many years.

The numbers clearly prove that Francis served the Canadian field biology community as an editor for an exceptionally long period, and perhaps longer than anyone else. However, his achievement was not only a function of time, it also had much to do with the way he did the job. The success of peer review in scientific journals ultimately relies on the expertise and good judgement of the editor, who acts as a mediator between reviewers and authors and ultimately decides if and when a paper is ready for publication. Francis consistently made clever editorial decisions and he brought the skills of a great field biologist to the role, which helped to maintain the quality of the science in the journal. He also had a kind and patient disposition that maximized the beneficial outcome of interactions with authors. Because he was so widely respected, he had no difficulty in gathering around him and leading a skilled group of Associate Editors from across North America.

Francis devoted much time to helping authors conceptualize their ideas and write their manuscripts so that acceptance and publication could be achieved and research findings could be effectively communicated. He was always particularly supportive of independent (non-institutional) contributors. Under his guidance and encouragement, the *Canadian Field-Naturalist* published the first of what unfolded as a lifetime of scientific contributions from more than a few independent researchers. When asked if he helped authors perfect their manuscripts more than may have been necessary to reach publication standard, Francis might have told this story (Cook 2002): Englishman James Smithson, the son of the Duke of Northumberland, mysteriously left his fortune to the United States of America, to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men. The mystery was, why did he leave his money to the United States? James may have admired the equalitarian society of the newly formed United States. It is also speculated that he became embittered by the rejection of one of his manuscripts by the editor of the Royal Society. The Smithsonian Institution, with the greatest collections in the world, was born in Washington in 1846. In other words, if the editor at the Royal Society had helped Smithson to bring his manuscript to publication standard, rather than reject it, the Smithsonian Institution might have ended up in the United Kingdom. This is an amusing way of saying that we cannot help each other enough!

Figure 1. Dr. Francis Cook working on the *Canadian Field-Naturalist* in 1984. The photo appeared originally in the Canadian Association of Herpetologists Bulletin 18(1). 2010. Photo: Joyce Cook.

At his core Francis has always been a field naturalist as well as a scientist. As editor, he openly promoted the importance of basic observational input into our understanding of the natural sciences, and he strongly supported publication of important observations in the *Canadian Field-Naturalist* to make the information available.

Francis was committed to the idea that an independent journal of natural history was needed and could only be supported in Canada by subscriptions by both lay naturalists and employed professionals, as neither group alone would be strong enough to finance a peer-reviewed journal. It has proven to be an extremely successful concept over the years. The *Canadian Field-Naturalist* is regarded both as an essential component of the Ottawa Field-Naturalists' Club and as an effective scientific journal.

In his first term as editor Francis learned the job from previous editor Robert A. (Bob) Hamilton who would stress again and again, that authors defended each manuscript submitted with the ferocity of a mother with a new child. "Each manuscript involved incredible labour, certainly psychological labour to bring to submission, and was often regarded as perfection in the same way a new child is seen by a parent as flawless. To bring to an author's attention that anonymous strangers have suggested that alterations would be a good idea, is a delicate matter indeed" (Cook 2002). Hamilton's observation reminds us that it is not always easy to be an editor, but Francis dealt effectively with the misunderstandings and differences of opinion among authors, reviewers, editors, and even readers that are routinely encountered in science.

As well as providing a lengthy tenure of excellent editing and leadership for the *Canadian Field-Naturalist*, Francis made many important contributions and innovations to the publications program of the Ottawa Field-Naturalists' Club. Especially notable was his work on the *ad hoc* Publications Review Committee, appointed by the Ottawa Field-Naturalists' Club council from 1980 to 1981, with a mandate to improve the definition of the editorial position and to develop a policy guiding the amount of scientific versus popular content published in the journal – an issue about which there were considerable and strong differences of opinion among council members and the editorial team. Francis was respected as both a naturalist and a scientist, and he successfully navigated the delicate relationship that had developed between the Ottawa Field-Naturalists' Club council and *Canadian Field-Naturalist* supporters. Francis then came to the rescue at a time when the future of the journal seemed uncertain, and stepped forward as editor for a long second term. His understanding of the important role of the *Canadian Field-Naturalist* as a key, nationally-focused output of the Ottawa Field-Naturalists' Club, as well as its role in the broader science publishing ecosystem in Canada, was exactly what was needed at the time. It continues to serve as a guiding principal for the journal.

From 1984 to 2002 Francis worked with Bob Campbell (Renaud 2011) of the federal Department of Fisheries and Oceans and the Canadian Wildlife Service to publish reports commissioned by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) on threat status. These included annual reports, status reports, and updates on 89 fishes and 51 marine mammals. In addition, the *Canadian Field-Naturalist* published status reports on one amphibian, two reptiles, two birds, two mammals, one invertebrate, and 12 plants. Publication in the *Canadian Field-Naturalist* was very important at the time because COSEWIC had no other way of disseminating the important conservation information presented in the status reports[3]. Additionally, a series of provincial government-supported "status evaluations" that updated status reports on British Columbia plants was published in 2006 (*Canadian Field-Naturalist* 120(2)). Papers that made contributions to our understanding of conservation status of species and ecosystems became a regular feature of the *Canadian Field-Naturalist* thereafter.

During his editorship, Francis strongly promoted "special issues" of the *Canadian Field-Naturalist* that focused on specific and important topics. The "1980s Peregrine Falcon Update" contained 13 articles reporting current research and updating the analyses presented in the original special issue a decade before (1970, *Canadian Field-Naturalist* 84(3)), which contributed to a number of successful conservation efforts. Other special issues of lasting value were: "The history of the exploration of the Vascular Flora of Canada, Saint-Pierre et Miquelon and Greenland" (1995, *Canadian Field-Naturalist* 109(3)); "A life with birds: Percy A. Taverner, Canadian Ornithologist, 1875–1947" (1996, *Canadian Field-Naturalist* 110(1)); "The orchids of the Ottawa District" (1997, *Canadian Field-Naturalist* 111(1)); and "A passion for wildlife: The history of the Canadian Wildlife Service" (1999, *Canadian Field-Naturalist* 113(1)).

Francis wrote 28 annual reports of editorial work and also made numerous contributions to the *Canadian Field-Naturalist* as an author in a non-editorial capacity. He published 115 reviews of books, mostly herpetology, and 22 scientific articles about reptiles and amphibians in the journal. He also served as author and co-author of many tributes to Canadian biologists in a number of different fields.

The significant improvements in the *Canadian Field-Naturalist* made by editors who preceded his second term, Ted Mosquin (vol. 81(1) – vol. 86(3)) and Lorraine Smith (vol. 86(4) – vol. 95(3)), were much appreciated by Francis. He noted that Ted gave the *Canadian Field-Naturalist* a social conscience and increasing conservation content, and that Lorraine raised editorial standards. Francis continued to promote these values. His recognition of previous editorial achievements also contributed to his success.

Honorary Membership of the Ottawa Field-Naturalists' Club was conferred on Francis "for service to the Club and herpetological work" in 1998 (OFNC 1998), but he remained editor of the *Canadian Field-Naturalist* for 12 more years and then served as an Associate Editor for five additional years. He received the Ottawa Field-Naturalists' Club Member of the Year Award in 1990 for getting the journal caught up to schedule (OFNC 1990) at a time when production and publication had slowed. In 2010 he received the Ottawa Field-Naturalists' Club Member of the Year Award (Allison *et al.* 2010), again in recognition of his contributions to the *Canadian Field-Naturalist*. Part of the citation read: "…he has maintained the *Canadian Field-Naturalist* as the most scientifically important and visible aspect of the club". For the success of the *Canadian Field-Naturalist*, the Ottawa Field-Naturalists' Club received the prestigious Richardson Natural History Education Award Trophy in 1996 from Ontario Nature. The award is given for special contributions to natural history education (Pope 1997; Catling *et al.* 2010: 84).

Francis has served as a very strong member of our Canadian biology team. During his more than 48 years of service to the Ottawa Field-Naturalists' Club, he has extensively advanced two of the three club objectives: "(1) To promote the appreciation, preservation, and conservation of Canada's natural heritage, and (2) To encourage investigation, publish the results of research in all fields of natural history, and diffuse the information as widely as possible". His immense contribution to Canadian and international field biology is a source of great pride.

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PAUL CATLING, DAN BRUNTON, JEFF SAARELA, FRANK POPE – OFNC PUBLICATIONS COMMITTEE

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[1] Publications-related work of Francis Cook for the Ottawa Field-Naturalists' Club and dates: Member of the Ottawa Field-Naturalists' Club Publications Committee from 1962 to 1966, and again from 1981 to 2010. Associate Editor for herpetology from 1972 to 1981, and for herpetology and tributes from 2011 to 2016. Editor-in-Chief of the *Canadian Field-Naturalist* from 1962 to 1966 and again from 1981 to 2010.

[2] There is an honourarium for the *Canadian Field-Naturalist* editor, but during most of the time Francis served as editor it was transferred to a research support fund at the Canadian Museum of Nature, where he was employed.

[3] Information about endangered species was broadly publicized in the *Canadian Field-Naturalist* and the journal thus contributed directly to the conservation of wildlife in Canada. COSEWIC status reports were later made available through the *Species at Risk Act* (SARA) Public Registry http://www.sararegistry.gc.ca/search/advSearchResults_e.cfm?stype=doc&docID=18.

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