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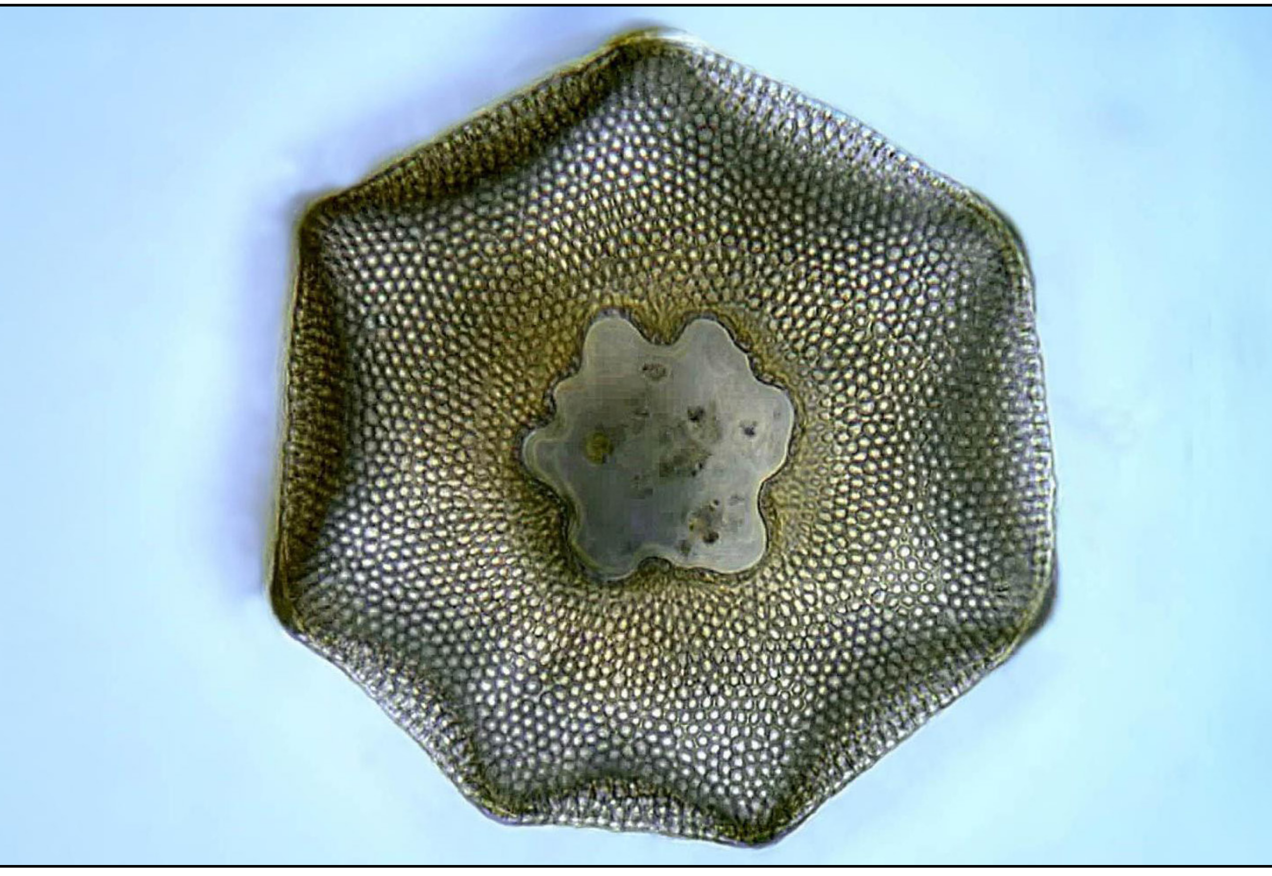

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The Ottawa Field-Naturalists' Club

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COVER: A new species of a free-living one-celled amoeba, *Arcella prismatica* sp. nov., discovered from two widely separated locations: Mer Bleue Bog Conservation Area in Ottawa and a subarctic peatland on the James Bay coast, Quebec. The photograph is of the ventral or lower surface of its shell, or test, viewed through a light microscope. The diameter is approximately 0.1 mm. See the article by Taylor *et al*. (1–15). Photo: Bruce D.S. Taylor.

The Canadian Field-Naturalist

A new species of testate amoeba, *Arcella prismatica* sp. nov. (Amoebozoa: Arcellinida), from peatlands in Ontario and Quebec, Canada

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Abstract
Arcella is a genus of testate amoebae with a radially symmetrical shell composed of secreted material arranged in hexagonal units. Within the genus, species are distinguished by the morphology and dimensions of the shell. We describe a new species, *Arcella prismatica* sp. nov., discovered in a brown-water lake in the Mer Bleue Bog Conservation Area, a protected wetland in the city of Ottawa, Ontario, Canada. Specimens of the same morphotype have also been found in a subarctic peatland on the James Bay coast, near the village of Chisasibi, Quebec, Canada. The species has a polyhedral shell with a relatively flat dorsal surface and an irregularly crenulated aperture, a combination of characters not found in other members of the genus. The discovery of a novel and evidently widely distributed *Arcella* within the limits of a populous North American city is a reminder that the diversity of microbial eukaryotes is still poorly understood. Further exploration of undersampled peatland habitats can be expected to reveal new organisms and new relationships among known species.

Key words: *Arcella*; Arcellidae; Arcellinida; testate amoebae; Mer Bleue; James Bay peatlands

Introduction

The genus *Arcella* Ehrenberg, 1830 comprises testate amoebae whose shells are radially symmetrical and composed of secreted material, presumably chitinous, arranged in hexagonal units (Meisterfeld 2002). These free-living protists are mainly found in freshwater and moist mosses, but also in soil and dry mosses.

Arcella was erected in 1830 by the pioneering protozoologist C.G. Ehrenberg, for "shelled infusoria" ("*Kapselthierchen*"; Ehrenberg 1830: 74) equipped with a "carapace [that is] shield-shaped" ("*Panzer schildförmig*"; Ehrenberg 1832: 90). Initially, Ehrenberg (1830) described three species, with *Arcella vulgaris* Ehrenberg, 1830 as the type of the genus. In following years, the number of species assigned to the genus increased steadily, and, by the first decade of this century, about 51 nominal species with 71 varieties and subspecies and 27 forms were accepted (R. Meisterfeld unpubl. list, pers. comm. to F.J.S., 24 September 2018). Another 52 species, varieties, and forms had been described, but these were (variously) synonyms, *nomen nudem* ("naked name", i.e., one that does not meet the requirements of the rules of zoological nomenclature), *lapsus calami* ("slip of the pen", i.e., errors), or species belonging to another genus (R. Meisterfeld, unpubl. list, pers. comm. to F.J.S., 24 September 2018).

Recently, the circumscription of *Arcella* has changed, following a major revision of the family based on molecular phylogenetics (González-Miguéns *et al.* 2022). In that work, the new genus *Galeripora* González-Miguéns, Soler-Zamora, Villar-dePablo, Todorov and Lara, 2021 was erected, comprising arcellid species whose shells carry pores around the mouth or aperture. Six new species of *Galeripora* were described and six species previously assigned to *Arcella* were formally transferred to the new genus. Appendix S1 in González-Miguéns *et al.* (2022) also compiled a synonymic list of names in the family, recognizing 63 valid species of *Arcella* and 48 varieties and forms.

A contribution towards the cost of this publication has been provided by the Thomas Manning Memorial Fund of the Ottawa Field-Naturalists' Club.

Since that work, three new species of *Arcella* have been described (Useros *et al.* 2023), and five more species historically placed in *Arcella* have been transferred to *Galeripora* (Siemensma 2021). The 61 species that remain in *Arcella* are those that have no pores. It is possible that this genus will be further split, in due course, on the basis of molecular sequence data.

As with other members of the order Arcellinida, which includes about 86 genera (Siemensma 2024), species of *Arcella* are distinguished from one another mainly based on shell morphology (Meisterfeld 2002). Features commonly used to characterize species of *Arcella* include the diameter and height of the test, the form of the aperture or pseudostome (the depth of the invagination, the margin of the opening, which may be smooth, lobed, or crenulate), the shape of the test in profile and ventral view, and notable characters such as depressions or undulations in the dorsal surface and spines or ribs on lateral faces (Nicholls 2005; Reczuga *et al.* 2015; Feres *et al.* 2016; González-Miguéns *et al.* 2022). However, since the application of molecular analysis, it has been demonstrated that the presence of cryptic morphologies makes it impossible to differentiate some closely related species based only on shell morphology (Porfírio-Sousa *et al.* 2017; Soler-Zamora *et al.* 2023).

In this paper, we describe a new *Arcella* species, *Arcella prismatica* sp. nov., based on morphometric and morphological characters. This distinctive and easily identified species was discovered in a drainage arm of the Mer Bleue bog, Ontario, Canada, among floating filamentous algae and aquatic plants, and subsequently found in the Eeyou Istchee region of Quebec, among *Sphagnum* L.

Methods

Mer Bleue

The Mer Bleue bog (45.392376°N, 75.509063°W; Figures 1a,b, 2a) is a large, raised, ombrotrophic peatland within the city limits of Ottawa, Ontario, Canada. It is a remnant wetland, located in a system of channels left by glacial meltwater streams formed during the retreat of the Champlain Sea, during the early Holocene (Mott and Camfield 1969; Fraser *et al.* 2001; Roulet *et al.* 2007; Elliott *et al.* 2012). As post-glacial isostatic uplift pushed the Champlain Sea to the east, the drainage basin now occupied by Mer Bleue filled with fresh water and began a gradual transition from lake and marsh to fen and finally to raised bog. The accumulation of peat began about 8500 years ago, and the transition from fen to bog began about 2000 years later (Bubier *et al.* 2006). As it exists today, Mer Bleue is an isolated pocket of subarctic habitat, supporting an assemblage of plant and animal species usually found much further north in the boreal (taiga) climate zone. Because of its regionally unique ecology, it is designated as a "wetland of international importance" under the Ramsar Convention and classified by the government of Ontario as an "Area of Natural Scientific Interest (ANSI)" (Ramsar n.d.; National Capital Commission n.d.).

On its west side, Mer Bleue has three drainage fingers which discharge slowly into a creek connected with the Ottawa River (Fraser *et al.* 2001).

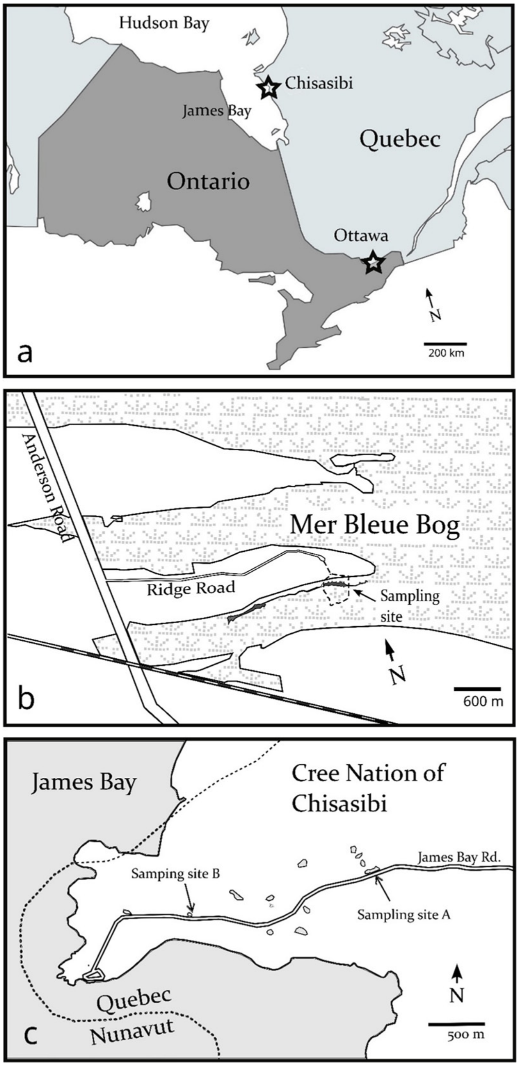

FIGURE 1. Map of study areas. a. Stars mark the locations of Mer Bleue bog, Ottawa, Ontario, and two sampling sites in Chisasibi, Quebec. b. Close view of Mer Bleue, showing the drainage fingers. The study site (45.392376°N, 75.509063°W) is marked with an arrow. c. Close view of two sampling sites on James Bay Road, outside the town of Chisasibi: site A 53.795167°N, 79.039833°W; site B 53.791556°N, 79.065139°W.

FIGURE 2. Sampling site at a. the type locality in Mer Bleue, Ottawa, Ontario, and b. site A at Chisasibi, Quebec. Photos: Bruce D.S. Taylor.

The southernmost of these channels contains a narrow brown-water bog lake fringed with Broad-leaved Cattail (*Typha latifolia* L.), at the east end of which is a boardwalk installed and maintained by Canada's National Capital Commission. In a shallow marsh accessible from the boardwalk, small mats of filamentous green algae (e.g., *Mougeotia* C. Agardh, *Zygnema* C. Agardh, and *Spirogyra* Link) form near the surface, sometimes among floating stolons of Greater Bladderwort (*Utricularia vulgaris* subsp. *macrorhiza* (Leconte) R.T. Clausen) and other pond species, such as Watershield (*Brasenia schreberi* J.F. Gmelin; Figure 2a). These mats provide a distinctive microhabitat in the low-nutrient water, often dominated by microbial phototrophs and their predators, as well as mixotrophic organisms harbouring algal endosymbionts, such as the ciliates *Stentor pyriformis* Johnson, 1893 and *Dileptus* cf. *viridis* (Ehrenberg, 1833) Foissner, 1987.

Water samples were collected by B.D.S.T. from the same location in 2014 and 2022. On 18 May 2014, samples were drawn from three sites along the Mer Bleue bog interpretive trail, all within 100 m of the location marked in Figure 1b. Three jars, each containing ~100 mL of material, were taken for further study. From each jar, 2–3 mL of material was transferred to a 100-mL polystyrene Petri dish, then examined under a stereo microscope (Acuter 2L, Taoyuan, Taiwan) at 40× magnification. Specimens of the novel arcellid were picked out individually with a glass micropipette, deposited in a watch glass, and rinsed several times in clear water to separate them from other organisms and attached detritus. Specimens were transferred to micro-centrifuge tubes and sent to F.J.S. for study, measurement, and light microscope imagery and to M.C.S.K. for imaging by scanning electron microscopy (SEM). Individual shells were picked from the ethanol-fixed sample, placed on SEM stubs with carbon tabs, arranged with the help of an eyelash brush, and air-dried. Observation and imaging were done in a Hitachi S-570 SEM (Hitachi, Tokyo, Japan) at various magnifications.

On 6 May 2022, the same sampling procedures were repeated, at six sites along the eastern boardwalk at Mer Bleue. Samples from two of these sites contained the novel species *A. prismatica*. Specimens were set aside for imaging and measurement in the light microscope. Observations and measurements were carried out with a Motic 310E compound microscope (Motic, Xiamen, China), equipped with a RisingCam 20 MP USB camera (RisingCam, Hangzhou, China). Digital microphotographs of each shell were recorded at 400× magnification, with RisingView v. 4.11 imaging software (a proprietary version of ToupView, from ToupTek Photonics, Hangzhou, China), and measured with tools incorporated in the same software. Morphometric data (Appendix S1) were gathered on seven traits: number of ribs, diameter of shell, height of shell at the centre, height of shell at the highest side, height of aperture, diameter of aperture, and angle of sides with respect to the ventral plane.

Chisasibi

The Cree Nation of Chisasibi is 944 km north of Mer Bleue in the drainage basin of James Bay, the southernmost part of the Arctic Ocean (Figure 1a). The climate is subarctic but modified by coastal weather effects (Hennigs and Bleau 2017). The biome is northern boreal (taiga), grading into tundra along the coast.

On 4 November 2022, samples were taken from two *Sphagnum* pools (sites A and B in Figure 1c), located ~12 km northwest of the community of Chisasibi. Both sites are small fens of the graminoid type (Sims *et al.* 1982), dominated by grasses and sedges, with shallow expanses of open water broken up by mats of *Sphagnum*. At site A (53.795167°N, 79.039833°W; Figure 2b) 200 mL of water and vegetation were extracted from a partly submerged hummock of Streamside Sphagnum (*Sphagnum riparium* Ångström). At site B (53.791556°N, 79.065139°W), a second sample was collected in a patch of Spiky Bogmoss (*Sphagnum squarrosum* Crome). Both samples were examined under a light microscope and found to contain *A. prismatica*. Sixty-five specimens collected from site A were measured with the same equipment and procedures used for the Mer Bleue samples (Appendix S1). Specimens from site A were imaged in SEM, using a Quanta FEG-250 (Quanta, Eindhoven, The Netherlands), at various magnifications.

Taxonomic Description

Amoebozoa Lühe, 1913, *sensu* Cavalier-Smith, 1998
Class Tubulinea Smirnov *et al.*, 2005
Order Arcellinida Kent, 1880
Infraorder Sphaerothecina Kosakyan *et al.*, 2016
Family Arcellidae Ehrenberg, 1843

Arcella prismatica sp. nov.

Diagnosis

Shell polyhedral with 5–8 ribs. Sides steeply angled and often nearly perpendicular to the ventral plane. Dorsal surface usually flat, concave or slightly domed, rarely with a pronounced dome or peak. Aperture circular, with a crenulated edge. Diameter of the ventral surface 81–115 µm; height 60–87 µm (data from 87 shells collected in Mer Bleue and 65 shells collected in Chisasibi). Pseudopods barely protruding from the aperture and never extending laterally beyond the outer margin of the shell.

Description

The proteinaceous shell is transparent and colourless when newly formed, then gradually darkening to gold, and eventually dark brown. The ventral margin is usually polygonal (Figures 3b,c, 4a), but sometimes nearly circular. The dorsal margin is angular, approximating a polygon (Figure 3h), with five to eight edges, which may be slightly convex or markedly concave. In most individuals, the dorsal region has no folds or creases, but is made up of a continuous surface, usually flat (Figure 3d,e), but also sometimes depressed at the centre (Figures 3i, 4d), or slightly raised (Figure 3a,g). In some cases, the top may be distinctly domed (Figure 4c) or equipped with a peaked ridge or creases (Figures 3f, 4e). The dorsal face may be nearly parallel to the ventral one (Figure 3e), or slightly sloped from side to side (Figure 3d,i). In lateral view some ribs are visible, mostly parallel (Figures 3d,g,i, 5b), but sometimes converging or tapering distally (Figure 3a).

The aperture is about a third as wide as the shell and slightly invaginated. The opening consists of 7–10 relatively large crenulations, often somewhat irregular or ragged in appearance (Figures 3b,c, 4a,f, 5a).

In vivo, the amoeba is usually entangled in filaments of eukaryotic algae or leaves of *Sphagnum*, often in large numbers. Cytoplasm is often greenish from ingested algae. Pseudopods are bluntly lobose, hyaline, and often numerous, but short.

ZooBank registration: urn:lsid:zoobank.org:pub:1767947E-F9D5-44B8-B11A-BA6E4A705344

Type material

The holotype of *A. prismatica* was preserved with Permount SP15-100 mounting medium (Fisher Scientific, Hampton, New Hampshire, USA) on a microscopic slide. Thirteen slides with paratypes were prepared in the same way. The slides were deposited in the Invertebrate Collection at the Canadian Museum of Nature in Ottawa, catalogue number CMNI 2022-0447 (holotype) and CMNI 2022-0448–4460 (paratypes).

Type locality

A cattail marsh at the east end of a brown-water lake in the Mer Bleue Bog Conservation Area, Ottawa, Ontario, Canada, at 45.392376°N, 75.509063°W, among floating filamentous algae and *Utricularia* sp.

Etymology

The species name refers to the typical shape of the shell and derives from the Late Latin *prisma*, meaning a polyhedron with parallel sides and flat parallel faces at each end. Feminine gender.

Morphometrics

See Table 1 and Figure 6.

Differential diagnosis

Arcella prismatica can be easily distinguished

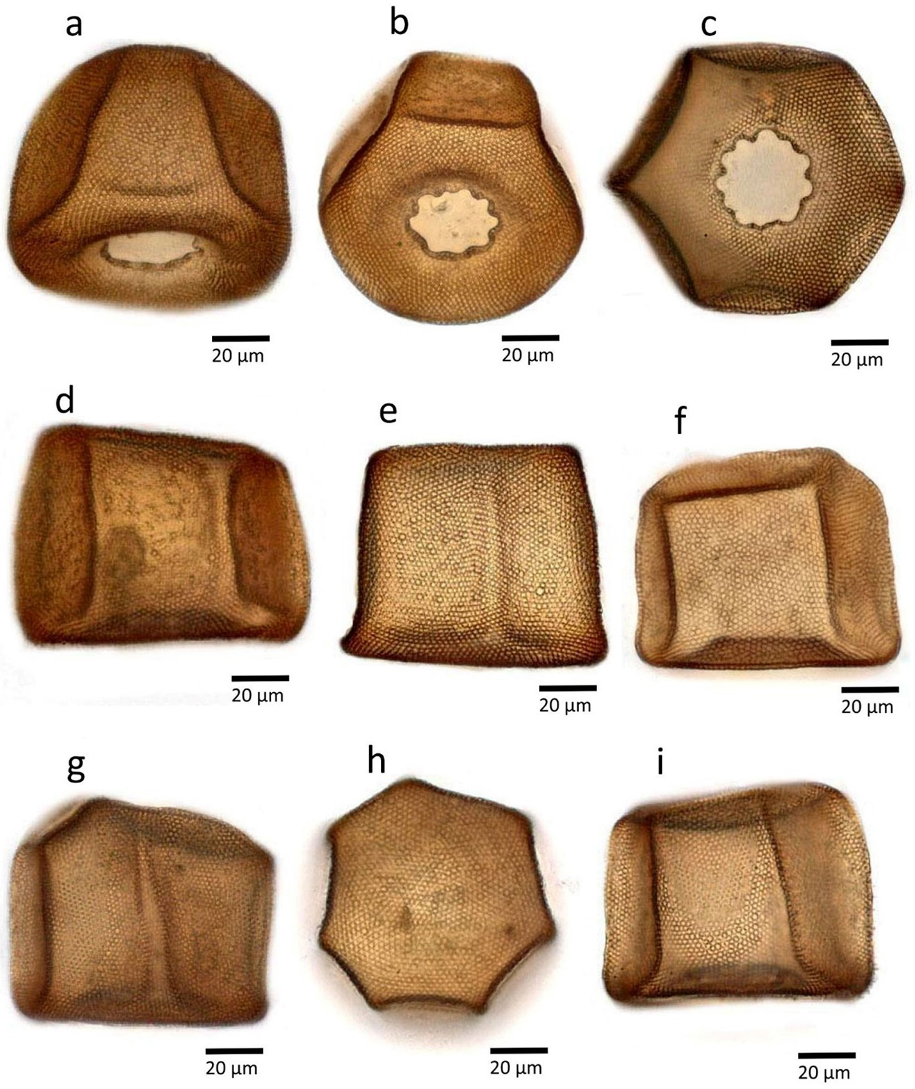

FIGURE 3. *Arcella prismatica* viewed with a light microscope. a. Shell in lateral view. b and c. Ventral area with crenulated aperture. d and e. Shells with flat dorsal surface, lateral view. f and g. Shells with slightly peaked dorsal surface, lateral view. h. Shell with flat dorsal surface, dorsal view. i. Shell with sunken (concave) dorsal surface, lateral view. Photos: Ferry J. Siemensma.

from *Arcella conica* (Playfair, 1918) Deflandre, 1926 and *Arcella costata* Ehrenberg, 1847 and its variety *angulosa* (Perty) Playfair, 1918, all of which have a smooth apertural edge. It can be distinguished from *Arcella spectabilis* Deflandre, 1928, which is more spherical, has many undulations, and never has a flattened dorsal area; and from *Arcella leidyana* Deflandre, 1928, which is almost twice as large, with its smallest diameter at the ventral face and a dorsal surface in the form of a rounded pyramid (Figure 7b from Deflandre 1928: 277)

Discussion

Comparison to similar species

In its type locality—where samples have been collected on numerous occasions between May and October, from 2014 to 2022—specimens of *A. prismatica* are very consistent in size and shape. Morphology and measurements of specimens from James Bay agree with those of specimens from Mer Bleue. The species is easily distinguished from other arcellids found in the same water, such as *Galeripora artocrea*

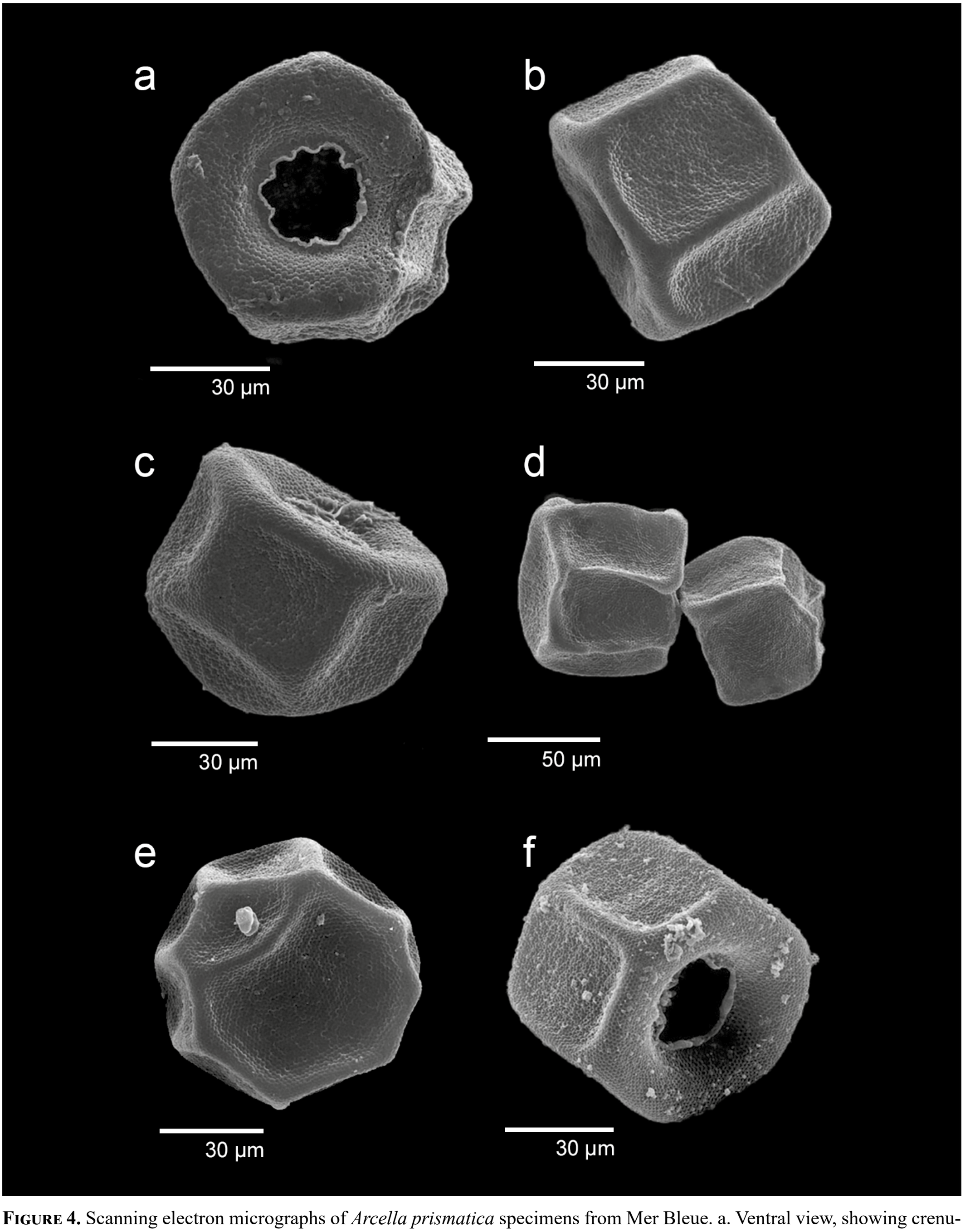

FIGURE 4. Scanning electron micrographs of *Arcella prismatica* specimens from Mer Bleue. a. Ventral view, showing crenulate aperture. b. Shell with flat or concave dorsal surface, lateral view. c. Shell with domed dorsal surface, lateral view. d. Two shells, one with a creased dorsal surface, lateral view. e. Shell with a creased dorsal surface, dorsal view. f. Shell with sides nearly perpendicular to the ventral face. Photos: Michaela C. Strueder-Kypke.

(Leidy, 1876) Gonzalez-Miguens, Soler-Zamora, Villar-Depablo, Todorov & Lara, 2021, *Arcella mitrata* Leidy, 1876*, A. spectabilis*, *Arcella crenulata* Deflandre, 1928, and members of the species complex made up of *Arcella hemisphaerica* Perty, 1852 and *Arcella rotundata* Playfair, 1918. *Arcella conica* (Playfair,

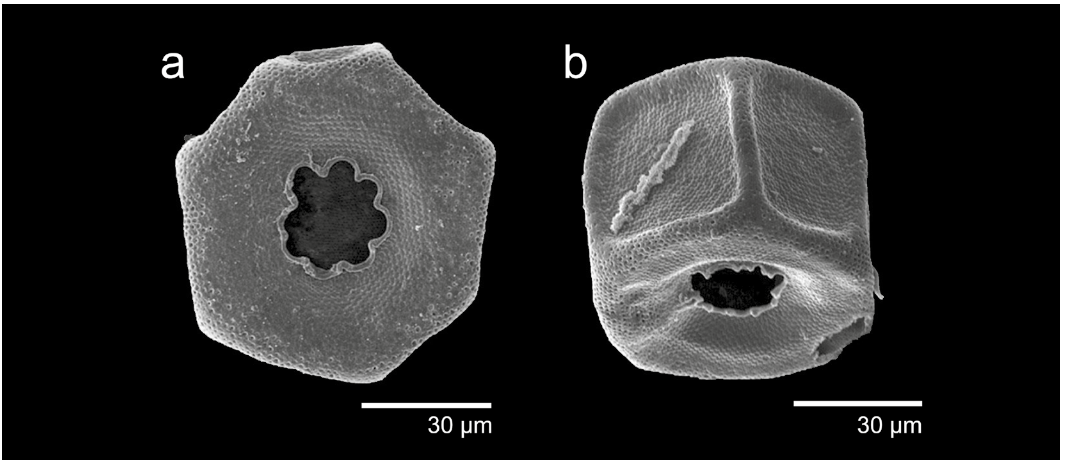

FIGURE 5. Scanning electron micrographs of *Arcella prismatica* specimens from Chisasibi. a. Ventral view, showing crenulate aperture. b. Semi-profile, showing the ribbed sides and flat dorsal surface of the shell. Photos: Michaela C. Strueder-Kypke.

TABLE 1. Morphometrics of *Arcella prismatica* sp. nov. population in Mer Bleue and Chisasibi (see Figure 8, Appendix S1). Measurements in µm.

Character	*n*	Mean	Median	Min.	Max.	SEM	SD	CV
Mer Bleue								
Base diameter	87	94.6	93.8	81.0	114.8	0.6	5.5	5.8
Top diameter	37	78.3	78.2	55.0	97.0	1.5	8.9	11.3
Height at centre	34	74.8	73.9	60.0	87.4	1.1	6.4	8.6
Height at side	34	71.2	72.0	59.7	84.4	1.1	6.2	8.7
Aperture diameter	41	30.5	31.0	26.6	32.9	0.3	1.8	5.9
Aperture height	16	11.1	11.2	8.9	13.2	0.4	1.6	14.8
Angle of sides	36	85.5	85.3	74.0	91.2	0.7	4.2	4.9
Number of ribs	42	6.1	6.0	5.0	8.0	0.1	0.7	12.1
Dorsal flatness*	34	1.0	1.0	0.8	1.1	0.0	1.0	9.4
Chisasibi								
Base diameter	65	97.4	96.8	86.0	114.4	0.8	6.4	6.5
Top diameter	54	84.0	85.2	66.0	95.6	1.0	7.4	8.8
Height at centre	38	71.5	71.3	60.9	86.3	1.3	11.6	7.3
Height at side	38	75.6	73.4	66.3	86.8	0.9	5.5	7.3
Aperture diameter	19	28.2	28.0	26.0	28.3	0.3	1.4	5.0
Aperture height	11	11.4	11.5	9.1	12.8	0.4	1.3	11.1
Angle of sides	35	85.4	85.9	74.1	90.3	0.7	4.0	4.7
Number of ribs	23	6.3	6.0	5.0	8.0	0.2	0.8	13.0
Dorsal flatness*	38	0.9	1.0	0.7	1.1	0.0	0.1	10.6

Note: CV= coefficient of variation; SEM = standard error of the mean.
*Dorsal flatness = height of shell at one side divided by the height at centre.

1918) Deflandre, 1926, which has a similar angular appearance, sometimes appears in samples taken nearby in Mer Bleue, but so far has not been found in the same samples as *A. prismatica*.

Although there are known arcellid morphospecies with which *A. prismatica* shares certain characters, none has the same combination of traits (Table 2).

In 1838, Ehrenberg published an illustration of a polygonal *Arcella* with a flat dorsal surface, which he identified as a variety of *Arcella dentata*. Perty (1852) later assigned this variety to the species *Arcella angulosa* Perty, 1852 and the same morphotype was

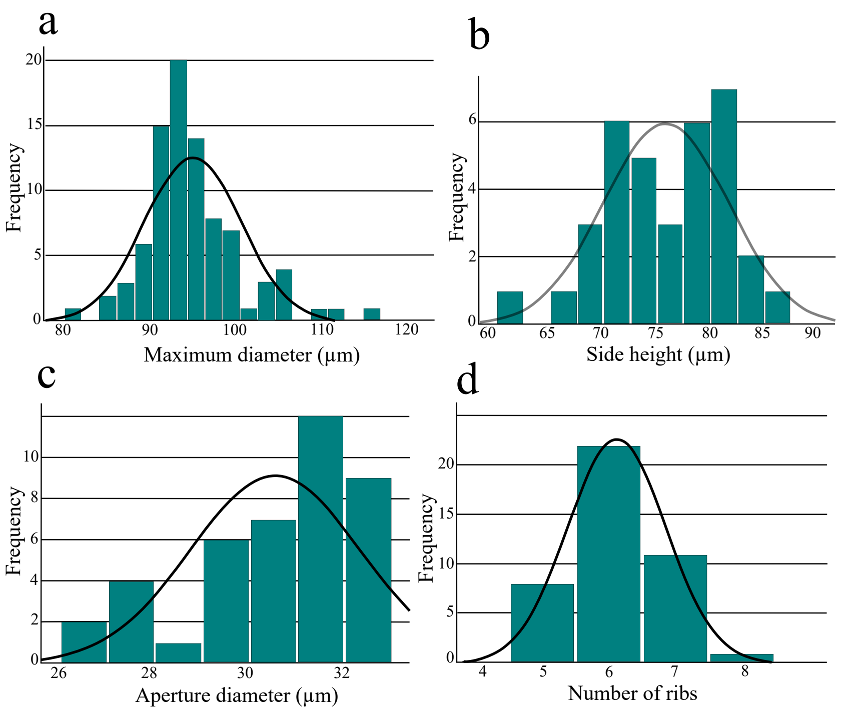

FIGURE 6. Distribution of traits of the Mer Bleue population of *Arcella prismatica*. a. Maximum diameter of the shell (mean = 94.62 µm, SD = 5.52 µm, *n* = 87). b. Height at highest side of the shell (mean = 75.80 µm, SD = 5.84 µm, *n* = 35). c. Diameter of the aperture (mean = 30.54 µm, SD = 1.79 µm, *n* = 41). d. Number of ribs on the sides of the shell (mean = 6.12, SD = 0.739, *n* = 42).

treated by Leidy (1879) as *Arcella vulgaris* var. *angulosa* (Perty, 1852) Leidy, 1879. Later authors regarded the form as belonging to the species *A. costata*, originally found by Ehrenberg in airborne dust (Ehrenberg 1847: 442; Penard 1902; Playfair 1918; Deflandre 1928). With its flat top and polygonal shape, Leidy's *A. vulgaris* var. *angulosa* (=*A. costata* var. *angulosa* *sensu* Playfair 1918) somewhat resembles *A. prismatica*. However, in that species, the aperture is smoothly circular, without crenulations or lobes, and the angle of the ribbed sides is less steep than that of *A. prismatica* (Figure 7a).

Leidy (1879) also recorded a faceted form of *A. mitrata*, which Deflandre (1928)—evidently without having observed the variant himself—promoted to species level as *A. leidyana* (Figure 7b). Similar to *A. prismatica*, it has nearly parallel sides and a polygonal outline in dorsal view. Deflandre (1928: 277) characterized its aperture as "ondulé plutôt que crénelé" (that is, "wavy rather than crenulate") and specified that the dorsal surface of the shell forms a "pyramidal dome" ("dôme pyramidal"). *Arcella leidyana* is also far larger—roughly twice as wide as the species we describe here, and about 2.35 times as tall—with a ventral face that is narrower than the shell at its maximum diameter (Deflandre 1928). That morphology is not seen in *A. prismatica,* in which the smallest diameter of the shell is never at the ventral face.

Arcella conica has a ribbed, polygonal shell, resembling that of *A. costata*. However, the shell has a peaked or conical dorsal surface, giving it, as Playfair (1918: 640) writes, "the appearance of a marquee-tent" (Figure 7c). The aperture is smoothly circular.

Among his illustrations of *A. mitrata*, Leidy (1879) included another faceted morphotype, which Deflandre (1928) redescribed as *A. mitrata* var. *spectabilis* (Figure 7d). Deflandre's dimensions, derived from Leidy's drawings, indicate that the subspecies is significantly smaller than the "balloon-shaped" forms of *A. mitrata*. Siemensma (2022) found the same morphotype in several Dutch peat bogs, and measurements of his populations (shell height 85–91 µm, diameter 91–98 µm, *n* = 25) agree well with Deflandre's (height 80–90 µm; diameter 86–91 µm). Because of its different shape and size and the fact that distinct populations bloom alongside the larger *A. mitrata*, Siemensma (2022) recognized *A. mitrata* var. *spectabilis* at species level as *A. spectabilis* Deflandre, 1928.

Arcella spectabilis has two characters in common with *A. prismatica*: a roughly polygonal shape

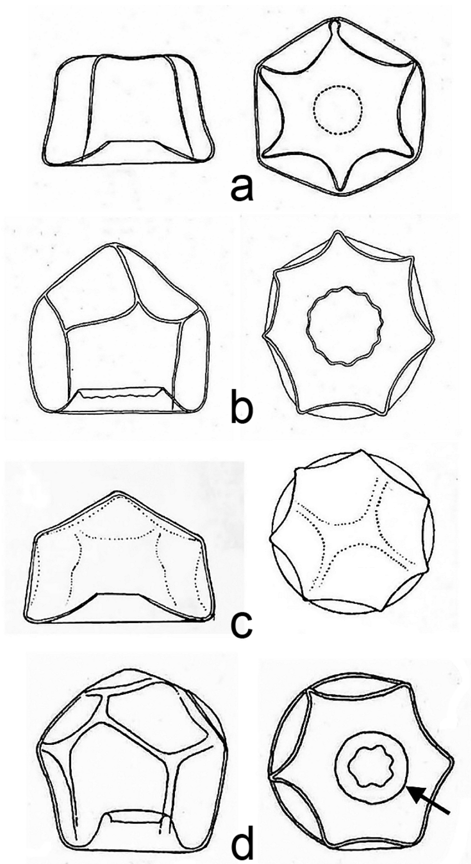

FIGURE 7. Illustrations of similar species, for comparison with *Arcella prismatica*. a. *Arcella costata* (after Ehrenberg, from Deflandre 1928). b. *Arcella leidyana* (after Leidy, from Deflandre 1928). c. *Arcella conica* (from Playfair, 1918). d. *Arcella spectabilis* (after Leidy, from Deflandre 1928). The arrow indicates the "concentric circle" mentioned by Deflandre as a character for *Arcella mitrata* var. *spectabilis*.

in ventral or dorsal view and a crenulate aperture. In Mer Bleue samples taken in 2022 from sites at which both *A. spectabilis* and *A. prismatica* occur, *A. spectabilis* individuals were always significantly ($P < 0.001$) larger than those of *A. prismatica*, with no significant overlap between any of the two species' important dimensions, except for the diameter of their apertures (Figure 9). In all populations of *A. spectabilis*, including those recorded by Leidy (1879) and Siemensma (2022) as well as those found in Mer Bleue, the appearance of the shell in lateral view is very different from that of *A. prismatica*. The dorsal face of *A. spectabilis* is domed and faceted, and never flat, smooth, or concave. Also, in that species the smallest diameter of the shell is at, or near, the ventral plane, whereas the shell of *A. prismatica* (as noted above) is widest at its ventral face. An additional difference concerns the depth of the apertural invagination (or "aperture height" as shown in Figure 8b). *Arcella spectabilis* has a deeply invaginated aperture—roughly twice as deep as that of *A. prismatica*—and a long, everted buccal tube, the top of which appears, in ventral view, as a concentric circle around the aperture, when examined by transmitted light microscopy (see arrow in Figures 7d, 10b). Deflandre (1928: 273) uses the presence of this circle as a diagnostic character for the variety: "bouche à bord crénéle avec cercle concentrique du au tube buccale" (that is, "mouth with crenulated margin with concentric circle due to buccal tube") and as a species character for *A. mitrata* itself. *Arcella prismatica* lacks a buccal tube, and this circular structure is not present in specimens from our study sites (Figure 3b,c) so does not fall within Deflandre's circumscription of var. *spectabilis*, or any variety of *A. mitrata*.

We do not have molecular data for *A. prismatica* or *A. spectabilis*. As there is some resemblance in

TABLE 2. Comparative morphometric data on species similar to *Arcella prismatica*.

Species	Shell		Aperture		Long buccal tube (concentric circle in ventral view)	Aperture crenulations	Dorsal surface
	Diameter, µm	Height, µm	Diameter, µm	Height, µm			
Arcella conica (Playfair, 1918) Deflandre, 1926	68–100	—	20–33	—	Absent	Absent	Peaked
Arcella costata Ehrenberg, 1847	52–100	—	—	—	Absent	Absent	Flat
Arcella leidyana (Leidy, 1879) Deflandre, 1928	184–188	168–176	56–88	22–23	Absent	Absent	Pyramidal
Arcella mitrata Leidy, 1876	100–180	100–162	20	23	Present	Present	Smooth dome
Arcella prismatica n. sp.	81–115	60–87	26–33	9–13	Absent	Present	Usually flat
Arcella spectabilis (Leidy, 1879) Deflandre, 1928*	107–136	109–131	26–36	22–32	Present	Present	Faceted dome

*Mer Bleue population.

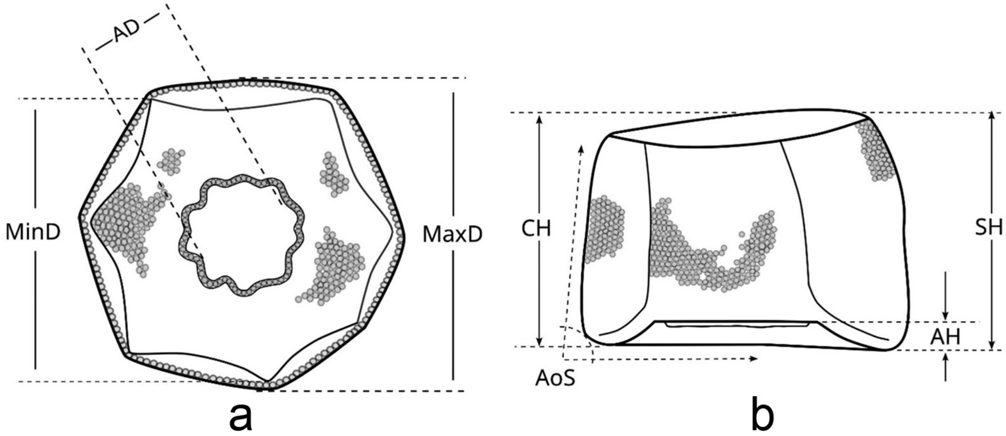

FIGURE 8. Outline of typical *Arcella prismatica*, illustrating measured characteristics. a. Ventral view. MaxD = diameter at base of shell; MinD = diameter at top; AD = aperture diameter. b. Lateral View. CH = height at centre; SH = height at highest side; AH = aperture height; AoS = angle of sides. Drawings: Bruce D.S. Taylor.

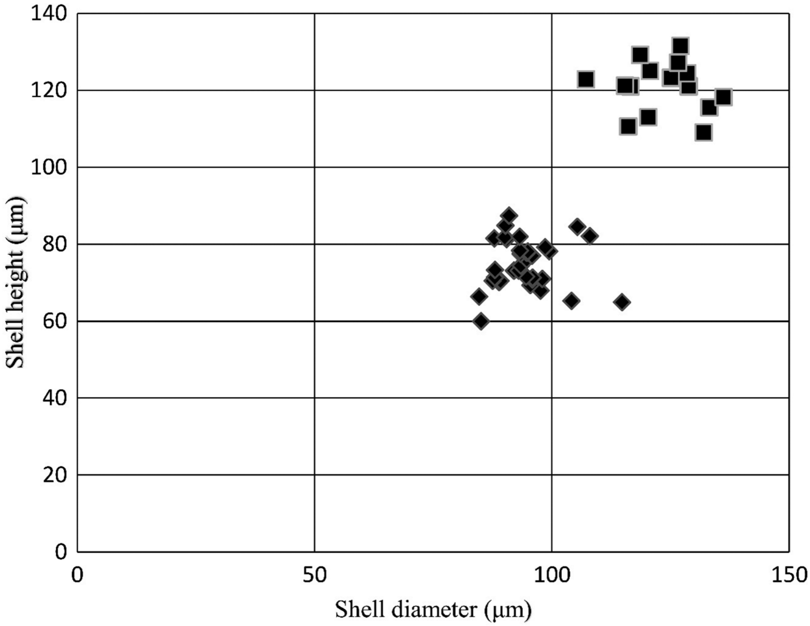

FIGURE 9. Comparison of shell size in populations of *Arcella prismatica* (diamonds) and *Arcella spectabilis* (squares) from Mer Bleue. Both height and diameter were measured (n = 50), and clustered tightly for both species. Shell height in *A. prismatica* (n = 87) differed significantly from *A. spectabilis* (n = 24; t_{106} = 20.09, P < 0.001). Shell diameter in *A. prismatica* (n = 35) differed significantly from *A. spectabilis* (n = 15; t_{48} = 29.58, P < 0.001). Not shown: aperture diameter did not vary significantly between *A. spectabilis* (n = 7) and *A. prismatica* (n = 41; t_{46} = 0.60, P = 0.55). Aperture height varied significantly between *A. spectabilis* (n = 12) and *A. prismatica* (n = 18; t_{28} = 20.71, P < 0.001).

shell shape, it may be asked whether both morphotypes are two different species or just display morphological variation within a single species. Such variation does not occur at random, but is an adaptation to environmental conditions, more influenced by external factors than by genetic inheritance (Mulot *et al.* 2017). Species living in similar environments may have the same overall shape but be distantly related (González-Miguéns *et al.* 2022). Also, intraspecific variability in the morphology of testate amoebae may be an adaptation to the environment, and morphological variability induced by environmental influences

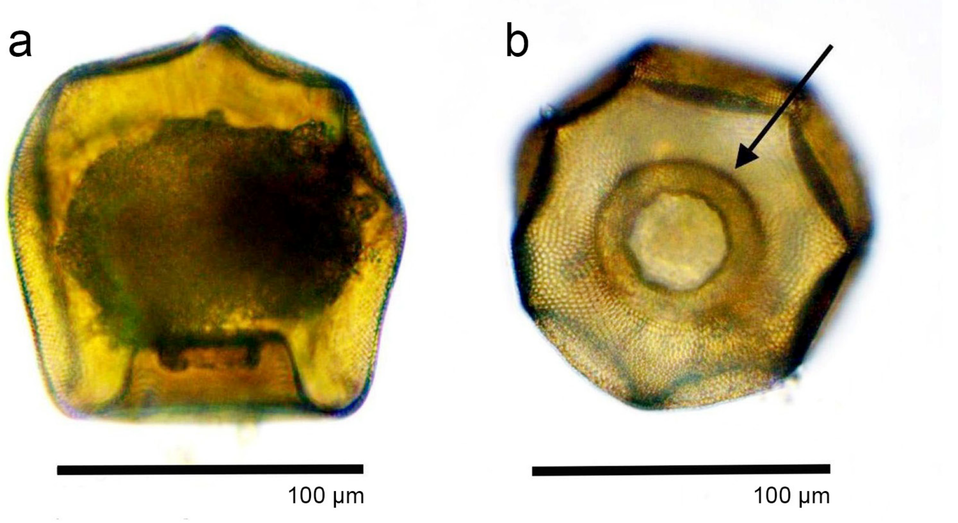

FIGURE 10. Two specimens of *Arcella spectabilis* from Mer Bleue. Arrow (b) indicates the characteristic "concentric circle" surrounding the aperture (Deflandre 1928: 277). The lateral view (a) shows typical features of *A. spectabilis*, with the smallest diameter of the shell at the ventral face, a pronounced buccal tube, and a deeply invaginated aperture. Photos: Bruce D.S. Taylor.

may result in taxonomical complications. Variability in, for example, pore numbers as well as size, is driven by phenotypic plasticity (Bobrov and Mazei 2004; Arrieira *et al.* 2016; Mulot *et al.* 2017). Although the morphotype described here could be a variation of *A. spectabilis,* the environmental conditions in our study were equal for both morphotypes as they are found living close together or intermixed in the same pond. In Mer Bleue populations, *A. spectabilis* blooms alongside *A. prismatica*, in company with other arcellid species (B.D.S.T. pers. obs.). A comparison of the two morphotypes in those populations shows significant differences in size and diameter of the shells, as well as the height (but not the diameter) of the aperture (Figure 9). In samples from Mer Bleue, the two species form distinct populations, with bimodal distribution of sizes and very little overlap in principal dimensions (Tables 1 and 3, Figure 9, Appendix S1 and S2). We consider this an important argument that these taxa are distinct species.

Deflandre's (1928) description of *A. mitrata* var. *spectabilis* is based on the observations and drawings of Leidy (1879). It is obvious that he never saw this species himself, as he mentions only North America in his comments on its geographic distribution. We have found *A. spectabilis* in Europe, at several locations in the Netherlands, always in water bodies with *Sphagnum*. A morphotype like *A. prismatica* has never been observed there. Also, Leidy (1879), who has seen and depicted *A. spectabilis* himself, does not record a morphotype like *A. prismatica* in the text or illustrations of his book. If *A. prismatica* is part of the phenotypic plasticity of *A. spectabilis*, that plasticity should also have been observed by Leidy and in the Dutch and Mer Bleue populations.

There is at least one early record of an arcellid that might be conspecific with *A. prismatica*. In a study of *Arcella* morphology*,* Cushman and Henderson (1906) included clear photomicrographs of a shell resembling our new species (Figure 11), but do not state where their specimens were collected. They identified it as *A. mitrata*, which Deflandre (1928) recognized as

TABLE 3. Morphometrics of *Arcella spectabilis* population at Mer Bleue (see also Appendix S2). Measurements in µm.

Characters	*n*	Mean	Median	Min.	Max.	SEM	SD	CV
Base (ventral) diameter	21	99.5	98.8	88.6	112.6	1.4	6.6	6.6
Maximum diameter	21	123.3	125.1	107.2	136.2	1.6	7.2	5.9
Height at centre	15	120.8	121.2	109.0	131.5	1.7	6.6	5.4
Aperture diameter	7	31.0	30.9	26.0	35.9	1.1	3.0	9.8
Aperture height	12	26.8	26.8	22.2	31.7	0.8	2.7	10.2

Note: CV = coefficient of variation; SEM = standard error of the mean.

a mistake, although he did not suggest an alternative identification. No view of the aperture was given, so reliable identification is not possible.

Ecology

In Mer Bleue, *A. prismatica* has been found in samples of surface water, in close association with algae and mixotrophic ciliates. It has so far not been retrieved from samples taken in the adjacent *Sphagnum*, the benthos, or in mineralized sediments at the north side of the drainage arm, where the lake is bounded by a forested ridge.

In Chisasibi, the novel amoeba was collected from the margins of two shallow ponds, in grassy fens, among hummocks of *Sphagnum*. These mires support a few small shrubs, but no trees, although they are surrounded on three sides by Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh). *Arcella prismatica* shells—both live and vacant—were most abundant in site A, where they were found entangled in the leaves of *S. riparium*, a transient species associated with wet minerotrophic conditions (Galka *et al.* 2018). The water at both sites is neutral to mildly acidic (pH 6.0–6.2, unpubl. data), and the assemblage of plant species identifies these as "open fens" according to the classification scheme outlined by Sims *et al.* (1982).

Habitat segregation within humic peatland lakes is still poorly understood (Kuczynska-Kippen 2008). It is evident that there are zones in these water bodies that support distinct and undersampled assemblages of microbial organisms and that close investigation of such microhabitats could reveal species rarely found elsewhere (Błedzki and Ellison 2003; Kuczynska-Kippen 2008). The possibility that floating clumps of vegetation in Mer Bleue represent a distinctive microhabitat is supported by the frequent occurrence of unusual ciliate taxa, including undescribed morphotypes of *Frontonia* Ehrenberg, 1838, *Dileptus* Dujardin, 1841, *Leptopharynx* Mermod, 1914, *Metacystis* Cohn, 1866, and *Pelagodileptus* Foissner, Berger & Schaumberg, 1999 (B.D.S.T. pers. obs). However, the appearance of a distinctive microbial life in such floating mats could also be an artifact of spotty sampling. Certainly, the occurrence of *A. prismatica* in less mature peatlands near the coast of James Bay shows that this species is not restricted to the conditions in which it blooms in Mer Bleue.

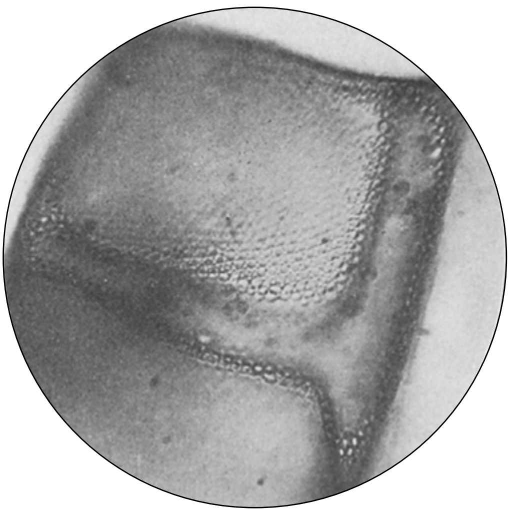

FIGURE 11. *Arcella* sp. ("1200× magnification"), reproduced from Cushman and Henderson (1906), originally identified as *A. mitrata*. Public domain.

In all our sampling sites, the species appears in heavily saturated vegetation in or adjacent to open water, so it is potentially of value for palaeohydrology as a wet indicator. The use of testate amoebae as proxies for palaeoecological conditions is well established (Hendon *et al.* 2001; Booth *et al.* 2008; Mitchell *et al.* 2008; Roe *et al.* 2017) and fossil testate amoebae found in Mer Bleue have already provided a detailed sequential record of environmental changes in the area (Elliott *et al.* 2012; Kopp *et al.* 2013). Although many species of *Arcella* and *Galeripora* have been recorded in analyses of Mer Bleue core samples (Talbot *et al.* 2010; Elliott *et al.* 2012), this novel arcellid has not been mentioned in the palaeoecological literature. To assess the suitability of the species as an indicator further investigation would be necessary.

Implications for arcellinid diversity

Arcella, compared to most groups of testate amoebae, is a well-known and well-characterized genus. The appearance of a novel species of this familiar genus within the limits of a populous North American city is a reminder that there are still large gaps in distributional data on freshwater protists. That this morphotype was quickly found again in samples taken nearly 1000 km away raises the possibility that it might be a common and widespread organism, at least in post-glacial peatlands of eastern Canada. However, genetic data would be needed to determine whether the morphotype, as we have described it, comprises a complex of cryptic species. Because this morphotype has been overlooked in earlier records from North America, its absence from studies conducted outside of the Nearctic biogeographic realm does not need to be interpreted as evidence of endemicity. This, too, could be an artifact of undersampling. That said, it is generally understood that arcellinid amoebae, with their durable and distinctive shells, are potentially useful organisms to test the hypothesis that some microbial species have biogeographically restricted ranges (Heger *et al.* 2012; Reczuga *et al.* 2015; Feres *et al.* 2016). As a species that is readily identified at low magnification and known to bloom prolifically in the locations where it occurs, *A. prismatica* might provide useful data for that discussion.

Author Contributions

Writing – Original Draft: B.D.S.T.; Writing – Review and Editing: B.D.S.T., M.C.S., and F.J.S.; Visualization: B.D.S.T., M.C.S., and F.J.S.; Conceptualization: B.D.S.T. and F.J.S.; Methods: B.D.S.T., M.C.S., and F.J.S.; Investigation: B.D.S.T., M.C.S., and F.J.S.

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SUPPLEMENTARY MATERIALS:

APPENDIX S1. Measurements of *Arcella prismatica* from Mer Bleue, Ontario, and Chisasibi, Eeyou Istchee, Quebec.
APPENDIX S2. Measurements of *Arcella spectabilis* shells from Mer Bleue, Ontario.

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Breeding pair and reproductive estimates of a recently expanded Red-necked Grebe (*Podiceps grisegena*) population in parkland Manitoba

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Abstract

Conservation of wildlife populations requires reliable information on population size, trends, and demographic processes. Such information is sparse for Red-necked Grebe (*Podiceps grisegena*), a species that is vulnerable to changing wetland conditions in the prairie pothole region. During 2008–2019, I collected breeding pair and reproductive estimates of a recently-expanded Red-necked Grebe population on 109 semi-permanent and permanent wetlands (mean ± SE: 2.92 ± 0.41 ha, range 0.01–24.2) in agriculturally-dominated habitat in southwestern Manitoba, Canada, to determine population status and reproductive success. I also looked for effects of changing wetland water levels and the presence of conspecifics and/or wetland size on productivity. Red-necked Grebe breeding densities were the highest reported for solitary-nesting pairs in North America and the breeding population currently appears to be stable. I found that chicks/breeding pair are mostly lower but chicks/successful pair are similar or greater than values reported from other studies. Pairs breeding with conspecifics appeared to be as productive as those on single-pair wetlands. Productivity was positively associated with wetland water levels suggesting that prolonged drought or climate change leading to warmer, drier summers on the prairies could reduce Red-necked Grebe breeding populations.

Key words: Red-necked Grebe; reproductive estimates; breeding densities; population; wetland water levels; Manitoba

Introduction

Red-necked Grebe (*Podiceps grisegena*) is a highly-specialized, wetland-obligate species that nests over-water in or near emergent vegetation on semi-permanent or permanent ponds. In North America, they usually occupy wetlands greater than 2 ha (Fournier and Hines 1998; Stout and Nuechterlein 2020). Males and females are similar in appearance and difficult to distinguish in the field. They are intra- and interspecifically territorial. Their distribution is Holarctic and, in North America, the breeding range extends from northwestern Ontario and the northern United States to the Northwest Territories and Alaska (Fink *et al.* 2020; Stout and Nuechterlein 2020). Breeding Bird Survey (BBS) data (% change per year; 1970–2019) indicate that Red-necked Grebe populations are stable in Canada, decreasing in Alberta potholes (−4.08%), and increasing in Saskatchewan (15.9%) and Manitoba (7.11%) potholes (Smith *et al.* 2020).

However, the reliability of BBS data in all geographic regions in Canada is considered medium to low due to small sample sizes; the lack of reliable, long-term reproductive data also hampers our understanding of this species population trajectory and environmental factors affecting reproductive rates. In agriculturally-dominated pothole habitat in southern Manitoba, an area where recorded historical populations were very low or nonexistent, Red-necked Grebes have recently experienced dramatic population growth (Hammell 2017). Field studies of Red-necked Grebe reproductive rates in the parkland ecoregion are few and not recent (see summary in Stout and Nuechterlein 2020), and to my knowledge, none focussed on the agriculturally-dominated pothole habitat in Manitoba or Saskatchewan. Furthermore, Red-necked Grebe population size, trends, and demographic processes are poorly understood (Stout and Nuechterlein 2020).

Accordingly, from 2008 to 2019, I opportunistically collected Red-necked Grebe breeding pair and brood data while conducting other waterfowl studies to determine baseline breeding pair and productivity data (broods/breeding pair, number of chicks/

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successful pair or breeding pair) for this recently expanded population in an agriculturally-dominated landscape in southern Manitoba. These data were used to assess (i) if the population was still expanding or had reached stability, (ii) if changing wetland water levels affected productivity, and (iii) if the presence of conspecifics and/or wetland size affected productivity. Reproductive rates in an agriculturally-dominated landscape may differ from those in less disturbed areas such as forested provincial parks (De Smet 1987) or the Taiga Shield ecoregion in the Northwest Territories, Canada (Fournier and Hines 1998). This has been attributed to anthropomorphic effects such as machinery (farm and recreational) and /or cattle disturbance (Wheeler 2001; Riske 1976 and Ohanjanian 1986 as cited in Stout and Nuechterlein 2020), nest loss from increased wave exposure in open landscapes (Nuechterlein *et al.* 2003), more diverse (Bayne and Hobson 1997) or differing predator community (e.g., absence of Raccoon [*Procyon lotor*] at higher latitudes, C. Wood pers. comm. 6 January 2020), or decline of aquatic vertebrate and invertebrate prey from pesticide and herbicide use in surrounding cultivated fields (Relyea 2005: Sura *et al.* 2012; Morrissey *et al.* 2015).

Study Area

I conducted surveys in the parkland pothole region near Erickson, Manitoba (50°30′N, 99°55′W). The intensively studied areas constitute a 6.8 km² block and a 15.8 km² roadside transect (21.7 km × 0.4 km on either side of the road), 4.0–12.5 km to the southeast (see Hammell 2016 for map of study areas). The transect was established in 2009 as preliminary data collection in 2008 indicated that the block area was too small to provide adequate sample sizes (Hammell 2014). The combined block and transect areas (22.6 km², hereafter, the primary study area) contained 97 (mean ± SE: 2.74 ± 0.45 ha, range 0.01–24.2) semi-permanent and permanent wetlands (class IV and class V; Stewart and Kantrud 1971) that required walking and driving to survey. Most years, additional pair success and brood size data were collected from 12 other, easily-accessible wetlands near the primary study area (4.3 ± 0.92 ha, range 0.9–9.5). Pair estimate and brood search protocols there were similar to those on the primary study area.

The uplands in the Erickson area are a mixture of lands sown to cereal and oilseed crops, hay, pasture, and native woodland. During 2009–2019, the approximate land use pattern for the primary study area was 25% cultivated, 34% pasture, 17% hayland, 15% wetland, 5% woodland, and 4% other (yard sites, ditches, commercial, etc.). Only one permanent small island occurred in a wetland on the block area and none on the transect. The area and changes to the landscape over time are described in more detail by Sunde and Barica (1975) and Hammell (2014).

Methods

Pair surveys

Because Red-necked Grebes require relatively deep (>1 m) wetlands with open water for breeding (Stout and Nuechterlein 2020), I restricted my observations to ponds equal to or greater than class IV (Stewart and Kantrud 1971). Red-necked Grebes are thought to attain full nuptial plumage at one-year old, but some adults may not breed until older (Stout and Nuechterlein 2020). The number of non-breeding Red-necked Grebes observed on breeding ponds is assumed to be low (Riske 1976 as cited in Stout and Nuechterlein 2020). Thus, I assumed that all birds observed represented members of breeding pairs and that there were no non-breeding pairs. Territory establishment and initial egg-laying occurs in May in Manitoba (De Smet 1987), and counts taken during mid- to late May would best represent the breeding population (Stout and Nuechterlein 2020; G.S.H. pers. obs.). Red-necked Grebes were recorded as pairs or single birds (representing a probable pair). Many pairs occurred on some larger lakes so long observation times (to 0.5 h) were necessary to estimate numbers. Repeated total counts from several elevated viewpoints, combined with field maps of bird locations (to determine territories), aided estimation.

Pair surveys were conducted from 2008 to 2018 approximately once per week from mid-May to mid-June with three to four visits to each of the 109 wetlands on the primary (n = 97) and nearby-wetland study area (n = 12). In 2019, visits were reduced for some wetlands (two visits one week apart). All wetlands were scanned with binoculars and spotting scopes from one or more elevated locations between 0530 and 1800. Block area wetlands were surveyed by walking a fixed route, whereas transect wetlands were surveyed from the road except distant or hidden wetlands were walked to and viewed from several locations. All wetlands with observable water (classes IV–V) within 400 m of the road were included in the transect survey, which took 17 h to complete over two days (except during 2009 and 2010, when only ~60% were surveyed). Some wetlands were bisected by the roadside transect; thus, with the exception of one large lake where I recorded pairs and broods on the "within" section of the transect only, I recorded pairs on the entire wetland and included this total in the transect pair count.

Unlike other grebes (e.g., Horned Grebe [*Podiceps auritus*] and Pied-billed Grebe [*Podilymbus podiceps*]) breeding in Manitoba, when disturbed, Red-necked Grebes usually remain visible to the observer in open water on the surface. If they are not obvious at arrival, usually one or both pair members swim out from emergent vegetative cover after a short time (G.S.H. pers. obs.). Therefore, recorded pair estimates were considered reasonably accurate.

Brood surveys

I recorded number of adults, number and age of chicks, and used information about brood age, size, and location to avoid duplication in counts. I collected data on number of broods only during 2008–2010, after which I also recorded chick number and survival data. I followed chicks until they reached 75% adult size or about one-month old, because chick losses are relatively low after this age (De Smet 1987). Thus, one-month old broods represent a good index of juveniles fledged. Grebe adults sometimes temporarily split their brood, each taking some chicks to feed and some adults depart early (Ferguson 1977; De Smet 1983 as cited in Stout and Nuechterlein 2020; G.S.H. pers. obs.), and these behaviours could confound brood size and success data obtained from surveys; thus, extra attention was required to determine true brood number and size. Brood search effort averaged about seven visits/wetland annually 2009–2019 (mean 7.3, range 4–9, n = 35–54 wetlands).

Wetland water level surveys

To look for possible correlations between productivity and wetland water conditions over time, I collected relative water levels measured from a fixed point on permanent stakes hammered into the pond substrate of 15 class IV and V wetlands on or near the block area and averaged the results. These measurements fairly represented local water level change but not all wetlands in this sample contained nesting Red-necked Grebes and no attempt was made to measure water level change on all wetlands occupied by nesting Red-necked Grebes. I developed a wetland scoring system (Table 1, Table S1), primarily for waterfowl (Hammell *et al.* 2021), but applicable here because the scoring periods are similarly reproductively significant for Red-necked Grebes. The scoring system established criteria for three periods: spring wetland condition (dry to flooded based on pers. obs.), pre-nesting and egg-laying wetland condition (water level drop or rise [cm] from early May to early June), and incubation and brood period wetland condition (water level drop or rise [cm] from early June to mid-July/early August). Red-necked Grebe egg-laying in Manitoba peaks in late May, and 85% of pairs initiate clutches by end of May and peak hatching occurs late June to early July (De Smet 1983 as cited in Stout and Nuechterlein 1999). An annual wetland score was determined for each of the three periods and the sum of these scores represented the wetland score for that year. Generally, the wetter the annual period (defined by higher and/or more stable water levels), the higher the score for that period. I chose these periods because for some waterfowl species (e.g., Lesser Scaup [*Aythya affinis*]; Afton 1984), breeding propensity is positively related to spring wetland condition, where conditions on arrival at the breeding grounds affect the pair's decision to remain and conditions up to the nesting period determine the decision of the female to initiate egg-laying; I propose that grebes may react similarly. Also, nest success for Red-necked Grebes and other grebes (e.g., Horned Grebe) and over-water nesting ducks is positively related to distance from wetland edge (Hammell 1973; Ferguson 1977; Koons 2001; Nuechterlein *et al.* 2003), so Red-necked Grebe productivity may be influenced by water level stability during the egg-laying and incubation period.

Data analysis

To calculate local breeding population density and population change over time, I used data from 2011 to 2019 from the primary study area only. I removed data from 2008 to 2010 because of incomplete survey data for those years. The 3–4 pair estimate surveys were averaged, representing the breeding population

TABLE 1. Assigned wetland score and scoring parameters describing spring wetland condition and water level change during Red-necked Grebe (*Podiceps grisegena*) pre-nesting–egg-laying and incubation–brood periods, 2009–2019, Erickson, Manitoba.

Score	Spring wetland condition	Pre-nesting–egg-laying and incubation–brood periods water level changes (cm)
5	Flooded beyond basin	>10
4	Wet grass zone flooded	5 to 10
3	Sedge* zone flooded	>0 to 4.9
2	Sedge zone dry	<0 to –4.9
1	Bulrush/cattail* zone dry	–5 to –10
0	Mudflats showing	>–10

*Sedge = *Carex* spp.; bulrush/cattail = *Scirpus* spp./*Typha* spp.

for that year. Brood number and pair data (collected 2008–2019) and chick data (collected 2011–2019) on and off the primary study area provided annual productivity estimates: mean broods/breeding pair, mean chicks/breeding pair, and mean chicks/successful pair. For my analysis, pairs recorded during the weekly pair census were considered breeding pairs and the total number of chicks divided by the breeding pair estimate for the same year resulted in the annual number of chicks/breeding pair. Pairs with one or more chicks at 75% adult size were considered successful pairs and the total number of chicks divided by the successful pair estimate for the same year resulted in the annual number of chicks/successful pair. In addition, I calculated weighted means as a comparative metric to account for annual variation in sample size and to make possible a comparison of my results with other studies. I used simple linear regression (data analysis using Microsoft Excel, Redmond, Washington, USA or McDonald 2014 [https://www.biostathandbook.com/index.html], earlier in my study) to test the following relationships: (i) breeding population versus year and productivity versus year, (ii) mean broods/breeding pair and chicks/successful pair versus yearly wetland score, and (iii) mean chicks/successful pair versus mean broods/breeding pair.

To examine the effect of the presence of conspecifics and/or wetland size (ha; Acme Planimeter [https://acme.com/planimeter/]) on reproduction, I calculated annual broods/breeding pair and chicks/successful pair values for wetlands with one pair (wetland size: 3.9 ± 0.5 ha, range 0.7–8.8, $n = 22$) and for wetlands with more than one pair (~50 % of surveyed wetlands; 8.3 ± 1.1 ha, range 1.7–24.2, $n = 22$). Multi-pair wetlands generally are larger than those with single pairs and exposure of nests and chicks to intraspecific aggression and/or wave action on larger wetlands may negatively affect productivity (Nuechterlein *et al.* 2003; C. Paszkowski pers. comm. 13 August 2016; Stout and Nuechterlein 2020). I tested for differences with Wilcoxon signed-rank test for paired data (McDonald 2014) within each year because the distribution of variables was unknown and sample sizes were small. Because data distributions (broods/breeding pair, chicks/successful pair; analyses not shown) indicated that they were similarly shaped and reasonably symmetric, I interpreted results as being tests of differences in mean values. Correlations and differences are considered significant at $P \leq 0.05$, and values reported are means ± SE.

Results

The average annual number of Red-necked Grebe pairs in the breeding population for 2011–2019 on the primary study area (22.6 km²) was 60.9 ± 1.2 (range 56–66) and showed no trend with year (β = −0.23, SE = 0.48, $r^2 = 0.032$, $P = 0.60$). Average annual pair density was 2.7 ± 0.05 pairs/km² (range 2.5–2.9).

Breeding Red-necked Grebes were recorded on 34 (35%) of the 97 class IV and V wetlands on the primary area. The majority of unoccupied class V wetlands were small dugouts. The occupied wetlands were 6.1 ± 0.8 ha (range 0.7–24.2, median 4.6) while the unoccupied wetlands were 0.7 ± 0.1 ha (range 0.01–2.36, median 0.44). Eighty-two percent (28 of 34) of occupied ponds were greater than 2 ha. The wetlands on the primary study area with only one pair for at least one year were 3.9 ± 0.5 ha (range 0.7–8.8, $n = 22$) and those with more than one pair were 8.3 ± 1.1 ha (range 1.7–24.2, $n = 22$); these categories (mean ranks) were significantly different (W = 82, $P < 0.001$). Consistency of wetland occupation across years was high (~100%) unless wetlands were altered by landowner draining.

First broods appeared during the last two weeks of June and hatching continued through July. Number of broods/breeding pair (2008–2019), chicks/breeding pair (2011–2019), and chicks/successful pair (2011–2019) are presented in Table 2. Broods/breeding pair (β = 0.03, SE = 0.02, $r^2 = 0.17$, $P = 0.18$, $n = 12$ years), chicks/breeding pair (β = −0.10, SE = 0.06, $r^2 = 0.27$, $P = 0.15$, $n = 9$ years), and chicks/successful pair (β = −0.03, SE = 0.04, $r^2 = 0.08$, $P = 0.46$, $n = 9$ years) were not correlated with year.

Mean broods/breeding pair was positively related to annual wetland score (β = 0.07, SE = 0.02, $r^2 = 0.49$, $P < 0.02$, $n = 11$ years; Figure 1) but mean chicks/successful pair was not (β = 0.02, SE = 0.06, $r^2 = 0.01$, $P = 0.80$, $n = 9$ years; Figure 2). Mean chicks/successful pair was positively related to mean broods/breeding pair (β = 0.99, SE = 0.35, $r^2 = 0.53$, $P = 0.03$, $n = 9$ years; Figure 3).

The number of broods/breeding pair on wetlands with a single pair was 0.36 ± 0.09 ($n = 9$ years and 139 broods; weighted mean: 0.36 ± 0.04; Table 3) and for those with multi-pairs was 0.37 ± 0.08 ($n = 9$ years and 482 broods; weighted mean: 0.35 ± 0.02); the difference between the two wetland categories was not significant ($W = 19$, $n = 9$ years, $P > 0.2$). Similarly, the number of chicks/successful pair on wetlands with a single pair was 1.59 ± 0.15 ($n = 9$ years and 50 broods; weighted mean: 1.84 ± 0.14; Table 3) and for those with multi-pairs was 1.87 ± 0.13 ($n = 9$ years and 170 broods; weighted mean: 1.98 ± 0.08); again the difference was not significant ($W = 12$, $n = 9$ years, $P > 0.2$). Interestingly, for most years (seven of nine), broods/breeding pair were lower on the largest lake (24.2 ha) than on wetlands with one pair (weighted means: 0.21 ± 0.06, $n = 47$ and 0.36 ± 0.04, $n = 139$, respectively; Table 3). Similarly, for eight of

TABLE 2. Red-necked Grebe (*Podiceps grisegena*) production on 109 surveyed wetlands near Erickson, Manitoba, 2008–2019. "–" indicates no data.

Year	No. breeding pairs	No. broods with chicks ~1 month of age (75% of adult size)	Broods/breeding pair	Total chicks	Mean no. of chicks per breeding pair (SE)	Mean no. of chicks per successful pair (SE)
2008*	15	7	0.47	–	–	–
2009*	28	6	0.21	–	–	–
2010*	33	20	0.61	–	–	–
2011	62	38	0.61	81	1.31 (0.18)	2.13 (0.20)
2012	86	17	0.20	30	0.35 (0.09)	1.76 (0.26)
2013	65	21	0.32	32	0.49 (0.10)	1.52 (0.13)
2014	65	44	0.68	94	1.45 (0.16)	2.14 (0.15)
2015	68	44	0.65	97	1.43 (0.16)	2.20 (0.14)
2016	71	27	0.38	46	0.65 (0.12)	1.70 (0.16)
2017	70	16	0.23	27	0.39 (0.10)	1.69 (0.20)
2018	65	6	0.09	8	0.12 (0.06)	1.33 (0.33)
2019	69	7	0.10	14	0.20 (0.08)	2.00 (0.44)
Total	697	253		429		
Mean (SE)			0.38 (0.06)		0.71 (0.22)	1.83 (0.10)
Weighted mean†			0.36 (0.02, 0–1, 697)		0.69 (0.04, 0–6, 621)	1.95 (0.07, 1–6, 220)

*Small data set due to reduced size of study area. See text for explanation.
†Weighted mean (SE, range, *n*). Means were weighted by number of years.

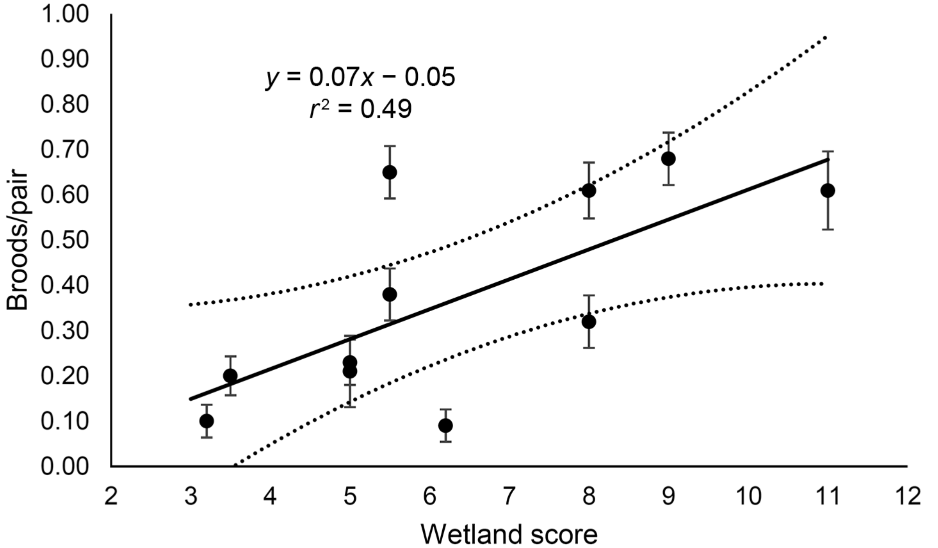

FIGURE 1. Linear relationship between Red-necked Grebe (*Podiceps grisegena*) mean broods/breeding pair and wetland score on 109 surveyed wetlands near Erickson, Manitoba, 2009–2019. (Note that ~70 wetlands were surveyed 2009–2010 due to smaller size of study area. See text for explanation.) Wetland score describes relative water conditions during the entire breeding season. Larger wetland scores denote improving wetland condition (see text for description of scoring system). Dotted lines represent a 95% CI (two SE). Bars associated with annual broods/pair means represent one SE.

nine years, annual mean chicks/successful pair ratios were lower on the largest lake than on wetlands with one pair (weighted means: 1.40 ± 0.16, n = 10 and 1.84 ± 0.14, n = 50, respectively; Table 3). Annual broods/breeding pair ratios were not significantly different between these categories (W = 10, n = 9 years,

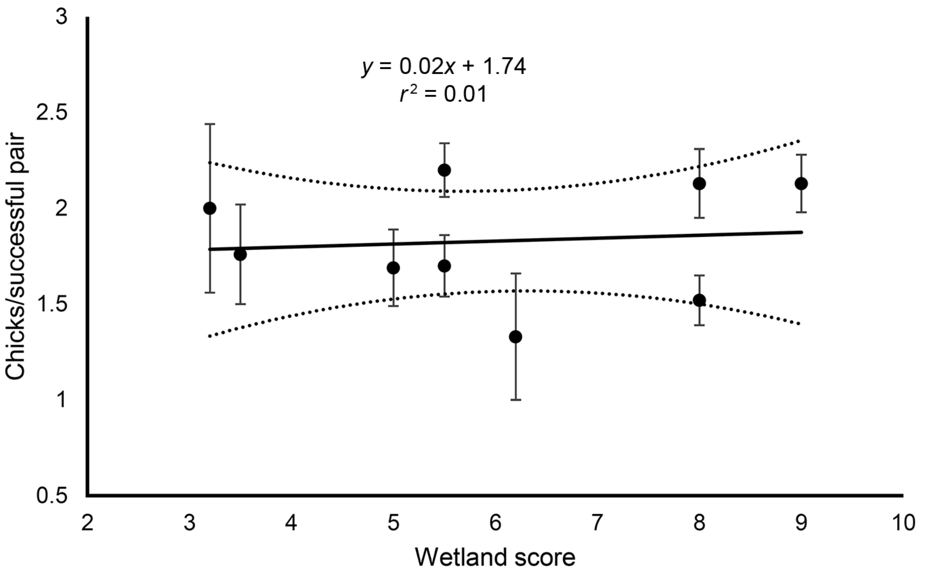

FIGURE 2. Linear relationship between mean chicks/successful pair for Red-necked Grebe (*Podiceps grisegena*) and wetland score on 109 surveyed wetlands near Erickson, Manitoba, 2011–2019. Wetland score describes relative water conditions during the entire breeding season. Larger wetland scores denote improving wetland condition (see text for description of scoring system). Dotted lines represent a 95% CI (two SE). Bars associated with annual chicks/successful pair means represent one SE.

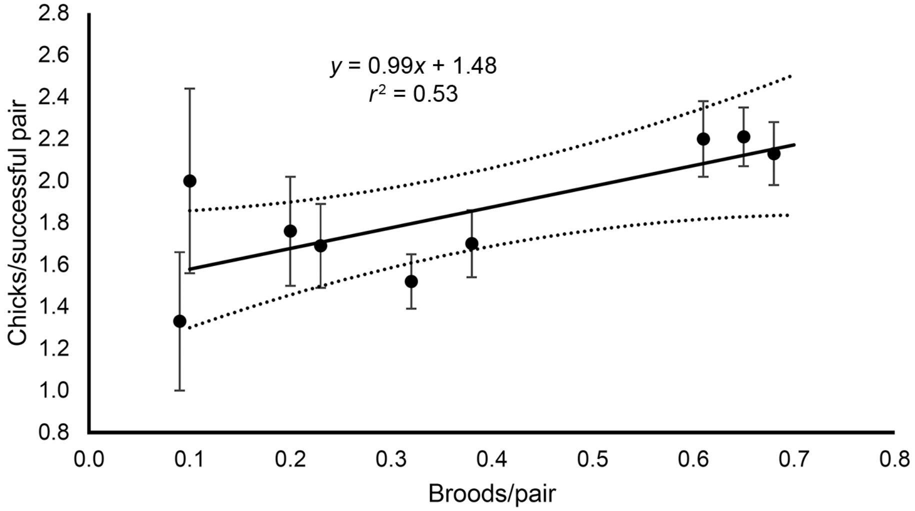

FIGURE 3. Linear relationship between mean chicks/successful pair and mean broods/breeding pair for Red-necked Grebe (*Podiceps grisegena*) on 109 surveyed wetlands near Erickson, Manitoba, 2011–2019. Dotted lines represent a 95% CI (two SE). Bars associated with annual chicks/successful pair means represent one SE.

$P > 0.1$) but annual chicks/successful pair ratios were ($W = 1$, $n = 9$ years, $P < 0.01$).

Discussion

Population density and change over time

Excluding semi-colonial or colonial nesting on large lakes (Wheeler 2001; Nuechterlein *et al.* 2003), the breeding population densities of greater than 2 pairs/km² in my study area in an agriculturally dominated prairie pothole region are some of the highest reported. Populations in boreal habitat in the Northwest Territories were 0.1–3.2 birds/km² or 1.6 pairs/km² (Fournier and Hines 1998; D. Kay pers. comm. in Fournier and Hines 1998) and in Alaska, were

TABLE 3. Red-necked Grebe (*Podiceps grisegena*) annual broods/breeding pair and chicks/successful pair for wetlands with one pair (n = 12–22) and the largest wetland (24.2 ha) in the dataset near Erickson, Manitoba, 2011–2019.

Year	Wetlands with one pair		Largest wetland: > one pair	
	Broods/breeding pair (no. of pairs)	Chicks/successful pair (no. of pairs)	Broods/breeding pair (no. of pairs)	Chicks/successful pair (no. of pairs)
2011	0.81 (16)	2.38 (13)	0.60 (5)	1.67 (3)
2012	0.25 (12)	2.00 (3)	0.25 (8)	1.50 (2)
2013	0.20 (15)	1.33 (3)	0.67 (3)	1.00 (2)
2014	0.67 (15)	1.70 (10)	0.25 (4)	1.00 (1)
2015	0.63 (16)	1.80 (10)	0.20 (5)	2.00 (1)
2016	0.42 (12)	1.80 (5)	0.17 (6)	1.00 (1)
2017	0.14 (22)	1.33 (3)	0.00 (6)	0.00 (0)
2018	0.07 (14)	1.00 (1)	0.00 (5)	0.00 (0)
2019	0.06 (17)	1.00 (2)	0.00 (5)	0.00 (0)
Mean (SE)	0.36 (0.09)	1.59 (0.15)	0.24 (0.08)	0.91 (0.25)

0.02–0.14 birds/km² (Stout and Nuechterlein 2020). Mean long-term (1991–2018) density at Yellowknife, Northwest Territories, is 0.84 pairs/km² (Environment and Climate Change Canada unpubl. data). Corrigan (2007) reported Red-necked Grebe densities during 1989–2007 in east-central Alberta were 0.06–0.66 birds/km². Such high densities near Erickson suggest that the pothole habitat in southern Manitoba is now very attractive to breeding pairs and provide a sharp contrast to very low breeding densities in the 1970s (0.0–0.1 pairs/km², Hammell 2017).

Why then, have breeding populations changed so dramatically in southern Manitoba? De Smet (2018) speculated that increases may be partly explained by wet conditions in the region over the past two decades, but numbers had begun increasing marginally from the early 1970s to the early 1980s (J. Austin unpubl. data). Also, high levels of organochlorine pesticides in grebe eggs were reported for many studies in the past (see De Smet 1987 for summary) and were thought to be negatively affecting many aspects of reproduction for grebes and other birds. Levels of these chemicals have declined since the 1970s (Forsyth *et al.* 1994) and Hammell (2017) speculated that this reduction may have led to increased productivity and consequently, increased juvenile recruitment and immigration into parkland habitat. But these hypotheses have not been tested and reasons for population increases remain unclear.

At Erickson, breeding pairs occupied all available wetlands of sufficient size and depth (semi-permanent and permanent ponds greater than 2 ha), similar to populations in other southern breeding areas (Stout and Nuechterlein 2020). However, in southwestern Manitoba (Hammell 2017; this study) some Red-necked Grebes occupied wetlands (not dugouts) less than 1 ha, consistent with Fournier and Hines' (1998) observations in the Northwest Territories. Such occupancy patterns suggest some flexibility in choice of breeding wetland, perhaps when suitable habitat configuration (wetland density) exists (Fournier and Hines 1998; Hammell 2017). During my study, breeding population size was stable and pair numbers on many ponds were usually the same or differed by only one or two pairs from year to year. In addition, broods/breeding pair and chicks/breeding and /successful pair, although annually variable, exhibited no significant trend over the study period, consistent with a population experiencing little long-term change. If the Erickson Red-necked Grebe breeding population exhibited the classic logistic S-shaped growth curve associated with species pioneering a novel environment (Odum 1959), then, collectively, these results suggest that the population may have moved beyond the rapid growth stage and probably has reached carrying capacity. This is most likely due to constraints of intraspecific aggression and territoriality although other unknown covariates could be additional factors. The permanent and semi-permanent breeding wetlands of Red-necked Grebes can be altered by periods of drought (Rogers 1964) resulting in reduced area and periphery and ultimately lower breeding populations (Corrigan 2007). Climate change projections for the prairie and parkland area suggest drier summers, potentially producing rapidly falling water levels and reduced Red-necked Grebe productivity (Sorenson *et al.* 1998; Sauchyn *et al.* 2020).

Comparative productivity estimates

The mean number of chicks/breeding pair I documented was lower than that reported from all but one other study area in Canada, however, the mean number of chicks/successful pair was similar or higher than all but one other study (Table 4). Therefore, in the agriculturally-dominated landscape of southern Manitoba, productivity (juveniles recruited/breeding pair) seems to be lower than in most other areas, including in forested habitat in southern Manitoba (De Smet 1987). Wetlands surrounded by forest may provide advantages not seen in areas experiencing greater human disturbance (e.g., protection of nests from wave action on forested wetlands, De Smet 1987). However, measures of reproductive success exhibit high interannual variability due to variation in environmental conditions and longer-term studies provide more accuracy in truly assessing reproductive rates.

A comparison of my results with those published from the longer-term study of boreal wetlands near Yellowknife conducted by Fournier and Hines (1998) might provide greater insight into differing reproductive rates. My results (Table 2) for average broods/breeding pair were lower (0.38 versus 0.72) and exhibited a wider range (0.09–0.68) than those reported for the Northwest Territories (0.51–0.85). Possible (but unsubstantiated) causes may include differing predator community and more stable wetland water levels in the boreal ecozone than in the parkland ecozone. Raccoons are a serious predator of over-water waterfowl and grebe nests in southern Manitoba (Hammell 1973; Ferguson 1977; De Smet 1987) but are not part of the predator community at Yellowknife (C. Wood pers. comm. 8 January 2020). In addition, wetlands in northern latitudes do not experience as dramatic a change in water levels as seen in lower latitudes because of short, cool summers with near equal annual precipitation and evapotranspiration (Woo and Winter 1993). Falling wetland water levels presumably allow mammalian predators easier access to over-water nests (see below). Consequently, Red-necked Grebe nests in boreal wetlands with more stable water levels and lacking Raccoons may be less vulnerable to mammalian predation than those in the parkland area, resulting in less overall nest predation. Similarly, Fournier and Hines (1999) found that mammalian predation on Horned Grebe nests at the same Yellowknife study area was lower than that reported in Manitoba by Ferguson (1977). Accordingly, boreal Red-necked Grebes may be more productive than those in the parkland because broods/breeding pair and chicks/breeding pair in all studies across the Canadian prairie provinces were lower than for boreal breeders at Yellowknife.

Productivity and wetland water levels

Red-necked Grebe productivity (broods/breeding pair) was positively related to annual wetland score, a proxy for water level that sums an initial score for the spring and changes in water levels for the pre-nesting–egg laying period and incubation–brood periods. This is not surprising because Red-necked Grebe nest exclusively over-water and width of emergent vegetation band and distance to dryland edge may be critical to success. Nuechterlein *et al.* (2003) working with Red-necked Grebes in central Minnesota, USA, found that experimental artificial nests located farther from adjacent shores were more successful than those located directly adjacent to shore concluding that nests that were located farther from land or over deeper water presumably were safer from terrestrial predators such as Raccoons. Similarly, Frederick and Collopy (1989), found that as little as 5–10 cm of water can greatly deter mammalian predators on shorebird nests. Hammell (1973) for Lesser Scaup and Ferguson (1977) for Horned Grebe found mean distance of successful overwater nests to pond edge was greater than that of unsuccessful nests suggesting that falling wetland water levels would place more nests closer to shoreline and potential predators. Collectively, these studies highlight the importance of wet, stable water level years to overwater nesting avian species.

TABLE 4. Measures of reproductive success (weighted mean ± SD, range, *n*) of Red-necked Grebe (*Podiceps grisegena*) in Canada. Means are weighted by number of years of study.

Study area	Source	Chicks/breeding pair	Chicks/successful pair
Erickson, Manitoba	My study (nine years)	0.7 ± 1.1 (0–6, 621)	2.0 ± 1.0 (1–6, 220)
Turtle Mountains, Manitoba	De Smet (1983; two years)*	0.9 ± 1.3 (0–6, 104)	2.1 ± 1.1 (1–6, 43)
Astotin Lake, Alberta	Kevan (1970; one year)*	1.1 ± 1.2 (0–5, 89)	1.8 ± 1.0 (1–5, 52)
Alberta potholes	Riske (1976; seven years)*	1.1 ± 0.1 (63)	1.6 ± 0.1 (41)
Pine Lake, Alberta	Riske (1976; seven years)*	0.4 ± 0.1 (267)	1.4 ± 0.1 (51)
Duck Lake, British Columbia	Ohanjanian (1986; three years)*†	No data	1.7 ± 0.5 (1–2, 34)
Yellowknife, Northwest Territories	Fournier and Hines (1998; 10 years)*	1.4†	2.0†

*Site-specific estimates as cited in Stout and Nuechterlein (2020).
†10-year average.

The number of chicks/successful pair (brood size) was not positively related to annual wetland score despite brood size being positively associated to broods/breeding pair which did show a positive trend with increasing annual wetland score. This lack of positive correlation between brood size and wetland score is surprising and unexplained. Ferguson and Sealy (1983), working 20 km south of my study area, proposed that water level was an important determinant of Horned Grebe nest success through its controlling influence on the distribution of emergent vegetation. Wet years usually produce wide peripheral bands of lush, new, emergent growth coupled with previous year's growth (e.g., *Scirpus* spp. and *Typha* spp.), areas where adult Red-necked Grebes with chicks on-back or older juveniles may be able to rest or hide, presumably safer from mammalian or aerial predators. During dry years, both adults and chicks are forced to abandon dry emergent beds for more exposed wetland centres (G.S.H. pers. obs.).

Productivity and the presence of conspecifics

Intraspecific aggression can impart both costs and benefits that potentially could affect productivity. By defending a territory, adults may gain additional resources for eggs and/or themselves leading to increased number of young, but costs may include eggs lost from unattended nests and injuries obtained in competitive interactions (De Smet 1987; Garner 1991). Increased expenditures of energy and time by adults during aggressive encounters could result in less time providing for young. I was unable to detect reproductive differences (broods/breeding pair and chicks/successful pair) between wetlands with only one pair and those with more than one pair, suggesting that pairs on multi-pair wetlands may be as productive as single pairs. De Smet (1987) found that depredation and organochlorine pollutants were responsible for most nesting losses; those from territoriality were minimal. Nuechterlein *et al.* (2003) found no effect of crowding on nest success among semi-colonial and solitary nesting Red-necked Grebes on a large (2537 ha) shallow lake in Minnesota, USA. However, semi-colonial pairs nested on floating cattail-mat islands, which may have lowered the risk of mammalian depredation (Nuechterlein *et al.* 2003). Klatt *et al.* (2004) concluded that the ability of Red-necked Grebes to change behaviour in response to social circumstances allows them to breed successfully in a variety of situations from strongly solitary to loosely colonial aggregations. At Erickson, solitary pairs nested around the wetland periphery; similarly, grebes on multi-pair wetlands nest around the periphery usually at distances exceeding 75 m (G.S.H. pers. obs.). Presumably such spacing provides adequate resources for adults and young with minimal disturbance from neighbouring pairs.

Nest destruction from wave action is commonly reported as a reason for nest failure in studies on large lakes (Wheeler 2001; Nuechterlein *et al.* 2003; Riske 1976 as cited in Stout and Nuechterlein 2020), but wave-related losses were few in sheltered small to medium-sized lakes in wooded habitat in southern Manitoba (De Smet 1987). How wetland size covaries with intraspecific aggression in Erickson area wetlands to affect production is unknown but few wetlands used by Red-necked Grebes are entirely surrounded by trees and all are windswept to some degree. My dataset comprised relatively small wetlands (all but one ≤15 ha), and on the largest lake (24 ha), broods/breeding pair and chicks/successful pair for most years were lower than those on smaller single-pair wetlands suggesting that wetlands larger than those involved in this study might have lowered productivity. C. Paszkowski (pers. comm. 13 August 2016) observed that, despite success at the egg laying, nesting, and even hatching phase, survival of young to fledging can be quite low on larger, but still shallow, lakes in central Alberta. Larger, shallow lakes (over 25 ha and up to several hundred ha in size) occur in the Erickson area, representing ~10% of permanent wetlands (G.S.H. pers. obs.), and therefore, further analysis using a dataset that included larger wetlands than surveyed here might provide additional insight into Red-necked Grebe productivity in southern Manitoba.

Conclusions

My study provides a comparative point of reference for the Red-necked Grebe population breeding in agriculturally-dominated habitat in southern Manitoba and provides additional data to aid the development of region-specific integrated population models (Zhao *et al.* 2020). Such modelling might identify drivers of population growth rate and help draft appropriate conservation strategies. My results introduce one potential driver of productivity in parkland pothole habitat, notably, wetland score as a proxy for water level.

To my knowledge, Red-necked Grebe breeding densities in southwestern Manitoba are the highest reported for solitary-nesting pairs in North America, and the breeding population appears to be stable during the study period, perhaps having reached carrying capacity. My productivity results suggest that chicks/breeding pair is lower but chicks/successful pair is similar or greater than reported in most other studies. Pairs breeding on larger wetlands along with other conspecifics appear to be as productive as solitary pairs on smaller, single-pair wetlands, but the range and diversity of wetlands included in my study was limited. Prolonged drought or permanent changes in climate leading to warmer, drier summers on the prairies and parklands could reduce breeding populations. Periodic review of the population and productivity status of Red-necked Grebes in areas with long-term datasets (e.g., southwestern Manitoba, Yellowknife study area) would provide added information beyond that obtained from the BBS, enabling better interpretation of trend data.

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SUPPLEMENTARY MATERIAL:

TABLE S1. Assigned scores for spring wetland condition, pre-nesting–egg-laying, and incubation–brood periods for Red-necked Grebe (*Podiceps grisegena*), near Erickson, Manitoba, 2009–2019.

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Barred Owl (*Strix varia*) activity and diet recorded with a camera trap at a natural cavity nest in Manitoba, Canada (2016–2017)

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Abstract
Camera trap images (*n* = 27 092) collected at a natural Barred Owl (*Strix varia*) nest site in Manitoba, Canada, 2016–2019, were used to quantify nesting behaviour and identify prey delivered to the nest. Adult Barred Owl activity increased prior to egg laying and again after incubation. Adults were mostly active at night, but daytime activity increased during the nestling period in 2016 and more so with a larger brood in 2017. Nestlings were active at the nest entrance both day and night for 8–9 days prior to fledging at ≤27–32 d old. Two of three nestling activity peaks (0400 and 2000 Central Daylight Time [CDT]) corresponded to prey delivery activity peaks whereas a third (1200 CDT) did not. Only 31/65 prey were identified to species, but 12 new prey taxa were documented for Barred Owl in Manitoba. Activity at the cavity during the non-breeding season before and after a nest predation event were documented; the nest site was abandoned after an American Black Bear (*Ursus americanus*) visited the nest cavity in May 2018. Factors affecting the quality and quantity of images, and hence data obtained from them, included camera position relative to the nest cavity entrance, light levels, camera trigger speed, non-target species, and the configuration and settings of motion detection sensors. Improved camera traps may overcome these limitations. This is the first published study on this owl species using this increasingly popular technology.

Key words: Barred Owl; *Strix varia*; nesting activity; behaviour; prey provisioning; diet; camera trap; Manitoba; Canada

Introduction

Barred Owl (*Strix varia*) is a large brownish-grey nocturnal owl with dark brown eyes and no ear tufts. Its raucous “Who-cooks-for-you? Who cooks for you all?” call is distinct from other owl species in its range (Duncan 2003). It is found over most of eastern North America and has expanded its range over the last 150 years to central and western parts of the continent due to European settlement of the Great Plains (Livezey 2009a,b). It has a wide distribution in Manitoba (Holland *et al.* 2003; Koes and Artuso 2018) and is detected every year during spring nocturnal owl surveys (Duncan 2021). Despite this, little is known about Barred Owl nesting behaviour or diet in Manitoba (Whiklo 2011).

Observational studies of animal behaviour provide information important to the scientific method. Sometimes a single observation can shed new light on a species’ natural history. The accumulation of this information can inform conservation action planning needed to sustain or manage populations of species, especially those that are invasive or of conservation concern. However, many species of wildlife are difficult to observe directly without affecting their behaviour, especially those that are active mainly at night, often hidden from view, and/or sensitive to disturbance, such as nesting Barred Owls.

It is surprising that studies of Barred Owl nesting behaviour have not been published despite the popularity and availability of live streaming nest box video cameras for at least a decade. These cameras (https://www.allaboutbirds.org/cams/barred-owls/) reveal intimate behaviours not otherwise visible; however, the technology to live stream video is expensive and logistically challenging for remote natural cavity nest sites in undisturbed habitats (Balin *et al.* 2022). In contrast, camera traps, also known as trail cameras, are simpler and less expensive. Camera traps are triggered by a motion sensor and/or an infrared sensor. Camera traps are battery powered and do not require

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an internet connection. They have been used to study animal behaviour, population trends, and spatial distribution (Kapfer *et al.* 2011; Duncan and Kerbrat 2022). The methods used to quantify nesting bird behaviour from image files and assessments of the effectiveness of camera traps are still being developed and assessed (Duncan and Kerbrat 2022).

Barred Owl nest cavities are hard to find due to their secretive nature (Frith *et al.* 1997). Prior to 2009, only one nest site had been described in Manitoba. In 2009 and 2010 an additional nine nests were found and documented (Whiklo and Duncan 2014). Between 2011 and 2022 eight more nests were discovered (J.R.D. unpubl. data). The discovery of a new natural active Barred Owl nest cavity in 2015 enabled the use of a camera trap that collected images over the 2016 and 2017 breeding seasons. Additional images were collected until spring 2019. Images were reviewed and analysed to assess the ability of this technology to quantify adult and juvenile behaviour and to identify prey delivered to the nest. This is the first published study of this owl species using this increasingly popular technology.

Methods

Nest site and study area

The study nest was located on 25 April 2015 when a female Barred Owl entered the cavity. The diameter at breast height (DBH) of the nest tree was calculated by measuring the circumference of the tree and then calculating the diameter ($D = C / \pi$). Internal nest cavity height (distance from the lowest point inside the cavity to the highest point inside the cavity), width (distance from the furthest right-hand point inside the cavity to the furthest left-hand point inside the cavity), and depth (distance inside the cavity perpendicular to cavity width) were measured after the young had fledged.

The nest was in relatively undisturbed habitat bisected by a gravel road in southeastern Manitoba (49.68504°N, 96.09040°W). The closest human residences were ~4.5 km from the nest site, which was in a 3630 ha ecologically significant area voluntarily protected since 1992 (Manitoba Natural Resources 1992). A 1-km radius centred on the nest location was used to estimate the 320 ha breeding home range of Barred Owl (Hamer 1988). Forest Resource Inventory (Gill 1955; Natural Resources Manitoba 1996) habitat variables within this home range were summarized and compared with those from similarly estimated home ranges associated with Manitoba Barred Owl spring survey locations (Duncan and Kearns 1997; Tables S1–S4).

Our study area is in the Boreal and Great Lakes–St. Lawrence Forest Regions (Rowe 1972) and the Lake of the Woods Ecoregion (Zoladeski *et al.* 1995; Smith *et al.* 1998). The area contains a variety of soil conditions and habitats resulting from both ground moraine from Pleistocene glaciers and lacustrine deposits of glacial Lake Agassiz (Teller 1984). Typical of boreal forest regions, the area is flat, poorly drained, with the predominant vegetation consisting of Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburg) and Tamarack (*Larix laricina* (Du Roi) K. Koch) interspersed with swamps and meadows (Rowe 1972). Jack Pine (*Pinus banksiana* Lambert) and Trembling Aspen (*Populus tremuloides* Michaux) occur in drier areas.

In this region, prior to 1958, fires burned large areas annually. More recently, logging and smaller, less frequent fires occur. The climate is boreal continental with January and July temperatures, −19.4 ± 0.5°C (SD) and 19.1 ± 0.4°C, respectively; snowfall 128 ± 11.1 cm/year; rainfall 41.1 ± 3.2 cm/year; and total annual precipitation 54 ± 3.9 cm/year of which 24 ± 3.9 cm/year falls as snow (Duncan 1992).

Data collection

We mounted a Reconyx PC900 HyperFire Professional High Output Covert IR Trail Camera (Holmen, Wisconsin, USA) 1 m from the nest cavity opening using a steel angled bracket attached to the nest tree (Figure S1). In 2016, we positioned the camera to point directly into the nest cavity entrance. In 2017, we positioned the camera to point at the side of the nest cavity entrance. A compact aluminum telescoping collapsible ladder carried into the nest site was used to access the camera and nest cavity.

Steen *et al.* (2016) determined that cameras placed <1 m missed behaviours and >1 m made prey identification more difficult. Cameras placed >1 m from nests were triggered excessively by moving branches, wasted limited image memory storage space, and depleted batteries faster (R. Steen pers. comm. 12 February 2015). The camera was custom focussed to 1 m by the manufacturer for our study. The camera was configured with the motion sensor = on; sensitivity = high; pictures per trigger = 3; picture interval = rapid fire; quiet period = no delay; and night mode = fast shutter. Images included an image number, time (hh:mm:ss), date (yyyy-mm-dd), and temperature (°C) stamp. Time was set for the Central Daylight Saving Time (CDT) zone.

The three images/capture/motion setting was a compromise between likelihood of identifying prey to species and limits of memory and battery capacity (R. Steen pers. comm. 12 February 2015). Reducing the frequency of camera memory and battery maintenance also reduced disturbance to the nesting owls (Caravaggi *et al.* 2017). The camera was checked on average every 24 days (range 12–35, $n = 4$) and 15 days (range 8–21, n = 4) during the 2016 and 2017 breeding seasons, respectively. On each visit the secure digital card was replaced whereas the batteries were replaced once in 2017. A total of 27 092 images were recorded from March to September 2016 and from March 2017 to May 2019 (Table S5). In 2016, the camera was set up before egg laying and was removed after the young had fledged. In 2017, the camera was set up after the first of three eggs were laid and was removed in May 2019 after the nest cavity remained unoccupied for two subsequent breeding seasons (Table S6).

Reviewing camera trap images

All camera trap images collected were reviewed and behaviours such as prey deliveries were transcribed into a spreadsheet by R.K., and quality controlled by R.K. and J.R.D. This took 172 h on 135 days (average of 1.27 h/day) spread out over a 389 day period from May 2020 to June 2021.

The time, mode (colour/day versus black and white/night), date and number of images with adult or juvenile activity were tabulated to determine activity duration, daily peaks, and changes over time (i.e., associated with pre-egg laying, incubation, and nestling stages). A series of continuous images associated with a behaviour was considered an 'image set'. The times that the camera switched between modes varied depending on light levels affected by cloud cover and vegetation density. In a similar study, this averaged 32 min before sunset and 35 min after sunrise (Duncan and Kerbrat 2022). The sex of adult activity was not noted because Barred Owls exhibit only slight reversed sexual size dimorphism (Mazur and James 2020) and no other sex-specific characteristics (i.e., plumage pattern) were distinguishable on images.

Identification of prey from camera trap images

When possible, prey items delivered to the nest were identified to the finest taxonomic level possible from images by consensus (R.K. and J.R.D.) and using diagnostic characteristics of species expected in this area at the time of the study (Banfield 1974; Godfrey 1986; Naughton 2012). Small mammal prey were identified using a combination of one or more visible features including relative tail or hind leg length, ear and/or eye size, and uniform versus contrasting pelage shading (Figure S2a). Bird prey were identified by bill, head, body, wing, and tail shape and size and plumage appearance to the extent possible. Prey were also identified as needed by consultation with experts with the relevant taxonomic expertise (see Acknowledgements). When poor image quality prevented the identification of prey items to species, they were assigned to one of eight categories: unidentified, unidentified invertebrate, unidentified vertebrate, unidentified mammal, unidentified rodent, unidentified mouse, unidentified vole, or unidentified passerine. No prey species were identified from pellets.

Results

Nest site and habitat

The nest cavity was 3.2 m above ground in a dead Balsam Poplar (*Populus balsamifera* L.) with a 42 cm DBH. The diameter at nest height was 45 cm. The northwest-facing cavity entrance was 32 × 11 cm (height × width). The interior of the nest cavity was 61 × 26 × 30 cm (height × depth × width). The nest stand was dominated by Trembling Aspen, with less than 5% Balsam Poplar, White Spruce (*Picea glauca* (Moench) Voss), Jack Pine, and Balsam Fir (*Abies balsamea* (L.) Miller; J.R.D. unpubl. data).

This pair's estimated breeding home range had more grass/forb, shrub/seedling, and mature forest habitat but less unproductive forest, pole/sapling, and overmature forest habitat (cutting class) than for those reported in Duncan and Kearns (1997); correspondingly, it had relatively more open-crown, less closed-crown forest stands, and an equal mix of softwood and hardwood dominated stands (Tables S1, S2, and S4).

Assessment of the effectiveness of camera traps for this species

Barred Owl activity at the cavity was summarized by the time, date, and number of images taken by the camera trap (Figure 1a). More images were recorded in 2016 (Table S5), when the camera directly faced the nest cavity entrance (Figure S1) because some of the adult and nestling activity inside the cavity also triggered the camera (Figure S2b). However, adult owls visiting the nest in 2016 often had their backs to the camera, thereby partially or completely blocking the view of prey being delivered. To address this issue the camera was repositioned in 2017 to face the side of the nest cavity entrance (Figures 1a, S2c). This enabled more prey items to be identified (Table S7). However, this camera position captured more images either without owls present or with just a small part of the owl visible.

Adult Barred Owl activity

Adult Barred Owl activity at the nest entrance varied daily but showed an activity peak in 2016 about two weeks before egg laying was complete, followed by lower activity during the first half of the incubation period (Figure 2a, Table S6). There was an expected increase in adult activity as nestlings developed and required more food, followed by a decrease corresponding to the fledging of the owlets in both 2016 and 2017 (Figure 2a,b, Table S6). There was a relatively early increase in adult activity during the latter

FIGURE 1. a. Adult Barred Owl (*Strix varia*) at the entrance to its nest cavity and b. Two nestlings inside nest cavity in southeastern Manitoba, Canada. Photos: James Duncan.

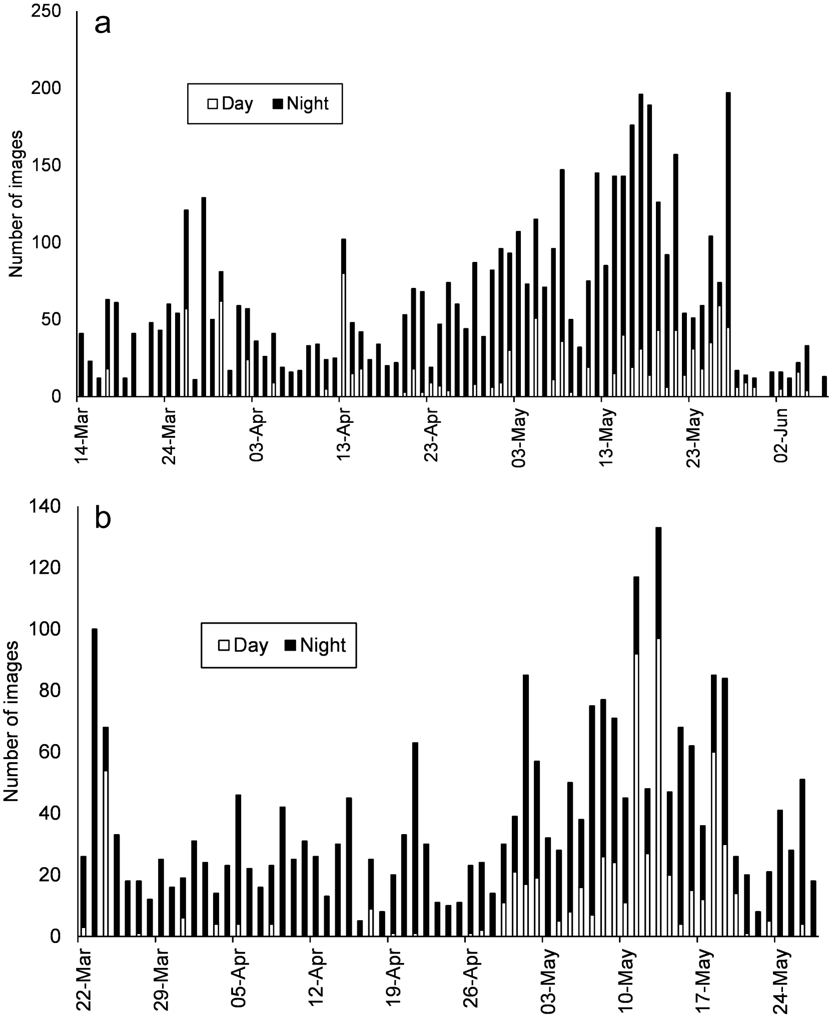

FIGURE 2. Chronology and timing of adult Barred Owl (*Strix varia*) nest activity based on number of images recorded in a. 2016 and b. 2017 during different nesting stages in southeastern Manitoba, Canada.

stage of incubation in 2016 (Figure 2a).

In 2016 and 2017, 80% of 7833 camera images were taken at night suggesting the Barred Owls were mainly nocturnal (Figure 2, Table 1). They were more active during the day in the nestling period (Figure 2, Table 1) when nights were getting shorter as summer equinox approached. The relative increase in daytime activity during the nestling phase was greater in 2017 when three nestlings were present (versus two nestlings in 2016), and the adults had to provide more prey (Table 1).

Nestling activity and fledging

Barred Owls have an asynchronous hatch and are only moderately sexually size dimorphic (Mazur and James 2020). Therefore, we assumed that the oldest nestling would be the largest and would have been readily identifiable in images (Figure 1b). However, it was too difficult to consistently assess nestling relative size based on images, especially when only one was visible (Figure S2c). Nestling Barred Owls developed quickly and climbed up to the nest cavity entrance to observe their surroundings (Figure S2c). Perching on and climbing around the nest cavity also afforded them an opportunity to strengthen their leg and wing muscles before leaving the nest permanently (fledging). We described fledging as occurring when the last image of a nestling was recorded by the camera trap.

In 2016, nestlings were first recorded at the nest entrance at 1931 CDT on 1 June and were last recorded there at 1936 CDT on 7 June. In 2017, the first and last images of nestlings at the nest entrance were at 1305 CDT on 21 May and at 1940 CDT on 28 May, respectively (Figure S3). The earlier fledging in 2017 corresponded to an earlier clutch initiation date (Table S6). The two nestlings were active at the nest entrance and fledged younger (≤27 d old) in 2016 than the three nestlings (≤32 d old) in 2017 (Figure S3, Table S6).

Despite there being two nestlings in 2016 and three in 2017, the number of days the nestlings were recorded at the nest cavity entrance before fledging were similar (8 and 9 days, respectively) in both years (Figure S3). The camera facing directly into the cavity resulted in more nestling activity images being recorded in 2016 versus 2017 (Figure S3), even though there were fewer nestlings present that year.

In contrast with adult Barred Owls, nestlings were equally active at the nest entrance day and night (2016 and 2017, n = 7259 images, 51% of which were taken during the day) and for the pooled data there were three evenly spaced activity peaks at 0400, 1200, and 2000 CDT (Figure 3). Two of these peaks (0400 and 2000 CDT) relate to prey delivery activity peaks (Figure 4).

Diet and prey delivery activity

About half (31) of 65 image sets (Table 2, Figure S2a) enabled the identification of prey items delivered to species; the remainder could only be identified to genus (7), subfamily (2), family (3), order (1), class (9), subphylum (4), or kingdom (8). Most prey items identified were vertebrates (52) consisting of 38 mammals, seven birds, two amphibians, and one reptile. The five invertebrates consisted of worms, beetles, bugs, and moths. Star-nosed Mole (*Condylura cristata*) was the most commonly (13) identified prey species (Table 2) and was prominent in both years (Table S7).

Most (~79%) prey deliveries, including all invertebrate and 73% of vertebrate prey, occurred at night (Figure 4) with at least two peaks at 2100 and 0400 CDT; the time between peaks generally corresponded with the time required for nestlings to digest food (Duncan 2003). More prey (63% of 65 prey items) were identified from images with the camera facing the side of the cavity (2017) compared to images with the camera facing directly into the cavity (2016; Table S7).

Barred Owl nest cavity activity outside the nesting season and nest site abandonment

In 2017, after successfully fledging three young, Barred Owls visited the nest cavity entrance five times at night in September and October. On two of these occasions, they entered the cavity and on one occasion two owls were there at the same time. The estimated duration of these visits averaged 2 min and 53 s (range 42 s to 5 min 56 s; Table S8). Barred Owls next visited the nest cavity briefly (24 s) in February 2018, followed by four longer (mean 4 min and 19 s, range 11 s to 22 min and 4 s) visits in each of March and April (Table S8). A 1 min and 18 s owl visit on 14 May 2018 was followed later that day by an American Black Bear (*Ursus americanus*) visit (Figure S4a), after which the owls abandoned the nest cavity and did not nest there in subsequent years (2019–2022). Only five short (<3 s) visits by Barred Owls

TABLE 1. Adult Barred Owl (*Strix varia*) activity at the nest cavity entrance based on number of images recorded in 2016 with two nestlings and in 2017 with three nestlings, southeastern Manitoba, Canada.

Nesting stage	2016		2017	
	Day	Night	Day	Night
Pre-egg laying	173	932	0	0
Incubation	266	1373	86	751
Nestling	528	2018	550	1156
Totals	967	4323	636	1907

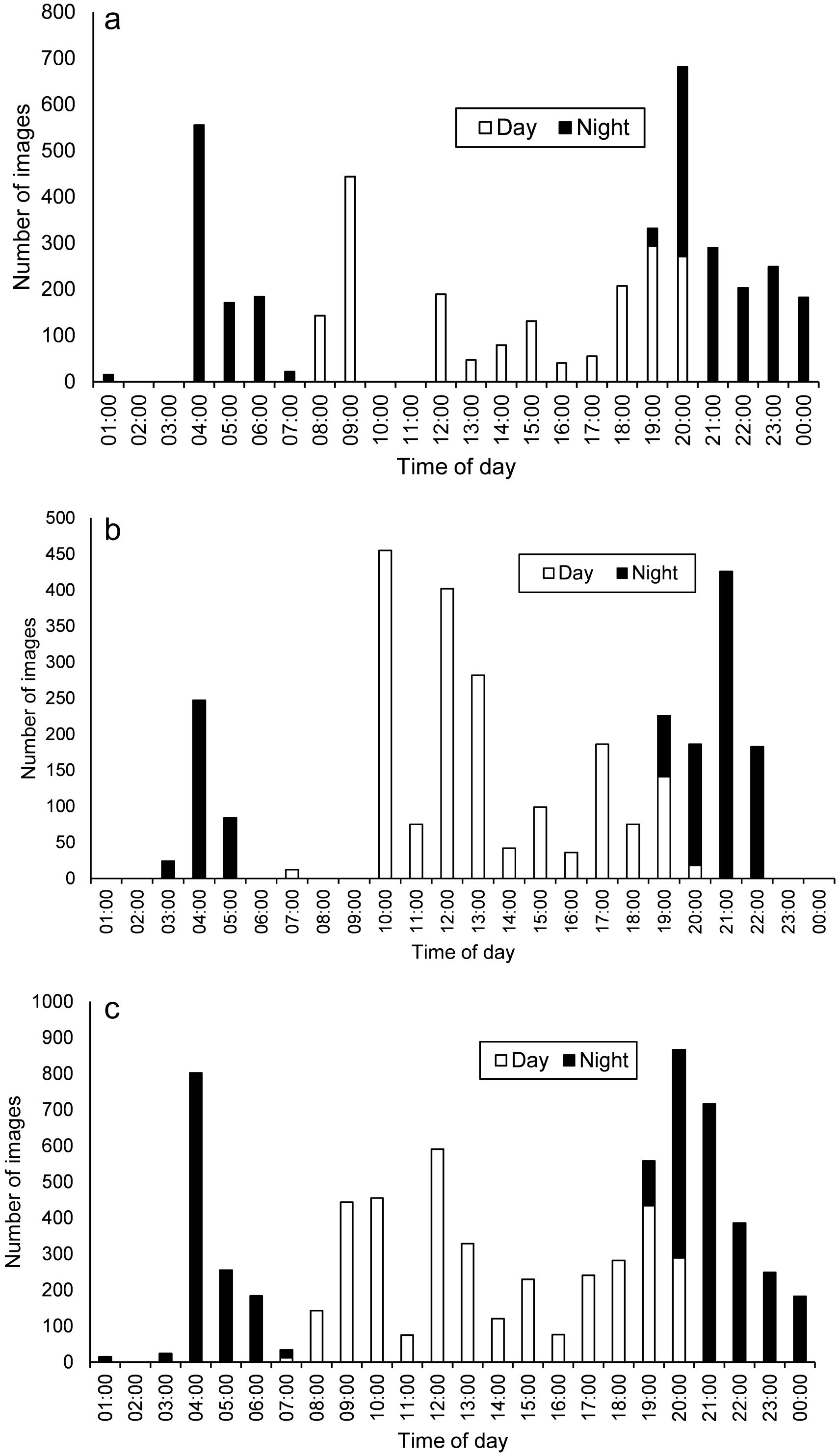

FIGURE 3. Timing of nestling Barred Owl (*Strix varia*) activity at the nest cavity entrance based on images recorded for a. 2016 with two nestlings, b. 2017 with three nestlings, and c. 2016 and 2017 combined in southeastern Manitoba, Canada.

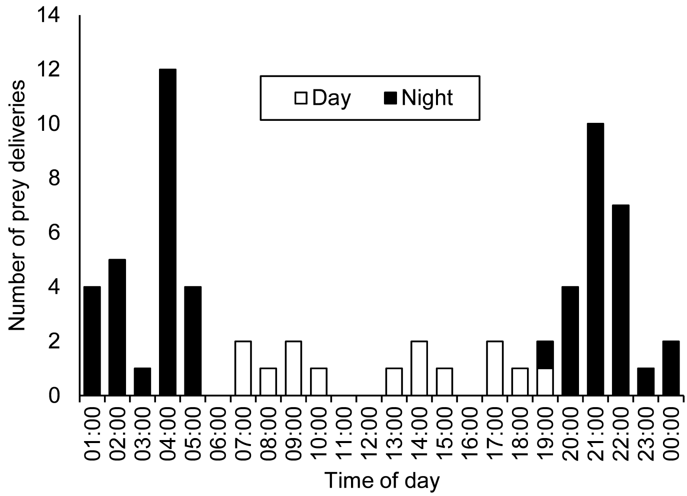

FIGURE 4. Time of Barred Owl (*Strix varia*) prey deliveries to the nest cavity based on 65 image sets recorded in 2016 and 2017 where prey items were visible in southeastern Manitoba, Canada.

TABLE 2. Barred Owl (*Strix varia*) prey identified from images taken by a trail camera at a nest cavity, southeastern Manitoba, Canada (2016–2017).

Number	Common name	Scientific name or taxonomic category
1	*Common Earthworm	*Lumbricus terrestris*
2	*Giant Water Bug	*Lethocerus americanus*
1	*Unidentified sphinx moth	Family: Sphingidae
1	*Unidentified predaceous diving beetle	Genus: *Dytiscus*
1	*Wood Frog	*Lithobates sylvaticus*
1	Unidentified frog (Wood or Leopard Frog)	Genus: *Lithobates*
1	*Unidentified garter snake	Genus: *Thamnophis*
1	American Robin	*Turdus migratorius*
1	*Downy Woodpecker	*Picoides pubescens*
1	Ruffed Grouse	*Bonasa umbellus*
1	*Sora	*Porzana carolina*
1	*Yellow-bellied Sapsucker	*Sphyrapicus varius*
2	Unidentified bird	Class: Aves
1	Deer Mouse	*Peromyscus maniculatus*
3	Meadow Vole	*Microtus pennsylvanicus*
2	*Northern Flying Squirrel	*Glaucomys sabrinus*
3	*Snowshoe Hare	*Lepus americanus*
13	Star-nosed Mole	*Condylura cristata*
3	Jumping Mouse	Genus: *Zapus*
1	*Unidentified weasel	Genus: *Mustela*—likely **Mustela erminea*
1	Unidentified rodent	Family: Cricetidae or Muridae
1	Unidentified squirrel	Family: Sciuridae
2	Unidentified vole	Subfamily: Arvicolinae
1	Unidentified rodent	Order: Rodentia
7	*Unidentified mammals	Class: Mammalia: one likely *Lepus americanus* and one likely **Martes americana*
4	Unidentified vertebrate	Subphylum: Vertebrata
8	Unidentified animal	Kingdom: Animalia

*New prey taxa in Manitoba based on Whiklo (2011). See also Table S7.

occurred in the following months until the camera was removed 25 May 2019 (Table S8).

Other species visiting the nest cavity

The nest camera recorded a variety of other bird and mammal species visiting the nest cavity prior to, during, and after the nesting season including nest predators such as American Marten (*Martes americana*) and American Black Bear (Figures S4, Table S9).

Discussion

Nest site and habitat

The nest cavity's dimensions were within the range of nest cavity dimensions for other Barred Owl nest cavities in Manitoba (Whiklo and Duncan 2014). The forest habitat within the estimated breeding home range was consistent with the characterization of Barred Owls being forest habitat generalists (Whiklo and Duncan 2014; Mazur and James 2020). The reuse of nest sites is well documented in this species (Elderkin 1987; Mazur and James 2020).

Adult activity

The rise and fall of adult Barred Owl activity at the nest before and after egg laying was consistent with that of most birds, which are generally secretive while incubating (Pettingill 1970). The relatively early increase in adult activity during the latter stage of incubation in 2016 seemed unusual. As expected, an increase in recorded adult activity corresponded to nestling growth, followed by a decrease associated with the owlets fledging. Elderkin (1987) reported that an adult female stopped brooding nestlings intensively about two weeks after the first egg hatched and at this time the female started to help with catching prey and feeding nestlings. An inferred similar change in adult female behaviour may explain the timing of the second peak in adult activity at the nest cavity in 2016 and the overall continued general increase in 2017.

Barred Owls are generally considered to be semi-nocturnal to nocturnal hunters (Mazur and James 2020). Elderkin (1987) documented adults at one nest in Nova Scotia hunted almost exclusively at night. We suggest that the adults we monitored had to also hunt during the day to feed their nestlings because the nights were shorter at our latitude, especially in 2017 when they had more nestlings. This pressure was relaxed in the nonbreeding season when all recorded activity was at night.

Nestling activity

Nestling activity at the nest entrance and fledging dates corresponded to clutch initiation dates and ages (27 to 32 d old) as reported for this species elsewhere (Mazur and James 2020). The larger brood size (two nestlings in 2016 versus three in 2017) only added one extra day (eight versus nine days) to the period when nestlings were active at the nest entrance before fledging. This contrasted with another study where the third hatched nestlings grew slower and took longer to fledge (Elderkin 1987).

Unlike primarily nocturnal adults, nestlings were equally active day and night with three evenly spaced activity peaks at 0400, 1200, and 2000 CDT. Two of these peaks corresponded to prey deliveries. Knowledge of when and how long nestlings are active at the nest cavity entrance can help researchers plan when to capture and band them before they fledge; fledged young typically perched high in tree canopies are harder to find and capture.

Diet and prey deliveries

While Barred Owls are known diet generalists, with small mammals and birds forming the bulk of their diet (Mazur and James 2020), knowledge of their diet in Manitoba is limited. Whiklo (2011) documented 123 prey taxa from nest sites, pellets, and stomach contents. Our camera trap study added 12 new taxa to the known diet of Barred Owls in Manitoba (Table 2). The predominance of Star-nosed Mole as prey suggests that they may be locally abundant. Another study in which camera traps were baited with carcasses documented carrion-feeding by Barred Owls in North Carolina (Kapfer *et al.* 2011).

Barred Owl nest cavity activity outside the nesting season and nest site abandonment

Barred Owls are known to vigorously defend territories year round (Mazur and James 2020) and to prospect potential nest sites as much as a year before use (Elderkin 1987). Our study documents nest cavity inspection behaviour in fall and winter and is evidence of their importance as a scarce or important resource worth the energy expended in defending them from conspecifics. The amount of nonbreeding season activity at the nest cavity in fall 2017 and the following winter was considerable.

An American Black Bear was previously suspected of predating a different Barred Owl nest site in Manitoba (Whiklo 2011) and a female Northern Spotted Owl (*Strix occidentalis caurina*) attacked an American Black Bear to defend its fledged young near its nest site in Washington State, USA (Alston *et al.* 2017). It is likely that Barred Owls had already laid eggs when an American Black Bear visited the nest cavity on 14 May 2018 (Figure S4a) given the clutch initiation dates in the three previous years (Table S6) and the prior increased Barred Owl activity at the nest cavity that spring (Table S8). The absence of eggs or young on two subsequent visits to the nest site (Table S6) suggests that the American Black Bear visit was a nest predation event that caused the owls to abandon the nest cavity in 2018 and in subsequent years (2019–2022). The significantly reduced nonbreeding activity in fall 2018 and winter 2018–2019, the abandonment of the nest cavity after the predation event, and the use of a Common Raven (*Corvus corax*) stick nest ~100 m to the east in 2021 (Table S6) suggests that resident Barred Owls avoid nest predation involving predators with long-term memory, as noted by Sonerud (1985) for Tengmalm's Owl (*Aegolius funereus*).

Camera trap effectiveness

The use of camera traps to document cavity nesting Barred Owl behaviour, activities, and diet were moderate to poor when compared to the success in using them for studying open-nesting owl species (Duncan and Kerbrat 2022). The camera trap model we used required both motion and temperature variances to trigger. We noticed considerable gaps in image sequences occurred due to a failure of the camera's passive infrared motion sensors to trigger. This likely happened when smaller nestlings were stationary in front of the camera and did not move across more than one detection zone (see red areas in Figure S5); this may have been mitigated by adjusting the camera upward such that both detection zones crossed the nest cavity opening (Figure S5). In addition, dense Barred Owl juvenile plumage, especially on the head and back, may have minimized relative differences between the owl's and the ambient temperatures below the camera's trigger threshold.

Adult Barred Owls often entered or departed the nest tree cavities quickly without lingering at the entrance, likely to avoid detection by predators. This makes finding Barred Owl cavity nests challenging. While Barred Owl flight speed has not been measured, Great Horned Owl (*Bubo virginianus*) can fly at speeds of 65 km/h in level flight (Voous 1988). Other tree cavity nesting species like Wood Duck (*Aix sponsa*) often enter and exit nest tree cavities fast without perching at the entrance to reduce the likelihood of nest predation and/or brood parasitism (M. Dyson pers. comm. 15 June 2022) and fly up to 56 km/h (Stewart 1958). The camera was often unable to trigger fast enough to record images with adult owls in frame or resulted in blurred, distorted, and empty images. This limited the detection of behaviour and prey identification. The resulting time gaps between recorded activities prevented a more detailed analysis of nesting behaviour such as how long the female was in the cavity and how that changed during the incubation and brooding periods.

The camera directly faced the nest cavity entrance in 2016 such that often only the back of the adult owl was visible when it was visiting the nestlings. This limited the number of identifiable prey deliveries and prevented an analysis of changes in prey type as nestlings aged. Conversely more images of young active in the nest cavity prior to fledging were obtained in 2016 versus 2017 even though there were fewer nestlings that year. The opposite occurred in 2017 when the camera was positioned to face the side of the cavity.

Conclusions

Despite the limitations of this camera trap model's technology, new detailed information on the chronology and activity patterns of adult and nestling Barred Owls were documented at a natural nest cavity in a protected area. In addition, an increased number of new Barred Owl prey species were identified in Manitoba (Table 2). These data will assist future research and banding efforts (i.e., when to access nestlings before they fledge). There are few documented Barred Owl nest sites and breeding habitats in Manitoba. The new nest site identified in our study corroborates previous knowledge of the habitat requirements for Barred Owl, which depend on large nest cavities in large trees and a diverse prey base.

Other automated image or video recording systems have demonstrated substantial technological, sample size, and human resource limitations while yielding new behaviours and ecology for species that are logistically challenging to study (Harms 2021; Balin *et al.* 2022; Duncan and Kerbrat 2022). Camera traps are cost effective, but the time required for data processing is large. The use of artificial intelligence, specifically deep learning, to process camera-trap data will make their use more efficient (Vélez *et al.* 2022). Improvements in technology will enhance our knowledge of such species by using less invasive research methods.

Author Contributions

Writing – Original Draft: J.R.D. and R.K.; Writing – Review & Editing: J.R.D., R.K., and T.M.W.; Conceptualization: J.R.D.; Investigation and Methodology: J.R.D. and R.K.; Analysis: J.R.D., R.K., and T.M.W.

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SUPPLEMENTARY MATERIALS:

FIGURE S1. Barred Owl (*Strix varia*) nest cavity with mounted camera trap, southeastern Manitoba, Canada. Photo: James Duncan.

FIGURE S2. Camera trap images of a. adult Barred Owl (*Strix varia*) delivering a Star-nosed Mole (*Condylura cristata*) to its nest cavity, b. nestling peering out of the nest cavity, and c. nestling Barred Owl (*Strix varia*) at the nest cavity entrance before fledging, in southeastern Manitoba, Canada. Photos: James Duncan.

FIGURE S3. Number of nestling Barred Owl (*Strix varia*) images recorded at the nest entrance in a. 2016 with two nestlings present 1–7 June and b. in 2017 with three nestlings present 21–28 May in southeastern Manitoba, Canada.

FIGURE S4. Camera trap images of a. American Black Bear (*Ursus americanus*), b. Red Squirrel (*Sciurus vulgaris*), c. American Marten (*Martes americana*) visiting a Barred Owl (*Strix varia*) nest cavity in southeastern Manitoba, Canada.

FIGURE S5. Camera trap image of Barred Owl (*Strix varia*) nestling at nest cavity entrance in southern Manitoba superimposed with 12 camera motion and relative temperature detection zones (individual red areas bordered by vertical black lines) arranged in upper and lower bands.

TABLE S1. Forest resource inventory habitat cutting class areas (ha) associated with estimated Barred Owl (*Strix varia*) breeding home ranges in southeastern Manitoba, Canada.

TABLE S2. Forest resource inventory habitat crown closure areas (ha) associated with estimated Barred Owl (*Strix varia*) breeding home ranges in southeastern Manitoba, Canada.

TABLE S3. Forest resource inventory habitat species composition areas (ha) associated with estimated Barred Owl (*Strix varia*) breeding home ranges in southeastern Manitoba, Canada.

TABLE S4. Forest cover type associated with a circular 314 ha estimated Barred Owl (*Strix varia*) breeding home range in southeastern Manitoba, Canada.

TABLE S5. Summary of camera trap recorded image files at a Barred Owl (*Strix varia*) nest cavity in southeastern Manitoba, Canada, 2016 to 2019.

TABLE S6. Chronology of observed and estimated breeding and other select events at a Barred Owl (*Strix varia*) nest cavity in southeastern Manitoba, Canada, 2015 to 2021.

TABLE S7. Barred Owl (*Strix varia*) prey identified from images taken by a trail camera at a nest cavity in southeastern Manitoba, Canada (2016–2017) in chronological order.

TABLE S8. Barred Owl (*Strix varia*) non-breeding season visits to a nest cavity in southeastern Manitoba, Canada (2017–2019).

TABLE S9. Birds and mammals visiting a Barred Owl (*Strix varia*) nest cavity in southeastern Manitoba, Canada, 2016 to 2019.

The Canadian Field-Naturalist

Distribution and breeding potential of the exotic False Map Turtle (*Graptemys pseudogeographica*) in Canada

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Abstract

False Map Turtle (*Graptemys pseudogeographica*) is widespread in the central United States, and its native range extends close to the Canadian border. It is common in the pet trade and has been released into the wild outside its native range. We examined observations of False Map Turtle from iNaturalist Canada, an online platform to document native and non-native species, and confirmed 20 observations in Canada from eight cities in three provinces. The earliest observation was in April 2014 from Victoria, British Columbia. Fourteen of the 20 observations (70%) were from 2020 to February 2024. All the turtles were either large juveniles or adults. Climate data from the northern part of the False Map Turtle's native range and from Canadian cities suggest that individuals could survive the winter in parts of southern Canada and successfully breed in parts of southern Ontario during the warmest years.

Key words: Community science; exotic species; False Map Turtle; *Graptemys pseudogeographica*; iNaturalist

Introduction

The trade in exotic pets is a large, international industry and reptiles are the second most common group of species in the global trade (Bush *et al.* 2014). Turtles have been common in the pet trade for decades (D'Aoust and Lior 1978; Kopecký *et al.* 2013). Red-eared Slider (*Trachemys scripta elegans*) has been the most commonly traded turtle species and many have been released into the wild making it the most widespread turtle species in the world (Ernst and Lovich 2009). Other turtle species, including False Map Turtle (*Graptemys pseudographica*), are becoming common in the pet trade (Kopecký *et al.* 2013; Lyons *et al.* 2013). A recent study found 120 species of turtles for sale (Sung *et al.* 2021).

We focussed on False Map Turtle because its northern range comes close to Canada and, therefore, it could survive Canadian winters, successfully breed in parts of Canada, and possibly become established in this country. Other species in the pet trade that have been released into Canada, such as Greek Tortoise (*Testudo graeca*), Florida Redbelly Turtle (*Pseudemys nelsoni*), and Florida Softshell (*Apalone ferox*), are rarely reported in the wild (iNaturalist Canada 2024); given their association with warmer climates, they are unlikely to be able to breed successfully in Canada.

The native range of False Map Turtle is limited to the United States, extending as far north as North Dakota, Minnesota, and Wisconsin (Ernst and Lovich 2009). The species is mainly limited to large streams and rivers that are part of the Missouri and Mississippi River systems (Ernst and Lovich 2009). Two subspecies have been identified, although there is some taxonomic uncertainty regarding this arrangement (Thomson *et al.* 2018): False Map Turtle (*G. p. pseudogeographica*), found in the northern part of the range, and Mississippi Map Turtle (*G. p. kohnii*), found in the southern part of the range.

Between 2011 and 2020, over 500 000 False Map Turtles were exported from the United States (CITES Secretariat 2022). Adult females can reach 27 cm in carapace length (Ernst and Lovich 2009), so pets that survive can become too large to easily maintain in captivity. Released pets have been found outside the native range in the United States (Spinks *et al.* 2003; Smith *et al.* 2020) and in other countries, such as Croatia (Jelić and Jelić 2015), Germany (Schradin 2020; Tietz *et al.* 2023), Italy (Ferri *et al.* 2021), Romania (Iftime and Iftime 2021), Spain (Poch *et al.* 2020), and the Republic of Korea (Koo *et al.* 2020). Nesting has been confirmed at two locations in Italy (Ferri *et al.* 2021), and successful reproduction has been confirmed in Germany (Tietz *et al.* 2023).

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To assess the current distribution of False Map Turtle in Canada, we used data from iNaturalist Canada, an online platform for naturalists to record observations of native and exotic species. To date, iNaturalist Canada has more than 13 million observations of more than 38 000 species reported by more than 200 000 people (iNaturalist Canada 2024). Data from iNaturalist have been used to examine the distribution of exotic species (Werenkraut *et al.* 2020; Martel *et al.* 2022; Mo and Mo 2022) and to better assess the distribution of rare species (Gaier and Resasco 2023). The >66 000 observations of turtles on iNaturalist Canada make it a rich database, and iNaturalist is an ideal tool for assessing the distribution of a rare, exotic species that can be readily identified from photographs. These data can be better at detecting rare species than more structured surveys (Roberts *et al.* 2022) because community science allows for many eyes (or cameras) in many places. We also compared the climate in the northern portion of False Map Turtle's native range with that in Canadian cities to assess the likelihood of successful breeding in Canada and the species' ability to survive the winter.

Methods

We obtained observations of False Map Turtles from iNaturalist Canada submitted before the end of February 2024. We examined each photograph and excluded any observations we could not confirm as a False Map Turtle based on the presence of the postorbital mark. Observations were mapped using QGIS 3.4 (QGIS Development Team 2022). We obtained the mean monthly climate normal data (1991–2020) for Minneapolis, Minnesota (NOAA 2022) and for selected Canadian cities (1981–2010; Government of Canada 2022). We used the mean monthly temperature of the warmest month as an indicator of hatching success as it is strongly correlated with where the exotic Red-eared Slider could successfully breed in Italy (Ficetola *et al.* 2009). To determine whether recent temperatures are warmer than the 30-year climate normal, we also obtained the mean monthly air temperature for Canadian cities for the last five years (2018–2022). We used the number of days between the average first date of fall frost and the last spring frost as a measure of the winter's length. Longer winters can reduce turtle survival more often than the severity of the winter as a result of prolonged hypoxia or anoxia (Ultsch 2006).

Results

We confirmed 20 observations of False Map Turtles in Canada, from eight cities in three provinces (Table 1). The earliest observation was in April 2014 in Victoria, British Columbia. Fourteen of the 20 observations (70%) were from 2020 to 2024. All of the turtles were either large juveniles or adults. Although determining the sex of adult map turtles is easy when the individual is in the hand, sexing from photographs can be difficult if the tail is not visible; thus, we do not report sex.

British Columbia

Nine of the 20 observations (48%) were from British Columbia. Six were from Beacon Hill Park in Victoria. The park contains a pond roughly 0.2 km long with small islands. Two individuals were observed on the same day in May 2021. Observations at Beacon Hill Park range from 29 April to 25 September. It is uncertain whether turtles observed in different years represent the same individuals or different turtles.

One False Map Turtle was observed in Cathers Lake in Nanaimo, a lake ~0.7 km long and surrounded by houses. False Map Turtles were reported from Stanley Park, Vancouver, in 2022 and 2024; one was observed in Lost Lagoon, a small, artificial lake roughly 0.5 km long.

Ontario

Eight of the 20 (40%) observations were from Ontario (Table 1). We found five observations of False Map Turtles in Toronto from five locations that were all parks or urban greenspaces with ponds or rivers. One of the locations was Rouge National Urban Park. The five sites in Toronto were all at least 7.6 km apart and spanned a distance of 47 km.

One False Map Turtle was observed in Lake Simcoe in Barrie in 2019, one was observed in Clergue Park in Sault Ste. Marie in 2023, and one was observed in the Ottawa River in Ottawa in 2018.

Quebec

Three observations of False Map Turtles were from Québec City (Table 1). The first was observed in the Saint-Charles River in the urban portion of the city in 2020. Two other observations were ~8 km to the west in a small, artificial lake ~0.7 km in length in Parc de la Base de Plein Air de Sainte-Foy in 2021 and 2022.

Climate data

The mean monthly temperature for July, the warmest month of the year, for Minneapolis, Minnesota, near the northern limit of False Map Turtle's range, is 23.5°C. All Canadian cities with observations of False Map Turtles are at least 2°C cooler than Minneapolis (Table 2). Windsor, Ontario, the southernmost city in Canada, has a July monthly temperature that is only 0.5°C cooler than Minneapolis (Table 2). In addition, the mean monthly temperature for September in Windsor (17.9°C) is warmer than Minneapolis (17.5°C).

TABLE 1. Reported observations of False Map Turtle (*Graptemys pseudogeographica*) in Canada.

City	Location	Date	Observation URL
British Columbia			
Nanaimo	Cathers Lake	22 May 2021	https://inaturalist.ca/observations/80115971
Victoria	Beacon Hill Park	29 April 2014	https://inaturalist.ca/observations/44371704
		14 May 2020	https://inaturalist.ca/observations/45882807
		21 May 2021	https://inaturalist.ca/observations/79732327
		21 May 2021	https://inaturalist.ca/observations/79732329
		10 July 2022	https://inaturalist.ca/observations/125892979
		25 September 2022	https://inaturalist.ca/observations/136477853
Vancouver	Stanley Park	1 June 2022	https://inaturalist.ca/observations/119786383
		1 February 2024	https://inaturalist.ca/observations/198364947
Ontario			
Sault Ste. Marie	Clergue Park	27 August 2023	https://inaturalist.ca/observations/180483960
Barrie	Lake Simcoe	9 June 2019	https://inaturalist.ca/observations/135585570
Toronto	Don Valley Brick Works Park	28 August 2018	https://inaturalist.ca/observations/16000852
	Centennial Park	13 May 2019	https://inaturalist.ca/observations/33046163
	Rouge National Urban Park	23 July 2019	https://inaturalist.ca/observations/71496738
	Humber River	19 July 2020	https://inaturalist.ca/observations/54776827
	Kariya Park	15 May 2022	https://inaturalist.ca/observations/119655401
Ottawa	Ottawa River	26 May 2018	https://inaturalist.ca/observations/20197044
Quebec			
Québec City	St. Charles River	4 July 2020	https://inaturalist.ca/observations/71464227
	Parc de la Base de Plein Air de Sainte-Foy	12 July 2021	https://inaturalist.ca/observations/108234441
		1 July 2023	https://inaturalist.ca/observations/170443123

Source: iNaturalist Canada 2024.

TABLE 2. Summer and winter climate data near the northern limit of distribution of False Map Turtle (*Graptemys pseudogeographica*) in cities with observations of False Map Turtle or where successful breeding could occur.

Location	July 30-year average temperature, °C*	July mean temperature, 2018–2022, °C (maximum)	Frost period, days†
United States			
Minneapolis	23.5		202
Canada			
Victoria	16.9	17.8 (18.3)	153
Vancouver	18.0	18.7 (19.4)	128
Ottawa	21.0	22.0 (24.0)	205
Toronto	21.5	23.1 (25.0)	196
Windsor	23.0	23.4 (24.6)	169
Québec City	19.3	20.0 (20.9)	219

*1991–2020 for Minneapolis (NOAA 2022); 1981–2010 for the Canadian cities (Government of Canada 2022).
†Number of days between the average dates of the first fall frost and the last spring frost.

Considering just the years 2018–2022, both Toronto (23.1°C) and Windsor (23.4°C) have mean monthly July temperatures within 0.5°C of the mean monthly July temperature in Minneapolis (Table 2). Both cities exceeded 23.5°C in some years: Toronto in 2020 and Windsor in 2019 and 2020. Although Ottawa was cooler than Minneapolis on average (22.0°C), in one year (2020) it exceeded the July mean monthly temperature of Minneapolis. The frost period in Minneapolis averages 202 days which is longer than cities in southern British Columbia and southern Ontario (Table 2).

Discussion

False Map Turtle has been observed in three Canadian provinces. Its range in Canada may be broader than documented here, as some observations of the species on iNaturalist Canada may have been misidentified as the native Northern Map Turtle (*Graptemys geographica*). Some False Map Turtle observations had originally been identified as Northern Map Turtle, but not all misidentifications may have been corrected. Misidentification of species can be a problem with iNaturalist data, but it is usually greater for smaller and harder to identify species (Barbato *et al.* 2021; McMullin and Allen 2022). Nonetheless, it would be easy for an observer to assume that a False Map Turtle was really a Northern Map Turtle, the only species of *Graptemys* native to Canada. We examined all 1953 observations of Northern Map Turtle on iNaturalist Canada for another project (Seburn *et al.* 2023) and found only two cases where False Map Turtle had been incorrectly identified as Northern Map Turtle (0.1%), suggesting that misidentification is not a major issue. It is possible that in photos that do not show the diagnostic head markings, False Map Turtle could be assumed to be the native Northern Map Turtle.

Overall, iNaturalist Canada should be a good resource for assessing the distribution of a large, exotic turtle species. iNaturalist data tend to be biased toward larger-bodied animals (Callaghan *et al.* 2021) and toward more urban areas (Di Cecco *et al.* 2021; Mesaglio and Callaghan 2021) where pet turtles are most likely to be released (Seburn 2015; Poch *et al.* 2020; Mitchell *et al.* 2022).

False Map Turtle likely remains fairly uncommon in Canadian waterbodies. During 2016–2019, intensive turtle surveys of multiple wetlands in Toronto found only one False Map Turtle (Dupuis-Desormeaux *et al.* 2021). In contrast, iNaturalist Canada has more than 3200 observations of Pond Slider (*Trachemys scripta*; iNaturalist Canada 2024). The number of exotic False Map Turtles in Canada could increase substantially in the future, if the species continues to be sold in pet stores and unwanted turtles are released into the wild when they are too big to care for.

Most (70%) False Map Turtle observations were from 2020 onward. This could reflect a growing number of False Map Turtle individuals in the wild, but could simply be a reflection of iNaturalist data being biased toward the recent past, as the number of users and observations has been growing exponentially over the past decade (Di Cecco *et al.* 2021; Mesaglio and Callaghan 2021). Similarly, 76% of Pond Slider observations on iNaturalist Canada were from 2020 onward.

The frost period in many Canadian cities with False Map Turtle observations is shorter than that of Minneapolis (Table 2) suggesting that False Map Turtle could successfully overwinter in southern British Columbia and southern Ontario. It may even be able to overwinter in Ottawa, which has a frost period only slightly longer than that of Minneapolis. The northern distribution limit of turtles may be more limited by cooler summers than colder winters because lower incubation temperatures result in reduced hatching success of eggs (Obbard and Brooks 1981; Bobyn and Brooks 1994; Iverson 2022). In terms of exotic species, successful reproduction of Red-eared Slider in Europe is strongly correlated with summer but not winter temperatures (Ficetola *et al.* 2009). In addition, many nests of the exotic Red-eared Slider in southwestern British Columbia failed to hatch because of relatively cool summer temperatures, and more eggs hatched during a warmer summer (Mitchell *et al.* 2022). Similarly, most eggs of the exotic Red-eared Slider failed to hatch in Toronto, Ontario (Dupuis-Desormeaux *et al.* 2022). It is noteworthy that some eggs did successfully hatch although the hatchlings did not emerge from the nest. Dupuis-Desormeaux *et al.* (2022) demonstrate that a species that is native to areas south of Canada can breed in Ontario and its eggs hatch under suitable conditions. Their results suggest that other species found close to the Canadian border may also be able to successfully breed in Canada under suitable conditions.

If the mean monthly temperature of the warmest month at the northern edge of the False Map Turtle's distribution is a good indication of thermal limits to successful reproduction, then it is possible that the species cannot successfully breed in British Columbia because the July mean monthly temperature in Vancouver and Victoria is more than 5°C cooler than Minneapolis. Considering just the climate normal data for Ontario, Toronto is 2°C cooler than Minneapolis and this may be sufficient to prevent nests from hatching except in the warmest locations or warmest years. Windsor, in extreme southwestern Ontario, is only 0.5°C cooler than Minneapolis, suggesting that eggs could hatch successfully. In addition, Windsor is 0.5°C warmer than Minneapolis in September which could give eggs more time to develop and hatch before fall. Considering just the last five years, Windsor, Toronto, and Ottawa had years where the mean monthly July air temperature was warmer than the average for Minneapolis. Given recent summer temperatures, it is quite possible that False Map Turtle nests could successfully hatch in the warmest years in many areas in southern Ontario. Continued warming from climate change could lead to summer temperatures 2–4°C warmer in the Great Lakes area by mid-century (Zhang *et al.* 2020), which could result in successful hatching in more years, or a larger area of southern Ontario where False Map Turtle could successfully breed.

Even if False Map Turtle cannot successfully breed in most of Canada, the release of unwanted pets can still pose a risk to native turtle species. In the past, False Map Turtle has successfully bred with Northern Map Turtle (Freedberg and Myers 2012). It is possible that released pets could breed with native Northern Map Turtles resulting in hybrid offspring, which may be less adapted to northern environments. In addition, turtles in the pet trade potentially face a number of extrinsic stressors, such as crowding, unhygienic handling, poor water quality, polluted feeding, and inadequate nutrition, which can predispose pet turtles to viral or bacterial infections which can be transmitted to other species or cause mortality (Brenes *et al.* 2014; McKenzie *et al.* 2019; Hossain and Heo 2021). The release of any exotic turtle into the wild poses a risk of the release of a novel pathogen that could harm native turtle species or other aquatic wildlife. Efforts should be undertaken to limit the release of unwanted pet turtles into the wild.

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Note

The "perrrck" vocalization of Ruffed Grouse (*Bonasa umbellus*)

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Abstract
The vocal repertoire of Ruffed Grouse (*Bonasa umbellus*) has been known for decades, but because of the rarity of vocal recordings in the field, few data exist on spectral characteristics of their vocalizations. Here, we provide a spectrogram and analysis of a vocalization rarely heard in the field: the "perrrck" call, which is ~0.5 s in duration and has a fundamental frequency of 613 Hz with several harmonics. We compare this call with the more commonly heard "peet" call, which is much shorter and of higher frequency. Although the function of the perrrck call remains unknown, our analyses show that Ruffed Grouse vocalizations vary in frequency, despite their purportedly weak syrinx.

Key words: Ruffed Grouse; *Bonasa umbellus*; vocalization; vocal repertoire

Ruffed Grouse (*Bonasa umbellus*) is a heavily managed gamebird species in North America, but many aspects of its behaviour remain understudied. For example, it produces several different vocalizations, but data and spectrograms (and, more important, spectral analyses) for most of these vocalizations are lacking, and some are only vaguely described (Bump *et al.* 1947; Atwater and Schnell 1989; Rusch *et al.* 2020). Unlike most other grouse species, the courtship display of Ruffed Grouse largely lacks vocalizations, except for a "hiss" produced by males when they cease drumming and engage in a tail-fanning visual display (Hjorth 1970). The "peet" (or "peta") call is the most commonly produced and heard vocalization (Bump *et al.* 1947; Atwater and Schnell 1989). Peets are typically produced before and after a grouse flushes (Bump *et al.* 1947; Atwater and Schnell 1989), which suggests that it may function as an alarm or distress call (Atwater and Schnell 1989). Despite their relatively weak syringeal musculature (Atwater and Schnell 1989), Ruffed Grouse can produce a range of sounds (Bump *et al.* 1947); however, they do so infrequently in the wild and so detailed information on the acoustic structure of their vocalizations is lacking.

Here we describe a circumstance in which we were able to record a rare vocalization in a male Ruffed Grouse, the "perrrck" call (Bump *et al.* 1947). In addition, we complete a spectral analysis of the perrrck call in comparison with the peet call, providing the first quantitative data on this rarely produced vocalization.

As part of a long-term study on Ruffed Grouse drumming behaviour near Buck Lake, Alberta (52.97°N, 114.77°W), A.N.I. conducted a series of playback experiments in April and May 2012–2014. Briefly, each consisted of positioning a speaker 35–40 m from a male's drumming structure and broadcasting the drumming sound of an unfamiliar male. Further details of the playback study and field site are provided in O'Neil *et al.* (2018).

On 11 May 2014, a playback trial began at 0750 (MDT) directed towards a male Ruffed Grouse that was actively drumming on a log. After presentation of the first drumming recording, this male stopped drumming and approached the speaker. He circled the speaker several times, occasionally emitting peet vocalizations. After the 9th drumming playback, he partly fanned his tail out and began producing a vocalization that we had not previously encountered over 10 breeding seasons. The bird continued to vocalize for 12.5 min while slowly walking around the speaker at a distance of 1–5 m. Based on the sound produced and slight tail fanning behaviour, we believe this is the perrrck vocalization described by Bump *et al.* (1947), which is also referred to as "cherp" by Atwater and

Schnell (1989). A.N.I. then removed the speaker from the area, while the male grouse remained stationary under a small Black Spruce (*Picea mariana* (Miller) Briton, Sterns & Poggenburgh) and continued to vocalize.

Although the sound pressure level was not recorded, it was difficult to hear the perrrck vocalization beyond 10 m. The male's behaviour was recorded on a Canon SX30 IS PowerShot (Canon USA Inc., Melville, New York, USA) digital camera (Iwaniuk 2024) and a WAV audio file extracted from the video. Spectrograms were then created and measured in Praat (version 6.2.15; P. Boersma and D. Weenink, University of Amsterdam, Amsterdam, Netherlands, http://www.praat.org/).

Spectral analysis was conducted and averaged across 20 bouts of vocalization by the same male Ruffed Grouse. The perrrck call averaged 0.47 ± 0.04 s in duration (± SD), had an inter-call interval of 0.21 ± 0.01 s, and a fundamental frequency of 613 ± 23 Hz. In addition to the fundamental frequency, the perrrck contained four harmonics centred on the following frequencies: 1225 ± 46 Hz, 1845 ± 69 Hz, 2460 ± 83 Hz, and 3102 ± 139 Hz (Figure 1a).

For comparison, a spectrogram of the more common peet call, downloaded from Xeno-canto (a wildlife sound sharing website based in the Netherlands) was analyzed (Figure 1b). The peet vocalization was from a single individual recorded in Minnesota, USA (Marvin 2014). In contrast to the perrrck call, the peet call was repeated rapidly. Each peet (averaged over 20 bouts) was of shorter duration (0.08 ± 0.01 s), shorter inter-call interval (0.12 ± 0.03 s), and higher fundamental frequency (5663 ± 132 Hz) than the perrrck. Structurally, the peet was also different in that it had a frequency sweep extending from 321 to 6133 Hz and lacked harmonics (Figure 1b), whereas the perrrck was a constant tone with several harmonics (Figure 1a).

Apart from the drumming display (Garcia *et al.* 2012; O'Neil *et al.* 2018), spectrograms of other Ruffed Grouse vocalizations are largely lacking in the literature (Rusch *et al.* 2020). Past research suggests (Bump *et al.* 1947) this is because Ruffed Grouse do not commonly vocalize in the wild. In fact, Bump *et al.* (1947) state that solitary Ruffed Grouse rarely vocalize and that maintaining habituated grouse in aviaries is what enabled them to document the different vocalizations. Territorial interactions in the wild appear to be rare; in 10 years, only one territorial interaction was observed (by A.N.I., unpubl. data). However, playbacks can stimulate agonistic displays in some males and may have contributed to the production of the perrrck call we have described.

The most common vocalization, the peet call, is

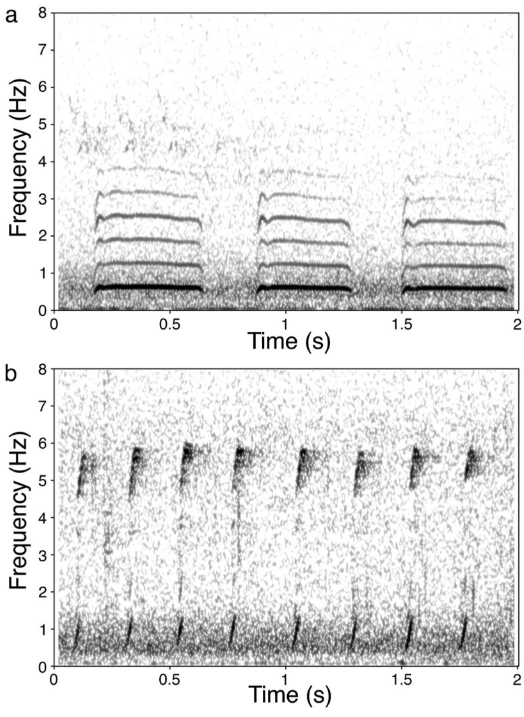

FIGURE 1. Spectrograms of two Ruffed Grouse (*Bonasa umbellus*) vocalizations: a. "perrrck" call and b. "peet" call. The perrrck call was extracted from a video recording (Iwaniuk 2024) and the peet call is from Xeno-canto (Marvin 2014).

often produced when Ruffed Grouse perceive a threat (Atwater and Schnell 1989; Bump *et al.* 1947). It is particularly prevalent in the fall among young birds that have not fully dispersed from their natal group (A.N.I. pers. obs.). The frequency modulation of the peet (Figure 1b), a vocalization typically produced by young-of-the-year, would likely make it easier for other grouse to localize, supporting a potential function as a distress or alarm call among brood mates (Atwater and Schnell 1989), but in the absence of experimentation, this remains speculative.

In contrast to the peet, the perrrck was markedly different in spectral structure and tempo (Figure 1a). Bump *et al.* (1947) describes the perrrck as being similar to the call of a Red Squirrel (*Tamiasciurus hudsonicus*) that is sometimes heard by deer hunters. It is unclear which squirrel vocalization the researchers are referring to because none of them appears to be similar in frequency or structure to the grouse's perrrck vocalization (Embry 1970).

As an indicator of how infrequently the perrrck was heard, 64 males were used in the playback study (O'Neil *et al.* 2018) with over 70 h of observations in total, but only one male produced the perrrck.

The perrrck vocalization was also not found in hundreds of hours of audio recordings of dozens of males recorded between 2011 and 2020 (O'Neil *et al.* 2018; Déaux *et al.* 2020; Martin 2021). The rarity of this vocalization makes it impossible to determine its function, although it is reasonable to conclude that it does not play a role in courtship given the hundreds of hours of recordings from the breeding season that we have examined. Now that we have a recording of the perrrck call, it could be played back to other Ruffed Grouse as an initial attempt to determine its function. Regardless of the function of the perrrck call, based on our spectrographic analyses, it is clear that Ruffed Grouse can produce a range of frequencies, but they do so rarely.

Author Contributions

Writing – Original Draft: A.N.I.; Writing – Reviewing & Editing: A.N.I. and B.B.; Observations: A.N.I.; Conceptualization: A.N.I.; Formal Analysis: A.N.I. and B.B.; Visualization: A.N.I. and B.B.

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The occurrence of introduced rosy red minnows (*Pimephales promelas*) in Alberta, Canada

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Abstract
Rosy red minnows are a golden morph of Fathead Minnow (*Pimephales promelas*) commonly sold in pet shops and used, in some jurisdictions, as baitfish. They have formed several naturalized populations in British Columbia, where they are considered a priority conservation concern. The Government of Alberta had noted two occurrences of rosy red minnows in 2016 and 2017, but their identification could not be independently confirmed without photographic or physical vouchers. Based on our own collections, Royal Alberta Museum specimens, community science initiatives, and enquiries to other field researchers, we report that rosy red minnows have been present in Alberta earlier than previously thought, are likely breeding in Alberta, and have a widespread distribution from Fort McMurray to Lethbridge. Given that Alberta has native populations of wild-type Fathead Minnow, the impacts of rosy red minnows on native populations requires immediate attention.

Key words: Invasive species; aquatic invasions; freshwater; baitfish

Introduction

The spread of invasive species is likely a major contributor to biodiversity loss worldwide (WWF 2020). Freshwater habitats that would otherwise be strongly resistant to invasions have experienced substantial degradation from human activities, potentially exacerbating the threat of invasive fishes (Dudgeon *et al.* 2006). Invasive species cost the government of Alberta, Canada, an estimated $2.1 billion annually (McClay *et al.* 2004; AISC 2022), yet the ecological costs of aquatic invasions are poorly understood, and may be complex. For example, the release of aquarium fish into Banff Hot Springs has been implicated in the extinction of Banff Longnose Dace (*Rhinichthys cataractae smithi*; Renaud and McAllister 1988), while introduced Whirling Disease (*Myxobolus cerebralis*) has impacted local salmonid populations (AEP 2018; James *et al.* 2021). The current spread of Prussian Carp (*Carassius gibelio*) throughout southern Alberta has had potentially negative impacts on native fish biodiversity (Docherty 2016; Docherty *et al.* 2017), but may also provide a novel, important food source for wetland birds. Invasive success is complex but likely requires, among other factors, the repeated introduction of a species into an area (Drury *et al.* 2007). However, because successful introductions begin with small population sizes, species in the early stages of invasion are difficult to detect; by the time they are detected, the species may have spread so far and increased in abundance so much that prevention is no longer feasible (e.g., Prussian Carp in Alberta; Docherty *et al.* 2017). Given the many unknowns about the threat of aquatic invaders in Alberta, the early detection of potentially invasive aquatic species is vital to ensure the future flourishing of local fishes.

One of Canada's newest invasive species is rosy red minnow, reported to be a colour variant of Fathead Minnow (*Pimephales promelas*; Government of Alberta 2023). First discovered in an aquaculture facility in Arkansas, USA in the early 1980s, the rosy red minnow (known commonly as rosy reds) combined the hardiness of Fathead Minnow with the beauty of Goldfish (*Carassius auratus*; Sutton 2018), making it an attractive option for live bait. Captive breeding of rosy red proved to be highly successful with aquarium enthusiasts and recreational anglers alike; rosy reds are now sold in pet stores and bait shops worldwide. In Alberta, rosy reds are sold as pet or feeder fish. Although the use of live baitfish is banned in Alberta, all members of Leuciscidae, including Fathead Minnow, are permitted for use as dead bait in some locations (Government of Alberta 2024). The rosy red's ability to withstand poor water quality conditions, as well as its flexible feeding strategies, make it a prime candidate for an aquatic invasion (Godard *et al.* 2013), and indeed both the so-called "normal colour" or wild-type Fathead Minnow and its rosy red counterparts have formed self-sustaining populations in Belgium (Verreycken *et al.* 2007), Britain (Godard *et al.* 2013), Germany (Dümpelmann and Freyhof 2015), and, in Canada, the provinces of Ontario (Funnell *et al.* 2009) and British Columbia (CCIS 2020).

Where they have invaded, rosy reds have been reported to act as vectors for pathogens and parasites (Michel *et al.* 1986; Iwanowicz and Goodwin 2002; McCann 2012), are suspected to compete with native fishes (ISCBC 2023), and may facilitate the invasion of other aquatic species (Docherty *et al.* 2017). Unlike British Columbia, Alberta has native Fathead Minnow populations that could be negatively impacted by rosy reds, especially if there is interbreeding. Mitigating the spread of rosy reds in the wild is therefore crucial for protecting Alberta's aquatic ecosystems. Identification of rosy reds is complicated by the possibility that related Bullhead Minnow (*Pimephales vigilax*), which is not native to Alberta, may also be sold as rosy red variants (Hubbs *et al.* 2004; Nico and Sturtevant 2024).

The Government of Alberta first documented the presence of rosy reds in a stormwater pond in Calgary in 2016 and Bolloque Creek, north of Edmonton, in 2017 (AEP 2021). These appeared to be isolated incidents, but there was no apparent follow-up in those locations and no samples were collected and vouchered for verification. Based on our own vouchered materials and photographic evidence from other sources, we report that (1) rosy reds appeared in the wild as early as 2011 in Alberta; (2) they have been observed in reproductive condition with nest-guarding behaviours; (3) Alberta's rosy reds are morphologically similar to Fathead Minnows as opposed to the related, non-native Bullhead Minnow; and (4) rosy red minnow distribution is widespread, from north of Edmonton and south to Lethbridge, with the 2022–2023 period showing a marked increase in sightings. Whether rosy reds are being consistently released into waterbodies, or if they have now become established, requires further investigation, as does the consequences of potential interbreeding with native wild-type Fathead Minnow.

Methods

On 28 May 2022, several rosy reds were captured by dip netting in Whitemud Creek, Edmonton (see Table 1 for coordinates). In July 2022, a single rosy red was observed off a pedestrian bridge spanning Fish Creek in Fish Creek Provincial Park, Calgary by M.R.J.M.'s six-year-old son. A similar, if not the same, fish was captured and photographed 30 m upstream on 22 August 2022, but was released. It was observed in the same location again several weeks later and was finally captured and euthanized with clove oil on 24 September 2022. Despite studies suggesting high predation of rosy reds in the wild (Dümpelmann and Freyhof 2015), this individual appeared healthy. It was captured schooling with juvenile White Sucker (*Catostomus commersonii*). Rosy reds from both locations (Table 1, Figure 1) were preserved in 70% ethanol (no separate tissue samples were vouchered) and sent to the Royal Alberta Museum (RAM), where they joined eight additional rosy reds that had been sent to the RAM in 2018 as part of a case involving the illegal release of baitfish (location unknown).

Nine of the 10 vouchered specimens (vouchers L18.7.1–L18.7.8, L22.2.1, L22.3.1; Table 1) were phenotyped according to Scott and Crossman (1973), Smith and Lamb (1976), Page and Burr (2011), and Hendrickson and Cohen (2022) to determine species identification (voucher L.18.7.9 was in poor shape and was excluded from analysis). They were scored for anal fin ray counts, dorsal fin ray counts, lateral line scale counts, herring bone line presence/absence, lateral line completeness, and peritoneum colour. All four species of *Pimephales* typically have seven anal fin rays. Fathead Minnow is distinguished by 8–9 dorsal fin rays; 39–54 lateral line scales; herringbone lines present along upper side; usually incomplete lateral line; and a mostly black peritoneum. Bullhead Minnow typically has eight dorsal fin rays, 37–45 lateral line scales, no herringbone lines, complete lateral line, and a silvery peritoneum with black specks.

Additional records of rosy reds were found by emailing government biologists, Trout Unlimited Canada staff, environmental consultants, and by searching iNaturalist using the Fishes of Alberta project page; members of the public also reported directly to the School of Fish (https://www.schooloffishid.com) with their discoveries. All 68 781 records of Fathead Minnow were downloaded from the Fish and Wildlife Internet Mapping Tool (FWIMT) and all comments were searched for mentions of "rosy", "rosey", "golden", "gold", "pink", or "invasive" Fathead Minnow. Two additional records were found this way, along with three possible records with ambiguous comments. The scientists who made the ambiguous comments were contacted over email; two responded that their comments did not refer to rosy reds and the third was unreachable. This last is included as a footnote to Table 1 but is not included in our results.

TABLE 1. Known occurrence of rosy red minnows (*Pimephales promelas*) in Alberta, Canada. All vouchered specimens are at the Royal Alberta Museum in Edmonton, Alberta, preserved in 70% ethanol. Photographs not found on iNaturalist are either published in this paper or held by the authors. FWMIT = Fish and Wildlife Internet Mapping Tool.

No.	Date collected	Location*	Latitude, longitude	Collected by	Documentation
1	30 Sept. 2011	Western Headworks Canal, Calgary	51.045°N, 114.010°W	L. Peterson, Trout Unlimited Canada	Photographed
2	Aug. 2012	Clearwater River, Fort McMurray	56.716°N, 111.339°W	T. Hancock, Fisheries and Oceans Canada (DFO)	Written record
3	6 June 2013	Irvine Creek, north of Beaumont	53.378°N, 113.419°W	S.D., School of Fish	Photographed, FWMIT
4	12 Sept. 2015	Dog Creek, Spruce Grove	53.568°N, 113.915°W	D. Wenckowski (EnviroMak Inc. 2015)	Photographed, FWMIT
5	16 Aug. 2016	Silverado Stormwater Drainage Pond, Calgary	50.883°N, 114.072°W	Alberta Environment and Parks (AEP)	Written record
6	17 Aug. 2016	McLaughlin Pond, Spruce Grove	53.551°N, 113.928°W	B. Tether and K. Thompson (EnviroMak Inc. 2016)	FWMIT
7	04 May 2017	Bolloque Creek	54.500°N, 113.681°W	AEP	Written record
8	29 Sept. 2017	Southwest of Three Hills	51.650°N, 113.066°W	J. Card	Written record
9	2018	Central Alberta	Unknown	AEP—involved in illegal release case	Vouchered (L18.7.1–L18.7.9)
10	12 Sept. 2019	Anders on the Lake, Red Deer	52.241°N, 113.786°W	Advisian (Advisian 2019)	FWMIT
11	13 May 2021	Country Hills, Calgary	51.156°N, 114.056°W	super_eng_chick	Photographed (iNaturalist)
12	28 May 2022	Whitemud Creek, Edmonton	53.448°N, 113.546°W	S.D.	Photographed, vouchered (L22.2.1)
13	24 Sept. 2022	Fish Creek Park, Calgary	50.926°N, 114.110°W	mrjmorris	Photographed (iNaturalist) Vouchered (L22.3.1)
14	2 Oct. 2022	Dale Hodges Park, Calgary	51.086°N, 114.169°W	quinnbirds	Photographed (iNaturalist)
15	29 Apr. 2023	Sunridge Park, Lethbridge	49.653°N, 112.877°W	charlie_myles	Photographed (iNaturalist)
16	5 May 2023	Nose Creek, north of Balzac	51.228°N, 113.999°W	D. Gastle, Triton Environmental Consultants	Photographed
17	12 June 2023	Mill Creek, Edmonton	53.527°N, 113.477°W	yegbio	Photographed (iNaturalist)
18	05 Aug. 2023	Unnamed wetland, Edmonton	53.496°N, 113.398°W	ryrudy	Photographed (iNaturalist)
19	31 Aug. 2023	Mill Creek Ravine South, Edmonton	53.514°N, 113.471°W	mumbum	Photographed (iNaturalist)
20	02 Oct. 2023	Western Headworks Canal, Calgary	51.045°N, 114.010°W	mrjmorris	Photographed (iNaturalist)

*28 August 2020, FWIMT reports, in an unnamed pond NE of Trochu, 51.835°N, 113.185°W, that numerous Fathead Minnow were collected and disposed of as an "invasive species", but not all Fathead Minnow collected at that location received such a comment. It is uncertain if the "invasive" Fathead Minnow refer to rosy reds, but it does not seem likely (Ghostpine Environmental Services Ltd. 2020).

Results

Descriptions of vouchers

Vouchered specimens were orange-red when captured (Figure 1), but colour was lost during preservation, giving fish a pale preserved colour in contrast to the dusky-coloured native Fathead Minnow. Standard length was on average 57.6 mm (range 35–74 mm, n = 10). The first dorsal fin ray was a half-ray and the anal fin had seven rays, as typical of *Pimephales*. Specimens had 8–9 dorsal fin rays, 45–47 lateral line scales, herringbone patterns present along the upper

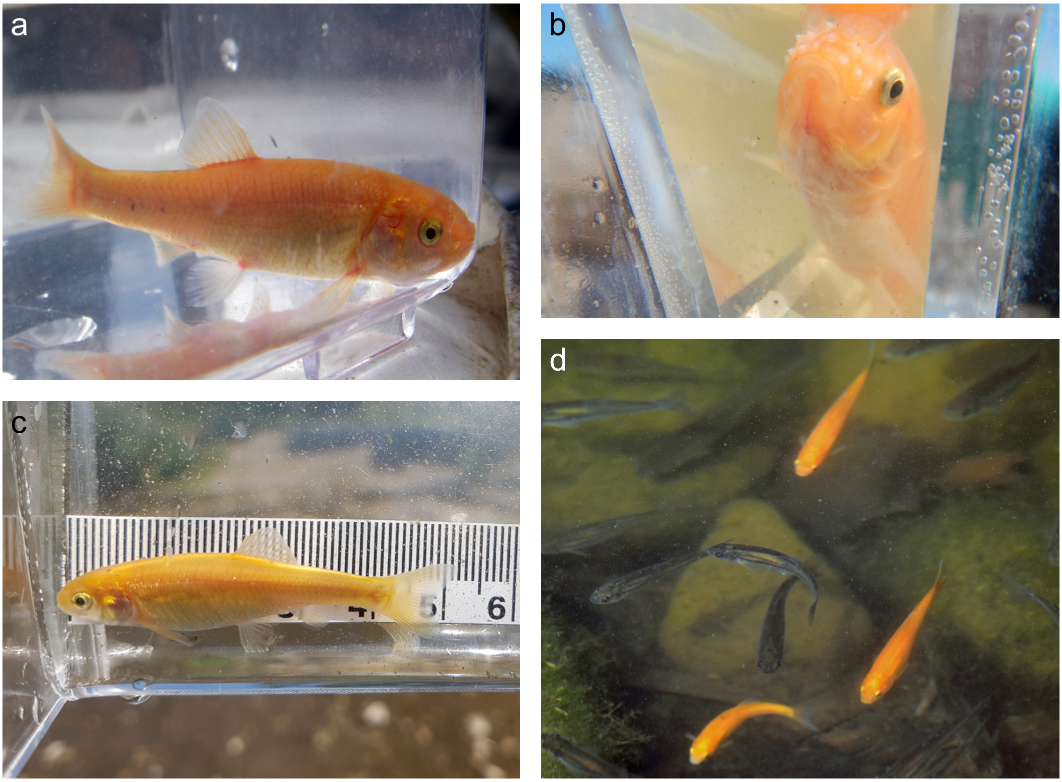

FIGURE 1. Rosy red minnow (*Pimephales promelas*) observed in Alberta. a. First known record of a rosy red in Alberta, from the Western Bow River Headworks Canal, Calgary, 2011 (no. 1, Table 1). b. Male with breeding tubercles, from Irvine Creek, north of Beaumont, 2013 (no. 3, Table 1). c. A single rosy red from Fish Creek Park, Calgary, 2022 (no. 13, Table 1). d. Rosy reds swimming alongside wild-type Fathead Minnows, Sunridge Park, Lethbridge, 2023 (no. 15, Table 1). Photo a: L. Peterson. Photo b: S. Derlukewich. Photo c: M. Morris. Photo d: C. Myles (charlie_myles 2023), Attribution-Non Commercial 4.0 International (CC BY-NC 4.0), photograph cropped.

side, and an incomplete or nearly (but never fully) complete lateral line. The peritoneum was inspected in a single sample and was mostly black.

Other records

Including the three vouchered records described above, we found a total of 20 records of rosy reds in the province—with four new records added as this paper was under review. The Government of Alberta had records of rosy reds from 2016 and 2017, but without documentary evidence (AEP 2021). Trout Unlimited Canada staff responded to our enquiries with what is now the earliest discovery of rosy reds in the province, having photographed a sample from Calgary in 2011 (Figure 1); the Trout Unlimited annual fish rescue turned up another individual at the same location in October of 2023 (mrjmorris 2023). Our own records included a photograph of a male in breeding condition north of Beaumont from 2013 (Figure 1b). Inquiries to biologists turned up several additional records, including our most northern record in Fort McMurray. Searching iNaturalist returned additional reports: Edmonton records from 2023 (mumbum 2023; ryrudy 2023), Calgary records from 2021 (super_eng_chick 2021) and 2022 (quinnbirds 2022), and a Lethbridge record from 2023 (charlie_myles 2023). In short, there are now 20 reports of rosy red minnows from Alberta, nine of which extended from Edmonton to Lethbridge between May of 2022 and October of 2023 (Table 1). These 20 records encompass three major river basins and seven sub-basins (Athabasca River Basin: Upper Central Athabasca, Lower Central Athabasca; North Saskatchewan River Basin: Upper North Saskatchewan, Central North Saskatchewan; South Saskatchewan River Basin: Red Deer, Bow, Upper South Saskatchewan; Figure 2) and the major urban centres of Fort McMurray, Edmonton, Red Deer, Calgary, and Lethbridge.

Discussion

Here we report the first vouchered and photographic evidence of rosy red minnows in Alberta,

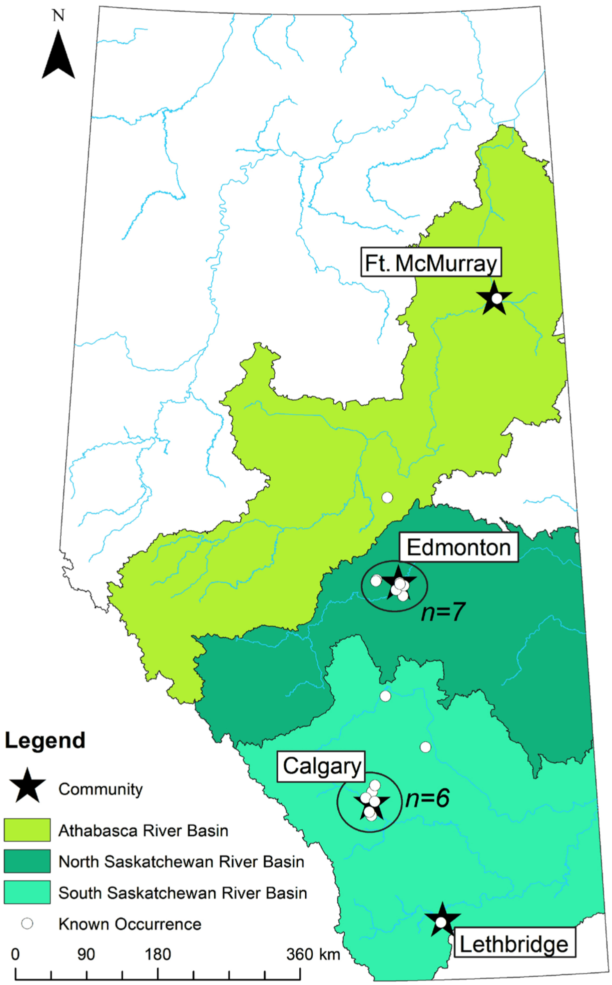

FIGURE 2. Known occurrences (white circles with black outlines) of rosy red minnow (*Pimephales promelas*) in Alberta, Canada, and their drainage basins: Athabasca; North Saskatchewan; and South Saskatchewan. Map generated by S. Derlukewich and J. Reilly, ArcGIS (ESRI, Redlands, California, USA).

Canada, from as early as 2011. Although there is not yet evidence for reproduction in the wild, a male found in 2013 was in breeding condition and exhibited nest-guarding behaviours (Figure 1b). In British Columbia, where self-sustaining populations are known, there are no native Fathead Minnow to interbreed with; such is not the case in Alberta.

Rosy reds purchased in Wisconsin in 1995 keyed out morphologically as the related Bullhead Minnow (Muller 2000). Hubbs *et al.* (2004) suggested that rosy red forms of Bullhead Minnow may be sold in shops along the Great Lakes. If true, the rosy reds in Alberta could constitute not only a new morphotype of fish for the province, but also a new species record. However, our vouchered specimens were most consistent with Fathead Minnow identification, at or exceeding the highest known count of 45 scales in Bullhead Minnow, having incomplete lateral lines, herringbone lines along the side, and mostly black peritoneum (Page and Burr 2011; Hendrickson and Cohen 2022).

The genetic cause of the rosy red mutation does not appear to be characterized in Fathead Minnow, nor is it clear how frequently it may spontaneously appear in the wild. Given that it appeared on at least two farms in Arkansas in the 1980s (Sutton 2018), it is possible this mutation could occur in the wild at a certain rate.

However, it seems unlikely that such forms are spontaneously occurring in Alberta, based on several lines of evidence: (1) Scott and Crossman (1973), Nelson and Paetz (1992), and Joynt and Sullivan (2003) do not mention seeing such forms among the many native Fathead Minnow individuals that have been sampled in Alberta and across Canada; (2) the RAM collection contains 10 916 preserved Alberta-caught Fathead Minnow, but there are no notes of rosy reds in the collection prior to 2018 (anecdotally, some of the oldest, palest preserved specimens in the collection were still more pigmented than recently-preserved rosy reds; sometimes extremely pale, almost pigmentless, specimens are found in museums having been collected from turbid waters or having been exposed to too much ultraviolet light over long time periods while in preservative); (3) the 2018 rosy reds found in the RAM collection were part of an investigation into released baitfish, suggesting at least some of Alberta's rosy reds are not native; (4) mutation rates should not change over time, so observations should be fairly consistent across years—yet most observations have occurred during 2022–2023; and (5) the occurrence of rosy reds near or within major urban centres that have pet stores suggest these are released fish. Although not definitive, such lines of evidence are suggestive of the introduced origin of these fish; genetic comparisons between wild-caught rosy reds and their conspecific wild-type Fathead Minnow could help address this issue.

The ecological implications of rosy red invasions are unclear. In British Columbia, where Fathead Minnow is not native, there is fear about the transfer of disease to native salmonids (CCIS 2020). Fathead Minnow is known to be susceptible to infections by *Yersinia ruckeri*; authors of a study on invasive Fathead Minnow in Europe (likely the normal colour variety, but the record is unclear) speculated that a sudden, unexplained outbreak of Enteric Redmouth Disease in salmonids in 1981 could have been caused by the shipment of infected Fathead Minnow from Arkansas and Missouri in 1979 (Michel *et al.* 1986). More recently, native Fathead Minnow from Manitoba have been found to carry the introduced Asian Fish Tapeworm (*Bothriocephalus acheilognathi*; Choudhury *et al.* 2006), while novel pathogens have been discovered in rosy reds in Arkansas baitfish farms (Iwanowicz and Goodwin 2002).

In Alberta, where salmonids have adapted to local Fathead Minnow populations, the threat of disease transfer is possibly lower, although captive-bred rosy reds could potentially bring new diseases into the province (McCann 2012). Ecologically, rosy reds released into ponds that lack native Fathead Minnow could reduce invertebrate abundance and taxon biodiversity, as has been documented for native Fathead Minnow in prairie ponds (Hanson and Riggs 1995). Introductions into ponds without local leuciscids could also permit the spread of gynogenetic Prussian Carp, which can use Fathead Minnow sperm to initiate embryogenesis (Docherty *et al.* 2017). Perhaps most strikingly, there appears to be nothing known about the possible introgression of rosy reds with wild Fathead Minnow. Reproductive success could be enhanced in introgressed minnows given the high fecundity of rosy reds (Clement and Stone 2003), but could also be reduced through outbreeding depression (for instance, rosy reds are known to have worse body condition than their wild counterparts when raised under similar conditions; Ludwig 1995) or increased predation by avian predators on rosy-coloured young (speculated in Dümpelmann and Freyhof 2015).

If Fathead Minnow are locally adapted to their environments (Klymus *et al.* 2022), and rosy reds are aquaculture products originally sourced from the United States, then rosy red introgression could introduce both the causative colour morph allele into Alberta's Fathead Minnow, as well as break up locally adapted gene complexes (e.g., as happened with wild and farmed Atlantic Salmon [*Salmo salar*]; Morris *et al.* 2010; Harvey *et al.* 2016). Indeed, aquaculture-reared Fathead Minnow show signs of adaptation to constant environments, including increased food consumption and lower thermal plasticity when compared to wild conspecifics (Hirakawa and Salinas 2020). If rosy reds similarly differ from wild Fathead Minnow, interbreeding could introduce non-adaptive genetic materials into wild populations.

Given how little is known about rosy red minnows, the precautionary approach is best—report and eliminate rosy reds when captured. We would urge the banning of rosy reds as baitfish, as the Government of Alberta has already done for Goldfish and species of carp (Government of Alberta 2024). Studies on the genetics of rosy red minnows and the possibility and consequences of interbreeding with local Fathead Minnow populations are sorely needed.

Author Contributions

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

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Plural breeding in Gray Wolf (*Canis lupus*) packs: how often?

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Abstract
The occurrence of more than a single female breeder in North American Gray Wolf (*Canis lupus*) packs, i.e., plural breeding, is well known, but its incidence has not been estimated since 1982. Using winter pack size as an index to plural breeding in wolves, I reviewed the literature from North American populations least exploited by humans to assess the general incidence of plural breeding. Generally winter packs >15 were associated with incidents of plural breeding. Wolf packs preying primarily on White-tailed Deer (*Odocoileus virginianus*) and in locations south of 52°N latitude seldom exceeded 10–15. Plural breeding occurred in packs preying primarily on larger ungulates in areas mostly above 52°N. The estimated incidence of plural breeding in the overall wolf population was <15% and perhaps <10%, which is lower than a 1982 estimate of at least 20–40%. I discuss reasons why plural breeding is associated with larger prey.

Key words: *Canis lupus*; Gray Wolf; multiple breeding; pack size; plural breeding; reproduction; Yellowstone

Introduction
Gray Wolf (*Canis lupus*) restoration to Yellowstone National Park (YNP), USA, has raised awareness of the occurrence of a considerable amount of plural breeding in some of the park's wolf packs. Plural breeding has long been documented (Murie 1944), and Harrington *et al.* (1982) concluded that it might occur in 20–40% of wolf packs or more. However, that assessment was based on data from only 27 free-ranging wolf-pack years and only from Bathurst Island, Canada; Denali National Park in Alaska; and five dissected breeding-season reproductive tracts in Alaska. (Note: Harrington *et al.* only provide data in terms of pack years without division into years and packs.) It included no packs from areas where plural breeding had not been reported. Thus, the estimate is highly upwardly biased and not necessarily applicable to wolves at lower latitudes.

The necessary condition for plural breeding is thought to be a surfeit of food, which would allow maturing females to remain in their natal pack longer instead of dispersing (Mech *et al.* 1998; Mech and Boitani 2003). Much of the literature on wolf-pack social structure indicates that the usual basic pack includes a single mated pair and their immature offspring, which disperse as they mature (Mech 1970; Harrington *et al.* 1982; Mech and Boitani 2003). In packs with plural breeding, however, maturing daughters that remain with their natal pack mate with stepfathers, immigrant males, or rarely with fathers and produce their own litters (vonHoldt *et al.* 2008). In the most extreme case, in 2008, one YNP pack included six pregnant females, producing at least four litters (Smith *et al.* 2020a).

Yellowstone's wolf population and the associated research has fostered some of the most notable scientific and popular literature on plural-breeding wolf packs. *Yellowstone Wolves: Science and Discovery in the World's First National Park* (Smith *et al.* 2020b) synthesizes the scientific literature about YNP wolves, and McIntyre's (2019, 2020, 2021, 2022) popular accounts have enlightened the public about them.

It is only natural then that questions should arise about just how common plural breeding is in wolf packs. The apparent novelty of such cases has encouraged researchers to report them, and several besides those mentioned above have done so (see Mech and Boitani 2003 for a summary). However, no one since Harrington *et al.* (1982) has attempted to estimate the incidence of this phenomenon in the wolf population at large. My objective was to determine what proportion of breeding in North American wolf packs involves plural breeding by examining data from a wide variety of locations in North America.

Methods
Despite several reports of plural breeding, most studies are not extensive enough or long enough to

assess the proportion of plural breeding accurately. However, a large enough sample can be studied to allow a general estimate by using an index of the proportion of successful plural-breeding packs. A convenient index is winter pack size, a commonly reported feature of most wolf studies and meta-analyses (Mech 1970; Ballard *et al.* 1987; Mech and Boitani 2003; Wydeven *et al.* 2009; Smith *et al.* 2020b).

Pack size is a suitable indicator of plural breeding because, with mean wolf litter sizes of five to six (Mech 1970), winter pack size would usually include more than about 10 if many pups of more than a single female survive. For example, in YNP, plural-breeding packs have numbered up to 37 members (Stahler *et al.* 2020). The distinction between packs larger and smaller than 10 would not always indicate plural breeding or the lack thereof. Large packs sometimes split into subgroups, and sometimes both pup and yearling survival is high and yearlings fail to disperse, making such packs larger than usual. In addition, pup survival in a plural-breeding pack could be unusually low, leaving that pack with fewer than 10. For example, three YNP packs included plural breeding in 1997, but only one of them contained more than 10 wolves by midwinter (Smith 1998).

I strived for a general gross estimate of plural breeding by examining pack-size data from as many published studies as possible from least-exploited wolf populations (Table 1), that is, those from parks or other areas where wolves are legally protected or, in one case, where the study area had low human use.

Results and Discussion

Over the long term, some 25% of YNP packs included plural breeders (Smith *et al.* 2020b); in 39% of pack years, packs had more than 10 members and in 16% more than 15 members (Table 1; one pack breeding for one year is one pack year, one pack breeding for two years is two pack years, four packs breeding for two years is eight pack years, etc.). Similarly, six (19%) of Denali's 32 packs produced multiple litters, and, during 29% of Denali pack years, pack sizes exceeded 10 individuals and 11% exceeded 15 (Mech *et al.* 1998). Thus, although pack size is not a perfect index, it is a reasonable indicator of populations that include plural breeding and it provides a general estimate of the proportion of such packs.

Plural breeding has also been reported from several other areas where wolf populations were being exploited or where insufficient data on pack sizes were available (Table 2). Although these reports provide useful relevant information, the populations studied were subject to anthropogenic disruption. Thus, pack size data could have been compromised,

TABLE 1. Proportion of Gray Wolf (*Canis lupus*) mean pack sizes >10 or >15, as a general estimate of plural breeding. Bold type indicates locations where plural breeding has been documented. One pack breeding for one year is one pack year, one pack breeding for two years is two pack years, four packs breeding for two years is eight pack years, etc.

Location (N latitude) years of study	Pack years	Primary prey	% pack years >10 (>15)	Reference
Superior National Forest (48°), 1966–67 to 1984–85	78	Deer	2 (0)	Mech 1986
Superior National Forest (48°), 1985–86 to 2006–07	315	Deer	7 (0)	Mech 2009
Superior National Forest east (48°), 1971–72 to 1972–73	13	Deer	0	Van Ballenberghe 1972
Wisconsin (46°), 1980–2007	1092	Deer	11 (0)*	Wydeven *et al.* 2009
Northwestern Minnesota (48°), 1972–73 to 1976–77	24	Deer	7 (0)	Fritts and Mech 1981
Voyageurs National Park (48°), 1987–88 to 1990–91	23	Deer	4 (0)	Gogan *et al.* 2004
Denali National Park (63°), 1986–94	106	Moose/Caribou	29 (11)	Mech *et al.* 1998
Yellowstone National Park (45°)†, 1998–2021	282	Elk	39 (16)	YNP Wolf Project 1995–2021
Isle Royale National Park (48°), 1971–91	50	Moose	24 (6)	Thurber and Peterson 1993
North-central Minnesota (48°) 1980–86	35	Deer	14 (0)	Fuller 1989
Algonquin Park (46°), 2002	14	Deer/Moose	0	Patterson *et al.* 2004
Northern Ontario (52°), 2009–10 to 2011–12	42	Moose	2 (0)	Kittle *et al.* 2015

*Based on proportion of years in which pack sizes exceeded 10; all entries except this one are based on the percent of pack years. This entry had to be based only on the percent of years (not pack years) because of the way the authors provided their data.
†Wolf founders transplanted from 52° and 56°N.

TABLE 2. Miscellaneous evidence of plural breeding in Gray Wolf (*Canis lupus*) packs.

Area (N latitude)	Primary prey	Proportion of plural breeding	Remarks	Reference
Baffin Island, Canada (69°)	Muskoxen, Caribou	1 (9%) of 11 pack years		Clark 1971
Kenai, Alaska (61°)	Moose	1 (20%) of 5 packs	50% of pack years >10; 22% >15	Peterson *et al.* 1984
South-central Alaska (63°)	Moose/Caribou	7–10% of 13 packs	Largest pack = 20 (fall)	Ballard *et al.* 1987
South-central Alaska (63°)	Moose/Caribou	1 pack	20	Van Ballenberghe 1983
Northwest Territories, Canada (63°)	Caribou	At least 1 pack of several during 4 or 5 years		Frame *et al.* 2004
Ellesmere Island, Canada (80°)	Muskoxen	2 (9%) of 22 pack years	Largest pack = 20	Anderson *et al.* 2019
Idaho (45°)	Elk	2 (3%) of 70 pack years	Population founders transplanted from 52° and 56°N	Ausband 2018

and I assessed those studies separately. I include the percentage of packs larger than 10 in Table 1 only as a one-way assessment of the maximum percentage of plural breeding. That is, given that packs of >10 could represent multiple breeders—even though they might consist of a single breeder with high pup and/or yearling survival—they still do not show a high rate of plural breeding.

Of the sites listed in Table 1, plural breeding has been documented only in Yellowstone and Denali National Parks, which host relatively large proportions of packs >15. They also include the most packs >10. The only other location in Table 1 that included any packs >15 was Isle Royale National Park. However, despite >60 years of studies there (Mech 1966; Peterson *et al.* 1984; Hedrick *et al.* 2019), plural breeding has not been documented. Based on the lack of large packs at locations listed in Table 1, it is reasonable to conclude that none hosted plural-breeding packs, which accords with the lack of documented plural breeding in those areas.

Plural breeding has been documented in five other locations (Table 2) where such information on pack sizes was not available. In none of those locations did evidence indicate that the incidence of plural breeding was more than 20%. That information, combined with the known 19% incidence in Denali (Mech *et al.* 1998), the known 25% incidence in Yellowstone, the complete lack of known plural breeding in the other areas listed in Table 1, and the low percentage of possible plural breeding in packs of >10 or >15 in Table 1 strongly counters the Harrington *et al.* (1982) conclusion. Rather, in the overall wolf population, I conclude that the rough incidence of plural breeding appears to be <15% and perhaps <10%.

It is also apparent from the existing data that wolf packs that include plural breeders tend to live in areas where their main prey is large, i.e., Elk *(Cervus canadensis*), Caribou (*Rangifer tarandus*), Moose (*Alces amerianus*), and Muskoxen (*Ovibos moschatus*), rather than White-tailed Deer (*Odocoileus virginianus*).

The reason plural-breeding packs tend to be much larger than those with single breeders may be twofold. First, the additional breeders are usually daughters of the original breeding female that have failed to disperse (vonHoldt *et al.* 2008). In those cases, the reason offspring remained with the pack instead of dispersing is thought to be because of a surfeit of food, resulting in less competition for food (Mech *et al.* 1998; Mech and Boitani 2003). An alternative explanation is that pack members might be more likely to remain with their natal packs as habitat becomes saturated (Sells *et al.* 2022). However, surplus food would seem to better explain the existence of Yellowstone's large packs within three years of reintroduction when the population was not yet saturated (Smith *et al.* 1999).

Just because prey are larger where packs might include plural breeders, however, does not necessarily mean that food supply is greater. Also, wolves do not fail to disperse in all places or times of larger prey. For example, in Denali, plural breeding was only found when food supply increased (Mech *et al.* 1998), and on Isle Royale where the only major prey is Moose, there is no documentation of plural breeding (Table 1).

Prey size might be a factor in plural breeding, though, through social competition. Murie (1944: 45) suggested the following about pack-size limitation:

> a pack might be so large that, after the strongest members had finished feeding on a kill,

> there would be little or nothing left for the rest. In such a situation, hungry ones would go off to hunt again, and the strong ones, already fed, would remain where they were. There, thus, might result a natural division of a band which was too large to function advantageously for all its members.

In other words, prey size might dictate pack size, such that with larger prey, more wolves can feed at individual kills concurrently with less competition than with smaller carcasses. About 13 wolves can simultaneously fit around an adult cow-Moose carcass (Mech 1966), but much fewer around a deer.

Not only would competition be reduced around larger carcasses, but another consideration about carcass size might come into play. Generally, wolves do not have to hunt as often for large prey as for smaller prey. For a given amount of food, wolves must find, catch, and kill more deer, for example, than Moose. The extra striving in packs that must hunt smaller prey might require more time and energy expenditure depending on the degree of tradeoff with the lower density of, and greater defense by, larger prey. If so, the greater effort required could lead to increased competitiveness among the pack members for the resulting benefits. The converse of this pattern might be that larger prey, then, translates into less competition, which in turn leads to decreased social pressure to disperse.

One other association with plural breeding that bears mention is that instances of plural breeding occurred at latitudes at 61°N or higher, except those in Yellowstone and Idaho (45°N), but those wolves were descendants from those translocated from 52° to 56°N (Fritts *et al.* 2020). No instance of plural breeding was found in latitudes from 46° to 52°N. This latitudinal association might just reflect areas with larger prey.

In summary, it appears that plural breeding occurs in <15% and perhaps <10% of North American wolf packs (a smaller proportion than previously reported) and that the phenomenon is associated with larger packs, larger prey, and higher latitudes.

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The Canadian Field-Naturalist

A tribute to Allan Harvey Reddoch (1931–2023), Canadian orchidologist and conservationist

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Reddoch, J.M. 2024. A tribute to Allan Harvey Reddoch (1931–2023), Canadian orchidologist and conservationist. Canadian Field-Naturalist 138(1): 63–68. https://doi.org/10.22621/cfn.v138i1.3447

In October 2023, Allan (Figure 1) passed away in Ottawa at the age of 92. He was an Honorary Member of the Ottawa Field Naturalists' Club and a member for 57 years.

> Allan is well known for his work on North American orchids done with his wife Joyce M. Reddoch. Their long-term population studies of Ottawa District orchids began in the 1960s and spanned half a century, resulting in many publications, including their classic 1997 monograph "The Orchids in the Ottawa District: floristics, phytogeography, population studies and historic review". They were key players in some of the most extensive and important work on the biology of North American orchids. Allan's interest, encouragement, and meticulous review of the work of others were unsurpassed. (Catling *in press*)

Early Years

Allan spent the first decade of his life at the eastern edge of urban Montreal. His Scottish father, Allan Reddoch, had served in the Royal Navy Reserve during World War I, and came to Canada in 1923 as the marine engineer accompanying the Glasgow-built ship, *Frank B. Baird*, bound for the Great Lakes trade. Using Montreal as his home base, he continued his career on merchant ships, travelling across much of the world until his son Allan's birth in January 1931. During World War II he served in the Canadian Navy Reserve as a Lieutenant Commander (Engineer). In 1941 Allan Jr. and his Scottish mother, Mary Love Harvey (Reddoch), accompanied his father to postings in Newfoundland and New Brunswick, and then arrived with him in Ottawa the following March. Allan's short stay in Newfoundland instilled in him a lifelong avoidance of eating—or even thinking about eating—cod.

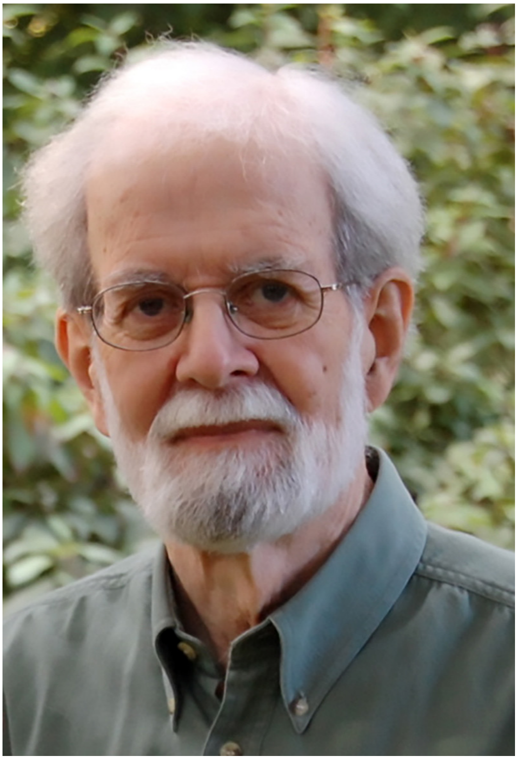

Figure 1. Allan Reddoch, 16 September, 2008. Photo: Joyce M. Reddoch.

Once in Ottawa, Allan was enrolled in Crichton Public School by the Scottish Principal, William MacSkimming, after whom the MacSkimming Outdoor Education Centre was named. Allan moved on through Glashan Public School to Lisgar Collegiate Institute, where his primary extracurricular activity was photography. One of his projects was photographing his fellow graduates for the 1949 year book.

His academic excellence was recognized by scholarships and prizes in mathematics, physics, and chemistry, and by the Silver Medal for having the highest marks in the graduating class. (That medal is now in Lisgar archives.)

University

At Queen's University, Allan enrolled in the Engineering Chemistry program in the currently named Faculty of Engineering and Applied Science. This is still the only program of its kind in North America in which the graduates are accredited as both charter chemists and professional engineers. Not that Allan wanted to be an engineer, although he did wear his iron ring until he retired.

In 1952, Allan, in his third year, and two fourth-year undergraduates made up the Queen's team that won first prize in the William Putnam Mathematical Competition, the only time that Queen's ever won the competition. This North American competition is widely considered to be the most prestigious university-level mathematical competition in the world. Among other academic awards at Queen's, Allan received the graduating year Chemistry Medal in 1953. (Allan's Putnam Medal and supporting material are now in the Queen's University Archives, and his Chemistry Medal is held by the Queen's Chemistry Department.)

In his teenage years, Allan had been impressed by Ansel Adams' glorious pictures of Yosemite and the Sierra Nevada, so it was not surprising that he chose to pursue his doctoral studies at the University of California, Berkeley. He and his friends took every opportunity to explore California's mountain landscapes.

After Allan had completed his degree in chemical physics (Ph.D. 1960), he returned to Ottawa as a Postdoctoral Fellow at the National Research Council of Canada (NRC). He subsequently became a Research Officer there, remaining until his retirement in 1991. His work involved the application of electron spin resonance spectroscopy to a variety of studies in physical chemistry and solid state physics. Allan was fortunate that most of his NRC career was during NRC's golden years. A change of government in 1984 resulted in declining support for scientific research.

Orchid Studies

Back in Ottawa, Allan continued to hike and photograph, but it was only when he joined an Ottawa Field Naturalists' Club (OFNC) field trip in 1967 that his interests began to focus on orchids. The trip leader was the widely respected researcher of North American and Mexican orchids, Ed Greenwood (Reddoch and Reddoch 2002). When Ed realized at the beginning of the trip that they had similar educational backgrounds, he introduced Allan to Joyce Dunston.

Allan and Joyce joined Ed's Native Orchid Location Survey that had as its goal to search out and record the orchid colonies in the Ottawa District (within 50 km [30 miles] of the Parliament Buildings in Ottawa). In the next decade the group mapped over 4000 locations. Allan and Joyce discovered that they were a great team, not only in orchid research but in the rest of life, and they were married in 1970. They shared a lively curiosity about nature (Figure 2), a passion for conservation and nature education, enjoyed being outdoors (Figure 3), and had complementary research skills to apply to botanical questions.

They were curious about how long orchid colonies lived, how long individual plants lived, and many other aspects of orchid ecology and taxonomy. They set out to answer some of these questions for some species in the Ottawa District: some, quantitatively, by marking every plant (Figure 4) and following them for one to several decades, and others, qualitatively, to find out whether colonies were still there from year to year. They also investigated the species status of Lesser Round-leaved Orchid (*Platanthera orbiculata* (Pursh) Lindley) and Greater Round-leaved Orchid (*Platanthera macrophylla* (Goldie) P.M. Brown). Allan wrote the statistical and other programs required to analyze the data from these studies. They published their results in many publications including their 1997 monograph "The orchids in the Ottawa District: floristics, phytogeography, population studies and historical review" (Reddoch and Reddoch 1997). Their herbarium base was the Canadian

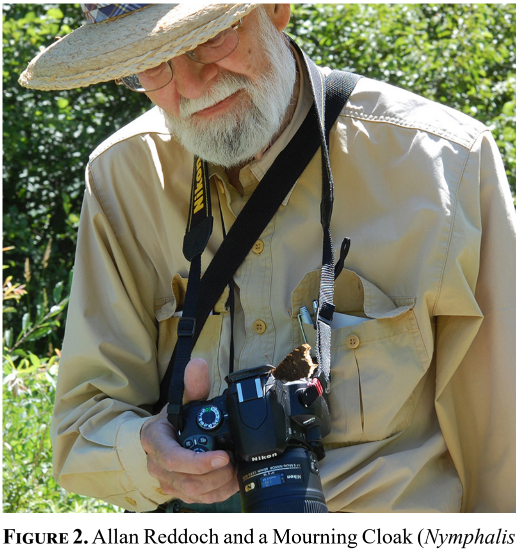

FIGURE 2. Allan Reddoch and a Mourning Cloak (*Nymphalis antiopa*) butterfly in the Larose Forest, Ottawa, 2 July 2010. Photo: Joyce M. Reddoch.

FIGURE 3. Allan Reddoch on the boardwalk of the Mer Bleue Bog Conservation Area, Ottawa, 20 August 2014. Photo: Joyce M. Reddoch.

Museum of Nature, where they were Research Associates. Their work was recognized by Honorary Memberships in the OFNC in 2000 (OFNC 2023; conferred in 2021) and by Certificates of Recognition from the Canadian Orchid Congress in 2014. The latter specifically recognizes their production of the largest assemblage of long-term studies in Canada.

FIGURE 4. Allan Reddoch measuring a Ragged Fringed Orchid (*Platanthera lacera* (Michaux) G. Don) in the Larose Forest, Ottawa, 25 June 2007. Photo: Joyce M. Reddoch.

Serving the Ottawa Field Naturalists' Club

Allan and Joyce joined the Club in 1967 in the midst of a decade of intense conservation activity, aimed primarily at educating the National Capital Commission on the biological significance of the Mer Bleue Bog and Gatineau Park. Allan became chairman of the Research and Briefs Committee in 1973. A year later that committee was combined with the Natural Areas Committee to form the Conservation Committee. Allan was the chairman of that committee in 1974 and 1975 and remained on it preparing briefs throughout the 1970s. The committee's major accomplishment during that decade was identifying and describing significant natural areas in the Regional Municipality of Ottawa-Carleton (now City of Ottawa) as guidance for the Region's Official Plan. The Club's submissions were based on the knowledge of its members and extensive field work by Conservation Committee members, and included, for example, the 76-page brief submitted in 1978 (Dugal *et al.* 1978). During his time on the OFNC Council (now Board of Directors), Allan also served

FIGURE 5. Allan Reddoch constructing a garden arbour in 2006. Photo: Joyce M. Reddoch.

as Corresponding Secretary.

Other Interests

Allan's interests were widespread and included wood identification, woodworking (Figure 5), astronomy, history, eastern art and architecture, and family history. He and an Australian cousin traced their rather uncommon surname back to Linlithgow, Scotland, where their ancestors had lived at least as far back as 1600, when parish records began.

Acknowledgements

Many thanks to Paul Catling (Figure 6), Barbara Beake, and Marilyn Light for their insights and suggestions. This account is based on Allan's notes and family knowledge, a copy of his 4-cm-thick Conservation Committee Diary, and my own memories.

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FIGURE 6. Allan Reddoch and Paul Catling examining Paul's recent discovery of Great Plains Ladies'-tresses (*Spiranthes magnicamporum* Sheviak) in the Burnt Lands Alvar, Ottawa, 19 September 2013. Photo: Joyce M. Reddoch.

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Book Reviews

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

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

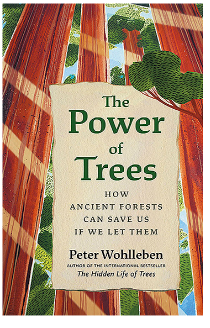
Conservation and Climate Change

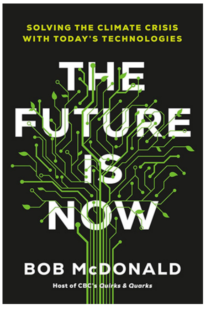
The Power of Trees: How Ancient Forests Can Save Us if We Let Them

By Peter Wohlleben. Translated by Jane Billinghurst. 2023. Greystone Books in association with the David Suzuki Institute. 280 pages, 34.95 CAD, Hardcover, 27.99 CAD, E-book.

The Future is Now: Solving the Climate Crisis with Today's Technologies

By Bob McDonald. 2022. Penguin Random House Canada. 304 pages, 32.95 CAD, Hardcover, 23.00 CAD, Paper, 15.99 CAD, E-book.





The two books under review here cover different categories—old-growth trees and so-called green technologies—but both wander into the same ecological neighbourhood: a human-caused climate crisis. Peter Wohlleben (*The Power of Trees*) is far more skeptical than Bob McDonald (*The Future is Now*) of the need for human innovation to solve this crisis, but both authors share a disdain for certain kinds of human interventions. Unfortunately, evidence is accumulating that indicates global catastrophe is imminent (Fiekowsky and Douglis 2022; Hansen *et al.* 2023; Dyer 2024). The timelines are tight, and neither ancient trees nor today's technologies will solve the climate crisis quickly enough.

Wohlleben has many supporters (including the David Suzuki Foundation, *A Trillion Trees* [Greystone Books, 2022] author Fred Pearce, and climate writer Tim Flannery), and he has sold millions of books. Wohlleben believes that humans should not interrupt the natural processes that have enabled old-growth trees to thrive—a welcome message. I feel obliged, however, to offer some dissent.

His narratives are frequently called into question for their persistent anthropomorphic characterizations of nature. Sharon Kingsland (2018) for this reason has written a harsh critique of his earlier bestseller, *The Hidden Life of Trees* (Greystone Books, 2016). In *The Power of Trees*, Wohlleben claims that trees are "just like people … they don't all learn at the same speed or draw the right conclusions from their life experiences" (p. 1). He writes about "panicky" chestnuts (p. 11); tree roots that "tell" the leaves to "shut their small, mouthlike openings [i.e., stomata]" (p. 17); and mother trees that cast shade "intentionally" to protect their offspring (p. 72). Trees that learn and pass "knowledge down to the next generation" (p. 22). Old trees that can "remember their ancestral homeland" (p. 31). Others that "worry" (p. 53), are "selfish" (p. 73), inherit "wisdom" (a contortion of epigenetics), or "continue to learn until their dying breath" (pp. 33–38).

You get the idea. It's distracting. One problem with this enthusiasm for analogy is the reader learns too little about how natural processes actually work.

Plant cells at root tips do not "function a bit like a plant brain" (p. 16), and that they don't is what makes them so interesting.

A controversial claim rehashed by Wohlleben is that trees can distinguish their relatives from strangers by sight. Canadian scientist Suzanne Simard—cited by Wohlleben in *The Power of Trees*—has reported how tree roots "share food, exchange information and even recognize their own seedlings" (p. 75). She has also been criticized for anthropomorphic thinking (Pollan 2013; Kingsland 2018; Taiz *et al.* 2019). This should not diminish the important work she does evaluating clear-cutting impacts exacerbated by climate change (Simard 2020). Wohlleben also approvingly refers to Monica Gagliano's claims of Pavlovian conditioning by pea plants (pp. 27–28). Gagliano's work extends to theories of plant consciousness, and some have challenged her claims due to experiment replication failure (Taiz *et al.* 2019; Markel 2020a,b).

Wohlleben admits that he doesn't know of any research supporting his idea that plantation trees show less inclination to "respect each other's space" than those in natural forests. But he assures readers that he "will keep an eye out for this behaviour when [he visits] ancient forests in the future" (p. 77).

Several of these shadier theories fit into the pseudo-discipline of plant neurobiology and sentience. Lincoln Taiz and his co-authors write:

> There is no evidence that plants require, and thus have evolved, energy-expensive mental faculties, such as consciousness, feelings, and intentionality, to survive or to reproduce. Plant development and behavior can be regarded as a series of nonintended consequences emerging from internal and external signaling networks that have evolved through natural selection. (Taiz *et al.* 2019: 684)

Much of Wohlleben's allegorical framing is intended to deliver one of his central messages, which is that old forests should be preserved at all costs. What is certainly true is that it takes decades to completely restore clear-cut forests (p. 69), and industrialized forestry can be disruptive of regional rainfall levels (p. 67). Yet wildfire (and insect) destruction of trees outpaces harvesting by a significant margin. In 2023, a record year in Canada, at least 185 000 km^2 of forest burned. In 2021, only about 7000 km^2 were harvested, and about 159 000 km^2 were defoliated by insects—although most defoliations do not cause large-scale tree mortality (NRC 2023).

Wohlleben agrees that humans will continue to use wood and forests can regenerate over time, even the Brazilian rainforest (pp. 69–70). In his view, however, "protecting forests is more important than using wood as a raw material, and [therefore] we need to cut back drastically on our consumption of planks and paper" (p. 69). It is "impossible to extract raw materials in a way that benefits nature" (p. 142).

The worst culprit according to *The Power of Trees* is, unsurprisingly, the forest industry and its clear-cutting policies (particularly where practices have not been modernized). Left to their own devices (and natural succession), Wohlleben is convinced that forests will thrive. He calls for logging to be "banned immediately in all intact deciduous forests" (p. 171) and that we stop burning wood for fuel.

On the climate crisis front, Wohlleben supports a carbon tax and argues that it should be extended to wood products (pp. 150–151). But he draws a line at deploying engineering to restrain greenhouse gases. "Instead of believing that smart engineers with their technological solutions" will save us, we can "turn to trees" that feed on carbon dioxide while we transition from traditional to ecological forest management practices (pp. 206, 243).

He is therefore also critical of carbon capture and storage (CCS) technologies. They compare unfavourably, he argues, to certain types of trees (such as species of beech and oak) storing tonnes of CO_2 per km^2 per year in their trunks and branches. However, this claim by Wohlleben cannot be generalized to all species, nor every ecological zone.

The Future is Now is a very different book than *The Power of Trees*. Bob McDonald (of CBC Radio's *Quirks & Quarks* fame) lays out a convincing argument for adopting—quickly—an array of technologies to transition global economies away from greenhouse gas-producing energies and lifestyles. While current solar power infrastructure alone could in theory supply the world's energy requirements, it would require an area the size of Spain to be saturated with solar panels (p. 17). The price of panels has dropped by 99% since the 1970s, mostly thanks to Chinese engineering (p. 25). While panels are only about 20% efficient in converting the sun's radiation to usable energy, this has been improving with time. Some researchers are looking into incorporating photovoltaics in greenhouse glass so that farmers can grow food and produce electricity simultaneously (p. 31). Photovoltaics capture the sun's radiation for conversion to electricity far more efficiently than plants do in their conversion to biomass through photosynthesis (Blankenship *et al.* 2011).

Biofuels utilize several biomass-generated options, from trees and other organic materials (including corn, canola, and sugarcane) to methane in waste dumps. McDonald claims that wood pellet combustion produces "90 percent fewer emissions than coal and 50 percent less than natural gas" (p. 45). Wood pellets are controversial, however, because they require transport to power plants, large tracts of scrub or damaged forests, and elaborate pelleting technology—for chipping, heating, drying, powdering, and compressing. In the case of the Drax facility in the United Kingdom—which produced 14.1 TW hours of power in 2020—much of the pellet stock was sourced from Mississippi, as mentioned in *A Trillion Trees* (Collins 2022). Sustainable aviation fuel may become the most significant role for biofuels, assuming jet passenger flights continue in the new decarbonized future (pp. 50–52). McDonald acknowledges that biofuels should only buy time while systems transition to something other than fossil fuels (p. 55).

Wind farms are now more familiar but constitute only about 7% of global energy production. The greatest challenge is finding areas where the wind blows frequently and steadily (such as the foothills of the Rockies, coastal areas, and offshore). One of the largest wind machines, the General Electric Haliade-X, costs about $13 million USD and produces 12 MW of power, or enough to light up 16 000 homes (p. 63). Future 20 MW models are considered possible, but 50 MW models are thought to be overly optimistic. Aside from their whishing noise, there is a well-known problem of rotating turbine blades killing bats and birds. But the big selling point of wind energy is that 1 kW-h of its electricity generates only 11 g of carbon dioxide, compared to 465 g for natural gas and 980 g for coal (pp. 76–77). And wind farms can be installed away from bird routes or disconnected during migratory seasons. Ultrasonic generators can emit sounds that deter bats and don't disturb humans.

Ocean wave power generation is mostly dismissed by McDonald as too expensive and difficult, even though waves roll day and night. It is disadvantaged because storms and corrosion are significant impediments (p. 85). Tidal power has better credentials, is more efficient than wind and extremely predictable, but it only works well in a few locales. Different environmentalists are pro- or anti-tidal power (p. 101), and in the latter camp concerns include threats to marine life, such as seals and Humpback Whales (*Megaptera novaeangliae*) being trapped behind barrage-style tidal projects. The largest tidal array is in Scotland with 250 turbines, and it is expected to eventually generate enough electricity for 175 000 homes (p. 97). McDonald suggests that North Atlantic Right Whales (*Eubalaena glacialis*) at risk in the Bay of Fundy can be protected using sonar tracking systems that would indicate when to shut down the turbines when the whales approach (p. 99).

The Future is Now devotes a chapter to energy storage technologies, including electric vehicle batteries. The challenges include their limiting range and charging times, particularly in cold climates, but also the availability of critical minerals (especially lithium, nickel, cobalt, and graphite). McDonald spends little time discouraging the use of personal vehicles entirely and more on promoting electric cars. He does agree, however, that personal cars "do not really belong in cities" (p. 241). High-speed trains and public transit are better alternatives, and he devotes several pages to that consideration.

While there is an 'infinite' amount of heat stored beneath the Earth's surface, geothermal energy is most accessible near tectonic plate boundaries such as those found in Italy, Iceland, Kenya, Ethiopia, and the Pacific Ocean's Ring of Fire. Ninety percent of Iceland's homes are heated geothermally, but only about 1% of energy is generated this way globally. One concern is that poorly drilled wells can cause localized earthquakes (p. 138).

Household heat pumps at smaller scales are expected to play a growing role as low-carbon, low-energy substitutes, particularly for new buildings. For much of Canada, both air- and (costlier) ground-source versions can almost entirely replace existing oil and gas furnaces. McDonald claims they lose their efficiency below –10º C (p. 140), but recent cold-climate versions that are popular in Sweden and utilize new inverter technology are said to operate down to –30º C, at which point they may need to be supplemented with other sources. One goal of the carbon tax is to help people transition to electrically powered heat pumps (Chung 2023).

McDonald makes a strong case for nuclear power in general and small modular reactors in particular. Nuclear is the "most dense fuel of all" (p. 145) and therefore technically the most efficient, second only to futuristic fusion power. But nuclear power has its unfortunate association with mushroom clouds, even though "a nuclear power generating station cannot explode like a nuclear bomb" and despite its proven "potential to provide plentiful, 24/7, emissions-free power" having the "best safety record of any energy production" (pp. 145–151).

Other technologies under consideration in *The Future is Now* are carbon capture, where CO_2 is pumped underground or into oceans—the concern is whether it will stay there, or possibly acidify the oceans—and substitutions for current cement manufacturing processes. Portland cement produced by kiln-heating limestone contributes 8% globally to CO_2 emissions, although locking carbon into concrete is being evaluated at scale (pp. 221–222). McDonald is also skeptical about direct air capture, which some believe requires too much energy to remove too little carbon (p. 224).

But he is supportive of upgrading building codes.

The Intergovernmental Panel on Climate Change claims that "50–90% energy savings have been achieved throughout the world through deep retrofits" (p. 230). Efficiency is already the world's greatest source of energy, "bigger than oil" (p. 231).

It is in the book's rejection of geoengineering (also known as climate restoration, or Solar Radiation Modification [SRM]) where I have a real bone to pick. "The outrageous scale and cost of extreme ideas [like SRM] underlines how much simpler it is to address the climate problem at its root cause", McDonald writes. "It's not the sun that needs to be dimmed down, it's the excess amount of carbon dioxide we're putting into the air that needs to be lowered" (p. 266).

These words are dated, in my view, because discussion of SRM engineering has come some distance. It is still controversial, but considering the accelerated global temperature rise, the frequency and extent of wildfires, and the warming of ocean surfaces, geoengineering now requires serious attention, not flippant dismissal (Collins 2024). The scientists involved do not see their proposals as substitutions for other necessary measures, but as means to buy time while the root of the problem is addressed through energy, transportation, and industrial transitioning and carbon capture technologies—many elements of which are addressed by McDonald in his book.

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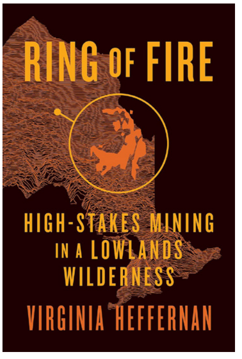
Ring of Fire: High-Stakes Mining in a Lowlands Wilderness

By Virginia Heffernan. 2023. ECW Press. 224 pages, 26.95 CAD, Paper, 16.99 CAD, E-book.



The subject of Virginia Heffernan's book *Ring of Fire* is a 5000 km^2 crescent-shaped geological formation in the Hudson Bay Lowlands on the southern coasts of Hudson Bay and James Bay featuring some of the densest critical mineral concentrations in the world. Governments seeking to meet their 2015 Paris Agreement commitments identify these rich deposits as essential to the transition from fossil fuel to climate-neutral energy production. This combination of rich deposits and global demand creates an attractive economic opportunity for the mining industry. Mining promotor and Johnny Cash fan, Richard Nemis, coined the name "Ring of Fire" for this formation when he discovered it in 2007 to highlight its resource potential and attract investment. The Hudson Bay Lowlands is also home to several Indigenous communities that recognize the opportunity and uncertainty that mining will bring. The tensions within and among the mining industry, Indigenous communities, and governments trying to balance the social, economic, and environmental costs and benefits of the Ring of Fire proposal is the main theme of this book.

The Ring of Fire is a new mining venture occurring at a time when environmental and social considerations are becoming a greater part of the political landscape, and court decisions are supporting Indigenous treaty rights. Heffernan proposes that there is an opportunity to create an ecological and social model for energy transition projects that "outweigh the environmental and social costs" (p. 9). She sets the book's tone by noting that failure to develop and apply such a model would be "irresponsible to all stakeholders" (p. 9).

The area's natural history is briefly and clearly covered in two chapters. Chapter 1 describes the geological history of the Ring of Fire, and Chapter 7 discusses the importance of the peat covering these mineral deposits for storing carbon and mitigating climate change. Readers interested in natural history will likely be familiar with this ecological background, but those seeking to understand how varying social and economic objectives influence decisions on whether and how mining proposals proceed will find an important introduction in this book.

Chapters 2 to 5 and 11 focus on tensions within the mining industry. The industry operates in high-risk boom and bust cycles resulting from narrow time frames for mining project exploration, promotion, and financial deals. As explained throughout the book, time frames are additionally narrowed by government-led consultation, assessment, and decision processes. The dichotomies within Indigenous communities, described in Chapters 6 and 9, are exacerbated by these narrow time frames. During the Berger Commission's Mackenzie Valley Pipeline Inquiry, Indigenous peoples were united in demanding that land claims be settled before pipelines were considered (Berger 1977). As Heffernan explains, Indigenous communities are now divided over the immediate economic gain of mining proposals versus demands for basic necessities (such as clean water, adequate housing, food safety, and health facilities) before consideration of these proposals. A legacy of broken promises, tailings dam failures, and understated environmental effects has created a lack of trust in new mining industry proposals and government promises.

Courts have typically upheld the requirement for governments to consult with Indigenous communities prior to approving mining operations. However, as the following examples illustrate, different understandings of the meaning and role of consultation has caused divisions within Indigenous communities and uncertainty for government decision-makers.

Jean Paul Gladu from Sand Point First Nation (Bingwi Neyaashi Anishinaabek) provides context for these disagreements in Chapter 6, Whose Land? Our Land:

> I must also question why our communities need 100 percent support for any project to be deemed credible. We are not a monolith; of course, as in any culture, we too have disagreements. Why are we held to an unreasonable and quite frankly unattainable standard when our current federal system can see a government make decisions on behalf of our entire country with often sub-50 percent support? (p. 93)

In Chapter 9, A Tale of Two Provinces, Chief Vernon Morris of the Oji-Cree Muskrat Dam First Nation describes an important meaning that consultation holds for other Indigenous community members:

> The government's view of duty to consult is that there will be basis for discussions to begin for planning and development. Our interpretation of the duty to consult is that we have a right to say 'No' when the actions for

development will have a harmful effect or no benefit to our First Nation. (p. 130)

Against a background of these differing interpretations and objectives, Heffernan explains how mining can improve regional and Indigenous community economic prospects using examples provided in Chapters 5, 6, 8, and 9.

Heffernan uses a conversational style with many asides to present the book's information. This style requires the reader to make topical notes and track connections to understand the nuances behind the issues and consider a framework for the future. Heffernan presents a few possible routes to this future. Among these is the *Canadian Impact Assessment Act* (CIAA), which passed in 2019 and repealed the *Canadian Environmental Assessment Act* (CEAA) of 2012. The 2012 legislation was exclusively aimed at determining a project's environmental impacts. The CIAA of 2019 expanded the role of assessment to include not only environmental, but also economic, social, and health impacts and mandated that the federal government lead all project reviews. After publication of the book in 2023, the Supreme Court of Canada ruled (in October 2023) that the CIAA is largely unconstitutional because it falls outside federal legislative jurisdiction (Supreme Court 2023). The government is currently working on amending the Act to respect provincial areas of jurisdiction and to ensure that opportunities for engagement of Indigenous peoples are still provided (ECCC 2023). Heffernan concludes the book with proposals for several mitigative actions for consideration in future impact assessments.

The overall message is that decision-makers with the ability to create models that incorporate each participant's varying objectives and interpretations will be able to implement proposals that outweigh the environmental and social costs of mining. Readers interested in these issues will find many sources in the book's notes to deepen their understanding of critical mineral mining proposals in Canada and elsewhere. Two recently released books helped me appreciate the context for the critical mining issues raised in Heffernan's *Ring of Fire*. The first was, *Cobalt: Cradle of the Demon Metals, Birth of a Mining Superpower* by Charlie Angus (House of Anansi Press, 2022), which covers the mining rush in Cobalt in the early 1900s and gives a historical perspective on current mining proposals like the Ring of Fire. The second was *True North Rising: My Fifty-Year Journey with the Inuit and Dene Leaders who Transformed Canada's North* by Whit Fraser (Random House Canada, 2023). This book provides an excellent summary of the innovative Indigenous consultation during the Berger Commission for the Mackenzie Valley pipeline question in the 1970s.

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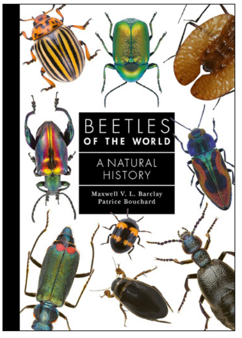
ENTOMOLOGY

Beetles of the World: a Natural History. A Guide to Every Family Series

By Maxwell V.L. Barclay and Patrice Bouchard. 2023. Princeton University Press. 240 pages, 300 colour photos, and 150 colour illustrations, 39.89 CAD, Hardcover, 29.99 CAD, E-book.



Beetles are diverse. They are the most diverse insects—the most diverse *anything*—living on this planet. Can a 240-page book do justice to this diversity? It does. However, the book may have been better titled, 'An Introduction to the Beetles of the World', because 240 pages offers only a taste (perhaps intentionally). It's enough to set the reader on their own journey to discover their favourite clades within the vastness of Coleoptera.

The introduction covers a myriad of topics, including anatomy (basic insect anatomy as well as that specific to beetles), feeding, and fossil history; it is well written and engaging. The depth in which each topic is covered is appropriate for this introductory book. The many photographs are crisp, detailed, and artistic. Just before turning over to the taxonomic section, a well-placed, current cladogram of the order is presented in the classification chapter to orient the reader to the rest of the book. The branches of this cladogram are colour coded to illustrate the richness of each superfamily—a nice touch.

Each two-page spread of the taxonomic section describes one of about 70 groups of beetles, usually at the family level, sometimes as narrow as subfamily, occasionally as broad as superfamily. There is a range map for each (but see below), accompanied by some basic information such as habitat, diet, and size range. The main text highlights a few species within each group and describes their impact on humans or gives more detailed information than that present in the table accompanying the map. Throughout the book there are typically three very nice images of different species representative of each group.

As a child, you may have had a book with a cartoon in the upper-right corner of every odd-numbered page, and as you riffled through the pages, the cartoon appeared to move. Do this with the range maps in this book and you will see very little movement. The range maps are more or less identical, because the described taxa are so broad (i.e., there are often tens of thousands of species dealt with). There is only one exception, that being the map for the very primitive, species-depauperate suborder Archostemata. All the other maps show distributions covering the entire Northern and Southern Hemispheres up to a hard-to-imagine straight line across the Arctic. Perhaps one map should have been included in the introduction and left at that.

Overall, this is a great book for any beetle enthusiast, but particularly for those early in their passion.

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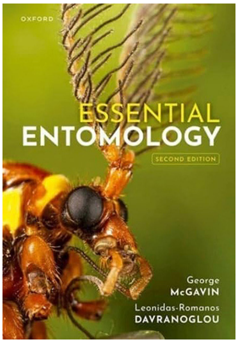
Essential Entomology. Second Edition

By George McGavin and Leonidas-Romanos Davranoglou. Illustrations by Richard Lewington. 2022. Oxford University Press. 314 pages, colour photos, and black and white illustrations, 97.00 USD, Hardcover, 48.99 USD, Paper. Also available as an E-book.



The world of insects is huge, and hugely diverse, with well over one million described species and estimates of unknown insects running from five million to as high as 30 million species. The literature attempting to make these numbers palatable and comprehensible at human scale is also rich, beyond anything that one humble reader can hope to digest. So what is the person interested in insects to do? If you have some smattering of biology somewhere in your background, and some tolerance for technical terms, you could do much worse than picking up a copy of McGavin and Davranoglou's *Essential Entomology*. The second term in the title is self-explanatory, but the first term is rather ambiguous, meaning 'must have' or the 'basic / important' elements of the topic. I'm fine with both definitions—glad to have it and satisfied that it conveys the essence of this deep, rich field.

Midway through the Preface—which begins by noting the 400-million-year history of insects and their relationships with plants, the other megadiverse group of Earth's living things—the authors raise my question, or something like it: "the study of insects is exciting and intellectually satisfying, but where do you start?" (p. viii). Their answer? "With classification, of course. In any study … the first thing you need to know is what sort of insect you're dealing with" (p. viii). Mercifully, they remind us that, given the sheer number of species, "you do not need to know them all individually" (p. viii). The two main sections of the book provide this information, while the third and final section is an extensive discussion of finding, collecting, and preserving insects.

Section 1, Introduction to Insect Evolution and Biology, begins with a brief overview of the evolution of the arthropods divided into two basic groups: the small, arthropod-like group Panarthropoda and the true arthropods, Euarthropoda, a group which contains everything else, including Insecta. The largest part of this Introduction is The Origins of Insects and Other Hexapods, a key focus of which is the Five Factors in a Winning Formula that outlines the reasons for the great success of insects. These factors are size, cuticle, central nervous system, flight, and rate of reproduction, and each is presented in crisp, interesting detail. Insects have a fascinating range of Interactions with Other Organisms (another section in the Introduction), which include bacteria, fungi, other arthropods and, most extensively, plants. Symbiosis, herbivory, and plant defenses are each considered. The section moves on to a discussion of the basic, shared body plan of insect structure, and then concludes on a note about the rarity of marine insect life.

The third and final section, Fieldwork, focusses on collecting, killing, recording data, and preserving specimens. These are timeless topics in the sense that it seems every serious book on insects includes them, but also that it took a lot of time for such procedures to develop. The authors are attached to the Oxford University Museum of Natural History, and their emphasis on the importance of proper collection techniques for the accurate determination of identities reflects that august institution's historical purposes and practices. The book does not address the tension between these approaches and the more casual approach of citizen scientists, who rely primarily on photography.

The first and third sections bracket the main section, The Insect Orders, 240 pages of introductions to each of the recognized 28 orders within Insecta. The first page provides a quick overview of Hexapoda, the subphylum comprised primarily of insects but also including three related 'near-insect' groups. A cladogram of the "latest [i.e., 2014] insect tree of life … at the time of writing this book" (p. 36) is squeezed in—a larger version would have been welcome. One page to present this information seems short shrift, but taxonomy / systematics / classification is a moveable feast; given the proposed audience for the book, simply noting 'here is what we're doing' without elaboration seems wise. Section 2 is well outlined in the detailed Table of Contents, to which I found myself referring frequently as several terms were unfamiliar. The important thing here is the descriptions themselves.

A one-page introduction is provided for each order, no matter how large or small. Seven data points are noted in a banner below the order title: Common Name, Derivation [of the scientific name], Size [i.e., body length], Metamorphosis, Distribution, Number of Families, and Known World Species. A fine, clear line drawing of a representative for each order includes labels of key body parts. Order descriptions begin with notes on Key Features, followed by colour photographs, a textual outline with keywords in bold frequently illustrated in the margins with line drawings, and tables of main families. A Key Reading list concludes the discussion of each order. Technical terms tend to be kept to a minimum; a six-page Glossary is there if needed, although several terms that I looked up were not included! For pretty much every order, the text includes an unusual, often surprising fact or two. Take, as one random example, the humble and oft-hated earwig: its ability to fold its hind wings under its fore wings "in an origami-like manner is so effective that it serves as an invaluable model in the design of biologically inspired technology" (p. 63). The mechanics for achieving this evolved some 280 million years ago.

In short, the text is, as the authors intended, "a readable introduction to the most abundant multicellular life forms on Earth" (p. ix). It is neither a field guide nor a textbook for entomology students, nor is it meant to be; it's intended for those of us without a formal background who take a serious interest in the subject—in a word, dedicated amateurs. As a member of that group, I can highly recommend this book to others, for this work sits satisfyingly between the college textbooks and the many popular accounts.

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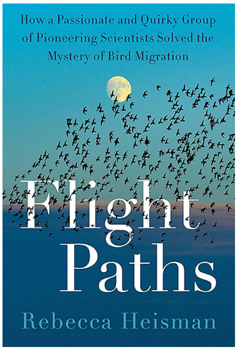
ORNITHOLOGY

Flight Paths: How a Passionate and Quirky Group of Pioneering Scientists Solved the Mystery of Bird Migration

By Rebecca Heisman. 2023. HarperCollins. 288 pages, 37.00 CAD, Hardcover, 18.99 CAD, E-book.



In the last few decades an explosion of new technologies has resulted in stunning revelations about bird migration and, subsequently, more books that chronicle these amazing feats. Two of these books I have reviewed in these pages (Smith 2021a,b): *Flights of Passage: an Illustrated Natural History of Bird Migration* by Mike Unwin and David Tipling (Yale University Press, 2020) and *A World on the Wing: the Global Odyssey of Migratory Birds* by Scott Weidensaul (W.W. Norton, 2022). Unwin and Tipling celebrated bird migration through stunning photographs of 67 species, while Weidensaul delved into the scientific methods used by researchers he visited around the globe. In this newest book, *Flight Paths*, Rebecca Heisman concentrates on how the science of bird migration has evolved, emphasizing the human angle, as hinted at in the subtitle.

Heisman starts with a history of the trapping and banding of birds (Chapter 1, A Bird in the Hand). People have been observing birds for centuries but were limited by their inability to identify individuals. Ornithologists started marking birds in the 1800s: John James Audubon tied silver threads on the legs of Eastern Phoebes (*Sayornis phoebe*), and Ernest Thompson Seton marked the breasts of Snow Buntings (*Plectrophenax nivalis*) with printer's ink. In 1899, Danish ornithologist Hans Christian Cornelius Mortensen was the first to mark birds with small metal bands engraved with his initials or banding locations. Still, the marking of individual birds was *ad hoc* until Leon J. Cole started advocating for centralized record-keeping in the early 1900s. This culminated in the United States federal government taking on the oversight of bird banding in 1920 and the start of the North American Bird Banding Program. Unfortunately, Heisman makes no further reference to whether there was a similar trajectory in Europe.

In Chapter 2 (Looking and Listening), Heisman leaves individual birds behind to follow the study of masses of birds through nocturnal flight calls. Most birds migrate at night, which creates an obvious gap in understanding their activities. Moreover, many of the species that vocalize regularly during long night flights produce nocturnal calls that are very different than those they use during the day. Starting in the 1980s, Bill Evans made it his life's work to record the sounds of migration and identify night calls (on his website, http://oldbird.org, material from his guide to flight calls is available for free). More recently, computer scientists are using artificial intelligence to not only detect individual calls in nocturnal recordings (a tedious task for humans), but to also automatically identify species. The availability of low-cost recording equipment, open-source software, and identification databases has brought this research into the realm of hobbyists. The "Looking" part of the chapter title refers to the limited study of migration by watching birds pass in front of the full moon using a telescope.

During World War II radar operators dubbed mysterious blobs they found on their screens "angels" (Chapter 3, Chasing Angels). Researchers discovered that radar beams reflect off the water within the blood and muscles of masses of birds in flight. While individual species cannot be identified with radar, radar images can be studied on a larger scale to track the abundance, distribution, and seasonality of migrating birds. The technology has improved dramatically since World War II, and migration intensity predictions are being used to issue lights-out alerts for participating cities to reduce bird mortality from lit buildings (check out https://birdcast.info).

Chapter 4 (Follow That Beep) and Chapter 5 (Higher, Further, Faster) explore the many advancements in radio telemetry, from its beginnings in the 1970s when researchers followed migrating birds from their vehicles, to the present-day when they follow them from the office via computer and satellite links. The Motus Wildlife Tracking System is a recent Canadian innovation that uses a network of towers to automatically pick up signals from the radio tags of birds flying by. Radio tags have become increasingly complex, smaller, and more precise, and their uses are too numerous to go into here—but knowing migration routes, stopover sites, and wintering and breeding areas all aid in land conservation. As with improvements in radar technology, advancements in radio telemetry have relied on collaborations between engineers and ornithologists, both professional and amateur.

The need for lighter devices to attach to birds led to the development of the light–level geolocator, which contains a light sensor, clock, memory chip, and batteries (Chapter 6, Navigating by the Sun). A geolocator uses daylight to determine its latitude (because the length of day varies with latitude)—this was a technique used by seafarers as early as the 1530s. British biologist Rory Wilson pioneered this work by studying Magellanic Penguins (*Spheniscus magellanicus*). The downside to these extremely light (and relatively cheap) devices is that they need to be physically retrieved to download data.

I expect that most readers of this journal know of Keith Hobson, a prolific researcher with Environment and Climate Change Canada. Hobson pioneered the use of stable isotopes to determine where a bird originated from geographically (Chapter 7, You Are Where You Eat). The isotope of most use to bird researchers is deuterium, a hydrogen molecule with an extra neutron that can be isolated from feathers. Feathers are moulted each year and retain the deuterium signature from the location where they are grown. Analysing the specific ratio of normal hydrogen to deuterium in a feather can be compared to maps (isoscapes) of deuterium across a landscape. There is more deuterium towards the equator and less towards the poles, which helps determine where a bird lived when the feather was grown. Samples can even be taken from museum specimens to compare historical and current breeding ranges. Hobson is an excellent example of cross-disciplinary thinking, having come to his work with a background in physics and a passion for birdwatching.

Feathers are also being used in the Bird Genoscape Project, which is mapping migration routes using the DNA in feathers (Chapter 8, The Feather Library). A genoscape is a map showing where genetically distinct populations of birds are distributed across a landscape. The term was coined by evolutionary biologist Thomas Smith, who began saving feathers from study birds in the 1980s hoping that someday genetic techniques would improve to the point where DNA could be extracted from them—which didn't happen until the early 2000s. Genoscape mapping brings population structure and migratory connectivity down to the regional scale from the more usual species-wide range maps. The regional space is often where population declines occur and conservation planning takes place.

In Chapter 9 (Vox Populi), Heisman switches from highlighting professional research to exploring the role of citizen scientists in gathering data for programs such as the North American Breeding Bird Survey and eBird, which are used to determine the statuses and trends of species. Then, in the final chapter (Sky Full of Hope), she expresses the concern of many researchers who wonder if these new technologies are

> allowing us to understand the intricacies of migration with greater clarity than ever before, [or] are actually just helping us document, in excruciating detail, the final decline of one of the natural world's most inspiring phenomena. (p. 105)

For any reader interested in delving deeper into these technologies there are 35 pages of Notes (by chapter) and two pages of links to websites. The 49 colour photos illustrate many of the technologies discussed in the book.

More than anything else, the technologies and studies referenced in this book highlight that bird conservation requires coordination on a global scale. While I doubt that any of the researchers that Heisman writes about would claim to have "solved the mystery" of bird migration, they have all contributed to the incremental growth in our understanding of it. This book is an excellent chronicle of that journey of discovery.

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Smith, C. 2021a. [Book Review] Flights of Passage: an Illustrated Natural History of Bird Migration, by Mike Unwin and David Tipling. Canadian Field-Naturalist 135: 89–90. https://doi.org/10.22621/cfn.v135i1.2843

Smith, C. 2021b. [Book Review] A World on the Wing: the Global Odyssey of Migratory Birds, by Scott Weidensaul. Canadian Field-Naturalist 135: 320–321. https://doi.org/10.22621/cfn.v135i3.2925

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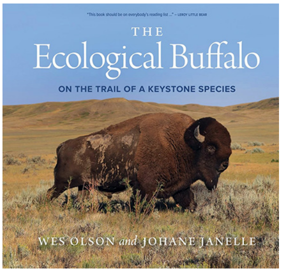
ZOOLOGY

The Ecological Buffalo: on the Trail of a Keystone Species

By Wes Olson. Photography by Johane Janelle. 2022. University of Regina Press. 304 pages, 39.95 CAD, Paper.



I thought I knew quite a lot about Bison (*Bison bison*, but referred to as buffalo in this book) until I attended a public lecture that Olson gave in 2022 in Banff, Alberta (see note at the end of this review for a link to the online recording). He painted a wonderful picture of the intricate web of relationships in the native grasslands of North America, making connections that I would have never considered—seriously, who else could draw a line from buffalo eating grass to a dung beetle (*Stenotothorax badipes*) that only lives in Northern Flying Squirrel (*Glaucomys sabrinus*) poop? (In the aspen parkland, Bison dung supports ants that are eaten by Northern Flickers [*Colaptes auratus*], which excavate nest cavities that the flying squirrels use. The squirrels use separate cavities for rearing young, socializing, escaping from predators, and for their toilet business … where the specialized dung beetle lives. See note at the end of this review for more.) If you buy one book about buffalo, make it this one.

This is a large coffee-table book full of more than 180 wonderful photos (taken by Olson's wife, Johane Janelle) that range from double-page spreads to small portraits of the many other species that share a habitat with buffalo. There is even a close-up photo of a buffalo defaecating! After all, fresh dung attracts at least six different guilds of arthropods (p. 84). Many detailed pen-and-ink sketches by Olson illustrate ecological concepts that it would be difficult to photograph, such as the extensive underground burrows of Northern Pocket Gophers (*Thomomys talpoides*).

The text is accessible and written in clear prose, but Olson does not shy away from using technical terms—such as "inquilines", which are "species that use dwellings built or used by another species" (p. 149). These terms are often explained in sidebars and can also be found in a five-page Glossary. There are 14 chapters—ranging from eight to 28 pages long—with more photos than text throughout the book. The chapters often include interesting and useful sidebars with photos, historical quotes, or additional information. Many of the captions are lengthy and full of information, which makes this book ideal for casual browsing.

Olson begins the book by describing the slaughter of millions of buffalo in the 18th and 19th centuries, making the case that this was not only disastrous for Indigenous peoples but also for grassland ecosystems. The maps showing the historical range of buffalo and native grasslands could have benefitted from including current provincial, territorial, and state lines. The first map might have been more poignant if it showed isoclines of extinction dates (a few terminal dates are given in its caption).

Olson then goes on to explain why buffalo are considered a keystone species and their vital connection to native grasslands. Here I learned some new terms: "zoochory", which is seed dispersal by animals; "endozoochory" is dispersal by internal transport (i.e., eating the seeds and defaecating them in a different area); and "epizoochory" refers to external transport, such as seeds caught in a buffalo's hair (pp. 49–50). Buffalo hooves also scarify the prairie, assisting in the germination of seeds. Olson explains the concept of a "grazing lawn", where intensive buffalo grazing creates an island of short grass in a sea of taller grasses, providing a diversity of habitats for other species to use (p. 42).

The next six chapters discuss the relationships between buffalo and many other taxa—insects, birds, small mammals, amphibians, reptiles, and ungulates—as well as predators. One example is the commensalist relationship between buffalo and Brown-headed Cowbirds (*Molothrus ater*). Historically, cowbirds consumed insects stirred up by buffalo hooves, becoming so dependent on following the moving herds that they could not take time to tend a nest: thus, they parasitized other birds' nests, laying their eggs in them and moving on. In the last century, cowbirds have expanded their range, now feeding alongside domestic cattle. As another example of these relationships, buffalo wallows form ephemeral wetlands in the spring and are used by amphibians and insects to lay their eggs. I enjoyed Olson's reference to "read[ing] the signatures of other species as they stopped to sign the prairie guest book on the dusty pages of a wallow" (p. 1).

Olson also devotes a chapter to efforts to return buffalo to their ancestral lands. For decades he was involved in work moving Plains Bison (*Bison bison bison*) across the Great Plains and Wood Bison (*Bison bison athabascae*) to Alaska and Siberia. There are many cultural underpinnings to the story of buffalo, and there is a short Afterword by Dr. Leroy Little Bear. However, this book is the ecological story of buffalo, not their cultural story. Their cultural story is best told by Indigenous peoples themselves in other books.

For readers who want more information there are appendices for the *Buffalo Treaty* (signed in 2014), a list of species discussed in the book, and a list of native terrestrial mammals that share habitat with buffalo. Besides the aforementioned Glossary, there are also 16 pages of Notes organized by chapter, and a 14-page Bibliography.

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Notes from Book Reviewer:

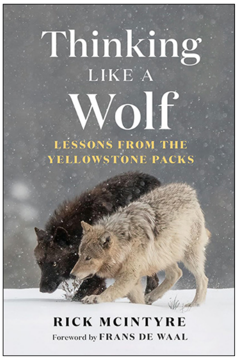
The public talk by Wes Olson in 2022 is available online at: https://bowvalleynaturalists.org/public-programs/the-ecological-buffalo-on-the-trail-of-a-keystone-species/.

For a deep dive into insects that live in cattle dung (which has replaced buffalo dung ecologically on most of the prairies), see:

Floate, K. 2023. Cow patty critters: an introduction to the ecology, biology and identification of insects in cattle dung on Canadian pastures. Agriculture and Agri-food Canada, Lethbridge, Alberta, Canada. Accessed 23 October 2024. https://publications.gc.ca/collections/collection_2023/aac-aafc/A59-90-2022-eng.pdf.

Thinking Like a Wolf: Lessons from the Yellowstone Packs

By Rick McIntyre. Foreword by Frans de Waal. 2024. Greystone Books. 272 pages, 34.95 CAD, Hardcover.



Thinking Like a Wolf, the fifth book in McIntyre's Alpha Wolves of Yellowstone series, is a fascinating account that brings readers closer to the present-day in the lives of the Yellowstone wolves. With this newest manuscript, the series has now documented the first 29 years of wolf reintroduction in Yellowstone (from 1995 to 2023). The latest book focusses mostly on the Lamar Canyon and Junction Butte Packs, two social groups that McIntyre has observed for more than a decade. *Thinking Like a Wolf* is a captivating read that highlights nature, wolves and other carnivores, wildlife, and national parks—especially Yellowstone. As with his previous books, McIntyre provides an extraordinary level of comprehensive information on wild Gray Wolves (*Canis lupus*). I was just as mesmerized reading the stories of these wolves as I was reading his other four books (Way 2019, 2020, 2021, 2022a).

I am most impressed by McIntyre's storytelling abilities and how he balances accurate depictions of wolf pack activity with the feats and tribulations of individual wolves. This book overlaps with *The Alpha Female Wolf* (Greystone Books), the fourth book in the series that focusses on 06 Female, or 06, and ends in 2015. *Thinking Like a Wolf* starts with some background information on the Lamar Canyon Pack from 2010 to 2012 to get the reader up to speed. It then details events in the park between 2012 and 2023, with the last sections of the book focussing on the Junction Butte wolves. The initial chapters follow members of the Lamar Canyon Pack—including 06's mate, 755, and one of her daughters, 926—after 06's death in late 2012. McIntyre has a particular appreciation and respect for 926, whom he dreams about nightly while recovering from open heart surgery in a hospital room in Billings, Montana (Chapter 1). He is so affected by 926 that by the end of the book, in a show of respect for her, he returns some of her blood—which he collected from the site where she was shot and killed at the age of 7.5 years near McIntyre's residence (pp. 69–70)—to the 'Den Woods' where she had multiple litters (pp. 210, 214). McIntyre says that he still thinks about 926 and the Lamar Canyon Pack nearly every day (p. 211). The motto he took away from this family was that you do not judge someone by how many times they get knocked down, but rather by how many times they get back up (p. 212).

As McIntyre follows 755, 926, and the rest of the Lamar Canyon Pack, he notes that resilience is a key character trait of these wolves (pp. 22, 46, 68). No matter what life throws at them, no matter how many packmates they lose, they always persevere. The Junction Butte wolves have a similar will to survive (e.g., p. 205). Wolf 907F of the Junction Butte Pack is almost 10-years-old at the end of the book and was alpha female of the pack three different times (at the time of this writing in September 2024, she was 11.5 years old and still alive). As I read *Thinking Like a Wolf*, I thought about the 9000-plus days that McIntyre has spent in Yellowstone studying and watching wolves (p. 183). I venture to guess that his collection of books and personal experiences offer more detail on a given species than anyone else's in history. Yes, in history!

Throughout the book, McIntyre depicts wolves as caring, family-oriented animals that have a level of cooperation similar to humans (p. 204). They have a theory of mind regarding other wolves as thinking, rational beings (pp. 141–143). McIntyre writes about the individual personalities of these wolves and how some, like Junction Butte's 907F, are successful by cooperating with pack mates and forming alliances to overtake other wolves (see Chapters 11 and 12). Despite the popular belief that males are dominant (which is debunked in *The Alpha Female Wolf*), McIntyre describes how wolves live in matriarchal societies (pp. 75, 116). Females make many of the major decisions for their families.

The part of McIntyre's books that I enjoy most are the stories, but with so many anecdotes over 29 years, his observations have become hard data revealing much about these creatures. In detailed accounts based on hundreds of observations, McIntyre describes:

- how and when wolves mate (p. 77);
- how Junction Butte wolf 911M, despite having three bad legs, brought down a cow Elk by himself (pp. 99–101) and then fought to his death eight wolves from the Prospect Peak Pack—it was the most courageous thing McInytre had ever seen (p. 105);
- that males never break up female fights (p. 121);
- the 10-plus layers of clothing that he wears in the winter to stay warm compared to wolves' fur coats allowing them to survive even in sub-zero temperatures (p. 122); and
- how Elk populations have significantly increased in the three-state region that surrounds Yellowstone

(i.e., Idaho, Montana, and Wyoming) since wolves returned to the region in 1995 (p. 148).

I wrote a picture e-book after observing the Junction Butte wolves for a couple of weeks during the 2021 summer (Way 2022b), so I was especially interested in McIntyre's observations of that pack. They are a remarkably effective social unit, living in a group that is double the average size for packs in Yellowstone, which already contains some of the biggest documented groups. McIntyre observed 35 wolves in the Junction Butte Pack one winter, including 18 surviving pups being raised cooperatively by multiple females (pp. 152, 158–159). He also saw 55 wolves from one spot in a day, including 29 Junctions (pp. 157–158), and 32 wolves at a summertime rendezvous site in August 2021 (p. 168). He watched one Grizzly Bear (aka Friend Bear) bed down with 27 Junction wolves in September 2021, as if the bear was part of the pack (p. 170). Friend Bear continued to follow and feed with the wolves for a couple of months until mid-November when he likely went into hibernation (p. 172). McIntyre describes Friend Bear as a Hulk-sized bouncer compared to the wolves (p. 170).

McIntyre's descriptions are tangible and make you feel like you are there in the park with him. Given all the wolves involved in the story, I am continually impressed with his ability to weave facts with narrative. The Alpha Wolves of Yellowstone series provides unprecedented levels of detail on pack dynamics and interactions among individuals. I only note some of these accounts in this review, so reading the book is a requirement for anyone interested in wolves and wildness. This series has been a joy to read. McIntyre has expanded upon his comprehensive field notes to offer powerful insights and perspectives into the amazing wolf behaviours that he has witnessed over his career. In the past 6.5 years, despite being officially retired, he went into the park nearly every day (although he occasionally leaves Yellowstone to lecture on wolves and his books), and then worked on his books after completing his daily field work (pp. 67, 120). As I've stated in previous reviews (Way 2022a), these books are one-of-a-kind, and McIntyre's attention to investigating a particular species in the wild is unlikely to be replicated again.

Literature Cited

Way, J. 2019. [Book Review] The Rise of Wolf 8: Witnessing the Triumph of Yellowstone's Underdog, by Rick McIntyre. Canadian Field-Naturalist 133: 180–181. https://doi.org/10.22621/cfn.v133i2.2407

Way, J. 2020. [Book Review] The Reign of Wolf 21: the Saga of Yellowstone's Legendary Druid Pack, by Rick McIntyre. Canadian Field-Naturalist 134: 392–393. https://doi.org/10.22621/cfn.v134i4.2739

Way, J. 2021. [Book Review] The Redemption of Wolf 302: from Renegade to Yellowstone Alpha Male, by Rick McIntyre. Canadian Field-Naturalist 135: 323–324. https://doi.org/10.22621/cfn.v135i3.2869

Way, J. 2022a. [Book Review] The Alpha Female Wolf: the Fierce Legacy of Yellowstone's 06, by Rick McIntyre. Canadian Field-Naturalist 136: 385–386. https://doi.org/10.22621/cfn.v136i4.3229

Way, J.G. 2022b. A Yellowstone summer with the Junction Butte wolf pack, Eastern Coyote/Coywolf Research. Accessed 26 September 2024. http://www.easterncoyoteresearch.com/YellowstoneSummerWithJunctionButteWolfPack.

JONATHAN (JON) WAY
Eastern Coyote/Coywolf Research
Osterville, MA, USA

EDITOR'S COMMENT: McIntyre's four other earlier books in his "Yellowstone series" are noted as being popular accounts enlightening the public's interest about Yellowstone wolves in the following article in this same issue of *The Canadian Field-Naturalist*:

Mech, L.D. 2024. Plural breeding in Gray Wolf (*Canis lupus*) packs: how often? Canadian Field-Naturalist 138(1): 58–62. https://doi.org/10.22621/cfn.v138i1.3271

NEW TITLES

Prepared by Jessica Sims

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

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

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

BIOLOGY

Bite: an Incisive History of Teeth, from Hagfish to Humans. By Bill Schutt. 2024. Algonquin Books. 320 pages, 40.00 CAD, Hardcover, 17.99 CAD, E-book.

Darwinizing Gaia: Natural Selection and Multispecies Community Evolution. Vienna Series in Theoretical Biology. By W. Ford Doolittle. 2024. MIT Press. 272 pages and 15 black and white illustrations, 60.00 CAD, Paper, 47.99 CAD, E-book.

A Drive to Survive: the Free Energy Principle and the Meaning of Life. By Kathryn Nave. 2025. MIT Press. 318 pages and 10 black and white illustrations, 73.00 CAD, Paper, 58.99 CAD, E-book.

Feminism in the Wild: How Human Biases Shape Our Understanding of Animal Behavior. By Ambika Kamath and Melina Packer. 2025. MIT Press. 208 pages and 12 black and white illustrations, 33.95 CAD, Paper, 27.99 CAD, E-book.

Is Anyone Listening? What Animals Are Saying to Each Other and to Us. By Denise L. Herzing. 2024. University of Chicago Press. 232 pages and 30 halftones, 36.50 CAD, Hardcover. Also available as an E-book.

†Maladaptation: Natural Selection in the Wrong Direction? By Philip G. Madgwick. 2024. Oxford University Press. 256 pages, 40.00 USD, Hardcover. Also available as an E-book.

Plasticity in the Life Sciences. By Antonine Nicoglou. 2024. University of Chicago Press. 320 pages and 16 halftones, 149.50 CAD, Hardcover, 48.95 CAD, Paper. Also available as an E-book.

BOTANY

***A Field Guide to Urban Plants: Common Species of Pavements, Walls and Waste Ground.** By Alexandra-Maria Klein and Julia Krohmer. 2024. Pelagic Publishing. 144 pages and colour illustrations, 33.00 USD, Paper.

Moss and Lichen. By Elizabeth Lawson. 2025. Reaktion Books. Distributed by University of Chicago Press. 256 pages, 96 colour plates, and 17 halftones, 35.50 CAD, Hardcover.

Oak Origins: from Acorns to Species and the Tree of Life. By Andrew L. Hipp. Illustrations by Rachel D. Davis. Foreword by Béatrice Chassé. 2025. University of Chicago Press. 288 pages and 43 halftones, 45.50 CAD, Hardcover. Also available as an E-book.

Rare Plants. Bloomsbury Wildlife Collection, Volume 14. By Peter Marren. 2025. Bloomsbury Wildlife. 400 pages and 300 colour photos, 73.00 CAD, Hardcover. Also available as an E-book.

Saving Orchids: Stories of Species Survival in a Changing World. By Philip Seaton and Lawrence W. Zettler. 2025. University of Chicago Press. 320 pages and 150 colour plates, 45.50 CAD, Hardcover.

***The Serviceberry: Abundance and Reciprocity in the Natural World.** By Robin Wall Kimmerer. Illustrations by John Burgoyne. 2024. Scribner. 128 pages, 25.00 CAD, Hardcover, 13.99 CAD, E-book.

Wildflowers: Discover the Science and Secrets Behind the World of Wildflowers. By Chris Thorogood. 2025. DK. 304 pages, 41.00 CAD, Hardcover.

CONSERVATION AND CLIMATE CHANGE

†Atlas of a Threatened Planet: 150 Infographics to Help Anyone Save the World. By Esther Gonstalla.

2024. Island Press. 224 pages and 150 colour illustrations, 43.95 CAD, Paper. Also available as an E-book.

The Carbon Tax Question: Clarifying Canada's Most Consequential Policy Debate. By Thomas F. Pedersen. 2024. Harbour Publishing. 264 pages, 26.96 CAD, Paper.

Climate Justice: What Rich Nations Owe the World—and the Future. By Cass R. Sunstein. 2025. MIT Press. 200 pages, 39.95 CAD, Hardcover, 31.99 CAD, E-book.

Coexistence: Learning to Live with Lynx, Wolves and Bears. By Jonny Hanson. 2025. Pelagic Publishing. 272 pages, 37.00 USD, Hardcover.

Decolonizing Environmentalism: Alternative Visions and Practices of Environmental Action. By Prakash Kashwan and Aseem Hasnain. 2025. Bloomsbury Academic. 224 pages, 109.50 CAD, Hardcover, 36.50 CAD, Paper.

Echoes from Eden: a Memoir from the Frontlines of Conservation. By Dax Dasilva and Eric Hendrikx. 2025. Victory Belt Publishing. 304 pages, 49.95 CAD, Hardcover, 15.99 CAD, E-book.

Epic of the Earth: Reading Homer's "Iliad" in the Fight for a Dying World. By Edith Hall. 2025. Yale University Press. 288 pages and 10 black and white illustrations, 39.00 CAD, Hardcover.

Lost Wonders: 10 Tales of Extinction from the 21st Century. By Tom Lathan. Illustrations by Claire Kohda. 2025. Pan Macmillan. 320 pages, 44.99 CAD, Hardcover, 24.99 CAD, E-book.

Our Vanishing Glaciers: the Snows of Yesteryear and the Future Climate of the Mountain West. Edition, Revised and Updated. By Robert William Sandford. 2025. Rocky Mountain Books (RMB). 224 pages, 40.00 CAD, Hardcover.

Power Metal: the Race for the Resources that Will Shape the Future. By Vince Beiser. 2024. Penguin Publishing Group. 272 pages, 42.00 CAD, Hardcover, 18.99 CAD, E-book.

Ecology

Bad Nature: How Rat Control Shapes Human and Nonhuman Worlds. By Andrew McCumber. 2025. University of Chicago Press. 224 pages, 27.50 USD, Paper.

Habitats of North America: a Field Guide for Birders, Naturalists, and Ecologists. By Phil Chaon and Iain Campbell. Photography by Benjamin Jacob Knoot. 2025. Princeton University Press. 376 pages, 44.00 CAD, Paper. Also available as an E-book.

Wetlands of Mountainous Regions: Biodiversity, Livelihoods and Conservation. Edited by Thammineni Pullaiah. 2025. Wiley. 384 pages, 268.75 CAD, Hardcover.

When the Earth Was Green: Plants, Animals, and Evolution's Greatest Romance. By Riley Black. 2025. St. Martin's Publishing Group. 304 pages, 39.00 CAD, Hardcover, 16.99 CAD, E-book.

Entomology

Dragonflies and Damselflies of the World: a Guide to Their Diversity. A Guide to Every Family Series. By Klaas-Douwe B. Dijkstra. 2025. Princeton University Press. 256 pages and 250 colour illustrations, 40.00 CAD, Hardcover. Also available as an E-book.

Moths of the World: a Natural History. A Guide to Every Family Series. By David Wagner. 2025. Princeton University Press. 240 pages and 300 colour illustrations, 38.00 CAD, Hardcover. Also available as an E-book.

Herpetology

The Lives of Frogs: a Natural History. The Lives of the Natural World Series. By Jim Labisko and Richard A. Griffiths. 2025. Princeton University Press. 288 pages and 150+ colour illustrations, 44.00 CAD, Hardcover. Also available as an E-book.

The Lives of Snakes: a Natural History of the World's Snakes. The Lives of the Natural World Series. By Chris Mattison. 2025. Princeton University Press. 288 pages and 150+ colour illustrations, 44.00 CAD, Hardcover. Also available as an E-book.

Ornithology

Birds at Rest: the Behavior and Ecology of Avian Sleep. By Roger F. Pasquier. 2025. Princeton University Press. 360 pages and 26 black and white illustrations, 44.00 CAD, Hardcover. Also available as an E-book.

The Book of Flaco: the World's Most Famous Bird. By David Gessner. 2025. Blair. 228 pages, 37.95 CAD, Hardcover.

†How Birds Fly: the Science and Art of Avian Flight. By Peter Cavanagh. 2024. Firefly Books. 336 pages and 350 colour photos and illustrations, 49.95 CAD, Hardcover.

National Geographic Field Guide to the Birds of the United States and Canada—East. Second Edition. By Ted Floyd. 2025. Disney Publishing Group. 448 pages, 33.99 CAD, Paper.

National Geographic Field Guide to the Birds of the United States and Canada—West. Second Edition. By Ted Floyd. 2025. Disney Publishing Group. 496 pages, 33.99 CAD, Paper.

Sea Bird: Explore the Charming Oceanside Song of Our Shoreline Feathered Friends. By Angela Harrison Vinet and Janis Hatten Harrison. 2025. Epic Ink. 128 pages, 17.99 CAD, Hardcover.

Zoology

Beautiful Shells: George Perry's Conchology. By Mark Carnall. 2024. Bodleian Library Publishing. Distributed by University of Chicago Press. 192 pages and 68 colour plates, 52.00 CAD, Hardcover.

Deer of the World: Ecology, Conservation and Management. Edited by Mario Melletti and Stefano Focardi. 2024. Springer Nature. 590 pages, 204.50 CAD, Hardcover.

***The Ellesmere Wolves: Behavior and Ecology in the High Arctic.** By L. David Mech, Morgan Anderson, and H. Dean Cluff. Foreword by Luigi Boitani. 2025. University of Chicago Press. 208 pages, 20 colour plates, and 20 halftones, 149.50 CAD, Hardcover, 41.95 CAD, Paper. Also available as an E-book.

Fur, Fleas, and Flukes: the Fascinating World of Parasites. By Michael Stock. 2024. University of Toronto Press. 312 pages and 35 colour illustrations, 32.95 CAD, Hardcover. Also available as an E-book.

The Lives of Bats: a Natural History. The Lives of the Natural World Series. By DeeAnn M. Reeder. 2025. Princeton University Press. 288 pages and 150+ colour illustrations, 44.00 CAD, Hardcover. Also available as an E-book.

The Marlin's Fiery Eye and Other Tales from the Extraordinary World of Marine Fishes. By Joe E. Meisel. Foreword by Rod Fujita. 2025. Comstock Publishing Associates. 384 pages and 36 black and white halftones, 33.95 CAD, Paper. Also available as an E-book.

Shark: the Illustrated Biography. By Daniel Abel and Sophie A. Maycock. 2025. Princeton University Press. 224 pages and 100 colour illustrations, 38.00 CAD, Hardcover. Also available as an E-book.

Other

The Arrival of the Fittest: Biology's Imaginary Futures, 1900–1935. By Jim Endersby. 2025. University of Chicago Press. 400 pages and 25 halftones, 149.50 CAD, Hardcover, 48.95 CAD, Paper. Also available as an E-book.

Catesby's Natural History. By Stephen A. Harris. 2024. Bodleian Library Publishing. Distributed by University of Chicago Press. 304 pages and 230 colour plates, 97.50 CAD, Hardcover.

Clouds: How to Identify Nature's Most Fleeting Forms. By Edward Graham. Foreword by Richard Hamblyn. 2025. Princeton University Press. 224 pages and 140 colour illustrations, 38.00 CAD, Hardcover.

How to Survive a Bear Attack: a Memoir. By Claire Cameron. 2025. Knopf Canada. 304 pages, 34.95 CAD, Hardcover, 16.99 CAD, E-book.

Wild Roses Are Worth It: Reimagining the Alberta Advantage. Edition, Revised and Updated. By Kevin Van Tighem. 2024. Rocky Mountain Books (RMB). 296 pages, 25.00 CAD, Paper, 10.99 CAD, E-book.

The Canadian Field-Naturalist

News and Comment

Compiled by Amanda E. Martin

Upcoming Meetings and Workshops

The Stewardship Network Conference

The Stewardship Network Conference to be held 23–24 January 2025 at the Kellogg Hotel & Conference Center, East Lansing, Michigan. Registration is currently open. More information is available at https://conference.stewardshipnetwork.org/.

Society for Range Management Annual Meeting

The annual meeting of the Society for Range Management to be held 9–13 February 2025 at the Spokane Convention Center, Spokane, Washington. Registration is currently open. More information is available at https://rangelands.org/annual-meeting-2025/.

The Forests Conference

The Forests Conference to be held 19–20 February 2025 at the Hilton Toronto Airport Hotel & Suites, Toronto, Ontario. Registration is currently open. More information is available at https://forestscanada.ca/en/event/annual-conference.

Colloque Annuel du CSBQ/Annual QCBS Symposium

The Colloque Annuel du CSBQ/Annual QCBS Symposium to be held 24–26 February 2025 at the Université de Sherbrooke–Campus Longueuil, Longueuil, Quebec. Registration is currently open. More information is available at https://qcbs.ca/symposium-2025/.

Wetland Science Conference

The annual Wetland Science Conference of the Wisconsin Wetlands Association to be held 25–27 February 2025 at the Radisson Hotel, La Crosse, Wisconsin. Registration is currently open. More information is available at https://conference.wisconsinwetlands.org/.

Eastern Bird Banding Association Annual Meeting

The 102nd annual meeting of the Eastern Bird Banding Association to be held 28 February–2 March 2025 at the Kiawah Island Golf Resort, Charleston, South Carolina. Registration is currently open. More information is available at https://easternbirdbanding.org/2025-Meeting.

Alberta Chapter of The Wildlife Society Conference

The Alberta Chapter of The Wildlife Society Conference to be held 7–9 March 2025 at the Badlands Community Facility, Drumheller, Alberta. The theme of the conference is: 'Digging Deeper Together: Big Data Insights'. Registration is currently open. More information is available at https://www.actws.ca/conference/.

Entomological Society of America, Southeastern Branch Meeting

The annual meeting of the Southeastern Branch of the Entomological Society of America to be held 9–12 March 2025 in Baton Rouge, Louisiana. More information is available at https://entsoc.org/event-calendar/southeastern-branch-2025-meeting.

American Fisheries Society, Washington-British Columbia Chapter Annual Meeting

The annual meeting of the American Fisheries Society, Washington-British Columbia Chapter to be held 10–13 March 2025 at the Pinnacle Hotel, Vancouver, British Columbia. The theme of the conference is: 'Beyond Borders: Connecting Communities, People and Fish'. Registration is currently open. More information is available at https://wa-bc.fisheries.org/2025-meeting/.

Entomological Society of America, Eastern Branch Meeting

The annual meeting of the Eastern Branch of the Entomological Society of America to be held 15–18 March 2025 at the Sheraton Harrisburg Hershey Hotel, Harrisburg, Pennsylvania. Registration is currently open. More information is available at https://www.entsoc.org/membership/branches/eastern/meeting.

International Conference on Forest Mycology and Mycorrhiza Research

The International Conference on Forest Mycology and Mycorrhiza Research to be held 18–19 March 2025 in Phoenix, Arizona. Registration is currently open. More information is available at https://itar.in/conf/index.php?id=2778593.

Entomological Society of America, Southwestern Branch Meeting

The annual meeting of the Southwestern Branch of the Entomological Society of America to be held 23–26 March 2025 at the Embassy Suites by Hilton Round Rock, Round Rock, Texas. Registration is currently open. More information is available at https://www.entsoc.org/membership/branches/southwestern/meeting.

Entomological Society of America, Pacific Branch Meeting

The annual meeting of the Pacific Branch of the Entomological Society of America to be held 30 March–2 April 2025 at the Hilton Salt Lake City, Salt Lake City, Utah. Registration is currently open. More information is available at https://www.entsoc.org/membership/branches/pacific/meeting.

James Fletcher Award for *The Canadian Field-Naturalist* Volume 137

The James Fletcher Award is awarded to the authors of the "best" paper published in a volume of *The Canadian Field-Naturalist* (CFN). The award is in its eighth year. The award honours James Fletcher, founder of the Ottawa Field-Naturalists' Club (OFNC) and the first editor of CFN's earliest iteration, *Transactions of the Ottawa Field-Naturalists' Club*. The editorial team of CFN sifted through all papers in Volume 137 of CFN and came up with a list of six papers. From these, the committee ranked the papers and selected the top paper. The award for Volume 137 of CFN goes to:

Sadie Parr. 2023. An overview of known species killed during Alberta's Gray Wolf (*Canis lupus*) strychnine program, 2005–2020. Canadian Field-Naturalist 137(3): 259–266. https://doi.org/10.22621/cfn.v137i3.3213

- A comprehensive review of wildlife mortality caused by the use of strychnine to control wolf populations in Alberta. This work highlighted how often these treatments lead to non-target wildlife mortalities, and its findings contributed to the decision made by Health Canada's Pest Management Regulator Agency to cancel all predacide uses of strychnine across Canada.

Congratulations to Sadie for their excellent paper.

Honourable Mentions *(in chronological order):*

Shaylyn Wallace, Douglas T. Munn, Kristine E. Hanifen, Gregory F.M. Jongsma, and Donald F. McAlpine. 2023. Preliminary estimate of a Gray Treefrog (*Hyla versicolor*) population at a protected site in New Brunswick using photo identification and community science. Canadian Field-Naturalist 137(1–2): 125–130. https://doi.org/10.22621/cfn.v137i1.3123

- This study provides the first estimate of *Hyla versicolor* population size in Canada's first amphibian conservation area. It also demonstrates how a pattern recognition software can be used to identify individual frogs from photographs—a non-invasive approach to mark-recapture sampling that can avoid some of the negative impacts of previously-used methods such as toe-clipping.

Brittni Scott, G. Randy Milton, Scott McBurney, and Donald T. Stewart. 2023. Population genetic structure of the provincially endangered mainland Eastern Moose (*Alces americanus americanus*) in Nova Scotia, Canada. Canadian Field-Naturalist 137(1–2): 136–149. https://doi.org/10.22621/cfn.v137i1.3127

- This study conducted an analysis of the genetic structure and diversity of the endangered mainland Eastern Moose in Nova Scotia, and provided evidence that gene flow is occurring between this population and moose in New Brunswick.

Donald F. McAlpine, Tonya Wimmer, Wayne Ledwell, Pierre-Yves Daoust, Laura Bourque, Jack W. Lawson, Wojtek Bachara, Zoe N. Lucas, G. Andrew Reid, Stéphane Lair, Anthony François, and Robert Michaud. 2023. A review of beaked whale (Ziphiidae) stranding incidents from the inshore waters of eastern Canada. Canadian Field-Naturalist 137(3): 201–231. https://doi.org/10.22621/cfn.v137i3.2967

- This study examines stranding incidents of beaked whales in eastern Canada, and provided new insights into these cryptic species. This is particularly significant because beaked whales spend most of their time in the remote offshore environment and are chronically understudied. These records provide insights into their spatial distribution and life history parameters.

Cyndi M. Smith, Brenda Shepherd, Mark Bradley, and Shelley Humphries. 2023. Declining population of Harlequin Duck (*Histrionicus histrionicus*) on the Bow River, Alberta, Canada: 25 years of monitoring. Canadian Field-Naturalist 137(4): 358–366. https://doi.org/10.22621/cfn.v137i4.3183

- This 25-year study of a small sea duck that breeds on fast-moving mountain streams in western North America and overwinters on the coast combines observations from a multitude of volunteers and professional biologists and population modelling to show a concerning population decline in a protected area. Because similar declines have been documented elsewhere in the Rocky Mountains and along the coast, a multifactorial explanation is warranted.

Emma Kominek, Olivia Cornies, Hannah McCurdy-Adams, and Arne Ø. Mooers. 2023. Evolutionary isolation of Canadian terrestrial vertebrate species. Canadian Field-Naturalist 137(4): 367–380. https://doi.org/10.22621/cfn.v137i4.2673

- This study estimates, for the first time, the evolutionary distinctiveness of each of Canada's tetrapods. Evolutionarily distinct species can have unique or rare biological features and represent millions of years of evolutionary history independent of other Canadian species. For example, Kominek *et al.* found that Canada's most distinct species, Spiny Softshell Turtle (*Apalone spinifera*), represents an astounding 178.4 million years of independent evolutionary history!

Congratulations to these finalists. We would also like to show our appreciation to all authors who chose to share their interesting and valuable field-based studies with the readers of Volume 137 of *The Canadian Field-Naturalist*.

AMANDA E. MARTIN, WILLIAM HALLIDAY,
and DWAYNE A.W. LEPITZKI
OFNC Publication Committee

The Canadian Field-Naturalist

Minutes of the 145th Annual Business Meeting (ABM) of the Ottawa Field-Naturalists' Club, 10 January 2024 (draft)

Chairperson: Jakob Mueller, President
82 people attended part or all of the Zoom meeting

The minutes of the previous Annual Business Meeting (ABM), the financial statements, Treasurer's Report, and annual reports of the Ottawa Field-Naturalists' Club (OFNC) committees for 2022–2023 had previously been available on the Club's website. Documents pertaining to the Articles of Amendment and By-laws had also been available on the website. The meeting was called to order at 7:37 pm. During the meeting, relevant documents were projected on the screen for the audience's information.

Before the meeting, the Zoom host, Ken Young, explained how the Zoom meeting would work.

1. Adoption of the Agenda

It was moved by Elizabeth Moore, seconded by Catherine Hessian, that the Agenda be adopted as distributed.

Carried

2. Welcoming Remarks – Jakob Mueller, President, welcomed the attendees.

3. Minutes of the Previous ABM

It was moved by Elizabeth Moore, seconded by Diane Lepage, that the minutes of the 144th ABM be accepted as distributed and published in *The Canadian Field-Naturalist* (CFN).

Carried

4. Business Arising from the Minutes

None.

5. Treasurer's Report by Ann Mackenzie

It was moved by Ann MacKenzie, seconded by Ken Young, that the Financial Statements be accepted as a fair representation of the financial position of the Club as of 30 September 2023.

Ann MacKenzie, Treasurer, presented the Financial Statements for 30 September 2023 as prepared and reviewed by the accounting firm, Welch LLP. Copies of the complete statement as well as the written Treasurer's Report had been available on the Club's website.

Ann reported that the Club had a surplus in the Fletcher Wildlife Garden (FWG) Fund of $11 631 and a deficit in the General Fund of $8256. These results were better than had been forecast at the previous year's ABM.

The plant sale continued to be a successful fundraiser for the Fletcher while donations to the FWG were at normal levels. Donations were also down for the General Fund and there were no bequests. Membership revenue was reported higher this year but that was primarily a bookkeeping correction.

The trip to Point Pelee, which the Club undertakes every couple of years, was a great success and raised about $10 000.

The CFN only published three issues compared to the usual four during the year. As a result, both revenues and expenses related to the CFN were lower than had been anticipated. Fewer research grants were awarded, also lowering the total annual expenses.

In 2023–2024 it is expected that deficits will increase as the CFN catches up issues and research grants are awarded. Legal fees related to the updating of the By-laws will also be a significant expense. However, the Club remains in a solid financial position.

John Prescott, a past Treasurer of Nature Guelph, commented on the Club's assets, and suggested that the Club should be looking to use more of its investments to support environmental needs in our community.

Ann explained that the sizable investments are the result of a very large bequest in 2015. Following this bequest several initiatives were started such as the Research Grant program and enhanced support for outdoor education through the school board. Ken Young noted that the Club has donated money to other organizations such as Ontario Nature and the Nature Conservancy, to purchase and manage environmentally sensitive land. The Board is always receptive to any ideas for projects needing support.

Carried

Approved financial statements available online at https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/3473/3259

6. Review for the FY 2023–2024 Financial Statements

It was moved by Ann MacKenzie, seconded by Ken Young, that a review, rather than an audit, of the OFNC's accounts be conducted for the fiscal year ending 30 September 2024.

Ann explained that the new Ontario legislation now requires us to get approval from 80% of the members voting at each annual meeting in order to have a review of our financial statements rather than an audit. The cost of a review is about $6000. An audit would be about twice that amount as well as requiring about twice as much volunteer time.

A member asked why the review costs so much. The price we pay is consistent with industry standards. Another member asked when we were last audited. Ken replied that a Club member, Janet Gehr, had audited the statements up until 2009. She only did a review of the statements in 2010 because of changes to the standards. Welch LLP began reviewing the statements in 2011. (Note: names and dates were added after the meeting.)

The motion was **Carried** by a majority of >80%

7. Nomination of the Accounting Firm

It was moved by Ann MacKenzie, seconded by Ken Young, that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending 30 September 2024.

A member inquired whether the review work had been put out for bids. Ann stated that it had not and questioned the cost versus the benefit of such a task. Anyone interested in pursuing this project should get in touch with her.

Carried

8. Consideration of the Articles of Amendment and By-laws

Ken Young, Chair of the Finance Committee, presented a motion that would change our Constitution and By-laws. There are two reasons to do this.

First, we last updated our Constitution and By-laws back in 2000. They do not correspond well with our current practices.

Second, the OFNC is incorporated in Ontario, and recently legislation has come into effect that affects us. It is the *Ontario Not-for-Profit Corporations Act* (ONCA). We are now governed by ONCA instead of the more general *Ontario Corporations Act*.

The Finance Committee, with the considerable help of our lawyer, Karen Cooper of the firm KPMG, has developed two documents which have been made available to you via the Notice of Meeting for tonight's meeting. The first of these, Articles of Amendment, deletes our existing articles and replaces them with new ones. The second, General Operating By-law No. 1, replaces our existing By-laws.

Ken said that there were three important changes:

1. Most generally, you can think of the OFNC's rules of operation as comprising the articles, the By-laws, and policies. In the past, the Club's articles and By-laws contained a great amount of operational detail that will now be in policies. The Club currently has a number of policies, covering everything from conduct at our events to investment strategy. The Board of Directors will be tasked with reviewing those policies to ensure that they are comprehensive and effective.
2. There is a change to our name, from "THE OTTAWA FIELD-NATURALISTS' CLUB" to "OTTAWA FIELD NATURALISTS' CLUB". The hyphen is replaced by a space, which will make our name conform to the style used by other Ontario field naturalist clubs. We've also been advised by our lawyer to drop the article "The" from the official title to make online searches easier.
3. Another change concerns the annual examination of our financial records. This is the process that results in the creation of our financial statements. It can be done in two ways, a review or an audit. Audits are more expensive than reviews, but are more likely to uncover problems with financial procedures. The OFNC has several checks and balances built into its financial procedures, so we've felt that a review is sufficient. However, ONCA requires that members approve the use of a review rather than an audit, every year. Further, the motion is an extraordinary resolution, meaning that at least 80% of members who vote must vote in favour of the resolution.

Ken then presented a motion to adopt the new articles and By-laws. It is a special resolution, requiring a ⅔ majority to pass.

SPECIAL RESOLUTION — THE OTTAWA FIELD NATURALISTS' CLUB
(hereinafter referred to as the "Corporation")

WHEREAS the Corporation was incorporated under the *Ontario Corporations Act* by Letters Patent in 1965 and amalgamated pursuant to Letters Patent of Amalgamation issued in 1884;

AND WHEREAS it is deemed in the best interest of the Corporation to update its constating documents as a result of the coming into force of the *Ontario Not-for-Profit Corporations Act*;

THEREFORE BE IT RESOLVED AS A SPECIAL RESOLUTION THAT:

1. The Articles of Amendment presented to this meeting and appended to these minutes are hereby approved.
2. The new General Operating By-Law No.1 presented to this meeting and appended to these minutes are hereby approved.
3. Any one of the Officers and Directors of the Corporation is authorized to take all such actions and execute and deliver all such documentation, which are necessary or desirable for the implementation of this resolution.

Carried

9. Committee Annual Reports

It was moved by Elizabeth Moore, seconded by Janette Niwa, that the committee annual reports be accepted as circulated.

Janette Niwa presented an illustrated slide show of some of the highlights of the work carried out by the various committees over the past year.

Carried

10. Nominations for Board of Directors positions

It was moved by Diane Lepage, seconded Ann MacKenzie, that the slate of nominees presented be accepted as members of the Board of Directors of the OFNC for 2024.

Diane noted that there has been little change to the Board for 2024 but that we are pleased to welcome two new Directors: Katriina Ilves and Jessica Sims.

Diane presented the slate of candidates nominated to the Board of Directors for 2024:

Slate of Nominees for Officers and Other Members of the Board of Directors

Officers	**Position**
Jakob Mueller	President
Owen Clarkin	Vice-President
Elizabeth Moore	Secretary
Ann MacKenzie	Treasurer

Other Members of the Board of Directors (in alphabetical order)

Annie Bélair	Morgan McAteer
Derek Dunnett	Janette Niwa
Edward Farnworth	Gordon Robertson
Catherine Hessian	Jessica Sims
Katriina Ilves	Ken Young
Kerri Keith	Eleanor Zurbrigg
Diane Lepage	

Carried

11. Adjournment

It was moved by Elizabeth Moore, seconded by Eleanor Zurbrigg, that the meeting be adjourned.

Carried

After the meeting was adjourned, a natural history quiz was presented by Diane Lepage.

ELIZABETH MOORE,
Secretary

GENERAL OPERATING BY-LAW NO. 1

A By-law relating generally to the conduct of the affairs of

OTTAWA FIELD NATURALISTS' CLUB
(the "Corporation")

SECTION I
INTERPRETATION

1.01 Definitions

In all By-laws and resolutions of the Corporation, unless the context otherwise requires:

(a) "**Articles**" means articles of incorporation, restated articles of incorporation, articles of amendment, articles of amalgamation, articles of arrangement, articles of continuance, articles of dissolution, articles of reorganization, articles of revival, letters patent, supplementary letters patent or a special Act of the Corporation;

(b) "**Act**" means the *Not-for-Profit Corporations Act*, S.O. 2010, c. 15 and, where the context requires, includes the regulations made under it, as amended or re-enacted from time to time;

(c) "**Board**" means the board of Directors of the Corporation;

(d) "**By-law**" or "**By-laws**" means this by-law and all other by-laws of the Corporation as amended and which are, from time to time, in force and effect;

(e) "**Chair**" means the chair of the Board;

(f) "**Corporation**" means the corporation that has passed this By-law under the Act or that is deemed to have passed this By-law under the Act;

(g) "**Director**" means an individual occupying the position of director of the Corporation, by whatever name he or she is called;

(h) "**Member**" means a Member of the Corporation and "**Members**" or "**Membership**" means the collective membership of the Corporation;

(i) "**Officer**" means an officer of the Corporation;

(j) "**Operating Policies**" or "**Operating Policy**" means the operating policy or policies approved by the Board in accordance with this By-law;

(k) "**Ordinary Resolution**" means a resolution that is (i) submitted to a meeting of the Members and passed at the meeting, with or without amendment, by at least a majority of the votes cast, or (ii) consented to by each Member entitled to vote at a meeting of the Members.

(l) "**Special Resolution**" means a resolution that is (i) submitted to a special meeting of the Members that is duly called for the purpose of considering the resolution and is passed at the special meeting, with or without amendment, by at least two thirds (2/3) of the votes cast, or (ii) consented to by each Member entitled to vote at a meeting of the Members.

1.02 Interpretation

In the interpretation of this By-law, unless the context otherwise requires, the following rules shall apply:

(a) other than as specified in this By-law, all terms contained herein and that are defined in the Act shall have the meanings given to such terms in the Act;

(b) words importing the singular will include the plural and vice versa;

(c) the word "person" shall include an individual, sole proprietorship, partnership, unincorporated association, unincorporated syndicate, unincorporated organization, trust, body corporate and a natural person in his or her capacity as trustee, executor, administrator, or other legal representative;

(d) the headings used in this By-law are inserted for reference purposes only and are not to be considered or taken into account in construing the terms or provisions thereof or to be deemed in any way to clarify, modify or explain the effect of any such terms or provisions;

(e) if any of the provisions contained in the By-laws are inconsistent with those contained in the Articles or the Act, the provisions contained in the Articles or the Act, as the case may be, shall prevail; and
(f) the invalidity or unenforceability of any provision of this By-law shall not affect the validity or enforceability of the remaining provisions of this By-law.

SECTION II
GENERAL

2.01 Execution of Documents

Deeds, transfers, assignments, contracts, obligations and other instruments in writing requiring execution by the Corporation may be signed by any one of the President, Treasurer or Chair of the Finance Committee, if the latter is a Director. In addition, the Board may from time to time direct the manner in which and the person by whom a particular document or type of document shall be executed. Any person authorized to sign any document may affix the corporate seal, if any, to the document. Any Director or Officer may certify a copy of any instrument, resolution, By-law or other document of the Corporation to be a true copy thereof.

2.02 Operating Policies

The Board may adopt, amend, or repeal by resolution such Operating Policies that are not inconsistent with the By-laws of the Corporation relating to such matters as terms of reference of Committees, duties of Officers, Board code of conduct and conflict of interest as well as procedural and other requirements relating to the By-laws as the Board may deem appropriate from time to time. Any Operating Policy adopted by the Board will continue to have force and effect until amended, repealed, or replaced by a subsequent resolution of the Board.

SECTION III
FINANCIAL AND OTHER MATTERS

3.01 Financial Year

Unless otherwise changed by resolution of the Board, the financial year end of the Corporation shall be the 30 of September in each year.

3.02 Banking Arrangements

The banking business of the Corporation shall be transacted at such bank, trust company or other firm or corporation carrying on a banking business in Canada or elsewhere as the Board may designate, appoint or authorize from time to time. The banking business or any part of it shall be transacted by an Officer or Officers of the Corporation and/or other persons as the Board may by resolution from time to time designate, direct or authorize.

3.03 Auditor and Level of Financial Review

The Corporation shall be subject to the requirements relating to the appointment of an auditor or a person to conduct a review engagement and level of financial review required by the Act.

SECTION IV
MEMBERS

4.01 Classes and Conditions of Membership

There shall be one (1) class of Members in the Corporation. Membership in the Corporation shall be available only to individuals interested in furthering the Corporation's purpose and who have applied for and been accepted into Membership in the Corporation by resolution of the Board or in such other manner as may be determined by the Board. Membership may be divided into categories of Membership for the purpose of assessing applicable Membership fees, as more particularly described in this By-law and in the Corporation's Operating Policies.

4.02 Rights of Members

A Member of the Corporation in good standing shall have the right to receive notice of, attend, speak and participate at all meetings of Members and the right to one (1) vote at all meetings of Members. Membership in the Corporation is not transferable.

4.03 Membership Fees and Good Standing

The Directors may determine the amount and the manner in which membership dues are to be paid. A Member shall be considered to be in good standing if the Member:

(a) became a Member of the Corporation at least thirty (30) days before the meeting of Members;
(b) has paid their annual membership fees to the Corporation by the date of the annual meeting; and
(c) is not in the course of disciplinary action pursuant to section 4.05.

4.04 Termination of Membership

Membership in the Corporation is terminated when:

(a) the Member dies;
(b) the Member ceases to maintain the qualifications for Membership set out in section 4.01;
(c) the Member is in default in accordance with section 4.03; or
(d) the Member resigns by delivering a written resignation to the President in which case such resignation shall be effective at the time the resignation is received by the corporation or at the time specified in the resignation, whichever is later.

Subject to the Articles, upon any termination of Membership, the rights of the Member automatically cease to exist. Where a person is no longer a Member, then such person shall be deemed to have also automatically resigned as a Director, an Officer and/or a Committee Member, as applicable, provided that the Board may, in its discretion, subsequently re-appoint such individual as an Officer or Committee Member if the Board deems it appropriate in the circumstances.

4.05 Discipline of Members

The Board may suspend or remove any Member from the Corporation for any one or more of the following grounds:

(a) contravening any provision of the Articles, By-laws, or other Operating Policies of the Corporation;
(b) carrying out any conduct which may be detrimental to the Corporation as determined by the Board in its sole discretion; and/or
(c) for any other reason that the Board in its sole and absolute discretion considers to be reasonable, having regard to the purposes of the Corporation.

In the event that the Board determines that a Member should be suspended or removed from membership in the Corporation, the process shall be done in good faith and in a fair and reasonable manner. The Board shall provide at least fifteen (15) days' written notice of suspension or removal to the Member and shall provide reasons for the proposed suspension or removal. The Member shall be given an opportunity to be heard orally by or to make written submissions to the Board not less than five (5) days before the suspension or removal becomes effective. In the event that the Member declines the opportunity to heard or to make written submissions, the Board may proceed to notify the Member that the Member is suspended or removed from membership in the Corporation. Where oral or written submissions are made by the Member in accordance with this section, the Board will consider such submissions in arriving at a final decision and shall notify the Member in writing concerning such final decision.

SECTION V
MEETINGS OF MEMBERS

5.01 Place of Meetings

Meetings of Members shall be held at the registered office of the Corporation or at any place within Ontario as the Board may determine. If a meeting is to be held entirely by electronic means, the notice of that meeting does not need state the place of the meeting and the place of the meeting is deemed to be the registered office of the Corporation.

5.02 Annual Meetings

The annual meeting shall be held on a day and at a place within Ontario fixed by the Board, provided that it must be held not later than fifteen (15) months after the preceding annual meeting.

The business transacted at the annual meeting shall include:

(a) receipt of the agenda;
(b) receipt of the minutes of the previous annual and subsequent special meetings;
(c) consideration of the financial statements;
(d) consideration of the audit or review engagement report, if any;
(e) reappointment or new appointment of the auditor or person to conduct a review engagement for the coming year;
(f) election of Directors; and
(g) such other or special business as may be set out in the notice of meeting.

No other item of business shall be included on the agenda for annual meeting unless a Member's proposal has been given to the Corporation of any matter that the Member proposes to raise at the meeting in accordance with the Act at least 60 days before the date of the meeting, so that such item of new business can be included in the notice of annual meeting.

5.03 Presentation of Annual Financial Statements to Members

Not less than five (5) business days before each annual meeting of the members, the Corporation shall send copies of the financial statements and any other documents required by the Act to all Members who have informed the Corporation that they wish to receive a copy of those documents. The Directors shall place before the Members at every annual meeting the financial statements of the most recently completed financial year and any other documents required by the Act.

5.04 Special Meetings

The Board may at any time call a special meeting of the Members. The Board shall convene a special meeting on written requisition of the Members of the Corporation who hold at least ten percent (10%) of votes that may be cast at a meeting for any purpose connected with the affairs of the Corporation that does not fall within the exceptions listed in the Act or is otherwise inconsistent with the Act, within twenty-one (21) days from the date of the receipt of the requisition.

5.05 Special Business

All business transacted at a special meeting of Members and all business transacted at an annual meeting of Members is special business except for the following:

(a) consideration of the financial statements, and the audit or review engagement report, if any;
(b) an extraordinary resolution to have a review engagement instead of an audit or to not have an audit or a review engagement;
(c) the election of Directors; and
(d) the re-appointment of the incumbent auditor or person appointed to conduct a review engagement.

5.06 Notice of Meeting

In accordance with and subject to the Act, notice of the time and place of a meeting of Members shall be given to each Member entitled to receive notice of the meeting, each Director, and the auditor or person appointed to conduct a review engagement of the Corporation, not less than ten (10) and not more than fifty (50) days before any annual or special Members' meeting. Notice shall be given in accordance with the manner provided in section 10.01 of this By-law.

Notice of any meeting of Members at which special business is to be transacted shall state the nature of that business in sufficient detail to permit the Member to form a reasoned judgment on the business and state the text of any Special Resolution to be submitted to the meeting.

If a meeting of the Members may be attended by electronic means, the notice must include instructions for attending and participating in the meeting by the telephonic or electronic means that will be made available, including, if applicable, instructions for voting by such means at the meeting. Notice of a meeting that is adjourned for less than 30 days is not required if the time and place of the adjourned meeting and, if applicable, the instructions for attending, participating, and voting by telephonic or electronic means are announced at the original meeting.

5.07 Waiving Notice

A Member and any other person entitled to attend a meeting of Members may in any manner and at any time waive notice of a meeting of Members, and attendance of any such person at a meeting of Members is a waiver of notice of the meeting, except where such person attends a meeting for the express purpose of objecting to the transaction of any business on the grounds that the meeting is not lawfully called.

5.08 Persons Entitled to be Present

The only persons entitled to attend a Members' meeting are the Members, the Directors, the Officers, the auditors of the Corporation (or the person who has been appointed to conduct a review engagement, if any), and others who are entitled or required under any provision of the Act, the Articles, or the Bylaws to be present at the meeting. Any other person may be admitted only on the invitation of the chair of the meeting or with the majority consent of the Members present at the meeting. Proxies are not permitted.

5.09 Participation in Meetings by Electronic Means

Any person entitled to attend a meeting of the Members may participate in the meeting by electronic means that permit all participants to communicate adequately with each other during the meeting. A person so participating at a meeting is deemed to be present in person at the meeting.

5.10 Meetings Held by Entirely Electronic Means

If the Directors or Members call a meeting of the Members, the Directors or Members (as the case may be) may determine that the meeting be held entirely by electronic means, or by a combination of electronic means and of in-person attendance. The electronic means must permit all participants to communicate adequately with each other during the meeting and to reasonably participate in the meeting.

5.11 Voting by Electronic Means

Any person participating in a meeting of Members and entitled to vote at such meeting may vote using electronic means, provided that the votes cast by such means may be verified as having been made by Members entitled to vote.

A vote at a meeting of the Members may be conducted entirely by electronic means or by a combination of electronic means and of voting in person.

5.12 Chair of the Meeting

The President shall be the chair of the Members' meeting. If the President is absent or unable to act, then a Vice-President shall chair the Members' meeting. If the President and the Vice-President are absent or unable to act then the Members present shall appoint by Ordinary Resolution another Director as chair.

5.13 Quorum

The quorum for a meeting of the Members is twenty (20) of the Members entitled to vote at the meeting, whether present in person or by electronic means. If quorum is present at the opening of a meeting of the Members, the Members present may proceed with the business of the meeting even if quorum is not present throughout the meeting. If quorum is not present at the opening of a meeting of the Members, the Members present may adjourn the meeting to a fixed time and place, but may not transact any other business.

5.14 Votes to Govern

Unless otherwise required by the provisions of the Act or this By-law, all questions proposed for consideration at a meeting of Members shall be determined by Ordinary Resolution of the votes cast in person. In the case of equality of votes, the chair of the Members' meeting, in addition to his original vote, shall have a second or casting vote.

5.15 Voting Procedure

Business arising at any Members' meeting shall be decided by a majority of votes unless otherwise required by the Act or the By-law provided that:

(a) each Member shall be entitled to one vote at any meeting;
(b) votes shall be taken by a show of hands among all Members present and the chair of the meeting, if a Member, shall have a vote;
(c) an abstention shall not be considered a vote cast;
(d) before or after a show of hands has been taken on any question, the chair of the meeting may require, or any Member may demand, a written ballot. A written ballot so required or demanded shall be taken in such manner as the chair of the meeting shall direct;
(e) if there is a tie vote, the chair of the meeting shall require a written ballot, and shall not have a second or casting vote. If there is a tie vote upon written ballot, the motion is lost;
(f) whenever a vote by show of hands is taken on a question, unless a written ballot is required or demanded, a declaration by the chair of the meeting that a resolution has been carried or lost and an entry to that effect in the minutes shall be conclusive evidence of the fact without proof of the number or proportion of votes recorded in favour of or against the motion; and
(g) all voting during an electronic meeting shall be done by electronic ballot.

5.16 Resolution in Lieu of Meeting

Any resolution signed by all the Members is as valid and effective as if passed at a meeting of the Members duly called, constituted, and held for the purpose.

SECTION VI
DIRECTORS

6.01 Number of Directors

The Board shall consist of the fixed number of directors in the Articles, or a number within the minimum and maximum numbers in the Articles that is determined from time to time by Special Resolution, or, if a Special Resolution empowers the Directors to determine the number, by resolution of the Directors. Notwithstanding anything else in this By-law, the Corporation must have at least three (3) Directors.

6.02 Qualifications

A person is disqualified from being a Director if they:

(a) are not a Member at the time of their election or fail to become one within ten (10) days of their election;
(b) are not an individual;
(c) are under 18 years old;
(d) have been found under the *Substitute Decisions Act, 1992* or under the *Mental Health Act* to be incapable of managing property;
(e) have been found to be incapable by any court in Canada or elsewhere; or
(f) have the status of bankrupt.

6.03 Election of Directors and Term

(a) Directors shall be elected by the Members by Ordinary Resolution at an annual meeting of Members at which an election of Directors is required.
(b) The Board shall establish a nominating Committee, the details of which shall be set forth in the

Operating Policies. The nominating Committee will present a report to the Members for the election of Directors and such report will be prepared in accordance with the requirements of this By-law and the Operating Policies.

(c) Directors shall be elected every year or as determined by Ordinary Resolution of the Members.

(d) If Directors are not elected at a meeting of Members, the incumbent Directors shall continue in office until their successors are elected.

6.04 Written Consent to Act as a Director

(a) An individual who is elected or appointed to hold office as a director is not a director, and is deemed not to have been elected or appointed to hold office as a director, unless the individual consents in writing to hold office as a director before or within 10 days after the election or appointment. This requirement does not apply to a director who is re-elected or reappointed where there is no break in his or her term of office.

(b) Despite paragraph (a), if an individual elected or appointed consents in writing after the period mentioned in that subsection, the election or appointment is valid.

6.05 Ceasing to Hold Office

The office of a Director shall automatically be vacated:

(a) if the Director dies;

(b) if the Director resigns office by written notice to the Corporation, which resignation shall be effective at the time it is received by the Corporation or at the time specified in the notice, whichever is later;

(c) if the Director no longer fulfils all of the qualifications to be a Director set out in section 6.02, as determined in the sole discretion of the Board; or

(d) if the Director is removed by the Members in accordance with section 6.07 and the Act.

6.06 Removal of Directors

Directors may be removed by an Ordinary Resolution of the Members passed at a special meeting.

6.07 Filling Vacancies

(a) If there is a vacancy created by the removal of a Director, it may be filled at the meeting of Members at which the Director was removed.

(b) If there is a vacancy created by a failure to elect the number or minimum number of directors provided for in the Articles, or if there is not a quorum of Directors, the Directors then in office shall without delay call a special meeting of the Members to fill the vacancy. If they fail to call a meeting, or there are no Directors in office, the meeting may be called by any Member.

(c) If (a) and (b) do not apply, a vacancy among the Directors may be filled by a quorum of Directors.

6.08 Committees

The Board may from time to time appoint any Committee or other advisory body, as it deems necessary or appropriate for such purposes and, subject to the Act, with such powers as the Board shall see fit. Any Committee Member may be removed by the Board. Unless otherwise determined by the Board, a Committee shall have the power to fix its quorum at not less than a majority of its Members, to elect its chair and to otherwise regulate its procedure. Notwithstanding anything else in this By-law, if the Corporation creates an Audit Committee it must comprise one or more directors, and the majority of the committee must not be officers or employees of the Corporation or of any of its affiliates.

6.09 Conflict of Interest

No Director shall, directly or through an associate, receive a financial benefit, through a contract or otherwise, from the Corporation unless the provisions of the Act are complied with and, if required by law, the approval of the court is obtained. A disclosure by a director or officer of a conflict of interest must be in writing.

6.10 Remuneration of Directors

Directors shall serve without remuneration, and no Director shall directly or indirectly receive any profit from his or her position as such, provided that a Director may be reimbursed for reasonable expenses incurred in performing his or her duties. A Director may receive compensation for services provided to the Corporation in another capacity.

6.11 Remuneration of Agents and Employees

The Directors of the Corporation may fix the reasonable remuneration of employees of the Corporation and may delegate any or all of this function as it determines to be appropriate. Any Officer, Committee Member or employee of the Corporation may receive reimbursement for their expenses incurred on behalf of the Corporation in their respective capacities as an Officer, Committee Member or employee, subject to any policy in this regard that may be adopted by the Board from time to time.

6.12 Confidentiality

Every Director, Officer, Committee Member, employee and volunteer, shall respect the confidentiality of matters brought before the Board or before any Committee of the Board. Employees and volunteers shall also keep confidential matters that come to their attention as part of their employment or volunteer activities.

SECTION VII
MEETINGS OF DIRECTORS

7.01 Calling of Meetings

Meetings of the Directors may be called by the President, Vice-President or any two Directors at any time on notice as required by this By-law.

7.02 Place of Meetings

Meetings of the Board may be held at the registered office of the Corporation or at any other place within or outside of Canada, as the Board may determine. If a meeting of the Directors is to be held entirely by electronic means, the notice of that meeting does not need state the place of the meeting.

7.03 Notice of Meeting

Notice of the time and place for the holding of a meeting of the Board shall be given in the manner provided in section 10.01 of this By-law to every Director of the Corporation 48 hours before the time when the meeting is to be held. If a meeting of the Board may be attended by electronic means, the notice must include instructions for attending and participating in the meeting by electronic means that will be made available, including, if applicable, instructions for voting by such means at the meeting. Notice of a meeting shall not be necessary if all of the Directors are present, and none objects to the holding of the meeting, or if those absent have waived notice or have otherwise signified their consent to the holding of such meeting. Notice of an adjourned meeting is not required if the time and place of the adjourned meeting and, if applicable, the instructions for attending, participating, and voting by electronic means are announced at the original meeting. A Board of Directors meeting may be held without notice immediately before or following the annual meeting of Members.

A notice of a meeting of directors need not specify the purpose of or the business to be transacted at the meeting, unless the meeting is intended to deal with one of the matters specified in subsection 36(2) of the Act.

7.04 Regular Meetings

Provided that meetings take place no less than once per year, the Board may fix the place and time of regular Board meetings and send a copy of the resolution fixing the place and time of such meetings to each Director, and no other notice shall be required for any such meetings.

7.05 Chair

The chair of all Board meetings shall be the President. If the President is absent or unable to act, then the Vice-President shall be the chair. If the President and the Vice-President are absent or unable to act, then a Director appointed by the Board by Ordinary Resolution shall be the chair.

7.06 Participation at Meeting by Electronic Means

Subject to the Articles and By-laws, a meeting of the Directors may be held entirely by electronic means or by any combination of electronic means and of in-person attendance. Any such meeting must provide that all persons attending the meeting are able to communicate with each other simultaneously and instantaneously. A Director who attends a meeting of the Directors through electronic means is deemed to be present in person at the meeting.

7.07 Quorum

Subject to the Articles, a majority of the number of Directors constitutes a quorum at any meeting of the Board, provided that a quorum shall be a majority of the number of Directors determined in accordance with section 6.01. For the purpose of determining quorum, a Director may be present in person, or, if authorized under this By-law, by teleconference and/or by other electronic means.

7.08 Votes to Govern

Each Director may exercise one (1) vote. At all meetings of the Board, every question shall be decided by a majority of the votes cast on the question. In the case of equality of votes, the chair of the meeting of Directors shall not be entitled to a second or casting vote and the motion shall be defeated.

7.09 Dissent at Meeting

Subject to the Act, a Director who is present at a Board meeting or a meeting of a committee of Directors is deemed to have consented to any resolution passed or action taken at the meeting unless:

(a) the Director's dissent is entered in the minutes of the meeting; or
(b) the Director requests that his or her dissent be entered in the minutes of the meeting; or
(c) the Director gives his or her dissent to the secretary of the meeting before the meeting is terminated; or
(d) the Director submits his or her dissent immediately after the meeting is terminated to the Corporation;

provided that a Director who votes for or consents to a resolution may not dissent.

7.10 Dissent of Absent Director

A Director who was not present at a meeting at which a resolution was passed or action taken is deemed to have consented to the resolution or action unless, within seven (7) days after becoming aware of the resolution or action, the Director:

(a) causes his or her dissent to be placed with the minutes of the meeting; or
(b) submits his or her dissent to the Corporation.

7.11 Voting Procedures

At all meetings of the Board, every question shall be decided by a show of hands unless a secret ballot on the question is required by the chair of Board Meetings or requested by any Director. When a recorded vote on the question is required by the chair of Board Meetings or requested by any Director, the Secretary shall record the names of the Directors and whether they voted in support or opposition. A declaration by the chair of Board Meetings that a Resolution has been carried and an entry to that effect in the minutes of the Board is conclusive evidence of the fact without proof of the number of proportionate votes recorded in favour or against the Resolution.

7.12 Resolutions in Writing

A resolution in writing, signed by all the Directors entitled to vote on that resolution at a Board meeting or committee of Directors, shall be as valid as if it had been passed at a Board meeting or committee of Directors. A copy of every such resolution in writing shall be kept with the minutes of the proceedings of the Board or committee of Directors.

SECTION VIII
OFFICERS

8.01 Appointment

The Board may designate the offices of the Corporation, appoint Officers, specify their duties and, subject to the Act, delegate to such Officers the power to manage the affairs of the Corporation. A Director may be appointed to any office of the Corporation. All Officers must be a Director unless this By-law otherwise provides. Two or more offices may be held by the same person, except the offices of President and Vice-President.

8.02 Description of Offices

Unless otherwise specified by the Board (which may, subject to the Act, modify, restrict or supplement such duties and powers), the offices of the Corporation, if designated and if Officers are appointed thereto, shall have the following duties and powers associated therewith, as well as such other duties and powers as the Board may specify from time to time:

(a) **President** - The President shall be a Director. The President shall, when present, preside at all meetings of the Board and of the Members.
(b) **Vice-President** - The Vice-President shall be a Director. If the President is absent or is unable or refuses to act, the Vice-President, if any, shall, when present, preside at all meetings of the Board and of the Members.
(c) **Secretary** - If appointed, the Secretary shall be a Director and attend and be the Secretary of all meetings of the Board. The Secretary shall enter or cause to be entered in the Corporation's minute book, minutes of all proceedings at such meetings; the Secretary shall give, or cause to be given, as and when instructed, notices to Members, Directors, the public accountant and Members of Committees; the Secretary shall be the custodian of all books, papers, records, documents and other instruments belonging to the Corporation.
(d) **Treasurer** - If appointed, the Treasurer shall be a Director and responsible for the maintenance of proper accounting records in compliance with the Act as well as the deposit of money, the safekeeping of securities and the disbursement of funds of the Corporation; whenever required, the Treasurer shall render to the Board an account of all such person's transactions as Treasurer and of the financial position of the Corporation.

The duties of all other Officers of the Corporation shall be such as the terms of their engagement call for or the Board or the President requires of them. The Board may from time to time and subject to the Act, vary, add to or limit the powers and duties of any Officer.

8.03 Term of Office

Any Officer shall cease to hold office upon resolution of the Board. Officers shall hold their position for a period of one (1) year, or, in those cases where an Officer is appointed by the Board to fill a vacancy during the year, until the first meeting of the Board immediately following the annual general meeting.

8.04 Vacancy in Office

In the absence of a written agreement to the contrary, the Board may remove, whether for cause or without cause, any Officer of the Corporation. Unless so removed, an Officer shall hold office until the earlier of:

(a) the Officer's successor being appointed;
(b) the Officer's resignation;
(c) the Board of Directors adopts an Ordinary Resolution to remove an Officer for any reason at a Board meeting duly called for that purpose, provided that such Officer is first offered an opportunity to be heard;

(d) if an Officer becomes prohibited from being an Officer by reason of any order made under the Act;
(e) such Officer ceasing to be a Director (if a necessary qualification of this appointment); or
(f) such Officer's death.

If the office of any Officer of the Corporation shall be or become vacant, the Board may appoint a person to fill such vacancy.

SECTION IX
PROTECTION AND INDEMNITY

9.01 Protection of Directors, Officers and Others

Except as otherwise provided in the Act, no Director, Officer, Member, Committee Member, employee or volunteer shall be liable for the acts, receipts, neglects or defaults of any other Director, Officer, Member, Committee Member, employee or volunteer of the Corporation or for any loss, damage or expense happening to the Corporation through the insufficiency or deficiency of title to any property acquired by the Corporation for or on behalf of the Corporation or for the insufficiency or deficiency of any security in or upon which any of the moneys, securities or effects of or belonging to the Corporation shall be placed or invested or for any loss or damage arising from the bankruptcy, insolvency or tortious act of any person (with "person" in this section to include corporations, partnerships, joint ventures, sole proprietorships, unincorporated associations and all other forms of business organizations) including any person with whom or which any moneys, securities or effects shall be lodged or deposited or for any loss, conversion, misapplication or misappropriation of or any damage resulting from any dealings with any moneys, securities or other assets belonging to the Corporation or for any other loss, damage or misfortune whatever which may happen in the execution of the duties of the Director's, Officer's, Member's, Committee Member's, employee's or volunteer's respective office or trust or in relation thereto unless the same shall happen by or through such person's wilful neglect or default.

9.02 Indemnity to Directors, Officers and Others

Every Director, Officer, Member, Committee Member, employee and volunteer of the Corporation, and his/her/its heirs, executors and administrators, and estate and effects, respectively, who has undertaken or is about to undertake any liability on behalf of the Corporation, shall from time to time and at all times, be indemnified and saved harmless out of the funds of the Corporation from and against the following:

(a) all costs, charges and expenses whatsoever that such Director, Officer, Member, Committee Member, employee and volunteer sustains or incurs in or about any action, suit or proceeding that is brought, commenced or prosecuted against the Director, Officer, Member, Committee Member, employee and volunteer for or in respect of any act, deed, matter or thing whatsoever, made, done or permitted by them, in or about the execution of the duties of their office or in respect of any such liability; and
(b) all other costs, charges and expenses that the Director, Officer, Member, Committee Member, employee and volunteer sustains or incurs in or about or in relation to the affairs thereof, except such costs, charges and expenses as are occasioned by their own wilful neglect or default.

9.03 Indemnity to Others

The Corporation may also indemnify such other persons in such other circumstances as the Act or the law permits or requires. Nothing in this By-law shall limit the right of any person entitled to indemnity to claim indemnity apart from the provision of this By-law to the extent permitted by the Act or the law.

9.04 Insurance

The Corporation may purchase and maintain insurance for the benefit of any person entitled to be indemnified by the Corporation pursuant to the immediately preceding section, provided that due consideration is first given to the requirements under the *Charities Accounting Act* (Ontario) for the purchase of Directors and officers liability insurance.

SECTION X
NOTICES

10.01 Method of Giving Notices

Any notice required to be sent to any Member or Director or to the auditor or person who has been appointed to conduct a review engagement shall be provided by telephone, delivered personally, or sent by prepaid mail, facsimile, email or other electronic means to any such Member or Director at their latest address as shown in the records of the Corporation and to the auditor or the person who has been appointed to conduct a review engagement at its business address, or if no address be given then to the last address of such Member or Director known to the Secretary; provided always that notice may be waived or the time for the notice may be waived or abridged at any time with the consent in writing of the person entitled thereto.

10.02 Undelivered Notices

Notwithstanding Section 10.01, if any notice given to a Member is returned on three (3) consecutive occasions because such Member cannot be found, the Corporation shall not be required to give any further notices to such Member until such Member informs the Corporation in writing of his or her new address.

10.03 Computation of Time

Where a given number of days' notice or notice extending over any period is required to be given, the day of service or posting of the notice shall not, unless it is otherwise provided, be counted in such number of days or other period.

10.04 Omissions and Errors

The accidental omission to give any notice to any Member, Director, Officer, member of a committee of the Board or auditor, or the non-receipt of any notice by any such person where the Corporation has provided notice in accordance with the By-law or any error in any notice not affecting its substance shall not invalidate any action taken at any meeting to which the notice pertained or otherwise founded on such notice.

10.05 Waiver of Notice

Any Member, Director, Officer, member of a committee of the Board or auditor may waive or abridge the time for any notice required to be given to such person, and such waiver or abridgement, whether given before or after the meeting or other event of which notice is required to be given shall cure any default in the giving or in the time of such notice, as the case may be. Any such waiver or abridgement shall be in writing except a waiver of notice of a meeting of Members or of the Board or of a committee of the Board, which may be given in any manner.

SECTION XI
AMENDMENT OF ARTICLES AND BY-LAWS

11.01 Amendment of Articles

Notwithstanding the Act, the Articles of the Corporation may only be amended by a resolution of the Board and sanctioned by a Special Resolution of the Members at a meeting of Members duly called for the purpose of considering the amendment, provided that notice of such Members meeting shall state the proposed amendment and the purpose thereof.

11.02 Amendment of By-laws

The By-laws of the Corporation not embodied in the Articles may be amended or repealed by a resolution of the Board and sanctioned by a Special Resolution of the Members at a meeting of Members duly called for the purpose of considering the said amendment or repeal. Except as otherwise provided, an amendment or repeal of a By-law approved by the Board has full force and effect from the time the resolution is passed or from such future time as may be specified in the resolution. A repeal or an amendment to a By-law passed by the Board shall be presented for confirmation at the next annual or special meeting of Members. The Members at the annual or special meeting may confirm the By-law by Special Resolution as presented or reject or amend it, and if rejected, it thereupon ceases to have effect, and if amended, it thereupon takes effect as amended. Any rejection, amendment or refusal to approve the By-law or part of the By-law made in accordance with this section shall not invalidate any act done or right acquired under any such By-law prior to its rejection, amendment or refusal to approve.

ENACTED by the Directors of the Corporation this ______ day of ____________________, ________, under the seal of the Corporation

____
President

____
Secretary

CONFIRMED by a Special Resolution of Members this ______ day of ____________________, ________.

____
Secretary

Annual OFNC Committee Reports for 2023

Awards Committee

The Awards Committee manages the process to annually recognize and thank those Ottawa Field Naturalists' Club (OFNC) members and other qualified persons who, by virtue of their efforts and talents, are deserving of special recognition. In late 2022, nominations were received and evaluated (see awards criteria at https://ofnc.ca/about-ofnc/awards), and recommended to the Board of Directors for approval. The awards were announced in January 2023 on the website. Biographies were written for the award recipients for inclusion in the Club's publications and posting on the website. Certificates were presented to award recipients on 1 April 2023 at the in-person annual awards appreciation event at St. Basil's Church. The recipients' names, type of award, and short rationale for recognition follow below.

- Chris Traynor—George McGee Service Award, in recognition of 25+ years of dedicated service with the Birds Committee and its subcommittees.
- Sharon Boddy—Conservation Award for a Member, for community leadership of habitat restoration projects at Carlington Woods and Hampton Park.
- John Sankey—Conservation Award for a Non-member, for conservation efforts to improve local greenspaces, in particular the Hunt Club Creek.

Eleanor Zurbrigg, Chair

Birds Committee

The Birds Committee:

- maintained four bird feeders on National Capital Commission (NCC) properties over the winter;
- produced a weekly regional birding report published to the OFNC Facebook site, the ontbirds listserv, and the OFNC website;
- responded to ~30 identification requests and other inquiries from the public;
- provided birders for the OFNC events committee and a Migration Day event;
- responded to a couple of media requests;
- participated in an Ottawa City focus group on the Hintonburg Heritage Pumphouse revitalization;
- began researching a project on a Kirtland Warbler habitat.

The OFNC Birds Committee and the Club des ornithologues de l'Outaouais (COO) organized the 103rd Ottawa-Gatineau Christmas Bird Count.

Many long-serving committee members retired from the committee this year, including Chair Bob Cermak whose many contributions are much appreciated. This will need to be a year of renewal.

Derek Dunnett, Chair

Conservation Committee

The year began with the supervision of a 4th-year Environmental Science Carleton University student (January–April). Activities focussed on basic winter fieldwork training at numerous sites in and around Ottawa. Methods were explored for surveying biodiversity and associated scientific literature. We similarly supervised a 10th-grade high school student in August.

Hemlock Woolly Adelgid (HWA), which was detected in a grove of trees at Grafton in 2022, was searched for throughout the year whenever Hemlocks were observed in eastern Ontario. A special trip was made in April to the shore of Lake Ontario (Grafton, Kingston); thankfully, no HWA was observed by our group this year.

Our year-long survey of Morris Island Conservation Area was completed, and a summary report submitted to Ontario Power Generation in early December. A number of significant finds were made during this work, with several new records of rare native species being made at the site.

Complete defoliation of American Elm due to the new invasive insect Elm Zigzag Sawfly (EZS) was observed for the first time in Canada this year by our group at Cornwall. We observed the first known occurrence of Rock Elm hosting EZS larvae as well. A presentation regarding the current status of EZS in Ontario will be made in February 2024 at the Invasive Species Centre's Annual Forum.

Survey work by OFNC president Jakob Mueller resulted in the observation of novel shoreline habitat use by Red-backed Salamander along the Ottawa River in west Ottawa.

Committee member Christine Hanrahan observed the spreading invasive species Box Tree Moth for the first time in eastern Ontario at Ottawa in September.

Some apparently new locations for rare native plants were discovered in eastern Ontario by our group in 2023: examples include Maidenhair Spleenwort in west Ottawa adjacent to the Ottawa River, and Yellow Jewelweed in Ontario east of Highway 416 at Williamstown.

Numerous surveys and public education tours were given by our members: notably near McAlpine with the Eastern Ontario Land Trust (two visits), south of Wendover in remote woods with Prescott-Russell forestry staff (Red Spruce-focussed), and near Oak Valley with members of the Society of Ontario Nut Growers (Swamp White Oak-focussed).

OWEN CLARKIN, Chair

Education and Publicity Committee

The Committee has had several members resign this year: Fenja Brodo, Sarah Wray, Dean Beebe, Leo Vander Wouden, Robyn Molnar, and Sheena Parsons. Some have moved away and some have other commitments. We thank them all for their contributions. Fenja has been a long-time member and has finally decided to take a break. We will miss her wisdom and advice.

The Ottawa-Carleton District School Board's Science Fair was again held live this year. Judges from the Science Fair selected four projects, which were each awarded $100.

Dean Beeby continues as our X (formerly Twitter) administrator. Find it at x.com/ottawafieldnat. Jakob Meuller continues to host a YouTube page for the OFNC—look for it at: youtube.com/channel/UCHry jAyoDoz7qnanrVaTJ_w. Sandy Garland keeps our Friends of the Fletcher Wildlife Garden's (FWG's) Facebook page up-to-date—facebook.com/groups/48901132335/. Thanks to Nina Stavlund for our OFNC Facebook page—facebook.com/groups/37999 2938552/.

Hannah Delion and Robyn Molnar started an Instagram page for the FWG at instagram.com/fletcher.wildlife.garden. Hannah and Gord are adding posts and reels (videos) regularly. The page has over 200 followers as of November 2023.

Our iNaturalist page has exceeded 880 species, 3100 observations, and 185 contributors. It is found at inaturalist.org/projects/fletcher-wildlife-garden.

Gord has made another wildlife quest for Hilda Road. More are planned for next year. Find them at: ofnc.ca/quests. A few "News Flashes" have been posted around the FWG to highlight recent wildlife occurrences, for example, the "Snowberry Clearwing", "Black-crowned Night-Heron", and "Snapping Turtle Attacks Dog in Pond". The latter may have encouraged more people to leash their dogs.

In April, Deb Doherty and Gord participated in the Ottawa Outdoors Adventure Show Held at the Nepean Sportsplex. Sandra Garland along with the Wild Pollinator Partners organized a "pollinator walk" as part of the Jane's Walk events for 6 May. Lloyd, Hannah, Sandra, and I guided people around the FWG. Also in May, Gord Robertson and Deb Doherty hosted a table at the Sandy Hill EcoFair on 13 May as part of the spring Migratory Bird Day.

Hannah Delion and I helped guide a tour of the FWG organized by a pride group on 13 August. Lloyd Mayeda, Sandra Garland, Hannah, and I gave three tours of the FWG to 30 girl and boy cubs from the 24th Ottawa Scouting Group. Deb Doherty with Bird Friendly Ottawa and Ottawa Wildflower Seed Library passed out pamphlets at the Adàwe Crossing and at Andrew Hayden Park during the fall Migratory Bird Day. Gord gave a tour for this event at Strathcona & Riverain Parks.

Gord presented to seniors at the Chartwell Rockcliffe Retirement Home on 20 January, 10 March, 5 May, 14 July, and 6 October, on "Birding in Scotland in Winter", "Birding in Florida", "Wildlife in the Galapagos", "Butterflies of Ottawa/Gatineau", and "Birding in Saskatchewan". Gord gave another talk on "Wildlife in Ottawa" at the Beacon Heights Retirement Home on 3 March for World Wildlife Day.

Joan Harrison initiated a project to find Anishnabemowin/Algonquin names for various native trees. She contacted elders at Kitigan Zibi to collate the correct names. So far 44 names have been collected; some are names for multiple tree species. These names will be added to our Flora and Fauna webpages.

With 13 storyboards in the FWG, members of the committee (Sandra Garland, Fenja Bordo, Kaitlyn Sjonnesen, Robyn Molnar, and myself) have created new stories for the various seasons. Thanks to Dr. Jean-Michel Weber and Diane Lepage for checking the French translations. Find these at: ofnc.ca/stories.

GORDON ROBERTSON, Ph.D., Chair

Events Committee

The past year provided a transition out of pandemic constraints and back into normalcy with respect to gatherings. Happily, this included the return of in-person monthly meetings in February at a new venue, which in turn necessitated moving the date of those meetings from the second Tuesday to the second Wednesday of the month. Field trips were numerous and well attended in the spring as the return to normalcy was embraced, but through the summer both leaders and participants became rather scarce as many people embarked on long-postponed trips and vacations. Numbers returned in September. Digital events persist and are expected to remain a permanent feature, particularly in winter when travel is unpleasant and temperatures are uninviting.

Past committee reports have counted the calendar year, but in order to create consistency with other reports, the below count represents the fiscal year (from 30 September 2022).

In total, the committee coordinated 60 events, including field trips, workshops, presentations for monthly meetings, and digital events. Birding was the most common focus (14) by a slight margin over botany (13). General interest and overall biodiversity was third (10), followed by conservation (nine), mycology (seven), entomology (three), mammals (two), herpetology (one), and astronomy (one).

As always, the committee extends its sincere gratitude to all individuals who lead, presented, or assisted with events.

JAKOB MUELLER, Representative on the Board of Directors

Finance Committee

This report covers financial matters during our last fiscal year 2022–2023, from 1 October 2022 through 30 September 2023. It also discusses the budget for the current fiscal year 2023–2024.

The primary task of the Finance Committee is to prepare a draft budget for consideration by the Board of Directors. The process stretches from the summer through October each year. First the committee receives suggestions, and estimates of revenues and expenses, from directors and committee chairs. The Finance Committee prepares a draft budget which is then discussed at the September meeting of the Board of Directors. After amendment, it is adopted at the October meeting. Members can see the budget in the minutes of October Board of Directors meetings, which are posted on the OFNC website.

The budget for FY2022–2023 was approved at the Board of Directors meeting of October 2022. The budget for FY2023–2024 was approved at the October 2023 Board meeting. The budget forecasts revenues of $138 700 and expenses of $206 913, giving a deficit of $68 213.

The size of the forecast deficit is of great concern. The Club has a sizeable reserve, so it can sustain deficits of this order in the short term, but not longer if it wishes to remain a going concern. The Board of Directors has directed the Finance Committee to advise it on possible changes to our operations.

The committee began an analysis of the impact of the Ontario *Not-for-Profit Corporations Act* on the Club. In order to comply with this law, while at the same time operating the Club as members wish, we will need to revise our Articles of Incorporation and By-laws. The committee plans to prepare draft Articles and By-laws for approval at the Annual Business Meeting in January 2024.

Committee members for 2023 were Bob Bergquist, Catherine Hessian, Ann MacKenzie, Gillian Marston, Bruce Simpson, and Ken Young.

KEN YOUNG, Chair

Fletcher Wildlife Garden Committee

The summer of 2023 presented some challenges to the volunteers at the FWG. Work teams had to cancel their work sessions due to high temperature/humidity conditions, high atmospheric smoke levels, and several rain days. In spite of these conditions our volunteers continued to maintain the gardens, pathways, and ponds on the property. Many storms left dangerous trees that had to be cleared. We now have a volunteer who is a certified chain saw operator who will facilitate dealing with dangerous trees in the future.

Early in the season we agreed to help a turtle nest protection group and this resulted in several turtle nests being located and covered.

Our excellent team of volunteers continued to plant a variety of native species and remove invasives in the Old Woodlot and surrounding areas. This year a “dead hedge” was added between it and the road to create shelter for wildlife, especially insects.

Our method of planting native species after removing invasives is working well. We also gave Virginia Waterleaf to Friends of the Farm to compete with Dog-strangling Vine around shrubs in the Arboretum. Buckthorn was removed along the west edge of the Old Field, uncovering a new layer of sumacs, a number of serviceberry trees, and a Red Maple.

In the gully, Comfrey removal continues but the end is in sight. New plantings were done in the wet central part of the gully, the sunny north slope and a shade garden started on the south slope. Trees and shrubs were planted on the slope near Prince of Wales Drive. Water flow was encouraged from the intermittent spring on the south slope and the updated culvert crossing Prince of Wales. The forest floor on both sides of the gully were opened up. Tiny short “dead hedges” were constructed.

An arbor has been constructed at the entrance way to the Back Yard Garden.

The Butterfly Meadow group worked on formalizing the paths throughout the butterfly meadow zone by paving them with wood chips and using downed tree limbs as edgings. The hope is that this will clarify where visitors can safely walk without disturbing the plants and compacting the soil.

A small group of volunteers worked in hip waders in the amphibian pond to remove two invasive aquatic plants and to thin the thickening cattail population.

The sightings of a fox, an otter, a Green Heron, a Blanding's Turtle, an ermine, and a Night Heron added to the longlist of animals, birds, and amphibians that call the Fletcher home.

Two scientific experiments were carried out in the Butterfly Meadow and the Gully by local university scientists to study the interaction of Monarch Butterflies with various wild plants and the effect of temperature on the growth of certain wild plants.

Our annual plant sale was a great success again this year. The plant team used the pre-order, pre-pay, scheduled pick-up format that is labour efficient for the volunteers and convenient for our customers.

Dogs not on leash continue to be a problem in the Garden. Polite requests by volunteers are met with disdain or are ignored. However, an incident in which a dog, not on a leash, entered the amphibian pond and was badly bitten on the leg by a large Snapping Turtle is being used as an example of why dogs should be on a leash while walking through the Fletcher.

The large number of photographers at the Fletcher this summer was interfering with the work of volunteers. Some sections of the Back Yard Garden are now roped off for short periods of time to allow volunteer work to continue.

EDWARD (TED) FARNWORTH, Representative on the Board of Directors

Macoun Field Club Committee

The Macoun Field Club is for kids aged eight to 18; activities take place on Saturdays during the school year. Events were organized by telephone and e-mail, and made known by posting a schedule on the Macoun Club's home page on the OFNC website.

During this fourth year of the COVID-19 pandemic, public health restrictions were easing. The Committee considered it just barely feasible to resume holding indoor meetings. This was because the federal regulations governing our meeting place permitted seating closer than 2 m apart, provided we wore masks. Masks, however, impaired speech and hearing, and concealed facial expressions; it was hard to feel part of a group. For the sake of safety, we kept the number attending indoors small. This limitation, together with the continuing risk of viral infection, discouraged us from inviting outside speakers. There was a reversal of normal patterns: field trips were consistently better attended than indoor meetings. At the beginning of May, the World Health Organization declared the emergency phase of the pandemic to be over, but some leaders and children have continued to wear masks on account of being over age 65 or having immunocompromised family members.

Committee members led 15 field trips (mostly to the Macoun Club Study Area in Ottawa's greenbelt and familiar locations in Lanark County) and delivered presentations at 15 indoor meetings. An account of each event was subsequently posted on the Macoun Club's home page.

The Macoun Field Club entered its 75th anniversary in the spring of 2023 (the inaugural meeting having taken place on 8 May 1948) and discussions with the Museum of Nature for a celebration in the autumn were begun.

For the first time since 2019 *The Little Bear* (the Macoun Club's normally annual publication) was produced for distribution at the annual party. It was issue no. 75.

ROBERT E. LEE, Chair

Membership Committee

Club participation includes:

1. Membership which consists of those who pay Club fees, are "Honorary" members, or participate in the "Macoun Club";
2. *Trail & Landscape* (T&L) Subscribers and;
3. An aggregate called Other which represents individuals and organizations that receive complimentary copies of T&L. The groups are reported separately.

The distribution of Club membership on 30 September 2022 and on 30 September 2023 is shown in Table 1. The slight decrease is consistent with the volatility in membership that the Club experiences from year to year.

TABLE 1. OFNC membership by type.

	2023	2022
Individual	408	434
Family	333	349
Student	13	14
Honorary	23	24
Life	37	39
Macoun Club	17	21
USA	11	11
Other International	1	1
Total	843	893

Members within 50 km of Ottawa comprised 703 of the total membership of 843.

The number of "T&L Subscribers" and "Other" on 30 September 2023 and on 30 September 2022 is shown in Table 2. The numbers do not vary greatly on a year-to-year basis.

TABLE 2. Non-member counts.

	2023	2022
T&L Subscribers	1	1
Other	25	25
Total	26	26

KERRI KEITH, Chair

Publications Committee

The Publications Committee manages publication of *The Canadian Field-Naturalist* (CFN), T&L, and Special Publications. The committee also advises OFNC with respect to issues relating to research, including managing the research grants program. We published four issues of T&L: 56(4) and 57(1–3) and three issues of CFN: 136(2) [mailing date 12 December 2022], 136(3) [22 March 2023], and 136(4) [21 June 2023]. The CFN Book Review Editor Barrie Cottam stepped down from the committee, and we welcomed new Book Review Editor, Jessica Sims, to the committee. Due to the impacts of the COVID-19 pandemic, the committee continued to conduct its meetings virtually.

This was the 9th year of the OFNC Research Grants program, which the Publication Committee administered. Research grants support field-based research activities that reflect and promote the Club's objectives within eastern Ontario and/or western Quebec, focussed particularly upon the Club's study area. The application deadline for proposals was 15 January 2023. The OFNC Board of Directors decided the final awards (see T&L 57(3):179) based on funding recommendations from a subcommittee of Jeff Saarela (chair), Carolyn Callaghan, and Paul Catling, who evaluated all proposals.

JEFFERY M. SAARELA, Chair

Safe Wings Ottawa Committee

Safe Wings continues to work through evolving changes in how the committee operates while managing the impact of HPAI (highly pathogenic avian influenza). The continued presence of HPAI requires more interaction with the public and with Environment and Climate Change Canada to make decisions on how to address potentially impacted birds, as well as providing more guidance and support to manage ducklings and goslings.

This year our volunteers documented just over 2000 window collisions (numbers to be confirmed) across approximately 99 species. This includes at least three Species at Risk: Wood Thrush, Canada Warbler, and Rusty Blackbird. And this year the third American Pipit was documented as a window collision victim in Ottawa.

The highest glass collision species in 2023 are (numbers to be confirmed for January reporting as required for permits):

Dark-eyed Junco	131
White-throated Sparrow	117
Brown Creeper	104
Golden-crowned Kinglet	96
Nashville Warbler	90

Safe Wings continues to work with Sandy Pines and The Owl Foundation for longer term needs and specialized care. Lily, a window collision victim we sent to The Owl Foundation several years ago, stayed as a foster and this year raised an owlet that Safe Wings rescued from Kemptville this spring.

Rescue

For the second year in a row, Safe Wings Ottawa stepped in to help orphaned ducklings and goslings in the Ottawa region. Over a period of two months between mid-May and mid-July we took in 149 ducklings, seven goslings, and one loonlet. A targetted donation campaign and an interview with CBC Ottawa highlighting the work that we were doing helped bring in additional donations to cover the unexpected costs. A new volunteer, experienced with fostering ducklings, took on the care after the initial quarantine and minimum 3-week period with our rehabber. They did a fantastic job supported financially by Safe Wings!

In addition to those 157 fluff balls, volunteers rescued and transported another 359 birds (representing 74 species) to our rehabilitation facility. Of those, 292 were admitted due to window collisions. Under our new protocol, our success rate (after the first 24 hours) increased to 92%, meaning that over 200 birds were treated and released.

The most common species seen this past year (excluding ducklings of course) were:

Brown Creeper	26
Golden-crowned Kinglet	24
Nashville Warbler	23

We also admitted 11 raptors including a Peregrine Falcon as well as an Eastern Whip-poor-will and an Evening Grosbeak (Threatened species and species of Special Concern).

Outreach

Safe Wings returned to holding an annual public display in 2023, hosting a well-attended Thursday evening display in March at the Museum of Nature. Two years of bird specimens were displayed totalling 2900 birds.

The committee also returned to public events with a total of 18 in-person engagements and one online presentation:

- 11 community engagement and speaking pre-

sentations were conducted, including a Jane's Walk and three World Migratory Bird Day/ Earth Day events,
- two media interviews,
- three sessions were held to engage youth in their school or after-school program,
- three events were held in partnership with universities.

Among the university events, of note was a partnership with Professors Rachel Buxton and Deborah Connors of Carleton University, along with CAFEs (Community Associations for Environmental Sustainability). Sociology/Anthropology students in a course on community engagement took Safe Wings' mandate of preventing bird-window collisions to four community associations and their communities to ascertain, via survey, awareness of the issue and willingness to take action. Presentations were made to the students as well as to a small public forum. Safe Wings expects the partnership to continue, especially with Professor Buxton who is also working with Safe Wings on data and advocacy issues.

Advocacy

The advocacy committee continued to speak up for birds in Ottawa through outreach with multiple levels of government, universities, and commercial buildings. Safe Wings pressed for enforcement of the updated Migratory Birds Regulations, which now specifically include window collisions. We continued our program of assessing and commenting on new development applications and are happy to report that many new buildings feature bird-friendly materials, although there is a long way to go. We advocated for the City of Ottawa to adopt the proposed High Performance Development Standards, which would include mandatory bird-friendly design, and will continue to do so despite council opting to delay a decision.

Advocacy committee members have been reaching out to organizations with large real estate holdings, such as school boards, and are actively engaged with encouraging them to commit to bird-friendly design for new buildings and major retrofits, as well as retrofitting identified collision hot spots. We have also seen positive change at Ottawa's major universities, with new bird-friendly buildings and major retrofits occurring. We are seeing positive results from our outreach efforts with OC Transpo as well, with the new LRT (Light Rapid Transit) stations using bird-friendly glass, although the existing stations remain a problem.

Overall, we are seeing considerable progress in making bird-friendly buildings more common and more accepted. We hope to see more progress on enforcement of bird-protection laws and higher adoption of bird-friendly design in 2024.

Janette Niwa, Chair

Treasurer's Report 2022–2023

The OFNC ended the 2022–2023 fiscal year with assets of $1 570 267. The General Fund had a net expense of $4914 and the FWG Fund had net revenue of $11 631. These figures compare with the previous year, which had a net revenue of $8256 for the General Fund and $15 122 for the FWG. The incredibly successful plant sale continues to generate great returns for a lot of hard work.

Last year we noted that we did not anticipate being able to maintain our revenues in excess of our expenses in the coming years. While there is a deficit in the General Fund this year it is not as much as we had forecast. Our expenses did increase but there were a few offsetting factors that resulted in less deficit than anticipated.

The Club had a very successful trip to Point Pelee in May. Given the number of volunteer hours required to organize these trips, the Board decided to make them a club fundraiser. This year the revenue exceeded the expenses by about $10 000, thereby helping our bottom line.

Publishing the scientific journal, CFN, is a major contributor to the Club's objectives. However, it costs more to produce an issue than it generates in subscription revenue. In addition, honorariums for the Editors and those producing the journal have increased by about $3000 per issue as was mentioned last year. This fiscal year only three issues were published compared to the usual four issues per year. This reduced revenue by over $4000 and costs by about $17 000. Consideration is being given to ways to reduce the deficit per issue.

Fewer research grants were awarded this year resulting in about $6000 less deficit. A change in calculating deferred membership also raised the reported membership revenue by about $4000. The deficit in the General Fund would have been closer to $40 000 without these variances.

From an administrative perspective, we are always seeking ways to function more efficiently. In May of this past year, we were successful in launching electronic donation receipts, thanks to the tireless efforts of Bob Bergquist. Increasingly money transfers are e-transfers, PayPal, and direct deposits, with cheques used only rarely.

Because the events of this past year will not be occurring in the next fiscal year, we continue to forecast higher deficits and are looking for ways to reduce expenses.

ANN MACKENZIE, Treasurer

Approved financial statements available online at: https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/3473/3259

The Canadian Field-Naturalist

The Ottawa Field Naturalists' Club Awards for 2023, presented April 2024

Eleanor Zurbrigg, Bethany Armstrong, Irwin Brodo, Christine Hanrahan, Karen McLachlan Hamilton, and Lynn Ovenden

The 2023 Ottawa Field Naturalists' Club (OFNC) awards were presented at the Club's Awards Night on 13 April 2024. 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. Five awards were conferred for 2023, for topics ranging from activities to keep the Club running smoothly, to community conservation efforts for local nesting turtles, wild bird education, and lifetime achievements in Canadian natural history and long-time service with *The Canadian Field-Naturalist* (CFN).

Member of the Year Award: Bob Bergquist

Bob Bergquist is a retired business professor at Nipissing University. He is responsible for the fact that donations to OFNC are recorded electronically and receipts are sent out electronically. Accurate donation records and receipts are critical to maintaining charitable status. The conversion to electronic donation receipts is a notable contribution saving countless hours of volunteer labour. It was no slight undertaking.

When Bob started helping the treasurer in 2017, OFNC issued hand-written receipts to donors. Bob developed a computer system for donation records and assigning receipt numbers. A mail merge program generated about 300 receipts and thank-you letters each year for the Treasurer to print, sign, fold, and put in an envelope to mail.

In 2023, Bob looked for a way to issue charitable receipts electronically. His first step was to find compatible software that could be modified to our existing record keeping and accounting software. It had to be reasonably priced and relatively easy to use. After an initial review, he focussed on the program called Software4Nonprofits.

Unfortunately, it is never enough to just subscribe to a software program and then input data. It took many hours to determine what it would and would not do. Bob got a trial subscription in March, watched tutorials, engaged with their tech support people, and generally twisted inside out. He wrote macros to allow data to move from our bi-weekly deposit records over to the donation receipt software. He tested the whole process with fake receipts to some Board members.

Another challenge was getting the software to run on both his computer and the Treasurer's computer so data can be transferred, reports created, and the proper checks and balances maintained.

On 25 May 2023, Bob sent out the first batch of electronic receipts. Since then, members get their receipts while they can still remember donating. The receipt states if the donation was for the General Fund, the Fletcher Wildlife Garden, Safe Wings or Seedathon, or if it was to more than one of them. Those who set up a monthly payment to the Club get a year-end list showing the date and amount of their contributions over the calendar year. With the new process, OFNC's charitable receipts are more timely and better documented.

Bob also volunteered his computer skills a few years ago, writing macros to translate payment reports from PayPal into the OFNC Deposit Record with account codes. This automated a task that had previously been done manually.

Bob has tirelessly gone above and beyond in enabling electronic receipts and in searching for workable solutions to OFNCs administrative issues. He has quietly operated behind the scenes but his impact is sizeable. It is for these reasons that we recognize Bob Bergquist as Member of the Year for 2023.

(Prepared by Ann MacKenzie and Lynn Ovenden)

George McGee Service Award: Elizabeth Moore

In recognition of a member who has contributed significantly to the smooth running of the Club over several years.

Elizabeth Moore has been a member of the OFNC for close to 15 years during which time her expertise, energy, and enthusiasm have helped keep the Club running smoothly. Elizabeth has served as Recording Secretary since 2019, keeping track of the goings on at Board meetings, dealing with correspondence, and writing up the minutes. This somewhat unglamorous but absolutely essential job is expertly done by Elizabeth, with minutes that are always very thorough and accurate, as well as on schedule. She takes the time to check on details or seek clarification on certain points so that there are rarely changes to be made in the minutes as presented at each meeting. Having someone doing the minutes both reliably and well is an incredible asset to the Club.

Elizabeth was also Recording Secretary on the Fletcher Wildlife Garden Committee from 2016 until 2018. At the Garden, she did much more than just take notes. From 2010 to 2016, she enthusiastically participated as a volunteer working to improve the Butterfly Meadow, planting flowers, pulling Dog-strangling Vine, weeding, sifting soil, and performing many other gardening tasks. She also got her daughter, Sarah (a teenager at the time), to join in the work. Elizabeth also helped with the pond project (again with Sarah), weeding the path along the pond and planting.

Elizabeth has been particularly active in the Events Committee, doing all the arrangements for the annual Awards Night for five years, 2016 through 2020, pausing only when the COVID pandemic made it necessary to switch to Zoom events for 2021 and 2022. This important job involves renting the room, setting it up (including tables, chairs, the screen, etc.), getting a sound system, arranging for food preparation and kitchen cleanup, getting someone to manage the auction and someone to run the photo contest, finding people to serve the wine who are certified with Smart Serve Ontario, and finding a suitable Master of Ceremony. Elizabeth either enlisted people to do the various jobs or did the work herself. She also ensured Awards Night was promoted and advertised in advance.

Elizabeth has also taken charge of preparing, dispensing, and collecting name tags at monthly meetings and has done so for many years. This involves keeping the name tags up-to-date after annual elections and new committee affiliations and, of course, obliges her to be at every meeting or find a replacement.

All those working with Elizabeth attest to her being self-reliant and competent as well as being funny and agreeable, quick to say 'yes' whenever she is asked for help. These are all attributes of selfless volunteers that make an organization like the OFNC function, and function smoothly. For her years of service, Elizabeth is much deserving of the 2023 George McGee Service Award.

(Prepared by Irwin M. Brodo, with thanks to Lynn Ovenden, Diane Lepage, and Jakob Mueller)

Conservation Award—Non-Member: Turtles of Old Ottawa East and South

In recognition of an outstanding contribution by a non-member in the cause of natural history conservation in the Ottawa Valley.

This year the award is presented to Turtles of Old Ottawa East and South for their innovative work in helping to preserve and protect turtles in Ottawa.

Canada has eight species of freshwater turtles, all of which are listed as Species at Risk by the Federal Government. Experts say this makes turtles one of the most at-risk groups of wildlife in Canada. While protecting critical habitat for these creatures is paramount, there are other ways to help them. Turtle nests are exceptionally vulnerable to predation, and any turtles that do survive to emerge from the nest, must then navigate their way to the nearest body of water. A daunting task for such tiny creatures.

Putting into practice the mantra of "thinking globally but acting locally", in 2021 a group of residents in the Brewer Park to Brantwood Park area along the Rideau River banded together to help the turtles. Aware that many turtle nests were being destroyed by predators in this corridor, they built nest protectors to keep eggs safe from predation. A Facebook group (now at over 900 members) linked concerned people together. With so many looking out for turtle nesting sites, word spreads swiftly and volunteers are able to quickly install nest protectors.

Once nest protectors are installed, community members routinely check on them and remove tall plants shading the nest area. Too much shade can reduce the soil temperature and keep the eggs from hatching. In late summer once nests start to hatch, volunteers put up signs and write chalk messages on sidewalks to alert walkers and cyclists to keep an eye out for hatchlings that may be on the move, and possibly crossing sidewalks. If hatchlings are found wandering away from the river, they are carried down to the river and released close to water. In 2023 the group installed 40 nest protectors, thus helping ensure more eggs hatch, and the hatchlings make it to water, with a fighting chance of survival. This committed group is taking care of their neighbours—only this time their neighbours are Painted and Snapping Turtles.

This engaged and committed group saw a problem, developed a solution, and is helping to preserve local Species at Risk. They are an excellent example of community conservation at work. For their dedication to protecting local turtle populations, Turtles of Old Ottawa East and South is a worthy recipient of the OFNC's Conservation Non-Member Award for 2023.

(Prepared by Christine Hanrahan and David Seburn)

Mary Stuart Education Award: Patty McLaughlin

Presented to members, non-members, or organizations, in recognition of outstanding achievements in the field of natural history education in the Ottawa Region.

This year the Mary Stuart Education Award goes to Patty McLaughlin, Education Program Manager, at the Ottawa Valley Wild Bird Care Centre (OVWBCC). The Mission of the OVWBCC is to provide care to injured, sick, or orphaned wild birds with the goal of releasing them back into their natural habitat … and to provide people of all ages an opportunity to learn about wild birds, their habitats, and conservation.

Patty is an outstanding educator who has been with the OVWBCC for over 20 years, beginning as a 16-year-old volunteer caring for injured birds. She continued work as a summer and high school co-op student and throughout her undergraduate degree in biology. In 2010, after completing her Master's in Biology at Carleton University, she returned on contract to the Centre. Whenever she could break away from bird care, she worked on creating the education program, starting with the Junior Avian Ambassador Program, which encourages and rewards small actions to help wild birds in backyards and communities.

In 2018, a Trillium Grant enabled Patty to focus on program development which now includes:

- a curriculum linked education outreach program for Kindergarten–Grade 6 with presentations and teacher resources for each grade. It has been delivered to schools in Ottawa's three English area school boards;
- over 100 presentations delivered annually to schools, Scouts, Guides, daycares, City run summer day camps, and other independent summer camps;
- a Naturehood program in Ottawa offering after school programs in three "priority neighborhoods" focussing on how to appreciate and coexist with wild birds in our urban environment.

In addition to the formal education program, Patty is also responsible for presentations at seniors/retirement homes, museums, local area field naturalist groups, and World Migratory Bird Day events. Behind the scenes, Patty creates the social media content for the OVWBCC with fun-filled, educational bird stories used at events and in informational products such as:

- webinar chats hosted by Wild Birds Unlimited,
- the OVWBCC yearly calendar and Baby Bird Posters,
- "Fun Fact Fridays" on Facebook,
- a feature on OWL TV,
- an episode for TVO Kids "The Green Squad".

Patty has a unique ability to communicate with all ages about the dangers facing wild birds (for example, window collisions, cats) and how we all can help minimize the numerous threats to their survival (such as proper feeding techniques, citizen science programs). Patty's care and passion for wild birds is evident in every interaction she has with the public, from her emails to people concerned about an injured bird at the OVWBCC, to the media events about the OVWBCC work. Thanks to Patty, many more people—young and old—know how they can "Help Save Ottawa's Birds".

(Prepared by Bethany Armstrong, Deborah Doherty, and Susan Phillips)

Honorary Member: Dr. Donald McAlpine

This award is given in recognition of outstanding contributions by a member, or non-member, to Canadian natural history or to the successful operation of the Club.

It is believed that Donald's love for the natural world began early in life, while spending summers at the family cottage along the Saint John River in New Brunswick, observing amphibians and reptiles. Then, as a young teen, he was volunteering at the New Brunswick Museum (NBM) after school and on weekends. Here he was introduced to the museum's natural history collections, its curators, and people passionate about natural history research. Over the years his interest and expertise has grown exponentially. Today he is Research Curator of Zoology, Department Head of the NBM, and a renowned naturalist throughout Canada and beyond.

Donald's breadth of knowledge and expertise is enormous. It spans the gamut from small invertebrates such as nematodes, earthworms, insects, and jellyfish, to large vertebrates including wolves, sea turtles, sharks, and whales. He is familiar with freshwater, marine, and terrestrial environments and the wildlife inhabiting them. His publications include studies in mammalogy, ornithology, parasitology, malacology, herpetology, museology ... the list goes on. A large portion of his research involves sightings of new species found regionally, provincially, and/or nationally.

His interest in conservation, biodiversity research, and public education are apparent through some of his numerous projects. He is a leading advocate for the role natural history museums play in fostering public awareness of Canada's incredible biodiversity and the importance of protecting natural areas. One project, conceived by Don, included the life-size model of a Northern Right Whale found dead after a nearby ship strike. This NBM exhibit heightened public awareness of the threats that large marine animals face in Canadian waterways and, most likely, contributed to the rerouting of a major shipping lane away from an important whale resting site. Then there's his BiotaNB project. Initiated in 2009, this annual event brings groups of biologists, students, artists, and volunteers together for a two-week intensive field study session at one of New Brunswick's larger protected areas. Its purpose is to not only enhance the understanding of the province's biodiversity and the need for its continued conservation, but also to engage local residents and to inspire future natural history enthusiasts and conservationists.

What are Donald's direct contributions to the OFNC? For more than 40 years, he has contributed to the OFNC through his support of CFN. He has been a prolific contributor to the CFN with more than 40 papers published where he is listed as author or co-author. His first publication, in 1976, described a shark sighting in the Bay of Fundy. As for his last, who knows, he continues to contribute his findings. Since 2003, he has served as one of CFN's Associate Editors. In this role he has reviewed submitted papers by other researchers on a wide variety of subjects. His knowledge and broad experience in many areas make him an invaluable asset to the CFN and to the OFNC—just check out CFN's volume 137. The first two issues were dedicated to him and his work.

Donald's lifetime achievements in Canadian natural history and his long-time service with CFN make him worthy of Honorary Membership to the Club.

(Prepared by Karen McLachlan Hamilton)

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