The CANADIAN FIELD-NATURALIST

A JOURNAL OF FIELD BIOLOGY AND ECOLOGY

Promoting the study and conservation of northern biodiversity since 1880

Volume 133, Number 3 • July–September 2019

Ottawa Field-Naturalists' Club
Club des naturalistes d'Ottawa

The Ottawa Field-Naturalists' Club

FOUNDED 1863 (CURRENT INCORPORATION 1879)

Patron

Her Excellency the Right Honourable Julie Payette, C.C., C.M.M., C.O.M., C.Q., C.D.
Governor General of Canada

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

Honorary Members

2019 Board of Directors

To communicate with the Club, address postal correspondence to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2, or e-mail: ofnc@ofnc.ca. For information on club activities, go to www.ofnc.ca.

The Canadian Field-Naturalist

The Canadian Field-Naturalist is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Website: www.canadianfieldnaturalist.ca/index.php/cfn

All manuscripts intended for publication—except Book Reviews—should be submitted through the online submission system at the CFN website: http://www.canadianfieldnaturalist.ca/index.php/cfn/user. Click the "New Submission" link on the right side of the webpage and follow the prompts. Authors must register for a cfn account at http://www.canadianfieldnaturalist.ca/index.php/cfn/user/register in order to submit a manuscript. Please contact the Online Journal Manager (info@canadianfieldnaturalist.ca) if you have any questions or issues with the online submission process. In only rare, exceptional circumstances will submissions other than online be considered and, in these cases, authors must contact the Editor-in-Chief (editor@canadianfieldnaturalist.ca) prior to submission. Instructions for Authors are found at https://www.canadianfieldnaturalist.ca/public/journals/1/CFN-author-instructions20Sept2019.pdf.

Book-review correspondence, including arranging for delivery of review copies of books, should be sent to the Book Review Editor by e-mail: bookrevieweditor@canadianfieldnaturalist.ca.

Subscriptions and Membership: Subscription rates for individuals are $40 (online only), $50 (print only), or $60 (print + online). Libraries and other institutions may subscribe for $120 (online only or print only) or $180 (print + online). All foreign print subscribers and members (including USA) must add $10 to cover postage. The Ottawa Field-Naturalists' Club annual membership fee of $40 (individual), $45 (family), or $20 (student) includes an online subscription to *The Canadian Field-Naturalist*. Members can receive printed issues of CFN for an additional $30 per volume (four issues). For further details, see http://ofnc.ca/membership-and-donations. The club's regional journal, *Trail & Landscape*, covers the Ottawa District and regional Club events and field trips. It is mailed to all club members. It is available to libraries at $40 per year. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be sent to subscriptions@canadianfieldnaturalist.ca or mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O., Ottawa, ON, K1Z 1A2 Canada. Canada Post Publications Mail Agreement number 40012317. Return postage guaranteed.

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

COVER: Rocky Mountainsnail (*Oreohelix strigosa*), one of the 44 terrestrial gastropod taxa found during extensive surveys in the northern Columbia River basin, southcentral British Columbia, 2007–2015. See the article in this issue by Ovaska *et al.* pages 221–234. Photo: K. Ovaska, September 2007.

The Canadian Field-Naturalist

Note

First recorded co-occurrence of *Valvata lewisi* Currier, 1868 and *Valvata lewisi ontariensis* Baker, 1931 (Gastropoda: Valvatidae) from Alberta, Canada, with notes on morphometric and genetic variability

Robert P. Hinchliffe[1,*], **Cheryl Tebby**[1], and **Tyler P. Cobb**[1]

[1]Royal Alberta Museum, 9810 – 103a Avenue, Edmonton, Alberta T5J 0G2 Canada
[*]Corresponding author: robert.hinchliffe@gov.ab.ca

Hinchliffe, R.P., C. Tebby, and T.P. Cobb. 2019. First recorded co-occurrence of *Valvata lewisi* Currier, 1868 and *Valvata lewisi ontariensis* Baker, 1931 (Gastropoda: Valvatidae) from Alberta, Canada, with notes on morphometric and genetic variability. Canadian Field-Naturalist 133(3): 189–192. https://doi.org/10.22621/cfn.v133i3.2237

Abstract

Sympatric populations of Loosely Coiled Valve Snail (*Valvata lewisi ontariensis* Baker, 1931) and Fringed Valvata (*Valvata lewisi* Currier, 1868) are documented from Alberta, Canada, for the first time. Both forms have been identified concurrently in aquatic invertebrate survey samples collected from three wetlands in northeastern Alberta by the Alberta Biodiversity Monitoring Institute. Molecular analysis (DNA barcodes) indicates that there is no genetic distinction between *V. lewisi* (*sensu stricto*) and *V. lewisi* var. *ontariensis*. Morphometric measurements show that the degree of open coiling, the character that defines *V. lewisi* var. *ontariensis*, is highly variable in Alberta specimens. Our findings confirm that *V. lewisi* var. *ontariensis* is a phenotypic morph of *V. lewisi*.

Key words: Distribution; range extension; Alberta; Valvatidae; *Valvata*; *Valvata lewisi*; *Valvata lewisi ontariensis*; Alberta Biodiversity Monitoring Institute; ABMI

Loosely Coiled Valve Snail (*Valvata lewisi ontariensis* Baker, 1931; common name from Clarke 1981) is a tiny, enigmatic freshwater gastropod that has rarely been collected since first being described by Frank Collins Baker in 1931. Originally thought to be confined to a few locations in western Ontario, Canada (Baker 1931; Clarke 1973; Figure 1), similar specimens have since been collected as Pleistocene fossils or empty shells in Manitoba, Canada (Clarke 1973), and Minnesota, USA (Bright 1981), with the only other confirmed record of living specimens from the Cottonwood Lake Study area in North Dakota, USA (Hanson *et al.* 2002; Figure 1). Here, we report on the first sympatric collections of *Valvata lewisi* (*sensu stricto*) and *V. lewisi* var. *ontariensis* from Alberta, Canada, and provide notes on morphometric and genetic variability.

In contrast to the distribution of *V. lewisi* var. *ontariensis, Valvata lewisi* Currier, 1868 (Fringed Valvata, according to Turgeon *et al.* 1998) is commonly found across the prairie, parkland, and boreal regions of Canada from Newfoundland to British Columbia, north into the Yukon and Alaska, and south into the northern United States (Clarke 1981; NatureServe 2017; Figure 1). *Valvata lewisi* is a small freshwater snail that seldom exceeds 5 mm in diameter and has a depressed spire, multi-spiral operculum, and bi-pectinate gill (Clarke 1973; Burch 1982). Shell sculpting consists of fine striations on the first one and a half to two whorls, which develop on subsequent whorls into axial lamellae that are usually elevated and blade-like, but may be reduced to coarse collabral threads (Clarke 1973). In comparison, *V. lewisi* var. *ontariensis* exhibits the same characteristics, but, unlike *V. lewisi* (*sens. str.*) where the body whorl directly contacts the preceding whorl, *V. lewisi* var. *ontariensis* exhibits open coiling in which the last one to one and a half whorls are separated (Baker 1931; Figure 2).

Valvata lewisi var. *ontariensis* has been detected at five wetlands in Alberta, Canada, through the ongoing activities of the Alberta Biodiversity Monitoring Institute (ABMI). The ABMI collects biological information on a wide range of terrestrial and aquatic organisms across the province using

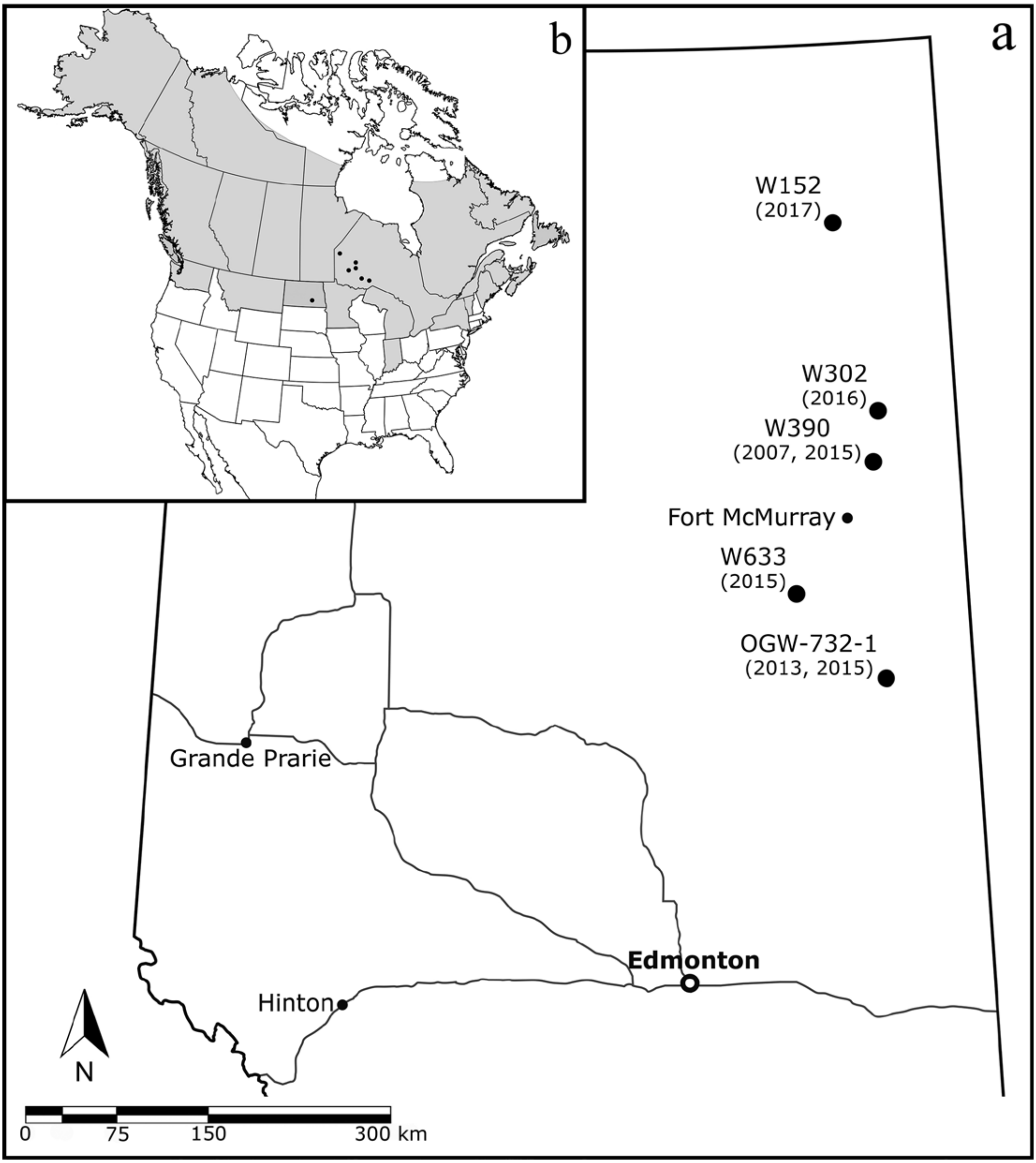


FIGURE 1. a. Alberta Biodiversity Monitoring Institute wetland site locations where specimens of *Valvata lewisi* var. *ontariensis* have been documented in Alberta (large solid circles, collection years in parentheses). Inset map b. shows known range of *Valvata lewisi* (*sensu stricto*) in North America (shaded area) with historical collection records of *V. lewisi* var. *ontariensis* (solid circles).

standardized, publicly available methods (e.g., ABMI 2015, 2018). During routine taxonomic analysis of aquatic invertebrate samples collected by the ABMI in 2007, we detected 12 *V. lewisi* var. *ontariensis* specimens in samples obtained from a permanent wetland in the northeastern part of the province (ABMI site W390; 57.26899°N, 110.72157°W; Figure 1). Following this initial detection, several additional *V. lewisi* var. *ontariensis* specimens were subsequently recovered from ABMI samples collected from the initial detection site and four additional wetlands in the same region—W152 (58.78107°N, 110.86238°W), W302 (57.80382°N, 110.65305°W), W633 (55.97079°N, 112.23922°W), and OGW-732-1 (55.25222°N, 110.91161°W; Figure 1)—for a total collection of 75 specimens. This sampling effort also

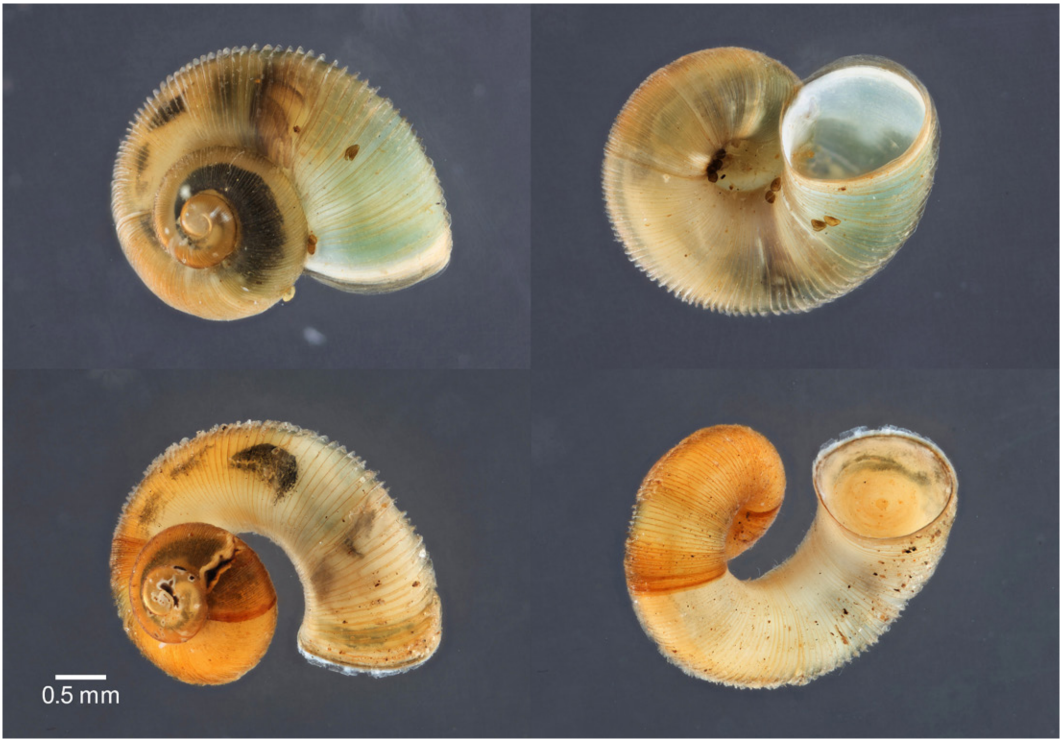


FIGURE 2. Dorsal and ventral views of *Valvata lewisi* (top) and *Valvata lewisi* var. *ontariensis* (bottom). Photos: Robert P. Hinchliffe.

revealed the co-occurrence of *V. lewisi* var. *ontariensis* and *V. lewisi* (*sens. str.*) at sites W390, W633, and OGW-732-1. Voucher specimens have been preserved in 80% ethanol and deposited in the invertebrate zoology collection at the Royal Alberta Museum in Edmonton, Alberta, Canada (ABMI.A.91, ABMI.A.5396, ABMI.A.11900, ABMI.A.15382, ABMI.A.18222, and ABMI.A.30673).

Morphometric analyses of *V. lewisi* var. *ontariensis* revealed considerable variation in the degree of open coiling in Alberta specimens. Measurements showed a clear gradation in the ratio of open-coiled gap to aperture diameter in specimens from both W390 (0.04:1 to 0.22:1, mean 0.10:1, *n* = 16) and OGW-732-1 (0.02:1 to 0.41:1, mean 0.13:1, *n* = 18), a pattern also noted, although not directly measured, by Baker (1931) when examining western Ontario specimens.

Our examination of intra- and inter-specific variability associated with the DNA barcode markers cytochrome c oxidase 1 (CO1) and internal transcribed spacer 2 (ITS2) for *V. lewisi* (*sens. str.*) and *V. lewisi* var. *ontariensis* specimens from sites W390 and OGW-732-1 indicated no genetic distinction between the two morphs. For CO1, the mean interspecific variation (± SD) was 0.17% ± 0.13 with intraspecific genetic distances at 0.16% ± 0.12 for *V. lewisi* (*sens. str.*; *n* = 12) and 0.16% ± 0.14 for *V. lewisi* var. *ontariensis* (*n* = 28). For ITS2, the mean interspecific variation (± SD) was 0.07% ± 0.14 and the intraspecific genetic distance of *V. lewisi* (*sens. str.*; *n* = 10) was 0.03% ± 0.07 and of *V. lewisi* var. *ontariensis* (*n* = 23) was 0.11% ± 0.17. DNA barcoding was conducted by the Canadian Centre for DNA Barcoding in Guelph, Ontario, Canada. Genetic sequences have been submitted to GenBank (CO1: MK721872 to MK721913, ITS2: MK721934 to MK721969).

Our detections of *V. lewisi* var. *ontariensis* constitute the first record of this morph in Alberta, Canada, and the first explicitly documented instances of co-occurrence of *V. lewisi* var. *ontariensis* with *V. lewisi* (*sens. str.*). Clarke (1973: 229) noted that loosely coiled specimens seemed to "occur also (rarely) in some apparently normal populations", but neglected to provide references or observational evidence for this statement. Furthermore, he suggested that the specimens he examined were uniform as all one morph or the other. Other published reports on this species do not make any mention of co-occurrence of the two morphs.

The taxonomic status of *V. lewisi* var. *ontariensis* as a valid subspecies has historically been uncertain (see Baker 1931; Clarke 1973, 1981; Burch 1982).

The working definition of a subspecies is two or more populations of the same species from separate geographic locations with one or more distinguishing characters (Mayr 1942, 1982). The initial Ontario collections identified by Baker (1931) and later expanded on by Clarke (1973) were originally thought to be an isolated and distinct population of the open-coiled morph. Our concurrent collections of *V. lewisi* (*sens. str.*) and *V. lewisi* var. *ontariensis* clearly show that the two morphs can occur in the same water body. This, in addition to the lack of a CO1 or ITS2 barcode gap between the two morphs, supports the conclusion that *V. lewisi ontariensis* is a phenotypic morph of *V. lewisi*.

Despite the broad and common distribution of *V. lewisi* (*sens. str.*), the open-coiled morph has, thus far, been collected in only three isolated regions of North America. Given the widely spaced and seemingly isolated locations where *V. lewisi* var. *ontariensis* has been collected, it is possible that the open-coiled morph is the result of some unknown and possibly localized environmental factor. However, it is also possible that *V. lewisi* var. *ontariensis* is more common than collection records indicate and is simply difficult to detect during routine aquatic invertebrate surveys because of its small size and propensity to burrow into the upper layer of soft substrates (R.P.H. pers. obs.). Targetted sampling in other regions is needed to more fully understand the complete distribution of *V. lewisi* var. *ontariensis*. We recommend that future collections of open-coiled *V. lewisi* specimens be identified and labeled as *V. lewisi* var. *ontariensis* to allow for better tracking of the localities where this morph occurs and perhaps yield additional clues as to the possible source of open coiling.

Author Contributions

Writing – Original draft: R.P.H.; Writing – Review & editing: R.P.H., C.T, and T.P.C.; Visualization: R.P.H.; Conceptualization: R.P.H. and T.P.C.; Investigation: R.P.H. and C.T.; Resources: C.T.; Formal analysis: R.P.H.

Acknowledgements

We thank Dr. Matthias Buck at the Royal Alberta Museum for assistance with the molecular analysis and valuable editorial suggestions on earlier versions of the manuscript. We also thank the Alberta Biodiversity Monitoring Institute for providing additional data. This research was supported by the Alberta Biodiversity Monitoring Institute and the Royal Alberta Museum.

Literature Cited

ABMI (Alberta Biodiversity Monitoring Institute). 2015. Processing aquatic invertebrates (10017) version 2015-07-23. ABMI, Edmonton, Alberta, Canada. Accessed 12 November 2018. https://www.abmi.ca/home/publications/351-400/396.

ABMI (Alberta Biodiversity Monitoring Institute). 2018. Wetland field data collection protocols (abridged version) 2018-05-07. ABMI, Edmonton, Alberta, Canada. Accessed 12 November 2018. https://www.abmi.ca/home/publications/501-550/510.

Baker, F.C. 1931. Description of a new variety of *Valvata lewisi* Currier. Nautilus 44: 119–121.

Bright, R.C. 1981. A new record of *Valvata sincera ontariensis* F.C. Baker from Minnesota. Nautilus 95: 20.

Burch, J.B. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. United States Environmental Protection Agency, Washington, DC, USA. EPA/600/3-82-026 (NTIS PB82207168). Accessed 25 May 2018. https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=ORD&dirEntryID=32218.

Clarke, A.H. 1973. The freshwater molluscs of the Canadian Interior Basin. Malacologia 13: 1–509.

Clarke, A.H. 1981. The Freshwater Molluscs of Canada. National Museum of Natural Science, Ottawa, Ontario, Canada.

Hanson, B.A., N.H. Euliss, Jr., and D.M. Mushet. 2002. First records of loosely coiled valve snail in North Dakota. Prairie Naturalist 34: 63–65.

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

Mayr, E. 1982. Of what use are subspecies? Commentary. Auk 99: 593−595.

NatureServe. 2017. *Valvata* species report. Accessed 27 April 2017. http://explorer.natureserve.org/servlet/NatureServe?searchSciOrCommonName=Valvata.

Turgeon, D.D., J.F. Quinn, Jr., A.E. Bogan, E.V. Coan, F.G. Hochberg, W.G. Lyons, P. Mikkelsen, R.J. Neves, C.F.E. Roper, G. Rosenberg, B. Roth, A. Scheltema, F.G. Thompson, M. Vecchione, and J.D. Williams. 1998. Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks. Second Edition. Special Publication 26. American Fisheries Society, Bethesda, Maryland.

Received 2 April 2019
Accepted 24 December 2019

The Canadian Field-Naturalist

Note

Spotless burnsi pattern in Northern Leopard Frog (*Lithobates pipiens*) in Maine

Scott B. Lindemann[1, *], **David E. Putnam**[2], **Malcolm L. Hunter, Jr.**[1], and **Trevor B. Persons**[3]

[1]Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, 5755 Nutting Hall, Room 210, Orono, Maine 04469 USA
[2]University of Maine at Presque Isle, 214 South Hall, Presque Isle, Maine 04769 USA
[3]206 Bigelow Hill Road, Norridgewock, Maine 04957 USA
[*]Corresponding author: lindemann.scott@gmail.com

Lindeman, S.B., D.E. Putnam, M.L. Hunter, Jr., and T.B. Persons. 2019. Spotless burnsi pattern in Northern Leopard Frog (*Lithobates pipiens*) in Maine. Canadian Field-Naturalist 133(3): 193–195. https://doi.org/10.22621/cfn.v133i3.2283

Abstract

We document the spotless "burnsi" morph in Northern Leopard Frog (*Lithobates pipiens*) in Maine.

Key words: Northern Leopard Frog; *Lithobates pipiens*; amphibian; pattern variant; Maine

The "burnsi" mutation in Northern Leopard Frog (*Lithobates pipiens*) results in loss of the frog's characteristic spots from the back, and sometimes also from the dorsal surface of the legs (McKinnell *et al.* 2005). Herpetologists have studied this mutation since the early 20th century, and Moore (1942) demonstrated that the burnsi mutation allele is dominant over the wild-type allele. More recently, this mutation has been used to study the effects of genetic bottlenecks in this species of conservation concern (McKinnell *et al.* 2005). This mutation is reported most frequently in central Minnesota and the surrounding area, where it occurs in 4.0–7.1% of *L. pipiens*, although it has also been documented rarely outside this region (Merrell 1965; Brown and Funk 1977; McKinnell *et al.* 2005; Rogers and Peacock 2012).

On 3 June 2018, S.B.L. and D.E.P. discovered a burnsi-type *L. pipiens* (Figure 1) along the bank of the north branch of Presque Isle Stream (46.641949°N, 68.177440°W) on Scopan Maine Public Reserved Land, T11 R4 WELS township, Aroostook County, Maine, USA. The frog was sitting in grass along a stream channel lined with Speckled Alder (*Alnus incana* subsp. *rugosa* (Du Roi) R.T. Clausen), which was further surrounded by scrub-shrub wetland and mixed coniferous–deciduous forest. The frog was identified as *L. pipiens* by the gold colouration of the dorsolateral fold, lack of colouration on the groin, white venter, and green dorsum. Four wild-type conspecifics were also found at the same site (Figure 1).

Burnsi-type *L. pipiens* have been collected from only one other locality in Maine, as determined from a review of the Maine Amphibian and Reptile Atlas Project (MARAP 2019) database, which is maintained by the Maine Department of Inland Fisheries and Wildlife. MARAP contains specimen records from most major North American herpetology collections, as well as most smaller regional ones. In addition, MARAP includes observations from the citizen science iNaturalist Web site (www.inaturalist.org). Four specimens at the American Museum of Natural History (AMNH 51343–6) were collected in 1940 in Woodland (i.e., Baileyville, located 175 km south-southeast of the June 2018 collection), Washington County; these were briefly noted by Merrell (1965), but he did not provide catalog numbers or specific locality data. In addition, the Museum of Comparative Zoology houses a series of specimens (MCZ 25541–50) collected on the same date and from the same locality as the AMNH specimens, and the MCZ catalog ledger notes: "Of the 36,000 frogs collected in three seasons, about 4% were unspotted, but in other respects wholly typical like the true *pipiens* occurring at the spot, intergrades between them were present also".

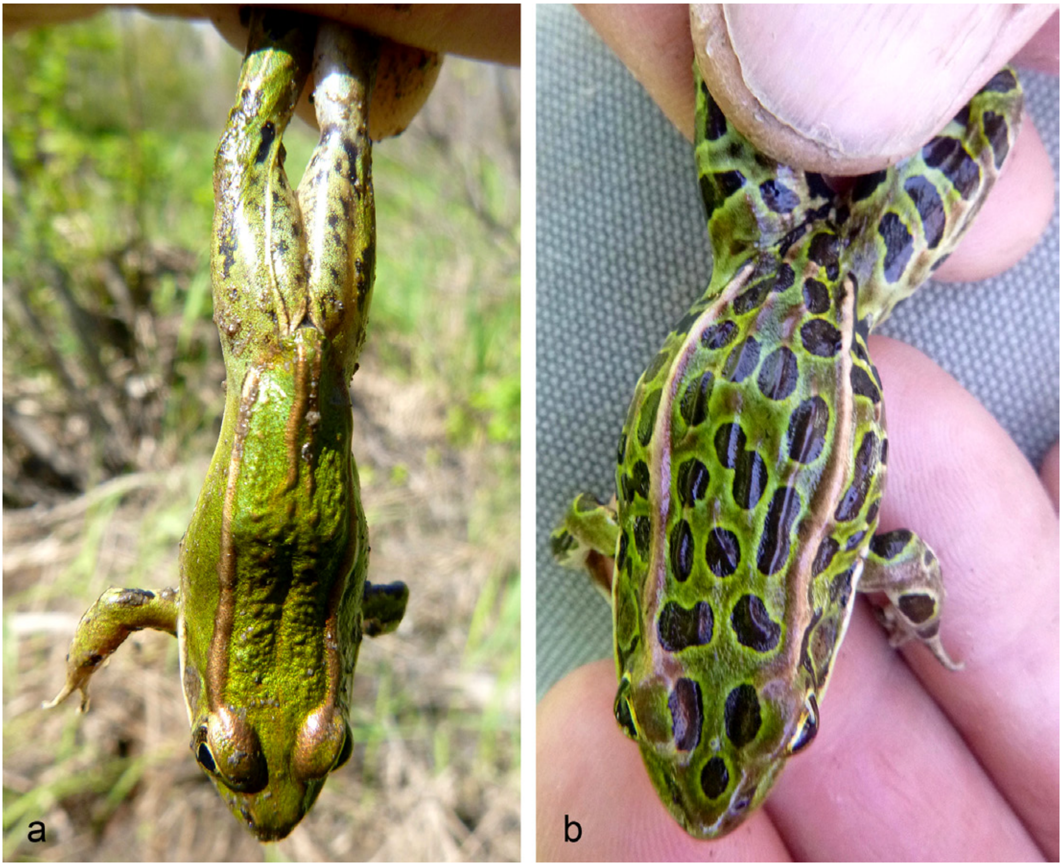


FIGURE 1. Burnsi-type (a) and wild-type (b) Northern Leopard Frogs (*Lithobates pipiens*) from Presque Isle Stream, Aroostook County, Maine, USA. Photos: Scott B. Lindemann.

Some of the specimens at both AMNH and MCZ retain spotting on the hind limbs similar to ours, while others are completely unspotted. Assuming the MCZ catalog ledger note is accurate, the burnsi mutation was apparently, at least at this location in Maine, as common as reported in central Minnesota and surrounding areas. We have not surveyed the Woodland area for Leopard Frogs, and the MCZ catalog ledger also states that "The pond has since been destroyed by peat cutting". Aside from this series of specimens, the Presque Isle Stream individual is the only example of unspotted *L. pipiens* we are aware of from Maine.

Acknowledgements

We thank David Dickey and David Kizirian (American Museum of Natural History) and Jose Rosado (Museum of Comparative Zoology) for providing photographs and information on specimens in their care. Our appreciation is extended to Malcolm Hunter, Aram Calhoun, and Kristine Hoffmann of the University of Maine and to Phillip deMaynadier, Derek Yorks, and Jason Czapiga of the Maine Department of Inland Fisheries and Wildlife for project guidance. Funding support was provided by the Maine Department of Inland Fisheries and Wildlife (Endangered and Nongame Wildlife Fund and United States Fish and Wildlife Service State Wildlife Grant), the Department of Wildlife, Fisheries, and Conservation Biology at the University of Maine, Eastern Maine Conservation Initiative, and the University of Maine Graduate Student Government. Fieldwork was performed under a Maine Department of Inland Fisheries and Wildlife scientific collection permit (#2018-184) issued to S.B.L. Animal use protocols were approved by the Institutional Animal Care and Use Committee of the University of Maine (#A2018-03-01). Publication #3695 of the Maine Agricultural and Forest Experiment Station. This project was supported by the United States Department of Agriculture, National Institute of Food and Agriculture, Hatch Project Number ME0-21705 through the Maine Agricultural and Forest Experiment Station.

Literature Cited

Brown, L.E., and R.S. Funk. 1977. Absence of dorsal spotting in two species of leopard frogs (Anura: Ranidae). Herpetologica 33: 290–293.

MARAP (Maine Amphibian and Reptile Atlas Project). 2019. Data files. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine, USA.

McKinnell, R.G., D.M. Hoppe, and B.K. McKinnell. 2005. Monitoring pigment pattern morphs of Northern Leopard Frogs. Pages 328–337 *in* Amphibian Declines. *Edited by* M. Lannoo. University of California Press, Berkeley and Los Angeles, California, USA. https://doi.org/10.1525/california/9780520235922.001.0001

Merrell, D.J. 1965. The distribution of the dominant burnsi gene in the leopard frog, *Rana pipiens*. Evolution 19: 69–85. https://doi.org/10.2307/2406296

Moore, J.A. 1942. An embryological and genetical study of *Rana burnsi* Weed. Genetics 27: 408–416.

Rogers, S.D., and M.M. Peacock. 2012. The disappearing Northern Leopard Frog (*Lithobates pipiens*): conservation genetics and implications for remnant populations in western Nevada. Ecology and Evolution 2: 2040–2056. https://doi.org/10.1002/ece3.308

Received 16 May 2019
Accepted 19 December 2019

The Canadian Field-Naturalist

Note

Axanthism in Green Frogs (*Lithobates clamitans*) and an American Bullfrog (*Lithobates catesbeianus*) in Maine

Scott B. Lindemann[1,*], **Aidan M. O'Brien**[1], **Trevor B. Persons**[2], and **Phillip G. DeMaynadier**[3]

[1]Department of Wildlife, Fisheries, and Conservation Biology, University of Maine, 5755 Nutting Hall, Room 210, Orono, Maine 04469 USA
[2]206 Bigelow Hill Road, Norridgewock, Maine 04957 USA
[3]Maine Department of Inland Fisheries and Wildlife, 650 State Street, Bangor, Maine 04401 USA
*Corresponding author: lindemann.scott@gmail.com

Lindemann, S.B., A.M. O'Brien, T.B. Persons, and P.G. DeMaynadier. 2019. Axanthism in Green Frogs (*Lithobates clamitans*) and an American Bullfrog (*Lithobates catesbeianus*) in Maine. Canadian Field-Naturalist 133(3): 196–198. https://doi.org/10.22621/cfn.v133i3.2285

Abstract

We document eight cases of axanthism in Green Frogs (*Lithobates clamitans*) and one case in an American Bullfrog (*Lithobates catesbeianus*) in Maine. Although this mutation has been previously reported for both species, this is the first confirmed documentation of "blue" *L. clamitans* and *L. catesbeianus* from Maine.

Key words: Green Frog; *Lithobates clamitans*; American Bullfrog; *Lithobates catesbeianus*; amphibian; blue colour variant; axanthism; Maine

Although "blue" frogs have been documented since 1885 (Haller 1885; also cited in Berns and Uhler 1966), Jablonski *et al.* (2014) note that axanthism is one of the least known colour aberrations in anurans. Axanthism results from the absence or alteration of xanthophores, the dermal chromatophores responsible for red and yellow pigmentation (Berns and Narayen 1970). Normally, these xanthophores contain pteridines and carotinoids, which cause the underlying blue iridophores to appear green; in their absence, the skin appears blue (Berns and Narayan 1970). Berns and Uhler (1966) noted that blue Green Frogs (*Lithobates clamitans*) and Northern Leopard Frogs (*Lithobates pipiens*) have been recorded from northeastern United States (mentioning Maine specifically) and southeastern Canada, although they did not state which species were found in which state or province. Of 111 blue frogs they examined from throughout eastern North America, 100 were *L. clamitans*, 10 were *L. pipiens*, and one was an American Bullfrog (*Lithobates catesbeianus*; from Kentucky). Dodd (2013) cited reports of blue *L. clamitans* from Massachusetts, Delaware, and Virginia, but not Maine. Desroches and Rodrigue (2004) illustrated a blue *L. clamitans*; although not stated, it was presumably from Quebec. Dodd (2013) included a photograph of a blue *L. catesbeianus*, but did not give its locality, and Gilhen and Russell (2015) reported three blue *L. catesbeianus* from Nova Scotia.

On 9 June 2018, S.B.L., James A. Elliott, and A.M.O. found an axanthic adult male *L. clamitans* (Figure 1) in a small pool with emergent vegetation in an ~10-year-old clearcut in coniferous forest, T5 R11 WELS township, Piscataquis County, Maine, USA (46.116659°N, 69.211416°W). Roughly 20 additional wild-type conspecifics were also found at the same location. Axanthic *L. clamitans* (all adults) have also been photo-documented from the following localities in Maine: Washington, Knox County, 11 August 2010; Wiscasset, Lincoln County, 4 October 2013; Buxton, York County, mid-June 2017; Phillips, Franklin County, 16 August 2017; Raymond, Cumberland County, 16 September 2017; and Bethel, Oxford County, 15 July 2018 (MARAP 2019). Although these were coloured similarly to the individual in Figure 1 (i.e., metallic greenish-blue over the entire dorsum), an additional one, from Hurd's Pond, Swanville, Waldo County (44.476658°N,

FIGURE 1. Axanthic adult male Green Frog (*Lithobates clamitans*) from T5 R11 WELS township, Piscataquis County, Maine, USA, 9 June 2018. Photo: Scott B. Lindemann.

69.032297°W) was piebald blue-green (Figure 2).

In contrast to *L. clamitans*, only a single axanthic *L. catesbeianus* has been documented from Maine (MARAP 2019). A subadult (or small adult) female (Figure 3) was photographed at Headquarters Pond, Cobscook Bay State Park, Edmunds Township, Washington County (44.849505°N, 67.167045°W) by Owen and Raymond Brown on 19 June 2011.

To our knowledge, these represent the first confirmed records of axanthic *L. clamitans* and *L. catesbeianus* from Maine. We do not know the true incidence of axanthic frogs in Maine. The MARAP database contains 773 records of *L. clamitans* and 445 of *L. catesbeianus*, but these records are not the result of systematic surveys, and the resulting ratios of axanthic frogs to normally pigmented ones (1:97 for *L. clamitans* and 1:445 for *L. catesbeianus*) are undoubtedly overestimates, as axanthic individuals are much more likely to be reported. Based on data from midwestern supply houses, Berns and Uhler (1966) estimated that out of a sample of roughly two million frogs, axanthics (mostly *L. clamitans*) occurred at a frequency of about 1:29 000, although in some local areas the rate was as high as 1:318 (22 of 7000). Our data support Berns and Uhler's (1966) finding that axanthism appears to be most common in *L. clamitans*. Like albinism, axanthism is presumably a heritable trait (Bechtel 1995). Whether there is a potential selective advantage or disadvantage to axanthism is unknown, but its rarity suggests that it is likely neutral or even potentially disadvantageous. Further documentation of axanthic specimens, such as those reported here, is conducive to an improved understanding of taxonomic and geographic patterns in this interesting colour aberration.

FIGURE 2. Piebald axanthic adult male Green Frog (*Lithobates clamitans*) from Swanville, Waldo County, Maine, USA, 27 June 2016. Photo: Trevor B. Persons.

FIGURE 3. Axanthic American Bullfrog (*Lithobates catesbeianus*) from Cobscook Bay State Park, Edmunds Township, Washington County, Maine, USA, 19 June 2011. Photo: Raymond Brown.

Acknowledgements

Our appreciation is extended to Malcolm Hunter, Aram Calhoun, and Kristine Hoffmann, of the University of Maine, and Derek Yorks and Jason Czapiga, of the Maine Department of Inland Fisheries and Wildlife, for project guidance. Funding support was provided by the Maine Department of Inland Fisheries and Wildlife (Endangered and Nongame Wildlife Fund), the United States Fish and Wildlife Service (State Wildlife Grant), the Department of Wildlife, Fisheries, and Conservation Biology at the University of Maine, Eastern Maine Conservation Initiative, and the University of Maine Graduate Student Government. Fieldwork was performed under a Maine Department of Inland Fisheries and Wildlife scientific collection permit (#2018-184) issued to S.B.L. Animal use protocols were approved by the Institutional Animal Care and Use Committee of the University of Maine (#A2018-03-01).

Literature Cited

Bechtel, H.B. 1995. Reptile and Amphibian Variants: Colors, Patterns, and Scales. Krieger Publishing, Malabar, Florida, USA.

Berns, M.W., and K.S. Narayan. 1970. An histochemical and ultrastructural analysis of the dermal chromatophores of the variant ranid blue frog. Journal of Morphology 132: 169–180. https://doi.org/10.1002/jmor.1051320205

Berns, M.W., and L.D. Uhler. 1966. Blue frogs of the genus *Rana*. Herpetologica 22: 181–183.

Desroches, J., et D. Rodrigue. 2004. Amphibiens et reptiles du Québec et des Maritimes. Éditions Michel Quintin, Waterloo, Quebec, Canada.

Dodd, Jr., C.K. 2013. Frogs of the United States and Canada, Volume 2. Johns Hopkins University Press, Baltimore, Maryland, USA. https://doi.org/10.1353/book.25108

Gilhen, J., and R.W. Russell. 2015. Three records of rare blue American Bullfrogs, *Lithobates catesbeianus*, in Nova Scotia, Canada. Canadian Field-Naturalist 129: 395–398. https://doi.org/10.22621/cfn.v129i4.1762

Haller, B. 1885. Über das blaue Hocheitskleid des Grasfrosches. Zoologischer Anzeiger 8: 611–617.

Jablonski, D., A. Alena, P. Vlcek, and D. Jandzik. 2014. Axanthism in amphibians: a review and the first record in the widespread toad of the *Bufotes viridis* complex (Anura: Bufonidae). Belgian Journal of Zoology 144: 93–101.

MARAP (Maine Amphibian and Reptile Atlas Project). 2019. Data files. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine, USA.

Received 15 May 2019
Accepted 19 December 2019

The Canadian Field-Naturalist

Harpalejeunea molleri subsp. *integra* (R.M. Schuster) Damsholt new to Atlantic Canada

Sean R. Haughian[1,2,*] **and Thomas H. Neily**[3]

[1]Botany & Mycology Section, Department of Natural Sciences, New Brunswick Museum, 277 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada
[2]Biology Department, Saint Mary's University, 923 Robie Street, Halifax, Nova Scotia B3H 3C3 Canada
[3]Mersey Tobeatic Research Institute, 9 Mount Merritt Road, P.O. Box 215, Kempt, Queens County, Nova Scotia B0T 1B0 Canada
*Corresponding author: sean.haughian@smu.ca

Haughian, S.R., and T.H. Neily. 2019. *Harpalejeunea molleri* subsp. *integra* (R.M. Schuster) Damsholt new to Atlantic Canada. Canadian Field-Naturalist 133(3): 199–205. https://doi.org/10.22621/cfn.v133i3.2052

Abstract

Harpalejeunea molleri subsp. *integra* (R.M. Schuster) Damsholt is reported for the first time in Atlantic Canada. It was found on the base of a large Eastern White Cedar (*Thuja occidentalis*) in a swamp in Nova Scotia. The specimen was examined using light microscopy, diagnosed using standard keys, and compared with reference specimens, including two European collections from the New Brunswick Museum, two North American collections annotated by R.M. Schuster, and the only material that may have been previously collected in Canada, by T. Drummond. We speculate on the original location of Drummond's collection, and the implications of this finding for conservation.

Key words: Liverwort; Nova Scotia; hepatic; Lejeuneaceae

Introduction

Harpalejeunea molleri (Stephani) Grolle (Lejeuneaceae) is a rare leafy liverwort (Note: liverworts typically do not have common names) with a disjunct global distribution, primarily around the North Atlantic, with European and North American populations recognized as subspecies. In Europe, *Harpalejeunea molleri* subsp. *molleri* has been collected on the west coast of Norway and in the United Kingdom, Ireland, and Spain (GBIF 2018), as well as Finland, Italy, Madeira, the Azores, the Canary Islands, and Corsica (Hodgetts 2015). The North American subspecies, *Harpalejeunea molleri* subsp. *integra* (R.M. Schuster) Damsholt, is known primarily from the Appalachian Mountain Range and Atlantic Coastal Plain in the southeastern United States, where it has been collected in Alabama, Georgia, Kentucky, and North and South Carolina (Schuster 1980; Consortium of North American Bryophyte Herbaria 2017), as well as Florida, Mississippi, Tennessee, and Virginia (Breil 1970). A single specimen is thought to have been collected from Canada by Thomas Drummond in the early 19th century, but the collection location is ambiguous, and no other specimens are known to have been collected in Canada since then. Two recent collections are also reported from Brazil, without subspecific designation (GBIF 2018).

The correct name for *H. molleri* and its infraspecific taxa has historically been a source of confusion. Schuster (1980) used the name *Harpalejeunea ovata* (Dickson) Schiffner, and, consequently, much of the material in North American herbaria has been accessioned under that name. However, Grolle (1989) demonstrated that this name is a synonym of *Douinia ovata* (Dickson) H. Buch (Scapaniaceae) and that *H. molleri* is the correct name for the taxon, as recognized recently by European authorities (Paton 1999; Damsholt and Pagh 2002). Nevertheless, the former taxonomic confusion continues to impede accurate delineation of the species' distribution because many herbarium records have not been revised to reflect current taxonomy.

In North America, *H. molleri* subsp. *integra* has been found in old growth swamps or riparian areas with relatively open forest canopies, most commonly as an epiphyte on the base of hardwood trees (Breil 1970; Schuster 1980) and in crevices on sedimentary rock (Consortium of North American Bryophyte Herbaria 2017). It is often in mixed species colonies (Breil 1970), and common liverwort associates in herbarium records include *Frullania asagray-*

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

ana Montagneagne, *Lejeunea lamacerina* (Stephani) Schiffner, *Lejeunea ruthii* (A. Evans) R.M. Schuster, *Lejeunea ulicina* (Taylor) Gottsche, Lindenberg & Nees, and *Radula obconica* Sullivant (Consortium of North American Bryophyte Herbaria 2017).

Methods

The collection site was a mixedwood swamp near Hectanooga, Digby County, Nova Scotia (~44.082°N, 66.056°W). Geologically, this part of Digby County is underlain by the Church Point Formation, which is composed primarily of grey to green, fine- to medium-grained metasiltstone and metasandstone, with rare shale deposits (White and Horne 2012). Soils are stony in places and poorly drained, being a mix of peat, sandy loam, and loam-till derived from slate (Hilchey *et al.* 1962). The habitat is a rich swamp forest, dominated by Eastern White Cedar (*Thuja occidentalis* L.), Red Maple (*Acer rubrum* L.), Balsam Fir (*Abies balsamea* (L.) Miller), and Yellow Birch (*Betula alleghaniensis* Britton). Hummock and hollow microtopography characterizes the ground layer, with hummocks dominated by sedges (*Carex* spp.) and Cinnamon Fern (*Osmundastrum cinnamomeum* (L.) C. Presl) and hollows dominated by *Sphagnum* spp. and standing water. The shrub layer is patchy, with Common Winterberry (*Ilex verticillata* (L.) A. Gray) and Grey Alder (*Alnus incana* (L.) Moench).

Collections of *H. molleri* subsp. *integra* were made opportunistically during searches for *Frullania selwyniana* Pearson, also rare in the province. Approximately 40 mature cedar trees were visually inspected during this search; eight were found to host visible mixed-species colonies of leafy liverworts. A mixed-species collection was made from each of the eight host trees and later examined using stereomicroscopy. Liverworts were identified using standard taxonomic keys (Schuster 1980; Paton 1999).

Two of these collections were found to contain *H. molleri* subsp. *integra*. The larger of the two collections was then compared with reference material from three sources: (1) two exsiccatae from the herbarium at the New Brunswick Museum (NBM), (2) two recent collections from the United States that were annotated by liverwort authority R.M. Schuster at the Field Museum (F), and (3) the original (supposedly) Canadian collection by T. Drummond, held by the New York Botanical Garden. Neither S.R.H. nor T.H.N. has since had the opportunity to return to this location to assess the population size or health of the colony.

In this paper, we provide a brief description of the morphology of the specimen that was deposited at the NBM as evidence for our subspecific designation. We also highlight noteworthy aspects of the historical collections for the sake of comparison.

Results

Harpalejeunea molleri subsp. *integra* was collected from two cedar trees in the Hectanooga Cedar Swamp. One of these collections was accessioned at the NBM, while the other is held in the private herbarium of T.H.N. Common species in these colonies included *Frullania asagrayana* Montagne, *Frullania oakesiana* Austin, *Ptilidium pulcherrimum* (Weber) Vainio, and *Radula complanata* (L.) Dumortier, while rarer species included *F. selwyniana*, *Lejeunea cavifolia* (Ehrhart) Lindberg, and *Lejeunea ulicina* (Taylor) Gottsche, Lindenberg & Nees. Both of the (mixed-species) colonies, in which *H. molleri* subsp. *integra* was detected, were ~40 cm^2 on the bases of large Eastern White Cedars (~25 cm diameter at breast height). *Harpalejeunea molleri* subsp. *integra* occupied only a small fraction (<10%) of the colonies and the subsequent collected material, but was distinct from the other species present, being obviously greener than *F. selwyniana*, larger than *L. ulicina*, and with more acutely angled leaves than *L. cavifolia*.

Shoot and colony architecture of *H. molleri* subsp. *integra* in the collected material corresponded to a previously published description (Schuster 1980). The collective, multi-species colony structure for our sample was that of a loose "smooth mat", although each individual species exhibited a thread-like growth form (*sensu* Bates 1998). Shoots of *H. molleri* subsp. *integra* were 0.4–0.6 mm wide (transverse axis, including leaves) and displayed a dichotomous irregular lateral branching pattern. Stem postical cortical cells were 13–15 µm wide on mature shoots. Leaves were two-ranked, spreading, and complicate-bilobed with alternate insertions along the stem (Figure 1). Antical leaf lobes were comma shaped and longer than broad (1.1–1.2 length to width ratio); proximal margins overlapped the stem above the transverse insertion (Figure 2), and distal margins were acute tipped, typically tapering to a single cell, or occasionally two cells and often curved toward the substrate (Figure 3). The smaller, postical lobe (lobule) attached to the stem along the entire length of its proximal margin and folded under the larger, antical lobes, forming a rounded keel along the anterior leaf margin (Figure 3); the angle between the distal edge of the keel and the free antical lobe ranged from 90° to 120°, and the joint was often strongly indented (Figure 2). The distal tips of most lobules bore a slightly elongated, tooth-like cell, located proximal to the distal margin of the keel; this cell projected away from the stem and was ~1.5–2 times the length of a median lobule cell (Figure 3). Immediately proximal

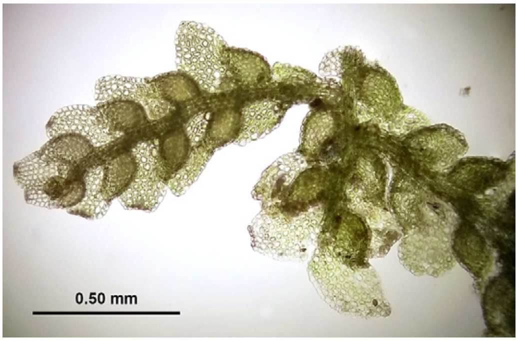


FIGURE 1. Postical view of *Harpalejeunea molleri* subsp. *integra* shoot (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

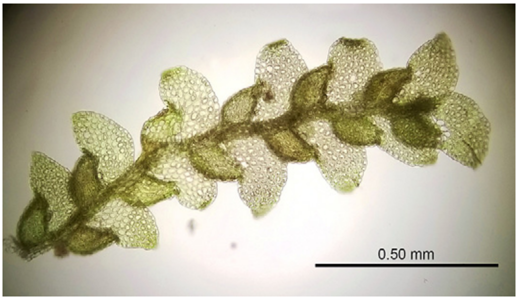


FIGURE 2. Antical view of *Harpalejeunea molleri* subsp. *integra* shoot, from newly collected material (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

to this tooth-like cell, some lobules also had a clavate, hyaline papilla (not shown). Underleaves were 0.12–0.16 mm across, shallowly bilobed, and widely divergent; each lobe was four cells wide at the base and rounded at the apex (Figure 4). The specimen had no obvious reproductive structures.

The two collections from North America (F) were consistent with Schuster's (1980) descriptions of *H. molleri* subsp. *integra*. They exhibited stem postical cortical cells 13–19 µm in width, bilobed underleaves with four cells at the base of each lobe, and strongly indented leaf margins where the distal terminus of the lobule's keel attached to the antical leaf lobe.

The two collections from Spain and Portugal (NBM) had characters consistent with Schuster's (1980) and Paton's (1999) descriptions of *H. molleri* subsp. *molleri*. Compared with the USA material, they had consistently wider postical cortical cells of 19–23 µm, more weakly indented joints (forming angles of ~90–135°) between the lobule and leaf lobe, and slightly more variable underleaf lobe widths (4–7 cells).

Drummond's collection was somewhat transitional between the European and the North American collections examined; the leaf lobe–lobule joints were strongly indented on mature stems, and the underleaf lobes were mostly 4 (-6) cells across. However, the postical cortical cells of the stem were wider (19–24 µm) than is typical for *H. molleri* subsp. *integra*. Associated taxa in this packet included *Diplophyllum albicans* (L.) Dumortier and *Frullania tamarisci* (L.) Dumortier. The only writing on the packet was the former Latin name of the species ("*Lejeunea ovata*") and the vague place-name, "British North America".

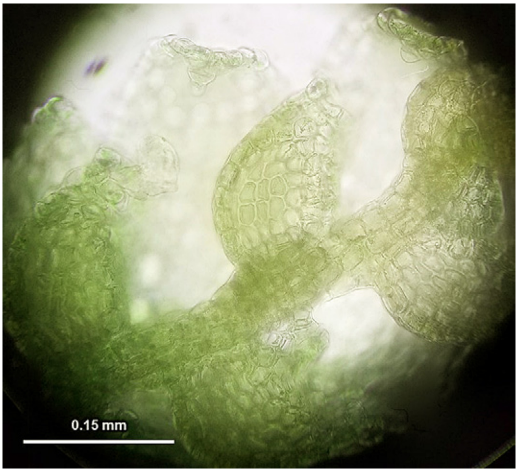


FIGURE 3. Postical view of *Harpalejeunea molleri* subsp. *integra* shoot, showing lobules, underleaves, and antical lobe tips, from newly collected material (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

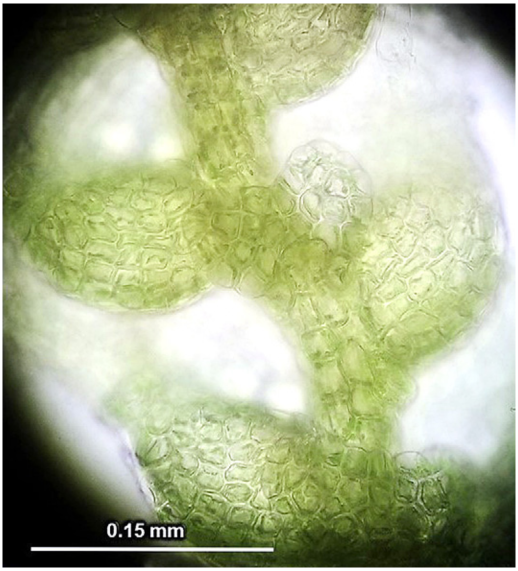


FIGURE 4. Postical view of *Harpalejeunea molleri* subsp. *integra* shoot, showing underleaves and cortical stem cells, from newly collected material (*Neily 1629*, New Brunswick Museum). Photo: Sean Haughian.

Discussion

This is the first report of *H. molleri* subsp. *integra* in Atlantic Canada, and the first reliable report of the species in Canada. The apparent disjunction of this occurrence from other known localities in North America suggests that the population is a relic of a previously more contiguous North American distribution, that it is a recent colonist from the southeast, or that the species is present between the new sites and the ones further south but unrecorded. We think the latter is unlikely given the search effort for mosses and liverworts in much of the northeastern United States and the uniqueness of the Nova Scotia habitat.

Alternatively, *H. molleri* subsp. *integra* may be a dispersal-limited disjunct of Nova Scotia's Atlantic Coastal Plain flora. This species is only rarely fertile, even in locations where it is more common and abundant (Breil 1970; Schuster 1980). Consequently, reproductive propagules are unlikely to have colonized any new habitats in recent years. Moreover, other species that are associated with this type of habitat (both vascular plants and epiphytes) are known to be associated with the Atlantic Coastal Plain, for which southwestern Nova Scotia forms a natural northern disjunction (Sweeny and Ogilvie 1993). Regardless, the combination of potential dispersal limitation with habitat and substrate associations, makes *H. molleri* subsp. *integra* an exceptional rarity, even among flora of the Atlantic Coastal Plain.

The first record in Canada?

Although our find was exceptional, it may not be the first detection of this species in Canada; a single collection of *H. molleri* was supposedly made by T. Drummond in the early 19th century and is held by the New York Botanical Garden. The location originally listed in the digital record of the specimen was "British Columbia" (Consortium of North American Bryophyte Herbaria 2018), but the writing on the packet says "British North America", a vague term, which, at the time the collection was made (ca. 1830), could have referred to all of the British territories north of the United States (Nicholson 2006) or primarily those west of Upper Canada, which was both the official name and a more commonly used descriptor for material collected by Drummond from what is now southern Ontario (Consortium of North American Bryophyte Herbaria 2018). If the specimen was indeed from Ontario, Drummond would probably have made this collection at the beginning of his expedition in 1825 (the only time he visited Ontario), which began in the Niagara area, and proceeded toward Lake Superior, and then on to the Rocky Mountains via the Saskatchewan River route (Bird 1967). It is possible that he considered much of northwestern Ontario to be outside of Upper Canada *sensu stricto*.

However, we have reasons to doubt that this collection was from Canada. First, the collection was part of William Mitten's herbarium, which was both extensive and somewhat poorly organized and annotated (Thiers 1983), casting a general doubt on the accuracy of packet labels.

Second, the associated taxa in Drummond's collection (*D. albicans* and *F. tamarisci*) are, in Canada, primarily known from either the British Columbia coast or the Atlantic provinces, where Drummond did not collect; other supposed early records of *D. albicans* (Macoun 1902) probably represent *Diplophyllum taxifolium* (Wahlenberg) Dumortier (Ley and Crowe 1999).

Third, most other Drummond bryophyte collections from the Ontario region list a specific area (e.g., "Lake Superior" or "Niagara Falls"; Consortium of North American Bryophyte Herbaria 2018), many of which would have been considered part of Upper Canada, rather than "British North America".

Fourth, while lands around Lake Superior are known to harbour some rare taxa associated with cedar swamps (e.g., COSEWIC 2019), neither Drummond's own records nor those of others who have studied Drummond's work (Bird 1967) suggest that he sampled extensively in cedar swamps of Ontario.

Fifth, the Drummond *H. molleri* collection could be from another location entirely: the specimen is somewhat morphologically ambiguous, with stem cortical cells suggestive of the European subspecies, perhaps from the United Kingdom (UK), and other morphological aspects suggestive of *H. molleri* subsp. *integra*, perhaps from the southeastern USA.

Drummond is known to have sampled bryophytes extensively in the UK before his work in North America, as exemplified in his two-volume *Musci Scotici* (Geiser 1937), and to have travelled widely throughout the southeastern USA in the 1830s, amassing thousands of specimens, including exsiccatae entitled *Musci Americani* and *Musci Louisiana*, which were posthumously released by Hooker and Wilson (Hooker 1840; Short 1841; Geiser 1937). The associated taxa in his *H. molleri* collection do not provide definitive guidance on alternative localities: in North America, *D. albicans* and *F. tamarisci* are known primarily from the Pacific Northwest or from Atlantic Canada and the Appalachian range of the USA, but have also been recorded in the UK. Nevertheless, we believe the collection was more likely to have been from the southeastern USA. Although hepatics were a minority in all of Drummond's collections and are not fully enumerated in any documents we could locate, Evans (1902) reports that Drummond's "Mosses of the Southern States" contains *Jungermannia serpyllifolia*. Although this name was later considered a synonym of *L. cavifolia* (Evans 1902), at the time Drummond was collecting, *H. molleri* subsp. *integra* was known as *J. serpyllifolia* subsp. *ovata* (Grolle 1989), and the omission of such a subspecific designation could have been easily overlooked by later handlers of this material. Even if the specimen to which Evans (1902) referred was, indeed, *L. cavifolia*, it suggests that Drummond collected in the right type of habitat to have also recovered *H. molleri*.

Significance and conservation

Although it may be the first Canadian record, our Nova Scotian collection of *H. molleri* subsp. *integra* was not entirely unexpected: the rich swamp forests of southwest Nova Scotia harbour several rare species that are unknown elsewhere (e.g., Neily and Anderson 2010) or are otherwise restricted to the southern Appalachians or Atlantic Coastal Plain of North America (Wisheu and Keddy 1989; Sweeny and Ogilvie 1993). The other liverworts found in the colony with *H. molleri* subsp. *integra* are themselves rare or uncommon in Atlantic Canada, having been reported only a handful of times in Nova Scotia (R. Newell pers. comm. 31 May 2017).

The Hectanooga Cedar Swamp, in which our specimens were collected, has been viewed as rare and exceptional in Nova Scotia for several decades (Ogilvie 1984), but its ecological importance has only been recognized more recently. In addition to an absence of historical disturbance in large parts, with some trees nearly 200 years old (Nova Scotia Department of Environment 2013a), the swamp harbours the largest number of naturally occurring Eastern White Cedar in mainland Nova Scotia (Nova Scotia Nature Trust 2010). The swamp also harbours many rare and at-risk species of lichens (COSEWIC 2009, 2010, 2015, 2016), birds (COSEWIC 2007, 2008), and trees, including Eastern White Cedar (Newell 2005). The Hectanooga Cedar Swamp is, therefore, of considerable value for biodiversity conservation and scientific research.

Historically, much of the Hectanooga Cedar Swamp was privately owned, but large parts are now scheduled to be protected by a provincial Nature Reserve. In 2010, the Nova Scotia Nature Trust purchased 75 ha of this land, and later transferred ownership of it to the provincial government with the protection of a conservation easement. These lands, combined with an adjacent area of Crown land to the north, are proposed as the Hectanooga Cedar Swamp Nature Reserve, including both important swamp forest and some mature mixed hardwood forest to reduce the negative edge influence (Nova Scotia Department of Environment 2013b). On the other hand, logging activities between 2008 and 2012 had already removed a substantial area of adjacent old-growth forest, and several roads run along the edges of the proposed reserve (S.R.H. and T.H.N. pers. obs.). As such, the reserve may yet suffer from negative edge influence, exacerbated by its small size (124 ha), fragmented configuration (divided into three sections), and elongate shape. Such forested wetlands may be declining in Nova Scotia, and these declines may be exacerbated in the future in a warming climate (Newell 2005; Lemieux 2010). We recommend enhancing protections for such unique hotspots of biodiversity by promptly conferring legal protected status upon them wherever possible, by adding additional parcels to make the reserves contiguous, and by increasing reserve sizes to increase protection from adjacent industrial activities.

Vouchers examined

Harpalejeunea molleri subsp. *integra* (R.M. Schust.) Damsh—CANADA, NOVA SCOTIA: Digby Co., Hectanooga Cedar Swamp, 44.082°N, 66.056°W, 17 May 2017, *T. Neily 1629* (NBM BH-2739); *ibidem*: 44.083°N, 66.052°W, 17 May 2017, *T. Neily 1654* (personal collection of T.H.N., Digby Co.); U.S.A., TENNESSEE: Pickett Co., rocky slopes W of Hwy 154 near Scott Co. line, Pickett State Forest, 17 April 1991, *P.G. Davison 1613* (F-C0074242, as *H. ovata* subsp. *integra*); SOUTH CAROLINA: Oconee, gorge of Whitewater River, 0.3–0.4 mi. (0.5–0.6 km) below Lower Falls, *ca.* 3 mi. (4.8 km) above Jocassee, 24 August 1958, *R.M. Schuster 40899a* (F-C0578334, as *H. ovata* subsp. *integra*); BRITISH NORTH AMERICA: *ca.* 1825–1835 (entered as 1906), *T. Drummond s.n.* (NY00265235, as *Lejeunea ovata*).

Harpalejeunea molleri (Steph.) Grolle subsp. *molleri*—SPAIN: 1927, P. Allorge, Exsiccata Bryotheca Iberica No. 11 (NBM BH-00858, as *H. ovata*); PORTUGAL: 1937, P. Allorge, Exsiccata Bryophyta Azorica No. 37 (NBM BH-00519, as *H. ovata*).

Author Contributions

Conceptualization – S.R.H. and T.H.N.; Investigation (specimen discovery & identification) – T.H.N.; Investigation (specimen verifications & comparisons) – S.R.H.; Investigation (nomenclatural & historical research) – S.R.H.; Methods – S.R.H. and T.H.N.; Visualization (photography) – S.R.H.; Writing (original draft preparation) – S.R.H.; Writing (review & editing) – S.R.H. and T.H.N.

Acknowledgements

This work was self-funded by the authors. We wish to thank Stephen Clayden and Kendra Driscoll for assistance in accessing specimens at the New Brunswick Museum, Ruth Newell for assistance with searching for Nova Scotian liverwort records at the

Acadia University Herbarium, Barbara Thiers for assistance in locating the Drummond record at the New York Botanical Garden, the Field Museum and New York Botanical Garden Herbaria for loans of material, and three anonymous reviewers, Jennifer Doubt, Jeff Saarela, and Dwayne Lepitzki for their insightful feedback on our draft manuscript.

Literature Cited

Bates, J.W. 1998. Is "life-form" a useful concept in bryophyte ecology? Oikos 82: 223–237. https://doi.org/10.2307/3546962

Bird, C.D. 1967. The mosses collected by Thomas Drummond in Western Canada, 1825–1827. Bryologist 70: 262–266. https://doi.org/10.2307/3240954

Breil, D.A. 1970. Liverworts of the Mid-Gulf Coastal Plain. Bryologist 73: 409–491. https://doi.org/10.2307/3241490

Consortium of North American Bryophyte Herbaria. 2017. *Harpalejeunea ovata* (Hooker) Schiffner subsp. *integra* R.M. Schuster. Accessed 23 November 2017. http://bryophyteportal.org/portal/collections/list.php.

Consortium of North American Bryophyte Herbaria. 2018. CNABH search results for: Country = Canada; Collector = Drummond; Dates = 1820 to 1908. Accessed 20 September 2018. http://bryophyteportal.org/portal/collections/list.php?db=all&country=Canada&collector=Drummond&eventdate1=1820&eventdate2=1908&page=1.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2007. COSEWIC assessment and status report on the Olive-sided Flycatcher *Contopus cooperi* in Canada. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2008. COSEWIC assessment and status report on the Canada Warbler *Wilsonia canadensis*. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2009. COSEWIC assessment and status report on the Vole Ears *Erioderma mollissimum* in Canada. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2010. COSEWIC assessment and status report on the Blue Felt Lichen *Degelia plumbea* in Canada. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2015. COSEWIC assessment and status report on the Black-foam Lichen *Anzia colpodes* in Canada. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2016. COSEWIC assessment and status report on the Wrinkled Shingle Lichen *Pannaria lurida* in Canada. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2019. COSEWIC assessment and status report on the White-rimmed Shingle Lichen *Fuscopannaria leucosticta* in Canada. COSEWIC, Ottawa, Ontario, Canada.

Damsholt, K., and A. Pagh. 2002. Illustrated Flora of Nordic Liverworts and Hornworts. Nordic Bryological Society, Lund, Sweden.

Evans, A.W. 1902. The Lejeuneae of the United States and Canada. Memoirs of the Torrey Botanical Club 8: 113–183.

GBIF (Global Biodiversity Information Facility). 2018. *Harpalejeunea molleri* (Steph.) Grolle. GBIF Backbone Taxonomy, GBIF Secretariat, Copenhagen, Denmark. Checklist dataset. Accessed 22 September 2018. https://doi.org/10.15468/39omei

Geiser, S.W. 1937. Thomas Drummond. Naturalists on the Frontier. Southern Methodist University, Dallas, Texas, USA.

Grolle, R. 1989. A technically new lectotypification of *Harpalejeunea* (Hepaticae). Taxon 38: 88–90. https://doi.org/10.2307/1220901

Hilchey, J.D., D.B. Cann, and J.I. MacDougall. 1962. Soil survey of Digby County, Nova Scotia. Nova Scotia Soil Survey, Truro, Nova Scotia, Canada.

Hodgetts, N. 2015. Checklist and country status of European bryophytes—towards a new Red List for Europe. Irish Wildlife Manuals, Department of Arts, Heritage, and the Gaeltacht, Ireland, Dublin, Ireland.

Hooker, W. 1840. Announcement: Thomas Drummond's Mosses and Hepaticae of Louisiana. Journal of Botany 1: 438.

Lemieux, M.J. 2010. A management plan for native occurrences of eastern white cedar (*Thuja occidentalis* L.) in Nova Scotia, Canada. Nova Scotia Department of Natural Resources, Truro, Nova Scotia, Canada. Accessed 26 February 2018. https://novascotia.ca/natr/wildlife/biodiversity/pdf/Management_Plan_EWC_NS_July_2010_MJL.pdf.

Ley, L.M., and J.M. Crowe. 1999. An Enthusiast's Guide to the Liverworts and Hornworts of Ontario. Lakehead University, Thunder Bay, Ontario, Canada.

Macoun, J. 1902. Catalogue of Canadian Plants. VII.—Lichenes and Hepaticae. Government Printing Bureau, Ottawa, Ontario, Canada. Accessed 26 February 2018. https://www.biodiversitylibrary.org/item/144111.

Neily, T., and F. Anderson. 2010. *Leptogium hibernicum* Mitch. ex P.M. Jørg. discovered in North America. Lichenologist 42: 629–630. https://doi.org/10.1017/S0024282910000162

Newell, R.E. 2005. Provincial (Nova Scotia) status report on Northern White Cedar *Thuja occidentalis*. Nova Scotia Department of Natural Resources, Truro, Nova Scotia, Canada. Accessed 26 February 2018. https://novascotia.ca/natr/wildlife/biodiversity/pdf/statusreports/StatusReportEasternCedar.pdf.

Nicholson, N.L. 2006. British North America. The Canadian Encyclopedia. Online. Historica Canada, Toronto, Ontario, Canada. Accessed 11 January 2020. https://www.thecanadianencyclopedia.ca/en/article/british-north-america.

Nova Scotia Department of Environment. 2013a. Our parks and protected areas: a plan for Nova Scotia. Nova Scotia Department of Environment, Halifax, Nova Scotia, Canada. Accessed 26 February 2018. https://novascotia.ca/parksandprotectedareas/pdf/Parks-Protected-Plan.pdf.

Nova Scotia Department of Environment. 2013b. Hectanooga Cedar Swamp Nature Reserve. Nova Scotia

Department of Environment, Halifax, Nova Scotia. Accessed 26 February 2018. https://www.novascotia.ca/nse/protectedareas/consult/AreaHandler.ashx?id=518&type=html.

Nova Scotia Nature Trust. 2010. Nature trust saves homes for imperiled species. News release. Nova Scotia Nature Trust, Halifax, Nova Scotia, Canada.

Ogilvie, R. 1984. Important ecological sites in Nova Scotia. Curatorial report 49. Nova Scotia Museum, Halifax, Nova Scotia, Canada.

Paton, J.A. 1999. The Liverwort Flora of the British Isles. Brill Academic Publishers, Leiden, Netherlands.

Schuster, R.M. 1980. The Hepaticae and Anthocerotae of North America, East of the 100th Meridian. Volume IV. Columbia University Press, New York, New York, USA.

Short, C.W. 1841. A sketch of the progress in botany in Western North America. Journal of Botany 3: 97–124.

Sweeny, S., and R. Ogilvie. 1993. The conservation of coastal plain flora in Nova Scotia. Maine Naturalist 1: 131–144. https://doi.org/10.2307/3858236

Thiers, B.M. 1983. Index to the genera and species of hepaticae described by William Mitten. Brittonia 35: 271–300. https://doi.org/10.2307/2806026

White, C.E., and R.J. Horne. 2012. Bedrock geology map of the Meteghan area, NTS sheet 21B/01, Digby and Yarmouth counties, Nova Scotia. Nova Scotia Department of Natural Resources, Mineral Resource Branch, Halifax, Nova Scotia, Canada. Accessed 26 February 2018. https://novascotia.ca/natr/meb/data/mg/ofm/pdf/ofm_2012-086_d127_dp.pdf.

Wisheu, I.C., and P.A. Keddy. 1989. The conservation and management of a threatened coastal plain plant community in eastern North America (Nova Scotia, Canada). Biological Conservation 48: 229–238. https://doi.org/10.1016/0006-3207(89)90120-1

Received 26 February 2018
Accepted 17 December 2019

The Canadian Field-Naturalist

Lichens and allied fungi of Sandbar Lake Provincial Park, Ontario

Hanna R. Dorval[1,*] **and Richard Troy McMullin**[2]

[1]Lakehead University, Natural Resources Management, 955 Oliver Road, Thunder Bay, Ontario P7B 5E1 Canada
[2]Canadian Museum of Nature, Research and Collections, P.O. Box 3443 Stn. D, Ottawa, Ontario K1P 6P4 Canada
[*]Corresponding author: hdorval@lakeheadu.ca

Dorval, H.R., and R.T. McMullin. 2019. Lichens and allied fungi of Sandbar Lake Provincial Park, Ontario. Canadian Field-Naturalist 133(3): 206–215. https://doi.org/10.22621/cfn.v133i3.2209

Abstract

Sandbar Lake Provincial Park (Sandbar Lake) covers 8053 ha in the boreal forest in northwestern Ontario. Within the park boundary are natural forests representative of those in the region, as well as forests that are heavily disturbed from resource extraction activities, which are prevalent in northwestern Ontario. The lichen biota in this part of the boreal forest is known to be rich and abundant, but lichen diversity is also known to be negatively impacted by disturbances (e.g., timber harvesting, mining, and climate change). Therefore, lichens can be used to monitor the effects of these disturbances, but baseline data are required. Here, we present the results of the first detailed inventory of the lichens and allied fungi of Sandbar Lake. We report 139 species in 69 genera from 16 sites that represent all macrohabitats present in the park. Seven species have a provincial conservation status rank from S1 to S3 (critically imperilled to vulnerable), and one species, *Arthrosporum populorum*, has previously been collected only once in northwestern Ontario. Our results fill biogeographic gaps for many species and allow lichens to be used as biomonitors during further study at Sandbar Lake. We show that Sandbar Lake has important conservation value, and our data provide an opportunity for further study in an area with no previous research on lichens.

Key words: Sandbar Lake Provincial Park; lichens; fungi; boreal forest; Great Lakes–St. Lawrence forest; conservation; biogeography; bioindicators; protected areas

Introduction

Provincial parks in Ontario are designed to maintain and preserve natural and cultural integrity while allowing for recreational and educational opportunities for the public and scientific communities (Ontario 2015). They are regulated under the *Provincial Parks and Conservation Reserves Act* and, since 1954, have been managed by Ontario Parks, a branch of the Ontario Ministry of Natural Resources and Forestry. Between 1920 and 1954, they fell under the Department of Lands and Forests. The first provincial parks in Ontario were created from land that was considered unsuitable for agriculture and settlement. However, now parks are also established to provide opportunities for outdoor recreation and the resulting economic benefits. Parks allow the public and researchers to gain knowledge of the natural heritage of Ontario; they also protect the biodiversity, ecosystems, and provincially significant elements within their boundaries (Ontario 2006). Currently, more than 7 420 816 ha in Ontario have been incorporated into 335 provincial parks, accounting for 7% of the land area in the province (Ontario 2017).

Sandbar Lake Provincial Park was established in 1970 (Ontario Parks 2012). It was initially classified as a recreation park but was changed to its current classification as a natural environment park in 1986 (Ontario Parks 2012). This designation dictates that the management goals include maintenance of ecosystem representativeness and natural and cultural heritage, while allowing for recreational, educational, and research activities (Ontario Parks 2012). The park area includes Sandbar Lake, sand beaches, and conifer-dominated forests. Since it was established, two additions to the park have doubled its size to over 8000 ha (Ontario Parks 2012). Sandbar Lake Provincial Park is in a region northwest of Lake Superior that is known for rich lichen diversity (Crowe 1994; Ahti and Crowe 1995) and as a hotspot for lichen diversity in North America (Brodo *et al.* 2001). However, the lichens of the Sandbar Lake area have not been documented previously.

The history of lichen collecting in Ontario has been summarized by McMullin and Lewis (2013). Of the 1083 species known from the province (McMullin *et al.* 2015, 2018), at least 455 occur in the region northwest of Lake Superior (Crowe 1994; Ahti and Crowe 1995). Despite the known diversity, the only

---

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

focussed studies within this region of Ontario have been in Slate Islands National Park (C. Wetmore unpubl. data accessed through the Consortium of North American Lichen Herbaria [CNALH]) and Voyageur National Park in Minnesota, USA (Wetmore 1981).

The aim of our study was to document the lichens and allied fungi in Sandbar Lake Provincial Park. Our objectives were to examine all major ecosystems in the park, create a checklist of lichens and allied fungi traditionally treated with lichens, compare our results with those from two other provincial parks in Ontario, and provide provincial conservation status ranks for each species. Our results will provide an increased understanding of the biodiversity in the park and a baseline that can be used to detect changes to the lichen community from disturbances, such as climate change, acid rain, or land use changes in or near the park (McMullin *et al.* 2017).

Study Area

Sandbar Lake Provincial Park is located in northwestern Ontario, ~4 km northeast of the town of Ignace and ~250 km northwest of Thunder Bay (Figure 1), along Highway 599. This protected area covers 8053 ha. When the park was established in 1970, its area was 3157 ha. In 1986, 1926 ha were added and, in 2003, Ontario's Living Legacy Land Use Strategy facilitated a second addition of 3720 ha on the north side of the park (Ontario Parks 2012). The latter comprises mainly wetland generated through paludification, where organic matter accumulation, especially *Sphagnum* spp., contributes to increased soil moisture (Lavoie *et al.* 2005; Ontario Parks 2012). This process results in reduced soil temperature, a reduction and overall change in tree and vascular plant cover, and shifts in nutrient availability, microbial activity, and decomposition rates (Lavoie *et al.* 2005).

This wetland is designated a nature reserve zone, which is a classification used to enhance protection of features represented within provincial parks that are considered unique within the region and the province (Ontario Parks 2012). Minimal to no development is permitted within these zones, but research may be permitted. Sandbar Lake Provincial Park contains five nature reserve zones, all of which were examined for lichens during this study. Natural environment zones are areas intended for limited development to generate and maintain low-intensity recreational activities. Development permitted in these zones includes the provision of signage for trail navigation and the maintenance of interpretive facilities. Two natural environment zones covering 6872 ha are present in Sandbar Lake Provincial Park (Ontario Parks 2012). Historical zones were also established in the park to mark and protect culturally and historically significant areas, including those that have historically been occupied by humans and human-made structures (Ontario Parks 2012). Sandbar Lake Provincial Park has four historical zones, each delineated based on human occupation during the Laurel Period (2200–1600 years B.P.) and the Blackduck Period (1200 years B.P. to European contact; Ontario Parks 2012). All nature reserve, natural environment, and historical zones within Sandbar Lake Provincial Park are illustrated in Figure 1.

The park provides opportunities for outdoor recreation, including hiking, canoeing, and seasonal camping at 75 campsites. All campsites and hiking trails are located in the campground area in the southeastern corner of the park adjacent to Highway 599. Use of the campground area and recreational fishing in Sandbar Lake accounts for the vast majority of park use by visitors; the remainder of the park is visited only infrequently.

Sandbar Lake Provincial Park is located within the transition zone between the boreal and Great Lakes–St. Lawrence forests (Ontario Parks 2012). The park comprises mostly conifer-dominated forests; however, mixed-wood forests, wetlands, exposed bedrock outcrops, and outwash plain ecosystem types are also represented (Ontario Parks 2012). Timber harvesting, sporadic fires, and windthrow events, which occurred mainly during the early 20th century, are largely responsible for shaping the vegetation communities currently in the park (Ontario Parks 2012). In recent decades, timber harvesting and mining operations have surrounded the park boundary (Ontario Parks 2012).

Methods

Sampling

Fieldwork was conducted in the fall of 2017. Collections were made throughout the park in all major ecosystems, nature reserves, and natural ecosystem zones over 12 days. Floristic habitat sampling, completed through the intensive study of large areas, was used to evaluate species presence (Newmaster *et al.* 2005). This sampling technique was used at 16 sites, shown with corresponding geographic coordinates and habitat descriptions in Table 1. As many microhabitats as possible were examined in each site: e.g., a variety of tree species, rocks, forest floor. Most sites were visited on only one occasion; however, sites I and II, Campground and Red Pine (*Pinus resinosa* Aiton) forest, were visited more than once. All collections have been deposited at the National Herbarium of Canada (CANL) at the Canadian Museum of Nature Natural Heritage Campus in Gatineau, Quebec.

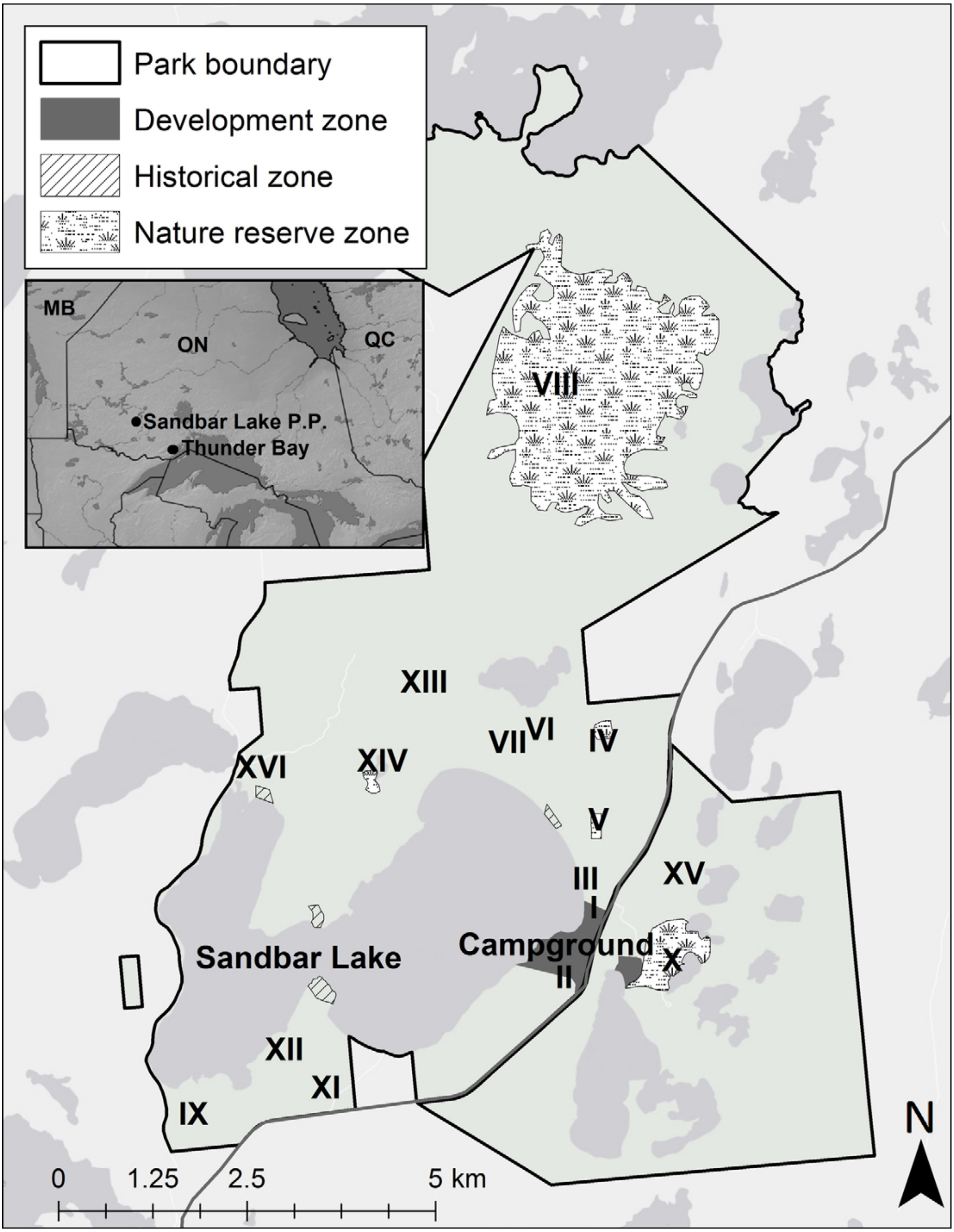


FIGURE 1. Sandbar Lake Provincial Park, showing designated zones and sampling sites.

Identification

All specimens were identified using standard techniques outlined by Brodo *et al.* (2001), including the use of microscopy and chemical spot tests. When necessary, an ultraviolet light chamber was used for additional chemical examination. Thin-layer chromatography was also used in further chemical analysis, following Orange and White (2001) using solvents A, B′, and C.

TABLE 1. Location and description of collection sites.

Site	Location	Latitude (°N)	Longitude (°W)	Habitat description
I	Campground	49.46517	91.55536	Campsites near Sandbar Lake with small, dense patches of forest between them, connected by gravel roadways.
II	Red Pine forest	49.46503	91.55407	Red Pine (*Pinus resinosa*)-dominated forest naturally regenerated after fire, with young Balsam Fir (*Abies balsamea*) in the understorey, adjacent to the campground.
III	Beach forest	49.47220	91.54784	Mixed-wood forest, dominated by Balsam Fir and Balsam Poplar (*Populus balsamifera*), adjacent to sandy beach along the eastern shoreline of Sandbar Lake.
IV	Mixed-wood forest*	49.48950	91.53708	Deciduous-dominated mixed-wood forest with abundant fallen logs and herbaceous groundcover.
V	Jack Pine forest*	49.47955	91.54389	Jack Pine (*Pinus banksiana*)-dominated forest with exposed bedrock, young Black Spruce (*Picea mariana*) understorey, and lichens and mosses forming large thick mats.
VI	Boulder cave	49.48659	91.54849	Caves formed by large boulders leaning against a bedrock cliff, with high humidity and limited light exposure.
VII	Cliff and exposed bedrock	49.48638	91.55068	Exposed bedrock and steep cliffs with mixed-wood forest surrounding the base.
VIII	Treed fen*	49.52254	91.55263	Large, humid, lowland area resulting from paludification, with sporadic Tamarack (*Larix laricina*) and Black Spruce, with sphagnum moss groundcover and a high diversity of wetland vascular plants.
IX	Forest at South Agimak River	49.47526	91.52035	Dense, late-successional, mixed-wood forest with little understorey vegetation, near the South Agimak River and associated wetland.
X	Silhouette trail*	49.46295	91.53601	Mixed-wood forest along Silhouette trail/roadway, with a vegetative community resulting from past resource extraction.
XI	Clearing at Flayers Road	49.45061	91.59702	Treeless clearing along gravel road (Flayers Road) surrounded by Jack Pine, with sandy soil, fallen logs, and exposed bedrock.
XII	Flayers Road fen	49.45850	91.60091	Fen, near Flayers Road, dominated by Tamarack and Black Spruce, with moss covering the ground and some pools of standing water.
XIII	Forest north of Sandbar Lake	49.49306	91.56565	Mixed-wood forest with highly variable structure and age, located between the northeastern shoreline and 1 km north of Sandbar Lake.
XIV	Shoreline of Bog Lake*	49.48997	91.58136	Sedge mat with abundant Tamarack and Black Spruce, few shrubs, and many dead standing trees, surrounding the small lake.
XV	Ontario rangers road	49.47526	91.52035	Road re-colonized by forest dominated by young Balsam Fir, between two lakes to the north and south of the road.
XVI	North Agimak River	49.49087	91.60870	River with exposed and mossy boulders, surrounded by dense mixed-wood forest.

*Indicates the sampling sites in each of the park's five nature reserve zones.

Sorensen–Dice coefficient of similarity

To compare the lichen community at Sandbar Lake Provincial Park with two other locations in Ontario, we used the Sorensen–Dice coefficient of similarity (Dice 1945; Sorensen 1948). This coefficient is calculated as follows:

$$2A/(2A + B + C)$$

where A is the total number of species at Sandbar Lake Provincial Park and another location (e.g., location 2), B is the number of species at Sandbar Lake Provincial Park that are absent from location 2, and C is the number of species at location 2 that are absent from Sandbar Lake Provincial Park (Dice 1945; Sorensen 1948).

The two locations included for comparison, Awenda Provincial Park (McMullin and Lendemer 2016) and Sandbanks Provincial Park (McMullin and Lewis 2014), are study sites with comparable search efforts nearest to Sandbar Lake Provincial Park.

Conservation status

We report the conservation status (S ranks) for each species recorded in the park. The Ontario Natural History Information Centre (NHIC) assigns these non-legal provincial conservation status ranks to species in Ontario, based on guidelines set out by NatureServe (2018). If adequate information is known about the presence of a species in the province, then a rank between 1 and 5 is assigned. An S rank of 1 denotes a species that is considered critically imperilled, 2 means imperilled, 3 is vulnerable, 4 is apparently secure, and 5 is secure. Other ranks include NR meaning not ranked, U meaning unrankable (because of lack of information), and ? meaning the rank is uncertain. Species with a rank of S1 to S3 are provincially tracked. Observations of these species in the province are considered remarkable and are reported to the NHIC. Species with a rank above S3 or are unranked are not provincially tracked and are considered to be fairly common within the province.

Results

We located 139 species in 69 genera at Sandbar Lake Provincial Park (see Annotated species list): 54 (39%) species are crustose, 52 (37%) are foliose, and 33 (24%) are fruticose. For 122 species (88%), green algae are the primary photobiont; for 13 (9%), cyanobacteria are the primary photobiont; and four (3%) are non-lichenized allied fungi.

Sorensen–Dice coefficient of similarity

Sorensen–Dice coefficients of similarity were determined for each of the two other provincial parks and Sandbar Lake Provincial Park. The lichen community at Sandbar Lake Provincial Park is more similar to that of Sandbanks Provincial Park (coefficient value of 0.65) than to that of Awenda Provincial Park (coefficient value of 0.49). The number of species (*n* = 139) at Sandbar Lake Provincial Park was also more similar to the number found at Sandbanks (*n* = 122) than Awenda (*n* = 203). Sandbar Lake Provincial Park is considerably larger than both other provincial parks in this comparison (Table 2).

Conservation status

Of the 139 species discovered at Sandbar Lake Provincial Park, 125 have been assigned conservation status ranks. Seven of these species have a conservation status rank between S1 and S3 (critically imperilled, imperilled, vulnerable) and are provincially tracked. One species is listed as S1S2: *Arthrosporum populorum* A. Massl.; two are S2: *Bacidia laurocerasi* (Delise ex Duby) Zahlbr. and *Ochrolechia pseudopallescens* Brodo; two are S2S3: *Calicium parvum* Tibell and *Chaenothecopsis pusilla* (Ach.) A.F.W. Schmidt; and two are S3: *Cetrelia chicitae* (W.L. Culb.) W.L. Culb. & C.F. Culb. and *Melanelixia glabratula* (Lamy) Sandler & Arup. The non-tracked species include 19 that are S4, seven that are S4?, 27 that are S4S5, 65 that are S5, nine that are not ranked, and five that are unrankable.

Annotated species list

This list is organized alphabetically by genus and species, and taxonomic authorities follow the 23rd version of the North American Lichen Checklist (Esslinger 2018), as does most of the nomenclature. Any differences between this list and Esslinger's reflects the opinion of the authors. Substrate follows species name and taxonomic authorities. Roman numerals indicate the collection site (Table 1). Provincial conservation status rank follows the collection site. Non-lichenized fungi typically treated with lichens are preceded by a dagger (†).

Acarospora fuscata (Schrad.) Arnold—Saxicolous. VII. S5

Amandinea punctata (Hoffm.) Coppins & Scheid.—Corticolous on Balsam Fir (*Abies balsamea* (L.) Miller). I. S5.

Arthonia sp.—Corticolous on a snag. I. SNR.

Arthrosporum populorum A. Massl.—Corticolous on a fallen Trembling Aspen (*Populus tremuloides* Michaux). XIII. S1S2.

Athallia pyracea (Ach.) Arup, Frödén & Søchting—Corticolous on a fallen *P. tremuloides*. XIII. SU.

Bacidia laurocerasi (Delise ex Duby) Zahlbr.—Corticolous. II. S2.

Baeomyces rufus (Huds.) Rebent.—Terricolous on sandy soil. IX. S4S5.

Biatora pycnidiata Printzen & Tønsberg—Corticolous on *A. balsamea* and Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh). IV, XV. SNR.

Biatora vernalis (L.) Fr.—Bryicolous. I. S5.

Bryoria sp.—Corticolous on *P. mariana* and dead *P. mariana*. I, XII, VIII. SNR.

TABLE 2. Sorensen–Dice coefficient of similarity between Sandbar Lake Provincial Park community and two other park communities in Ontario.

Provincial park	Approximate distance from Sandbar Lake Provincial Park	Area (ha)	No. of species	Sorensen–Dice coefficient
Sandbar Lake	0	8053	139	1
Awenda	1018 km southeast	2915	203	0.49
Sandbanks	1254 km southeast	1551	122	0.65

Bryoria furcellata (Fr.) Brodo & D. Hawksw.—Corticolous on *P. mariana* and Jack Pine (*Pinus banksiana* Lambert). I, III, IX, XIII, XIV. S5.

Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw.—Corticolous on *A. balsamea*. XII. S5.

Bryoria kockiana Velmala, Myllys & Goward—Corticolous on *A. balsamea* and White Spruce (*Picea glauca* (Moench) Voss. I. S4.

Bryoria trichodes subsp. *trichodes* (Michx.) Brodo & D. Hawksw.—Corticolous on *P. mariana*. XII, XIV. S5.

Buellia erubescens Arnold—Corticolous on *A. balsamea* and Paper Birch (*Betula papyrifera* Marshall). I, X, XV. S5.

Calicium parvum Tibell—Corticolous on *P. resinosa*. II. S2S3.

Calicium trabinellum (Ach.) Ach.—Lignicolous on a snag. X. S4S5.

Caloplaca arenaria (Pers.) Müll. Arg.—Saxicolous. VII. S5.

Caloplaca cerina (Ehrh. ex Hedwig) Th. Fr.—Corticolous on a fallen *P. tremuloides*. XIII. S5.

Caloplaca chrysophthalma Degel.—Corticolous on a fallen *P. tremuloides*. I, IV. S4?

Candelariella lutella (Vainio) Räsänen—Corticolous on *Alnus* sp. and on a fallen *P. tremuloides*. I, XIII. SNR.

Candelariella vitellina (Hoffm.) Müll.—Saxicolous. VII. S5.

Carbonicola anthracophila (Nyl.) Bendiksby & Timdal—Lignicolous on burned wood. II. S4?

Cetrelia chicitae (W.L. Culb.) W.L. Culb. & C.F. Culb.—Saxicolous. XVI. S3?

Chaenotheca brunneola (Ach.) Müll. Arg.—Lignicolous on a snag. II. S4.

Chaenotheca chrysocephala Turner ex Ach.) Th. Fr. —Corticolous on *P. mariana*. XIII. S4.

Chaenotheca ferruginea (Turner ex Sm.) Mig.—Corticolous on a charred conifer and *P. resinosa*. II, X. S4.

†*Chaenothecopsis nana* Tibell—Corticolous on *P. mariana*. XIII. SU.

†*Chaenothecopsis pusilla* (Ach.) A.F.W. Schmidt—Corticolous on *P. resinosa*. II. S2S3.

Chrysothrix caesia (Flot.) Körb—Corticolous on *B. papyrifera*. I. S5.

Cladonia botrytes (K.G. Hagen) Willd.—Lignicolous on dead *P. mariana*. VIII. S5.

Cladonia cenotea (Ach.) Schaerer—Lignicolous on rotting wood. II. S5.

Cladonia cornuta (L.) Hoffm.—Terricolous. XI. S4S5.

Cladonia cristatella Tuck.—Lignicolous on a rotted stump; saxicolous; terricolous. I, V. S5.

Cladonia deformis (L.) Hoffm.—Terricolous on thin soil. V. S5.

Cladonia digitata (L.) Hoffm.—Lignicolous on rotting wood and a stump. I, II. S4S5.

Cladonia macilenta var. *macilenta* Hoffm.—Terricolous. XI. S5.

Cladonia merochlorophaea Asah.—Terricolous. I. S4.

Cladonia mitis Sandst.—Saxicolous. V. S5.

Cladonia ochrochlora Flörke—Lignicolous on rotting wood; terricolous. II, XI. S5.

Cladonia parasitica (Hoffm.) Hoffm.—Lignicolous on a log. II. S4.

Cladonia phyllophora Hoffm.—Terricolous. V, XI. S5.

Cladonia pyxidata (L.) Hoffm.—Terricolous. I. S5.

Cladonia rangiferina (L.) F.H. Wigg.—Saxicolous on bedrock. V. S5.

Cladonia stellaris (Opiz) Pouzar & Vězda—Saxicolous on bedrock. V. S5.

Cladonia uncialis (L.) F.H. Wigg.—Terricolous. V. S5.

Cladonia verticillata (Hoffm.) Schaer.—Terricolous. XI. S4S5.

Dermaatocarpon luridum (With.) J.R. Laundon—Saxicolous. XVI. S5.

Dimelaena oreina (Ach.) Norman—Saxicolous. VII. S4.

Evernia mesomorpha Nyl.—Corticolous on *A. balsamea, P. mariana*, and a snag. I, II, III. S5.

Flavoparmelia caperata (L.) Hale—Corticolous on *B. papyrifera*; saxicolous. I, VI. S5.

Flavopunctelia flaventior (Stirt.) Hale—Corticolous on *A. balsamea*. I. S5.

Fuscidea arboricola Coppins & Tønsberg—Corticolous on *A. balsamea*. XV. SU.

Heterodermia speciosa (Wulfen) Trevisan—Bryicolous. I. S4S5.

Hypogymnia incurvoides Rass.—Corticolous on *P. mariana*. XIV. S4.

Hypogymnia physodes (L.) Nyl.—Corticolous on *A. balsamea* and *Picea* sp. I, II, IV, XII, XV. S5.

Hypogymnia tubulosa (Schaer.) Hav.—Corticolous on *A. balsamea* and *Picea* sp. I, XIII. S4?

Imshaugia aleurites (Ach.) S.F. Meyer—Corticolous on a burned snag and dead Eastern White Cedar (*Thuja occidentalis* L.). II, VIII. S5.

Imshaugia placorodia (Ach.) S.F. Meyer—Corticolous on a *P. mariana* log. IX. S4S5.

Julella fallaciosa (Arnold) R.C. Harris—Corticolous on *B. papyrifera*. I. S4?

Lasallia papulosa (Ach.) Llano—Saxicolous. VI. S5.

Lecanora albella var. *rubescens* (Imshaug & Brodo)—Corticolous on *B. papyrifera*. XIII. SNR.

Lecanora allophana (Ach.) Nyl.—Corticolous on a snag. I. S5.

Lecanora allophana f. *sorediata* Vain.—Corticolous on *B. papyrifera* and *P. tremuloides*. I, IX. S5.

Lecanora circumborealis Brodo & Vitik.—Corticolous on Tamarack (*Larix laricina* (Du Roi) K. Koch). VIII. S5.

Lecanora polytropa (Ehrh.) Rabenh.—Saxicolous. VII. S5.

Lecanora pulicaris (Pers.) Ach.—Corticolous on *B. papyrifera*; lignicolous on a *Pinus* sp. cone. I, XIII. S5.

Lecanora symmicta (Ach.) Ach.—Corticolous on *B. papyrifera* and Eastern White Pine (*Pinus strobus* L.). I, X. S5.

Lecanora thysanophora R.C. Harris—Corticolous on *A. balsamea* and a deciduous tree. XIII. S4S5.

Lepra trachythallina (Erichsen) Lendemer & R.C. Harris—Corticolous on *T. occidentalis*. IV. S4.

Lepraria finkii (B. de Lesd.) R.C. Harris—Corticolous on *T. occidentalis*; saxicolous. VI, XVI. S5.

Leptogium cyanescens (Rabenh.) Körb.—Saxicolous on a mossy boulder. I, XVI. S5.

Leptorhaphis epidermidis (Ach.) Th. Fr.—Corticolous on *B. papyrifera*. IX. S4.

Lobaria pulmonaria (L.) Hoffm.—Corticolous on *P. tremuloides*. VII. S4.

Melanelixia glabratula (Lamy) Sandler & Arup—Corticolous on dead *P. strobus*. XIV. S3.

Melanelixia subaurifera (Nyl.) O. Blanco *et al.*—Corticolous on *B. papyrifera*; saxicolous. I, X. S5.

Melanohalea exasperatula (Nyl.) O. Blanco *et al.*—Corticolous on *Alnus* sp. I. S4S5.

Mycobilimbia berengeriana (A. Massal.) Hafellner & V. Wirth—Terricolous. I. S4S5.

Mycoblastus sanguinarius (L.) Norman—Corticolous on *P. mariana*. VIII. S4S5.

Mycocalicium subtile (Pers.) Szatala—Lignicolous on a snag. I, II. S4S5.

Myelochroa glabina (Ach.) Elix & Hale—Corticolous on *B. papyrifera*. I. S4S5.

Nephroma helveticum Ach.—Saxicolous. XVI. S4S5.

Nephroma parile (Ach.) Ach.—Saxicolous on a mossy rock; terricolous. I, XVI. S4S5.

Nephroma resupinatum (L.) Ach.—Corticolous on Mountain Maple (*Acer spicatum* Lamarck); saxicolous on a mossy rock; terricolous. I, XIII. S4.

Ochrolechia arborea (Kreyer) Almb.—Corticolous on *B. papyrifera* and *P. mariana*. I, XIV. S4S5.

Ochrolechia pseudopallescens Brodo—Corticolous on *P. mariana* and dead *P. mariana*. VIII, XIV. S2.

Parmelia squarrosa Hale—Corticolous on *B. papyrifera*. I, XIII. S5.

Parmelia sulcata Taylor—Corticolous on *B. papyrifera* and on a snag. II, X. S5.

Parmeliopsis capitata R.C. Harris ex J.W. Hinds & P.L. Hinds—Corticolous on a conifer, *L. laricina, P. mariana,* and dead *P. strobus*. I, V, VIII, XII. S5.

Parmeliopsis hyperopta (Ach.) Arnold—Corticolous on dead *P. strobus* and a snag. I, V. S5.

Peltigera aphthosa (L). Willd.—Terricolous on mossy soil. II. S5.

Peltigera canina (L.) Willd.—Lignicolous on a rotted log; terricolous on the base of a rock. I, IV. S5.

Peltigera elisabethae Gyeln.—Terricolous on sandy soil. I, III, IV. S5.

Peltigera evansiana Gyeln.—Bryicolous on a mossy boulder. XVI. S4.

Peltigera extenuata (Nyl. ex Vainio) Lojka—Saxicolous and terricolous. I, XIII, XVI. S4?

Peltigera horizontalis (Huds.) Baumg.—Lignicolous on a rotted log; saxicolous; terricolous on the base of a rock. I, IV, XIII. S5.

Peltigera malacea (Ach.) Funck—Terricolous. X. S4S5.

Peltigera neckeri Hepp ex Müll. Arg.—Saxicolous. XI. S5.

Peltigera polydactylon (Neck.) Hoffm.—Saxicolous. I. S5.

Peltigera rufescens (Weiss) Humb.—Terricolous. I. S5.

Pertusaria rubefacta Erichsen—Corticolous on *A. spicatum*. XIII. S4?

Phaeophyscia adiastola (Essl.) Essl.—Saxicolous. I, XVI. S4.

Phaeophyscia hirtella Essl.—Corticolous on *P. tremuloides*. I. S4.

Phaeophyscia pusilloides (Zahlbr.) Essl.—Bryicolous; corticolous on *A. spicatum* and *P. tremuloides*. I, XIII. S5.

Physcia adscendens (Fr.) H.Olivier—Corticolous on *Alnus* sp.; saxicolous. I. S5.

Physcia caesia (Hoffm.) Hampe ex Fürnr.—Saxicolous. I. S4S5.

Physcia millegrana Degel.—Saxicolous. I. S5.

Plasmatia tuckermanii (Oakes) W.L. Culb. & C.F. Culb.—Corticolous. XII. S4S5.

Polysporina simplex (Taylor) Vězda—Saxicolous. VII. S4S5.

Porpidia crustulata (Ach.) Hertel & Knoph—Saxicolous. XIII. S5.

Protoparmelia hypotremella Herk, Spier & V. Wirth—Corticolous on dead *T. occidentalis*. VIII. SNR.

Punctelia rudecta (Ach.) Krog.—Corticolous on *A. balsamea*. I. S5.

Pyxine sorediata (Ach.) Mont.—Saxicolous. VI. S5.

Ramalina dilacerata (Hoffm.) Hoffm.—Corticolous on *Picea* sp. I, XIII. S4.

Ramalina intermedia (Delise ex Nyl.) Nyl.—Saxicolous on a boulder. VII. S5.

Rhizocarpon concentricum (Davies) Beltr.—Saxicolous. VII. SNR.

Rhizocarpon timdalii Ihlen & Fryday—Saxicolous. VII. SNR.

Rinodina freyi H. Magn.—Corticolous on a fallen *P. tremuloides*. XIII. S4S5.

Scoliciosporum chlorococcum (Stenh.) Vězda—Lignicolous on a *Pinus* sp. cone. I. S5.

†*Sphinctrina anglica* Nyl.—Lichenicolous on *P. hypotremella* on *T. occidentalis*. VIII. S4.

†*Stenocybe pullatula* (Ach.) Stein—Corticolous on *Alnus* sp. I. SU.

Stereocaulon dactylophyllum Flörke—Saxicolous. I. S4.

Stereocaulon grande (H.Magn.) H. Magn.—Saxicolous. XVI. S4.

Stereocaulon tomentosum Fr.—Terricolous on mossy soil and on sandy soil. IX, X, XI, XVI. S4S5.

Trapeliopsis granulosa (Hoffm.) Lumbsch—Terricolous on sandy soil. III. S5.

Tuckermanopsis americana (Sprengel) Hale—Corticolous on *B. papyrifera* and on a snag. II, XIII. S5.

Tuckermanopsis sepincola (Ehrh.) Ach.—Corticolous on *L. laricina*. VIII. S5.

Umbilicaria deusta (L.) Baumg.—Saxicolous. VII. S5.

Umbilicaria mammulata (Ach.) Tuck.—Saxicolous. III, VI. S4S5.

Umbilicaria muehlenbergii (Ach.) Tuck.—Saxicolous on a boulder. V, VII. S4S5.

Usnea cavernosa Tuck.—Corticolous on *A. balsamea* and on *P. mariana*. I, III, VIII, XII. S4S5.

Usnea dasopoga (Ach.) Nyl.—Corticolous on a conifer. XII. S5.

Usnea hirta (L.) Weber ex F.H. Wigg.—Corticolous on a snag. II. S5.

Usnea lapponica Vain.—Corticolous on a snag. II. S4?

Usnea subfloridana Stirt.—Corticolous on dead *P. mariana*. VIII. S4S5.

Vulpicida pinastri (Scop.) J.-E. Mattson & M.J. Lai—Corticolous on burned wood and on *P. mariana*; lignicolous on rotting wood. II, V, VIII, XV, XIV. S5.

Xanthomendoza hasseana (Räsänen) Schøting, Kärnefelt & S.Y. Kondr.—Corticolous on *P. tremuloides*. XIII. S5.

Xanthoparmelia plittii (Gyeln.) Hale—Saxicolous. VII. S4S5.

Xanthoparmelia viriduloumbrina (Gyeln.) Lendemer—Saxicolous. VII, XVI. SU.

Discussion

Sandbar Lake Provincial Park hosts a rich diversity of lichens, including many species that are rare in the region and province. For example, *A. populorum*, of which we made a single collection, is only known from nine collections in Ontario, of which only one is in northwestern Ontario (MIN 879779). This species is almost exclusively collected from the bark of Trembling Aspen, as it has been from Sandbar Lake Provincial Park. Although it is provincially tracked, this species is inconspicuous and may be overlooked in the province. Three species, *B. laurocerasi*, *C. parvum,* and *O. pseudopallescens*, are also considered rare or very rare in southern Ontario (Wong and Brodo 1992). Within the province, *B. laurocerasi* has been collected mainly from the area directly surrounding the Great Lakes. Given the distance of this provincial park from this location (~200 km northwest), this observation is notable. Similarly, *C. chicitae* is only known from near Lake Superior in Ontario (Brodo *et al.* 2001). Geographic patterns found in previous reports of these species are likely affected by past collection efforts being almost exclusively in the area surrounding the Great Lakes, solidifying the need for further study in inland areas of northwestern Ontario. Overall, the species composition of the community found at Sandbar Lake Provincial Park reflects the boreal forest in the region; representative species include *P. aphthosa*, *V. pinastri*, and 17 species in the genus *Cladonia* (Brodo *et al.* 2001). The most common species in Sandbar Lake Provincial Park were *B. furcellata* and *P. canina*, which we collected six times each, at two and six collection sites, respectively. Both species are reported frequently from the province, as well.

Although the northwest region of Ontario is known for a high diversity of lichens, previously, only one study has been geographically focussed (an intensive study within a relatively small, delineated boundary such as within a provincial park of a few hundred ha as opposed to within the entire province or not in a delineated area) in the region, on the Slate Islands (C. Wetmore unpubl. data accessed through CNALH). Focussed studies in areas with delineated boundaries, such as ours, are important for establishing baseline data. Lichens are effective indicators of climate change and ecological integrity and, with a sound baseline, can be used to monitor changes in the local environment over time (McMullin *et al.* 2017).

Coefficients generated through a Sorensen–Dice comparison showed a low level of similarity between the lichen community at Sandbar Lake Provincial Park and two other provincial parks in Ontario. Given the distance and difference in climate and forest types among the parks, this result was not surprising. Awenda and Sandbanks Provincial Parks are over 1000 km southeast of Sandbar Lake Provincial Park and both border large freshwater bodies (Georgian Bay and Lake Ontario). Sandbar Lake is located within the boreal forest region, while Awenda and Sandbanks are in the Great Lakes–St. Lawrence forest region, which has a higher diversity of deciduous trees. Both Awenda and Sandbanks Provincial Parks are smaller than our study area. Although the size of Sandbar Lake Provincial Park would likely relate to higher diversity of lichen species, access to most parts of this park are limited, with few roads and trails outside the campground. Access by trails and roads is also limited in some areas of Sandbanks; however, the small size of the park may make it easier to sample a greater proportion of its area. In contrast, Awenda has trail networks that can be used to access most portions of the park. Nonetheless, these parks were selected because they were the nearest areas with similar search efforts (McMullin and Lewis 2014; McMullin and Lendemer 2016).

Sandbar Lake Provincial Park is surrounded by resource extraction operations, especially timber harvesting. The park, therefore, provides protection for important habitats in the area. Expansions to the park have also facilitated increased ecosystem representativeness, and over time there is potential for mature or old-growth forests to develop—a habitat that is rare in this region (Ontario Parks 2012). Much of the current area of Sandbar Lake has experienced a variety of disturbances in recent history, including natural processes, such as wildfire, and anthropogenic ones, such as industrial-scale timber harvesting (Ontario Parks 2012). Forest management practices in northern Ontario have been shown to have direct effects on lichen community composition (e.g., herbicide contact, loss of microhabitats) and indirect effects (e.g., light exposure, tree species presence, changes in structural diversity, changes to available moisture; McMullin *et al.* 2013). As a result, previous disturbances in the park will have influenced the lichen biota present now. Our baseline data provide the first foundation that can be used to acknowledge and monitor future changes to the lichen community. Our results can also be used to compare with lichen communities on lands outside the park to better understand the effects on lichen biodiversity of resource extraction in the region.

Author Contributions

Writing – Original Draft Preparation: H.R.D. and R.T.M.; Writing – Review & Editing: R.T.M. and H.R.D.; Conceptualization: R.T.M.; Formal Analysis: H.R.D.; Investigation: H.R.D. and R.T.M.; Methodology: H.R.D. and R.T.M.; Project Administration: H.R.D. and R.T.M.; Resources: H.R.D. and R.T.M.

Acknowledgements

We thank the Ministry of Natural Resources and Forestry, Ontario Parks, and the staff of Sandbar Lake Provincial Park for allowing this study to take place and for providing accommodations and natural heritage information to ensure that fieldwork could be conducted with the greatest efficiency.

Literature Cited

Ahti, T., and J. Crowe. 1995. Additions to the lichens of Thunder Bay district, Ontario. Evansia 12: 21–23.

Brodo, I.M., S.D. Sharnoff, and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven, Connecticut, USA.

Crowe, J. 1994. The lichens of Thunder Bay district, Ontario, Canada. Evansia 11: 62–75.

Dice, L.R. 1945. Measures of the amount of ecologic association between species. Ecology 26: 297–302. https://doi.org/10.2307/1932409

Esslinger, T.L. 2018. A cumulative checklist for lichen-forming, lichenicolous, and allied fungi of the continental United States and Canada, version 22. Dr. Theodore L. Esslinger, North Dakota State University, Fargo, North Dakota, USA. Accessed 15 November 2018. https://www.ndsu.edu/pubweb/~esslinge/chcklst/chcklst7.htm.

Lavoie, M., D. Paré, N.J. Fenton, A. Groot, and K. Taylor. 2005. Paludification and management of forested peatlands in Canada: a literature review. Environmental Reviews 13: 21–50. https://doi.org/10.1139/A05-006

McMullin, R.T., K. Drotos, D. Ireland, and H. Dorval. 2018. Diversity and conservation status of lichens and allied fungi in the Greater Toronto Area: results from four years of the Ontario BioBlitz. Canadian Field-Naturalist 132: 394–406. https://doi.org/10.22621/cfn.v132i4.1997

McMullin, R.T., and J.C. Lendemer. 2016. Lichens and allied fungi of Awenda Provincial Park, Ontario: diversity and conservation status. American Midland Naturalist 176: 1–19. https://doi.org/10.1674/0003-0031-176.1.1

McMullin, R.T., and C.J. Lewis. 2013. New and interesting lichens from Ontario, Canada. Opuscula Philolichenum 12: 6–16. Accessed 21 September 2019. http://sweetgum.nybg.org/science/op/biblio_list.php?BucVolume_tab=12.

McMullin, R.T., and C.J. Lewis. 2014. The unusual lichens and allied fungi of Sandbanks Provincial Park, Ontario. Botany 92: 85–92. https://doi.org/10.1139/cjb-2013-0227

McMullin, R.T., J. Maloles, and S.G. Newmaster. 2015. New and interesting lichens from Ontario, Canada II. Opuscula Philolichenum 14: 93–108. Accessed 21 September 2019. http://sweetgum.nybg.org/science/op/biblio_list.php?BucVolume_tab=14.

McMullin, R.T., I. Thompson, and S. Newmaster. 2013. Lichen conservation in heavily managed boreal forests. Conservation Biology 27: 1020–1030. https://doi.org/10.1111/cobi.12094

McMullin, R.T., D. Ure, M. Smith, H. Clapp, and Y.F. Wiersma. 2017. Ten years of monitoring air quality and ecological integrity using field-identifiable lichens at Kejimkujik National Park and National Historic Site in Nova Scotia, Canada. Ecological Indicators 81: 214–221. https://doi.org/10.1016/j.ecolind.2017.05.069

Natureserve. 2018. National and subnational conservation status definitions. NatureServe, Arlington, Virginia, USA. Accessed 16 April 2018. http://explorer.natureserve.org/nsranks.htm.

Newmaster, S.G., R.J. Belland, A. Arsenault, D.H. Vitt, and T.R. Stephens. 2005. The ones we left behind: comparing plot sampling and floristic habitat sampling for estimating bryophyte diversity. Diversity and Distributions 11: 57–72. https://doi.org/10.1111/j.1366-9516.2005.00123.x

Ontario. 2006. Provincial Parks and Conservation Reserves Act, 2006, S.O. 2006, c.12. Government of Ontario, Toronto, Ontario, Canada. Accessed 24 May 2018. https://www.ontario.ca/laws/statute/06p12.

Ontario. 2015. Ontario Department of Lands and Forests: history and function. Ontario Ministry of Government and Consumer Services, Toronto, Ontario, Canada. Accessed 14 April 2018. https://tinyurl.com/ybke3veu.

Ontario. 2017. Ontario's parks and protected areas. Ontario Ministry of Natural Resources and Forestry, Toronto, Ontario, Canada. Accessed 20 April 2018. https://www.ontario.ca/page/ontarios-parks-and-protected-areas.

Ontario Parks. 2012. Sandbar Lake park management plan. Ministry of Natural Resources and Forestry, Toronto, Ontario, Canada. Accessed 21 September 2019. https://www.ontario.ca/page/sandbar-lake-provincial-park-management-plan.

Orange, P.W., and F.J. White. 2001. Microchemical Methods for the Identification of Lichens. British Lichen Society. London, United Kingdom.

Sørensen, T. 1948. A method for establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation on Danish commons. Biologiske Skrifter Kongelige Danske Videnskabernes Selskab 5: 1–34. Accessed 21 September 2019. http://www.royalacademy.dk/Publications/High/295_S%C3%B8rensen,%20Thorvald.pdf.

Wetmore, C.M. 1981. Lichens of Voyageurs National Park, Minnesota. Bryologist. 84: 482–491. https://doi.org/10.2307/3242555

Wong, P., and I. Brodo. 1992. The lichens of southern Ontario, Canada. Syllogeus 69. Canadian Museum of Nature, Ottawa, Ontario, Canada.

SUPPLEMENTARY MATERIAL:

Appendix S1. Collection details of specimens.

Received 7 January 2019
Accepted 14 October 2019

The Canadian Field-Naturalist

Do turtle warning signs reduce roadkill?

David C. Seburn[1,*] and **Hannah McCurdy-Adams**[1,2]

[1]Canadian Wildlife Federation, 350 Michael Cowpland Avenue, Ottawa, Ontario K2M 2W1 Canada
[2]Current address: Wildlife Preservation Canada, 5420 Highway 6 North, Guelph, Ontario N1H 6J2 Canada
[*]Corresponding author: davids@cwf-fcf.org

Seburn, D.C., and H. McCurdy-Adams. 2019. Do turtle warning signs reduce roadkill? Canadian Field-Naturalist 133(3): 216–220. https://doi.org/10.22621/cfn.v133i3.2279

Abstract

Roadkill is a serious threat for many species of freshwater turtles. One of the most common road mitigation tools is wildlife warning signs to alert drivers. These warning signs have commonly been used for large mammals, although there is little evidence that they are effective in reducing roadkill. We tested the effectiveness of turtle warning signs at four known roadkill hotspots along a provincial highway in eastern Ontario and compared the results with four control sites on a nearby major road in a before-after-control-impact (BACI) study. We found 30 dead turtles in the four hotspots in 2017 before the signs were installed and 27 in 2018 after the signs were installed. The number of turtles killed on the road after the signs were installed did not change significantly ($\chi^2_1 = 1.1$, $P > 0.2$). Although turtle warning signs may alert some drivers, they should not be considered a replacement for more effective road mitigation tools, such as wildlife fencing and crossing structures.

Key words: Turtles; reptiles; road mitigation; wildlife signs; BACI design

Introduction

Roadkill is a major risk for many species of freshwater turtles (Gibbs and Shriver 2002; Steen and Gibbs 2004; Aresco 2005). It can lead to population declines (Gibbs and Shriver 2002) or male-biased populations from disproportionate roadkill of female turtles (Steen and Gibbs 2004; Dupuis-Désormeaux *et al.* 2017). Turtle populations are sensitive to any threat that increases the adult mortality rate (Congdon *et al.* 1993; Cunnington and Brooks 1996) and are extremely slow to rebound from declines (Keevil *et al.* 2018). As a result, roadkill can have a negative effect on turtle populations near roads (Rytwinski and Fahrig 2012).

Wildlife warning signs are one of the most commonly used tools to attempt to reduce roadkill, although there is little evidence that they are effective (Huijser *et al.* 2015). They can take the form of standard road signs as well as enhanced road signs with flashing lights or symbols (Pojar *et al.* 1975; Huijser *et al.* 2015). Most studies on the effectiveness of wildlife warning signs have found that they do not significantly reduce roadkill (e.g., Pojar *et al.* 1975; Coulson 1982; Bullock *et al.* 2011; but see Found and Boyce 2011). Most wildlife warning sign studies have focussed on large mammals, and we are unaware of any published studies on the effectiveness of standard wildlife signs on reducing turtle roadkill.

Given that all eight species of freshwater turtles that occur in Canada are listed as species at risk (Government of Canada 2019), it is important to assess whether turtle warning signs lead to a significant reduction in roadkill. To test the effectiveness of turtle signs (Figure 1) we examined roadkill before and after signs were installed at known hotspots in eastern Ontario. The importance of before-after-control-impact (BACI) research design has been stressed in evaluating the effectiveness of road mitigation strategies (Lesbarrères and Fahrig 2012); thus, we also compared roadkill rates with those on a control road over the same period.

Methods

As part of a larger project on turtle conservation, road surveys were conducted in eastern Ontario in 2017, and from those surveys four hotspots were identified. In spring 2018, the Ministry of Transportation installed standard turtle signs at these hotspots to help reduce roadkill. The four hotspots were located along provincial highway 15 north of Smiths Falls in Lanark County, along a section of road ~36 km in length (45.0°N, 76.0°W; Figure 2). Turtle warning signs were installed facing oncoming traffic at both ends of each hotspot. The signed road segments at each location averaged 1010 m (range 750–1675 m) in length. Daily traffic at these locations ranged from an

---

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

Figure 1. Example of turtle sign installed by the Ministry of Transportation along provincial highway 15 in eastern Ontario in May 2018. Photo: David Seburn.

annual average daily traffic of 4950 to 9400 vehicles (Ministry of Transportation 2019).

The four control road segments were located along Roger Stevens Drive east of Smiths Falls in Lanark County, along a section of road ~28 km in length (Figure 2). Highway 15 and Roger Stevens Drive intersect in Smiths Falls and the two roads are less than 25 km apart at any point. Each control segment was 1000 m in length and was selected based on the presence of at least four roadkilled turtles during 2017. Daily traffic in the four control segments varied by section, and ranged from an annual average daily traffic volume of 2860 to 3900 vehicles (roads department, Lanark County unpubl. data). Both the control and impact roads were paved, two-lane roads, with a posted speed limit of 80 km/h, although this limit was frequently exceeded by drivers (D.C.S. and H.M.-A. pers. obs.).

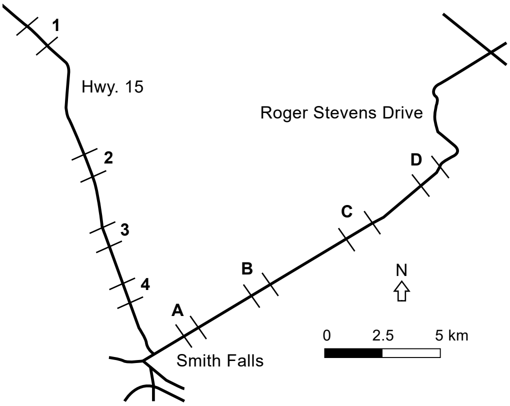


Figure 2. Location of two roads used in test of the effectiveness of turtle signs in eastern Ontario in 2017 and 2018. Roadkill hotspots were located along provincial highway 15 and are numbered 1–4. Turtle signs were installed at each end of all four hotspots in spring 2018. Four segments of road along Roger Stevens Drive, labelled A–D, served as control sections.

Road surveys were usually conducted with at least two people in the vehicle, but on some occasions, only one person conducted a road survey. Surveys were conducted during the day, typically from 0900 to 1600. Roads were surveyed by driving at ~50–60 km/h and scanning the road surface and road shoulders for dead turtles. The location of each roadkilled turtle was recorded using a handheld global positioning system unit (eTrex or eTrex 20×, Garmin Ltd., Olathe, Kansas, USA) with a spatial accuracy of at least ± 5 m. All dead turtles were removed from the road or road shoulder to prevent double counting on a subsequent survey. Road surveys were conducted approximately weekly from May until early September in 2017 and 2018. Both control and impact roads were typically surveyed on the same day.

The turtle warning signs were installed at the end of May 2018. Only dead turtles found in 2018 after the signs were installed were included in the analysis for both control and impact roads. Similarly, for 2017, only turtles from after the end of May were included so that the same period in both years was compared. In addition, all live turtles found on the road were excluded to examine only the effect of the road signs on turtle mortality. Live turtles made up <10% of all turtles found on roads. This is as expected, as, if turtles successfully cross a road, they are only present for a few minutes and would only be detected if the crossing coincided with the survey.

A chi-squared 2×2 contingency table was used to compare differences in the number of turtles in 2017 and 2018 for both roads (Minitab 8.3; Minitab Inc., State College, Pennsylvania, USA). The turtles from all four hotspots were pooled to prevent pseudoreplication (Hurlbert 1984) and the two years compared. Similarly the four control road segments were pooled and the two years compared. Statistical significance was defined as $P < 0.05$.

Results

Three species of turtles were found during surveys: Painted Turtle (*Chrysemys picta*), Snapping Turtle (*Chelydra serpentina*), and Blanding's Turtle (*Emydoidea blandingii*). We found 30 dead turtles in the four hotspots in 2017 before the signs were installed, and 27 in 2018 after the signs were installed. In the four control sections, we found 19 dead turtles in 2017 and 26 in 2018 after the signs were installed along the other road. There was no statistically significant difference in the number of turtles found before or after the signs were installed (Table 1; $\chi^2_1 = 1.1, P > 0.2$).

Discussion

Our road surveys likely did not detect all of the turtles killed on the roads, as they were conducted approximately weekly and turtle carcasses along roads may not persist that long (Santos *et al.* 2011). In addition, compared with walking surveys, driving surveys may fail to detect some carcasses (Santos *et al.* 2016). There is no reason to assume that carcass persistence or detectability would have differed significantly between the two years, and survey methods and survey frequency were the same in both years.

There were similar numbers of roadkilled turtles in the control road sections in both years, suggesting that roadkill numbers in the impact road sections would also have been similar in both years without the presence of any mitigation. Thus, any significant changes in roadkill numbers in the impact road sections between 2017 and 2018 should be attributable to the road signs. The lack of any significant decrease in roadkill indicates that the signs were not effective. A larger sample size would have increased our chances of detecting a statistically significant difference in the amount of roadkill, if one existed. Nonetheless, a decrease of only 10% in roadkill in 2018 from 2017 is not indicative of effective mitigation, as wildlife barriers and crossing structures can reduce roadkill by more than 90% (Dodd *et al.* 2004). Any road mitigation strategy that results in only a 10% reduction in roadkill should be considered a failure.

Wildlife warning signs are one of the most commonly installed road mitigation tools (Huijser *et al.* 2015), likely because of their low cost. However, despite their wide use, there is little evidence that such warning signs are effective at reducing roadkill. Few drivers are even aware of such warning signs. In one study, only 5–10% of drivers who were stopped 200 m after passing a warning sign were able to recall the sign (Drory and Shinar 1982).

For warning signs to be effective, they should result in drivers reducing their speed. Animated deer (*Odocoileus* spp.) warning signs have led to a reduction in speed, but only by <5 km/h (Pojar *et al.* 1975). Similarly, camel (*Camelus* spp.) warning signs have resulted in a decline in vehicle speed, but only by 3–7 km/h (Al-Ghamdi and AlGadhi 2004). Moose (*Alces americanus*) warning signs reduced driving speeds by only 1.5 km/h in a driving simulator (Jägerbrand *et al.* 2018). Greater speed reductions (~10 km/h) have occurred when deer carcasses were placed next to warning signs to emphasize the reality of the threat (Pojar *et al.* 1975). The effectiveness of animal warning signs on driving speed may also decline over time as drivers become habituated to the signs (Pojar *et al.* 1975; Khalilikhah and Heaslip 2017). Hence, it seems that even large-mammal warning signs may only have a small effect on vehicle speeds, even though collisions can result in the injury or death of the driver (e.g., Conover *et al.* 1995; Niemi *et al.* 2017).

Table 1. Results of 2×2 chi-squared contingency table comparing the observed number of dead turtles on the control and impact roads, both before and after turtle signs were installed.

Site	Roadkill (expected value)	
	Before	After
Impact (with signs)	30 (27.4)	27 (29.6)
Control (no signs)	19 (21.6)	26 (23.4)

Ultimately, the main issue is whether animal warning signs result in a reduction in collisions and roadkill. Deer crossing signs did not reduce the number of deer killed in Colorado (Pojar *et al.* 1975), but deer collisions were reduced, at least for the first year, after warning signs were installed at known hotspots in the city of Edmonton, Alberta (Found and Boyce 2011). Temporary, flashing warning signs installed at known deer migration locations resulted in a significant reduction in vehicle collisions, but this effect lessened during the second year of the study (Sullivan *et al.* 2004). Warning signs were also not effective at reducing roadkill of kangaroos in Australia (Coulson 1982; Shima *et al.* 2018), mammals and birds along a major road in South Africa (Bullock *et al.* 2011), or snakes in Illinois (Shepard *et al.* 2008).

Enhanced warning signs may be effective under some limited circumstances. Diamond-backed Terrapins (*Malaclemys terrapin*) suffer high rates of road mortality during nesting forays, which are associated with diurnal high tides (Crawford *et al.* 2014). Flashing warning signs installed but only activated for a 2-h period each day corresponding to the diurnal high tide during the nesting season, significantly reduced Diamond-backed Terrapin roadkill (Crawford *et al.* 2018). It is also possible that wildlife warning signs may be more effective along roads with a lower speed limit as speed limit is often positively correlated with roadkill (Farmer and Brooks 2012).

Although wildlife warning signs may not significantly reduce roadkill, they can still be valuable within a comprehensive mitigation strategy for public education and sending a message that roadkill of wildlife is a serious issue. Wildlife warning signs should not replace more effective road mitigation tools such as wildlife fencing and crossing structures (e.g., Dodd *et al.* 2004; Aresco 2005; Baxter-Gilbert *et al.* 2015; Crawford *et al.* 2017).

Acknowledgements

We are grateful to all of the Canadian Wildlife Federation summer staff who assisted with road surveys in 2017 and 2018: Mackenzie Burns, Hannah Delion, Brandon Holden, Holly Jasmine Long, and Georgia McLay. Thanks to the Ministry of Transportation for their concern about turtle roadkill and for installing the turtle signs. Financial support for this work came from the Rogers Foundation, the Canada Summer Jobs Program, and the CleanTech Internship program of Environment and Climate Change Canada. We are grateful to the reviewers for their comments, which helped us improve this paper.

Literature Cited

Al-Ghamdi, A.S., and S.A. AlGadhi. 2004. Warning signs as countermeasures to camel–vehicle collisions in Saudi Arabia. Accident Analysis and Prevention 36: 749–760. https://doi.org/10.1016/j.aap.2003.05.006

Aresco, M.J. 2005. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69: 549–560. https://doi.org/10.2193/0022-541x(2005)069[0549:mmtrhm]2.0.co;2

Baxter-Gilbert, J.H., J.L. Riley, D. Lesbarrères, and J.D. Litzgus. 2015. Mitigating reptile road mortality: fence failures compromise ecopassage effectiveness. PLoS ONE 10: e0120537. https://doi.org/10.1371/journal.pone.0120537

Bullock, K.L., G. Malan, and M.D. Pretorius. 2011. Mammal and bird road mortalities on the Upington to Twee Rivieren main road in the southern Kalahari, South Africa. African Zoology 46: 60–71. https://doi.org/10.1080/15627020.2011.11407479

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. Conservation Biology 7: 826–833. https://doi.org/10.1046/j.1523-1739.1993.740826.x

Conover M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sandborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23: 407–414.

Coulson, G.M. 1982. Road-kills of macropods on a section of highway in central Victoria. Wildlife Research 9: 21–26. https://doi.org/10.1071/wr9820021

Crawford, B.A., J.C. Maerz, N.P. Nibbelink, K.A. Buhlmann, T.M. Norton, and S.E. Albeke. 2014. Hot spots and hot moments of diamondback terrapin road-crossing activity. Journal of Applied Ecology 51: 367–375. https://doi.org/10.1111/1365-2664.12195

Crawford, B.A., C.T. Moore, T.M. Norton, and J.C. Maerz. 2017. Mitigating road mortality of diamond-backed terrapins (*Malaclemys terrapin*) with hybrid barriers at crossing hot spots. Herpetological Conservation and Biology 12: 202–211.

Crawford, B.A., C.T. Moore, T.M. Norton, and J.C. Maerz. 2018. Integrated analysis for population estimation, management impact evaluation, and decision-making for a declining species. Biological Conservation 222: 33–43. https://doi.org/10.1016/j.biocon.2018.03.023

Cunnington, D.C., and R.J. Brooks. 1996. Bet-hedging theory and eigenelasticity: a comparison of the life histories of loggerhead sea turtles (*Caretta caretta*) and snapping turtles (*Chelydra serpentina*). Canadian Journal of Zoology 74: 291–296. https://doi.org/10.1139/z96-036

Dodd, Jr., C.K., W.J. Barichivich, and L.L. Smith. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118: 619–631. https://doi.org/10.1016/j.biocon.2003.10.011

Drory, A., and D. Shinar. 1982. The effects of roadway environment and fatigue on sign perception. Journal of Safety Research 13: 25–32. https://doi.org/10.1016/0022-4375(82)90015-9

Dupuis-Désormeaux, M., V. D'Elia, C. Cook, J. Pearson, V. Adhikari, and S.E. MacDonald. 2017. Remarkable male bias in a population of midland painted turtles (*Chrysemys picta marginata*) in Ontario, Canada. Herpetological Conservation and Biology 12: 225–232.

Farmer, R.G., and R.J. Brooks. 2012. Integrated risk factors for vertebrate roadkill in southern Ontario. Journal of Wildlife Management 76: 1215–1224. https://doi.org/10.1002/jwmg.358

Found, R., and M.S. Boyce. 2011. Warning signs mitigate deer–vehicle collisions in an urban area. Wildlife Society Bulletin 35: 291–295. https://doi.org/10.1002/wsb.12

Gibbs, J.P., and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16: 1647–1652. https://doi.org/10.1046/j.1523-1739.2002.01215.x

Government of Canada. 2019. Species at risk public registry. Government of Canada, Ottawa, Ontario, Canada. Accessed 4 February 2019. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html.

Huijser, M.P., C. Mosler-Berger, M. Olsson, and M. Strein. 2015. Wildlife warning signs and animal detection systems aimed at reducing wildlife-vehicle collisions. Pages 198–212 *in* Handbook of Road Ecology. *Edited by* R. van der Ree, D.J. Smith, and C. Grilo. John Wiley & Sons, Chichester, United Kingdom. https://doi.org/10.1002/9781118568170.ch24

Hurlbert, S.H. 1984. Pseudoreplication and design of ecological field experiments. Ecological Monographs 54: 187–211. https://doi.org/10.2307/1942661

Jägerbrand, A.K., H. Antonson, and C. Ahlström. 2018. Speed reduction effects over distance of animal–vehicle collision countermeasures—a driving simulator study. European Transport Research Review 10: 40. https://doi.org/10.1186/s12544-018-0314-8

Keevil, M.G., R.J. Brooks, and J.D. Litzgus. 2018. Post-catastrophe patterns of abundance and survival reveal no evidence of population recovery in a long-lived animal. Ecosphere 9: e02396. https://doi.org/10.1002/ecs2.2396

Khalilikhah, M., and K. Heaslip. 2017. Improvement of the performance of animal crossing warning signs. Journal of Safety Research 62: 1–12. https://doi.org/10.1016/j.jsr.2017.04.003

Lesbarrères, D., and L. Fahrig. 2012. Measures to reduce population fragmentation by roads: what has worked and how do we know? Trends in Ecology & Evolution 27: 374–380. https://doi.org/10.1016/j.tree.2012.01.015

Ministry of Transportation. 2019. Ontario provincial highways traffic volumes on demand. Ministry of Transportation, Toronto, Ontario, Canada. Accessed 20 January 2019. http://www.raqsa.mto.gov.on.ca/techpubs/TrafficVolumes.nsf/tvweb?OpenForm& Seq=1.

Niemi, M., C.M. Rolandsen, W. Neumann, T. Kukko, R. Tiilikainen, J. Pusenius, E.J. Solberg, and G. Ericsson. 2017. Temporal patterns of moose–vehicle collisions with and without personal injuries. Accident Analysis & Prevention 98: 167–173. https://doi.org/10.1016/j.aap.2016.09.024

Pojar, T.M., R.A. Proscence, D.F. Reed, and T.N. Woodard. 1975. Effectiveness of lighted, animated deer crossing sign. Journal of Wildlife Management 39: 87–91. https://doi.org/10.2307/3800469

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

Santos, R.A.L., S.M. Santos, M. Santos-Reis, A.P. de Figueiredo, A. Bager, L.M. Aguiar, and F. Ascensão. 2016. Carcass persistence and detectability: reducing the uncertainty surrounding wildlife–vehicle collision surveys. PLoS ONE 11: e0165608. https://doi.org/10.1371/journal.pone.0165608

Santos, S.M., F. Carvalho, and A. Mira. 2011. How long do the dead survive on the road? Carcass persistence probability and implications for road-kill monitoring surveys. PLoS ONE 6: e25383. https://doi.org/10.1371/journal.pone.0025383

Shepard, D.B., M.J. Dreslik, B.C. Jellen, and C.A. Phillips. 2008. Reptile road mortality around an oasis in the Illinois corn desert with emphasis on the endangered Eastern Massasauga. Copeia 2008: 350–359. https://doi.org/10.1643/CE-06-276

Shima, A.L., D.S. Gillieson, G.M. Crowley, R.G. Dwyer, and L. Berger. 2018. Factors affecting the mortality of Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*) by vehicle strike. Wildlife Research 45: 559–569. https://doi.org/10.1071/WR17143

Steen, D.A., and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18: 1143–1148. https://doi.org/10.1111/j.1523-1739.2004.00240.x

Sullivan, T.L., A.F. Williams, T.A. Messmer, L.A. Hellinga, and S.Y. Kyrychenko. 2004. Effectiveness of temporary warning signs in reducing deer–vehicle collisions during mule deer migrations. Wildlife Society Bulletin 32: 907–915. https://doi.org/10.2193/0091-7648(2004)032[0907:eotwsi]2.0.co;2

Received 13 May 2019
Accepted 20 December 2019

The Canadian Field-Naturalist

Surveys for terrestrial gastropods in the Kootenay region of British Columbia, with new records and range extensions

Kristiina Ovaska[1,*], **Lennart Sopuck**[1], and **Jennifer Heron**[2]

[1]Biolinx Environmental Research Ltd., 1759 Colburne Place, North Saanich, British Columbia V8L 5A2 Canada
[2]Ministry of Environment and Climate Change Strategy, Conservation Science Section, Suite 200, 10428 153rd Street, Surrey, British Columbia V3R 1E1 Canada
[*]Corresponding author: ke.ovaska@gmail.com

Ovaska, K., L. Sopuck, and J. Heron. 2019. Surveys for terrestrial gastropods in the Kootenay region of British Columbia, with new records and range extensions. Canadian Field-Naturalist 133(3): 221–234. https://doi.org/10.22621/cfn.v133i3.2287

Abstract

The northern Columbia River basin, extending from the Kootenay region in British Columbia southward to the Idaho panhandle and northwestern Montana, contains a unique terrestrial gastropod fauna, but in Canada few surveys have specifically targetted this group. Here we report on terrestrial gastropods detected during surveys of 314 sites distributed in five biogeoclimatic zones across the Kootenay region. The surveys occurred on 65 days over seven years from 2007 to 2015, usually in September–October. We detected 45 taxa identified to species, belonging to 33 genera; micro-snails of the genus *Vertigo* (apart from *Vertigo ovata*) were combined into a single category, and snails belonging to Succineidae were not identified further. Regionally endemic species previously reported from the region included Western Banded Tigersnail (*Anguispira kochi occidentalis*), Coeur d'Alene Oregonian (*Cryptomastix mullani*), Rocky Mountainsnail (*Oreohelix strigosa*), Subalpine Mountainsnail (*Oreohelix subrudis*), and Pale Jumping-slug (*Hemphillia camelus*), which was widespread across the region. Magnum Mantleslug (*Magnipelta mycophaga*), the distribution of which extends beyond the Kootenay region, was detected at several widely spaced sites. Two species new to Canada were detected, Pygmy Slug (*Kootenaia burkei*) and Sheathed Slug (*Zacoleus idahoensis*), both of which were subsequently assessed to be of conservation concern both provincially and nationally. Other notable observations included the detection of Fir Pinwheel (*Radiodiscus abietum*), a regional endemic, which has been previously reported only once, and three species common in coastal forests but not previously reported from the region: Pacific Banana Slug (*Ariolimax columbianus*), Robust Lancetooth (*Haplotrema vancouverense*), and Northwest Hesperian (*Vespericola columbianus*). Further surveys, especially at higher elevations, may reveal other additional or unusual species.

Key words: Terrestrial gastropods; new distribution records; Kootenays; inventory

Introduction

Mesic forests of the northern Columbia River basin support many unique plants and animals and species with vicarious distributions, separated from their Pacific coastal counterparts by 300 km or more of arid landscapes (Brunsfeld *et al.* 2001). This unique area extends from southeastern British Columbia (BC) and northeastern Washington southward through the Idaho Panhandle into northwestern Montana. In BC, it encompasses the Kootenay region, which supports a diverse gastropod fauna, including species that are found nowhere else in Canada (Forsyth 1999, 2004). Few studies have specifically targetted this group, and until recently our knowledge of it was based on brief historical accounts, records in Pilsbry's (1939, 1940, 1946, 1948) monograph, and largely serendipitous observations (reviewed by Forsyth 1999). Recent targetted surveys include the Royal British Columbia Museum's Living Landscape expedition (Forsyth 1999) and surveys by Nekola *et al.* (2011) in the central Selkirk Mountains and their vicinity in support of a proposed Selkirk Mountains Caribou Park. Increased survey efforts in this biologically rich area continue to provide new records and document species new to the province.

Here we report on surveys targetting terrestrial gastropods in southeastern BC during seven annual surveys from 2007 to 2015 (no surveys were conducted in 2011–2013), including documentation of two species of slugs new to Canada. The surveys were in support of conservation assessments by the province of BC and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and focussed on species deemed to be rare or at risk.

Focal species initially included the snails Western Banded Tigersnail (*Anguispira kochi occidentalis*), Coeur d'Alene Oregonian (*Cryptomastix mullani*), and mountainsnail (*Oreohelix*) species, and the slugs Magnum Mantleslug (*Magnipelta mycophaga*) and Pale Jumping-slug (*Hemphillia camelus*). Two species, Pygmy Slug (*Kootenaia burkei*) and Sheathed Slug (*Zacoleus idahoensis*), were added after their discovery as part of this study in 2007 and 2009, respectively. The primary objective was to clarify distributions of the focal species. A secondary objective was to investigate the presence of possible undocumented species of the northern Columbia basin fauna, the distributions of which may extend northward across the international border into Canada.

Study Area

This study was conducted in the Kootenay region of southeastern BC, bounded by the Rocky Mountains to the east, the Canada–United States (USA) border to the south, Shuswap/Okanagan Highlands to the west, and the 51.6° latitude to the north (Figure 1). The area consists of a series of rugged northwest–southeast oriented mountain ranges (Rocky, Purcell, Selkirk, and Monashee), separated by large valleys, rivers, and lakes. The varied terrain and climate, which can change across short distances, result in a diversity of ecosystems, which have strong influences on terrestrial gastropod distributions.

The study area overlaps five of 14 biogeoclimatic zones in BC (BECP n.d.). A zone is classified according to the unique assemblage and distribution of climax and late-seral plant communities, energy flow, nutrient-cycling and soils, topography, and regional climate of a geographic area. Biogeoclimatic zones of the study area include high elevation Interior Mountain-heather Alpine (IMA) and Engelmann Spruce (*Picea engelmannii* Engelmann)–Subalpine Fir (*Abies lasiocarpa* (Hooker) Nuttall) (ESSF) zones; mid-elevation Interior Cedar–Hemlock (ICH) and

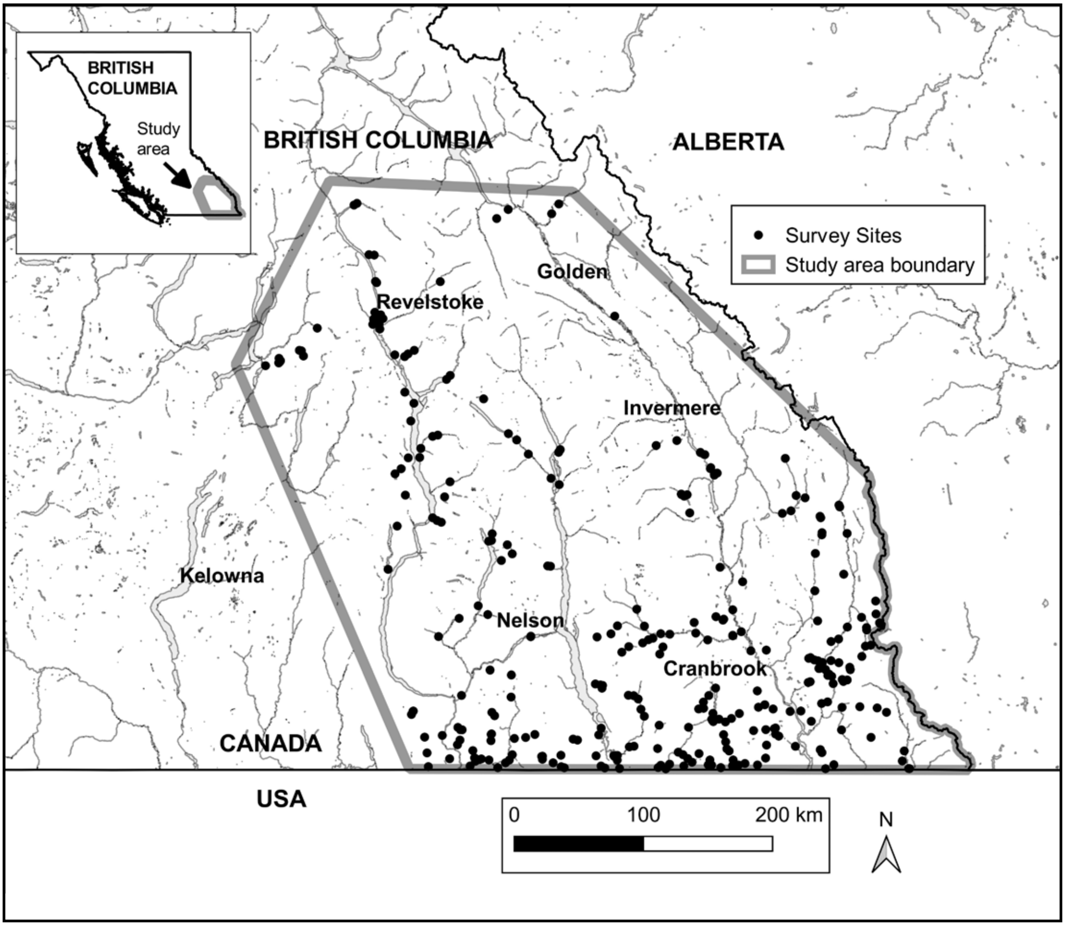


FIGURE 1. Location of the study area and sites surveyed in 2007–2015 in southeastern British Columbia.

Montane Spruce (MS) zones; low-elevation Interior Douglas Fir (*Pseudotsuga menziesii* (Mirbel) Franco) (IDF) zone; and Ponderosa Pine (*Pinus ponderosa* Douglas ex Lawson & C. Lawson) zone (MacKillop *et al.* 2018; BECP n.d.). Of the forested zones, the ESSF and ICH zones tend to have wet climates, whereas the MS and IDF zones tend to be dry. Moist Engelmann Spruce–Subalpine Fir forests dominate the higher elevations; White Spruce (*Picea glauca* (Moench) Voss), Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), and Western Redcedar (*Thuja plicata* Donn ex D. Don) forests dominate the wetter low- to mid-elevations; Lodge-pole Pine (*Pinus contorta* Douglas ex Loudon), Western Larch (*Larix occidentalis* Nuttall), and Douglas Fir forests occur on the drier mountain slopes; Ponderosa Pine and grasslands occur in the dry, low-elevation valley bottoms.

In recent years, logging, wildfires, hydroelectric reservoirs, and Mountain Pine Beetle (*Dendroctonus ponderosae*) epidemics have disturbed large areas of forest in the study area. The effects of cattle ranching are localized, occurring mainly in grassland and open forest habitats at low elevations. Human developments are relatively sparse, with settlements and farming occurring mainly in low-elevation river valleys, such as along the Columbia and Kootenay rivers. Several federal and provincial parks contain large areas of relatively undisturbed forest, but these are mostly restricted to higher elevations.

Methods

Survey sites and effort

We surveyed 314 sites, which were at least 500 m apart and distributed across the study area (Figure 1, Appendix S1); geopositions were recorded with a handheld global positioning system unit (GPSMAP 60Cx; Garmin, Olathe, Kansas, USA). Survey efforts focussed on BC Crown forestry lands, which were accessed through logging roads that crisscrossed the area. The sites also included provincial parks ($n = 5$), national parks ($n = 4$), Ktunaxa First Nation reserve lands ($n = 17$), municipal lands ($n = 6$), and private lands used for forestry, ranching, or recreation ($n = 22$). Most sites were searched only once, but repeated surveys were conducted at eight sites. The total time spent intensively searching for gastropods was 347 person-hours, with the median survey time one hour per site during 65 days over a seven-year period.

Survey dates, conditions, and methods

The surveys took place on the following dates: 10–16 July and 22–27 September 2007; 3–8 September and 4–7 October 2008; 6–9 October 2009; 20 July and 6–16 September 2010; 20–25 September 2013: 15–29 September 2014; and 20–25 September 2015. It rained during 16.5% of the surveys, and the median ambient temperature (measured at ground level at the start of the survey) was 11°C in September–October and 24°C in July.

To locate gastropods, usually two observers (K.O. and L.S.) walked along meandering transects through habitat deemed suitable for gastropods and examined decaying logs, piles of bark, stumps, rocks, other moist refuges, and accumulations of leaf litter, focussing on points where concentrations of such features were present. Most surveys took place during daylight hours, but a few ($n = 5$) took place on wet nights after dark to detect gastropods active on the surface. At night, we used high-watt flashlights to scan the ground surface and tree trunks while walking along trails or traversing suitable habitat and/or driving slowly along side-roads using fog lights to illuminate the road surface.

Identification and vouchers

We identified all gastropods found, in some cases only to genus (such as micro-snails of *Vertigo*), based on external characteristics. Identification was usually done in the field, but we collected samples of small snails and confirmed identification in the laboratory of the Royal British Columbia Museum (RBCM) using a dissecting microscope. Three specimens of *Hemphillia* were sent to Lyle Chichester to confirm identity through examination of distal reproductive anatomy; several species of *Hemphillia* occur south of the border in the USA and have not been reported from Canada. Identification was based on descriptions in Pilsbry (1940, 1948), Forsyth (2004), and Burke (2013). Nomenclature for species followed Forsyth (2004) and, for families, Bouchet *et al.* (2017). Voucher specimens were deposited in collections at the RBCM (Appendix S2); photographic vouchers were retained in personal collections by the authors.

Results

The surveys resulted in the detection of 45 taxa identified to species, belonging to 33 genera (Table 1). Micro-snails of the genus *Vertigo* (apart from Ovate Vertigo, *Vertigo ovata*) were combined into a single category, which included nominal taxa of *Vertigo columbiana*, *Vertigo cristata*, *Vertigo gouldii*, *Vertigo modesta*, and possibly other taxa (vouchers at RBCM). Collections of *Vertigo* from British Columbia await re-examination in light of the recent revision of the genus (Nekola *et al.* 2018). Snails of the family Succineidae were not identified below this level because of complications associated with identification based on shell morphology.

The most commonly encountered taxa were Brown Hive (*Euconulus fulvus*, 57% of sites surveyed), Forest Disc (*Discus whitneyi*, 45%), *Vertigo* species group

TABLE 1. Terrestrial gastropod species detected during surveys in the Kootenay region, 2007–2015. See Appendix S1 for coordinates and description of sites. Site numbers 104 and 295 were not used.

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total (n = 314)	% of all sites	No. of individuals (no. dead)
	ESSF (n = 37)	ICH (n = 192)	IDF (n = 33)	MS (n = 39)	PP (n = 13)			
AGRIOLIMACIDAE								
Deroceras laeve (Meadow Slug)	—	19, 42, 60, 63, 70, 87, 92, 93, 102, 122, 150, 163, 192, 194, 197, 281 (8.3)	168, 169, 182, 225, 232, 234, 242, 271 (24.2)	229, 233, 243, 246, 257, 307 (15.4)	202, 214, 216, 218, 224, 227, 251 (53.8)	37	11.7	130
Deroceras invadens (Tramp Fieldslug)*†	—	—	—	292 (2.6)	—	1	0.3	9
Deroceras reticulatum (Grey Fieldslug)*	—	1, 66, 68, 87, 93, 99, 130, 226, 263, 268, 274, 275, 280, 281, 282, 294 (8.3)	136, 168, 195, 299 (12.1)	181, 223, 236, 277, 303, 304 (15.4)	202, 206, 208, 216 (30.8)	30	9.5	204
ANADENIDAE								
Kootenaia burkei (Pygmy Slug)	115, 132 (5.4)	49, 50, 62, 67, 71, 76, 80, 81, 83, 84, 86, 90, 97, 101, 106, 125, 131, 144, 146, 147, 150, 152, 158, 164, 167, 174, 179, 180, 185, 187, 188. 192, 193, 196, 200, 205, 207, 221, 228 (20.2)	—	220, 230, 237 (7.7)		44	14.0	128
Prophysaon andersonii (Reticulate Taildropper)	17 (2.7)	1, 10, 19, 23, 41, 44, 47, 48, 58, 60, 68, 69, 80, 87, 93, 99, 101, 141, 165, 174, 178, 180, 207, 263, 268 (13.0)	—	—	—	26	8.3	249
ARIOLIMACIDAE								
Ariolimax columbianus (Pacific Banana Slug)	—	10, 17 (1.0)	—	—	—	2	0.6	14
Magnipelta mycophaga (Magnum Mantleslug)	115, 267, 293 (8.1)	13, 18, 25, 160, 178, 252 (3.1)	—	220 (2.6)		10	3.2	14
Zacoleus idahoensis (Sheathed Slug)	210, 231 (5.4)	71, 158, 180, 198, 200, 207, 228 (3.6)	—	—	—	9	2.9	16
ARIONIDAE								
Arion circumscriptus (Brown-banded Arion)*	—	1, 47, 60, 84, 92, 199, 274, 275, 282, 294 (5.2)	272 (3.0)	181, 277 (5.1)	—	13	4.1	111
Arion intermedius (Hedgehog Arion)*	—	23, 66 (1.0)	—	—	—	2	0.6	11
Arion rufus (Chocolate Arion)*	—	14, 23, 29, 48, 59, 92, 97, 105, 199, 207 (5.2)	—	—	—	10	3.2	39
Arion sp. (unidentified juveniles)*	—	33, 66, 91, 93, 97, 112, 199 (3.6)	—	—	—	7	2.2	30
BINNEYIDAE								
Hemphillia camelus (Pale Jumping-slug)	17, 45, 107, 108, 109, 120, 121, 143, 145, 217, 231, 245, 289, 293 (37.8)	12, 18, 20, 26, 28, 29, 31, 35, 36, 38, 39, 42, 48, 61, 67, 69, 72, 75, 80, 81, 82, 83, 91, 94, 99, 101, 113, 114, 116, 122, 123, 124, 125, 127, 129, 131, 133, 134, 135, 139, 154, 155, 156, 160, 161, 162, 163, 166, 167, 176, 178, 179, 180, 184, 187, 188, 193, 194, 207, 211, 226, 228, 252, 259 (33.2)	171, 172 (6.1)	181, 235, 237, 238, 244 (12.8)	—	85	27.0	261

TABLE 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total	% of	No. of
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)	($n = 314$)	all sites	individuals (no. dead)
CHAROPIDAE								
Radiodiscus abietum (Fir Pinwheel)	—	85, 91 (1.0)	—	—	—	2	0.6	2
COCHLICOPIDAE								
Cochlicopa lubrica (Glossy Pillar)	—	92, 130 (1.0)	190 (3.0)	—	—	3	1.0	4
DISCIDAE								
Anguispira kochi occidentalis (Western Banded Tigersnail)	—	57, 61, 64, 65, 67, 71, 76, 78, 79, 95, 96, 99, 112, 113, 123, 126, 131, 134, 137, 141, 146, 159, 163, 167, 174, 178, 180, 193, 207, 221 (15.5)	182 (3.0)	—	—	31	9.8	276 (102)
Discus shimekii (Striate Disc)	—	81, 275, 282 (1.6)	272 (3.0)	292, 300, 315, 316 (10.3)	—	8	2.5	82
Discus whitneyi (Forest Disc)	2, 115, 121, 245, 267 (13.5)	7, 10, 13, 14, 18, 19, 20, 22, 23, 26, 32, 33, 36, 37, 46, 49, 50, 51, 54, 55, 58, 60, 61, 62, 63, 64, 65, 66, 67, 69, 70, 73, 76, 78, 79, 80, 81, 82, 84, 85, 86, 87, 89, 90, 92, 93, 95, 96, 97, 99, 101, 102, 106, 113, 114, 116, 117, 119, 122, 123, 126, 129, 134, 146, 147, 148, 149, 151, 153, 154, 164, 166, 174, 176, 178, 179, 180, 185, 187, 192, 196, 199, 200, 207, 212, 221, 222, 228, 254, 259, 274, 280, 282, 286, 287, 294 (49.7)	168, 169, 173, 175, 182, 183, 186, 189, 191, 232, 234, 239, 241, 242, 270, 271, 272, 285, 299 (57.6)	157, 181, 230, 233, 237, 238, 244, 246, 250, 277, 283, 292, 303, 304, 305, 308, 309 (43.6)	202, 214, 218, 218, 227 (38.5)	142	45.1	780 (20)
Discus sp. (juveniles)	—	33, 42, 72, 98, 111, 112, 131, 144, 161, 163, 167, 180, 219, 282 (7.3)	—	181, 229 (5.1)	—	16	5.1	60
EUCONULIDAE								
Euconulus fulvus (Brown Hive)	2, 9, 45, 132, 217, 245, 260, 262, 265, 298, 312 (29.7)	7, 10, 13, 14, 19, 20, 22, 23, 26, 28, 29, 33, 35, 36, 37, 41, 47, 49, 51, 52, 54, 55, 56, 57, 58, 60, 63, 64, 65, 66, 68, 69, 70, 71, 72, 75, 76, 78, 79, 80, 81, 84, 85, 86, 87, 88, 89, 91, 92, 93, 95, 97, 99, 100, 101, 102, 106, 111, 112, 113, 114, 116, 117, 118, 119, 126, 128, 129, 131, 135, 138, 139, 146, 148, 149, 150, 151, 152, 153, 154, 159, 160, 161, 162, 163, 165, 166, 167, 174, 176, 180, 184, 185, 188, 192, 193, 196, 198, 199, 200, 205, 207, 211, 222, 226, 228, 252, 254, 259, 280, 281, 282, 294, 296 (59.1)	136, 168, 175, 183, 189, 190, 191, 225, 234, 239, 240, 242, 247, 253, 255, 271, 285, 299 (54.5)	157, 181, 220, 229, 230, 233, 235, 236, 237, 238, 244, 246, 250, 257, 258, 277, 283, 292, 300, 302, 303, 304, 305, 307, 308, 309, 311, 313, 315 (74.4)	202, 208, 214, 215, 216, 218, 227, 249 (61.5)	180	57.1	659
Euconulus aff. *alderi* (Marsh Hive)‡	—	27, 37 (1.0)	168 (3.0)	—	214, 216 (15.4)	5	1.6	25
GASTRODONTIDAE								
Nesovitrea binneyana (Blue Glass)	—	77 (0.5)	169, 270, 272 (9.1)	246 (2.6)	—	5	1.6	13

TABLE 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total	% of	No. of
	ESSF (n = 37)	ICH (n = 192)	IDF (n = 33)	MS (n = 39)	PP (n = 13)	(n = 314)	all sites	individuals (no. dead)
Nesovitrea electrina (Amber Glass)	260 (2.7)	13, 20, 22, 37, 58, 60, 89, 102, 119, 282 (5.2)	168, 183, 190, 191, 271 (15.2)	—	216, 227 (15.4)	18	5.7	53
Nesovitrea sp. (*N. electrina* or *N. binneyana*)	—	11, 19, 23, 26, 28, 31, 32, 33, 36, 50, 53, 58, 61, 64, 65, 66, 69, 79, 85, 86, 90, 91, 114, 123, 125, 149, 153, 166, 228 (15.0)	182, 232 (6.1)	181, 304 (5.1)	208, 214 (15.4)	35	11.1	67
Striatura pugetensis (Northwest Striate)	—	67, 95, 200 (1.6)	—	—	—	3	1.0	7
Zonitoides arboreus (Quick Gloss)	9, 266, 267 (8.1)	11, 19, 23, 32, 37, 47, 50, 51, 53, 54, 57, 58, 60, 61, 63, 64, 65, 67, 69, 71, 77, 80, 85, 86, 89, 91, 96, 99, 100, 101, 102, 113, 116, 118, 123, 129, 138, 150, 162, 163, 165, 166, 184, 196, 199, 226, 228, 252, 259, 280, 281 (26.4)	168, 173, 182, 183, 186, 190, 191, 204, 225, 232, 247, 270, 271 (39.4)	181, 201, 220, 229, 233, 238, 246, 277, 303, 304, 313 (28.2)	208, 215, 216, 227, 256 (38.5)	83	26.3	230
Zonitoides nitidus (Black Gloss)	—	23, 52, 59, 73, 74, 78, 87, 97, 102, 116, 165, 286, 291, 294 (7.3)	169, 175, 189, 234, 253 (15.2)	236, 246, 250, 258, 283, 284, 288, 300 (20.5)	206, 214, 224, 249, 251 (38.5)	32	10.2	134
Zonitoides sp. (*Z. arboreus* or *Z. nitidus*)	—	26, 27, 33, 35, 54, 59, 66, 92, 111, 160, 161, 165, 174, 228, 254, 279 (8.3)	182 (3.0)	244, 316 (5.1)	224 (7.7)	20	6.3	33
HAPLOTREMATIDAE								
Haplotrema vancouverense (Robust Lancetooth)	—	68, 82, 87, 90, 97 (2.6)	—	—	—	5	1.6	8
HELICIDAE								
Cepaea nemoralis (Grovesnail)*	—	1, 48, 105 (1.6)	—	—	—	3	1.0	71
LIMACIDAE								
Limax maximus (Giant Gardenslug)*	17 (2.7)	1, 14, 23, 105, 112, 137, 207, 278, 280, 281 (5.2)	195 (3.0)	—	—	12	3.8	29
OREOHELICIDAE								
Oreohelix strigosa (Rocky Mountainsnail)	265, 312 (5.4)	47, 69, 71, 73, 74, 77, 113, 130, 134, 137, 138, 141, 142, 174, 180, 196, 223, 259, 269, 274, 278, 279, 280, 282, 286, 290, 291, 294 (14.5)	255, 272, 273, 299 (12.1)	258, 261, 277, 288, 300, 303, 304, 307, 308, 314, 315, 316 (30.8)	—	46	14.6	1566 (948)
Oreohelix subrudis (Subalpine Mountainsnail)	267 (2.7)	278 (0.5)	—	302, 304 (5.1)	—	4	1.3	11 (10)
Oreohelix sp.	—	70, 71, 91, 123 (2.1)	239 (3.0)	220 (2.6)	—	6	1.9	8

TABLE 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total	% of	No. of
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)	($n = 314$)	all sites	individuals (no. dead)
POLYGYRIDAE								
Allogona ptychophora (Idaho Forestsnail)	267 (2.7)	1, 14, 22, 23, 32, 35, 38, 39. 47, 48, 50, 54. 68, 71, 73, 78, 93, 102, 112, 126, 130, 135, 137, 138, 140, 141, 142, 159. 162, 163, 166, 174, 196, 200, 207, 221, 223, 259, 269, 274, 278, 279, 280, 282, 286, 290, 294 (24.5)	255, 270, 272, 273 (12.1)	220, 230, 261, 277, 300 (12.8)	216, 218, 227 (23.1)	59	18.8	1011 (558)
Cryptomastix mullani (Coeur d'Alene Oregonian)	—	1, 14, 23, 26, 28, 31, 33, 47, 50, 53, 57, 61, 64, 65, 66, 67, 69, 70, 71, 73, 74, 76, 78, 79, 84, 89, 105, 123, 126, 137, 138, 140, 142, 159, 161, 163, 196, 199 (19.7)	—	277 (2.6)	—	39	12.4	247 (64)
Vespericola columbianus (Northwest Hesperian)	—	87 (0.5)	—	—	—	1	0.3	1
PRISTILOMATIDAE								
Pristiloma chersinella (Black-foot Tightcoil)	9, 115, 120 (8.1)	23, 111, 122, 296 (2.1)	—	—	—	7	2.2	12
PUNCTIDAE								
Paralaoma servilis (Pinhead Spot)	—	50 (0.5)	189 (3.0)	—	—	2	0.6	6
Punctum randolphii (Conical Spot)	115, 231, 260, 297 (10.8)	22, 23, 44, 65, 74, 78, 86, 95, 96, 99, 100, 125, 128, 129, 131, 146, 147, 149, 151, 160, 164, 174, 176, 178, 192, 196, 200, 205, 252, 281, 296 (16.1)	183, 204, 225, 234, 270 (15.2)	237, 304, 309, 311 (10.3)	224, 227 (15.4)	46	14.6	80
Punctum sp.	—	19, 28, 53, 57, 58, 60, 68, 84, 98, 167, 221 (5.7)	—	—	—	11	3.5	37
SUCCINEIDAE								
Succineid spp.	—	—	—	—	214, 227 (15.4)	2	0.6	4
THYSANOPHORIDAE								
Microphysula ingersollii (Spruce Snail)	107, 108, 231, 245, 260, 267, 293, 297, 310, 312 (27.0)	1, 7, 10, 11, 31, 33, 36, 42, 46, 49, 50, 55, 60, 64, 68, 72, 73, 74, 76, 79, 80, 81, 85, 87, 89, 97, 113, 125, 126, 128, 131, 139, 144, 147, 149, 150, 151, 152, 160, 164, 184, 188, 192, 193, 194, 196, 198, 200, 205, 211, 219, 252, 254, 281, 291 (28.5)	204, 225, 240, 242, 270, 285 (18.2)	220, 233, 235, 236, 244, 250, 257, 258, 277, 304, 311 (28.2)	208, 215, 218 (23.1)	85	27.0	184
VALLONIDAE								
Planogyra clappi (Western Flat-whorl)	—	50 (0.5)	—	—	—	1	0.3	6
Vallonia cyclophorella (Silky Vallonia)	—	142, 165, 174 (1.6)	—	246 (2.6)	—	4	1.3	11
Vallonia excentrica (Iroquois Vallonia)*	—	—	195 (3.0)	—		1	0.3	6

Table 1. *Continued.*

FAMILY and species	Sites where detected (% of sites in the BEC zone)					Total	% of	No. of individuals
	ESSF ($n = 37$)	ICH ($n = 192$)	IDF ($n = 33$)	MS ($n = 39$)	PP ($n = 13$)	($n = 314$)	all sites	(no. dead)
Zoogenetes harpa (Boreal Top)	—	84 (0.5)	—	—	—	1	0.3	10
VERTIGINIDAE								
Columella columella (Cylindrical Mellow Column)	—	23, 75, 79, 275 (2.1)	—	309 (2.6)	—	5	1.6	9
Columella sp.	—	49, 78 (1)	—	311 (2.6)	—	3	1.0	10 (8)
Vertigo ovata (Ovate Vertigo)	—	27 (0.5)	203, 204 (6.1)	—	—	3	1.0	7
Vertigo spp. (several taxa except *V. ovata*)	2, 121, 217, 245, 260, 297, 298 (18.9)	1, 7, 10, 19, 20, 23, 28, 29, 31, 36, 44, 49, 50, 51, 54, 55, 56, 57, 60, 66, 68, 72, 75, 80, 81, 84, 85, 91, 92, 94, 98, 101, 111, 113, 116, 117, 129, 131, 133, 135, 144, 147, 149, 150, 152, 155, 156, 160, 161, 164, 167, 176, 184, 187, 188, 192, 193, 196, 197, 205, 207, 211, 219, 221, 222 (33.7)	168, 169, 182, 225, 270, 271 (18.2)	229, 230, 235, 237, 244, 250, 301, 305, 307, 308, 309, 313 (30.8)	—	90	28.6	324
VITRINIDAE								
Vitrina pellucida (Western Glass-snail)	109, 245, 265, 266, 297 (13.5)	1, 11, 23, 31, 33, 36, 41, 46, 49, 50, 60, 64, 66, 78, 80, 87, 94, 99, 131, 134, 138, 140, 148, 164, 165, 187, 207, 222, 252, 280, 294 (16.1)	168, 182, 183, 225, 234, 242, 272, 273, 299 (27.3)	181, 292, 302, 303, 304, 305, 308 (17.9)	206, 215, 218, 276 (30.8)	56	17.8	163

Note: BEC = Biogeoclimatic Ecosystem Classification, ESSF = Engelmann Spruce–Subalpine Fir, ICH = Interior Cedar–Hemlock, IDF = Interior Douglas Fir, MS = Montane Spruce, PP = Ponderosa Pine.

*Introduced species of Eurasian origin.

†Forsyth (2004) applied the name *Deroceras panormitanum* to this species. Subsequently, Reise *et al*. (2011) described the widespread invasive form as *Deroceras invadens*.

‡Forsyth (2004) applied the name *Euconulus praticola* for snails from BC that were clearly separate from *Euconulus fulvus* in shell morphology and habitat. Subsequent work by Horsáková *et al.* (2019) supported the existence of a cryptic species within *Euconulus alderi* (Clade G in their analysis) in southeast BC, which corresponds to this taxon.

(29%), *H. camelus* (27%), Spruce Snail (*Microphysula ingersollii*, 27%), Idaho Forestsnail (*Allogona ptychophora*, 19%), and Western Glass-snail (*Vitrina pellucida*, 18%). Four species, *A. kochi occidentalis*, *C. mullani*, *K. burkei*, and Reticulate Taildropper (*Prophysaon andersonii*), were found predominantly in the ICH zone, while others showed no obvious affinities with specific biogeographic zones. Species common in coastal forests and with vicarious or potentially vicarious coastal–inland distributions included Pacific Banana Slug (*Ariolimax columbianus*), Robust Lancetooth (*Haplotrema vancouverense*), Western Flatwhorl (*Planogyra clappi*), Conical Spot (*Punctum randolphii*), Northwest Striate (*Striatura pugetensis*), and Northwest Hesperian (*Vespericola columbianus*); all were encountered at only a small number of sites (Table 1).

Of the focal species, *M. mycophaga* was detected infrequently at widely spaced sites, all except one of which (Mount Revelstoke) represented new localities for the species (Figure 2); the previous record from Mount Revelstoke, a specimen collected in 1937 by K. Racey, was discovered in February 2014 by one of us (K.O.) during examination of unidentified gastropod specimens catalogued in the RBCM collection. *Hemphillia camelus* was widespread within the study area and the most commonly encountered slug. We detected no obvious morphological differences among individuals or sites that would suggest the presence of more than one species; reproductive anatomy of a small number of dissected specimens ($n = 3$) conformed with this species. *Anguispira kochi occidentalis*, *C. mullani*, and *K. burkei* were detected mainly in the western portion of the study area. Records for *Z. idahoensis* were confined to a relatively small area in the south within ~25 km of the Canada–USA border (Figure 2), while the other species were more widespread. In contrast, *Oreohelix* species were found mainly toward the Rocky Mountains in the eastern portion of the study area, where they appeared to be exceedingly abundant at many sites. We identified most of the specimens as Rocky Mountainsnail (*Oreohelix strigosa*) based on shell morphology, but there was much variability in shell shape and size both within and among sites. Snails in subalpine habitats with a relatively high spire were identified as Subalpine Mountainsnail (*Oreohelix subrudis*). As noted by Forsyth (2004), taxa referred to as *O. strigosa* and *C. mullani* in BC may in fact each consist of species complexes that may include as yet unidentified species, as also appears to be the case on the USA side of the border to the south (Burke 2013). Selected species detected during the surveys are featured in Figure 3.

Discussion

Terrestrial gastropods detected during the surveys represent several faunal elements including widespread species, some with holarctic distributions, regional endemics to the Columbia basin and surrounding mountains, those with vicarious distributions with a coastal and interior component, and introduced species of Eurasian origin. Examples of widespread native species include Meadow Slug (*Deroceras laeve*), *D. whitneyi*, *E. fulvus*, *M. ingersollii*, and Quick Gloss (*Zonitoides arboreus*). Regionally endemic species previously reported from the region include *A. kochi occidentalis*, *C. mullani*, *H. camelus*, *O. strigosa*, and *O. subrudis*.

In addition to providing numerous new records for the regionally endemic focal species, the surveys resulted in the documentation of two species of slugs new to Canada, *K. burkei* and *Z. idahoensis*. Both species were subsequently determined to be of conservation concern in Canada (COSEWIC 2016a,b). *Kootenaia burkei* was described only recently from specimens from Idaho (Leonard *et al.* 2003), and before this study it was known from the Idaho Panhandle and northwestern Montana. The known distribution of *Z. idahoensis* was similar (Burke 2013). This study revealed that a large proportion (~35%) of the global distribution of *K. burkei* is in Canada, whereas the Canadian distribution of *Z. idahoensis* appears to be much more restricted.

Other interesting observations include the detection of Fir Pinwheel (*Radiodiscus abietum*), a regional endemic, at two sites in September 2013 (Figure 4). To our knowledge, this species has been documented from Canada previously only by Nekola *et al.* (2011), who found it at five localities in New Denver, BC, and in the lowlands southward in 2011. We detected Boreal Top (*Zoogenetes harpa*), a species with a holarctic distribution, at only one site. This species is known to occur sporadically in northern BC and along the Rocky Mountains (Forsyth 2004), but appears to be rare and/or patchily distributed in the Kootenay region.

Of the species common in Pacific coastal forests and with apparently vicarious distributions, *P. clappi* and *S. pugetensis* were detected infrequently and appear to be very patchily distributed in the study area. Both species have been reported previously from a small number of sites in the Kootenay region (Nekola *et al.* 2011). Additional species with such distributions detected for the first time during the surveys were *A. columbianus* at two sites, both of which receive heavy recreational use, *H. vancouverense* at five sites, and *V. columbianus* at one site, a moist, disturbed site along the highway near the international border where the latter two species co-occurred. Whether the presence

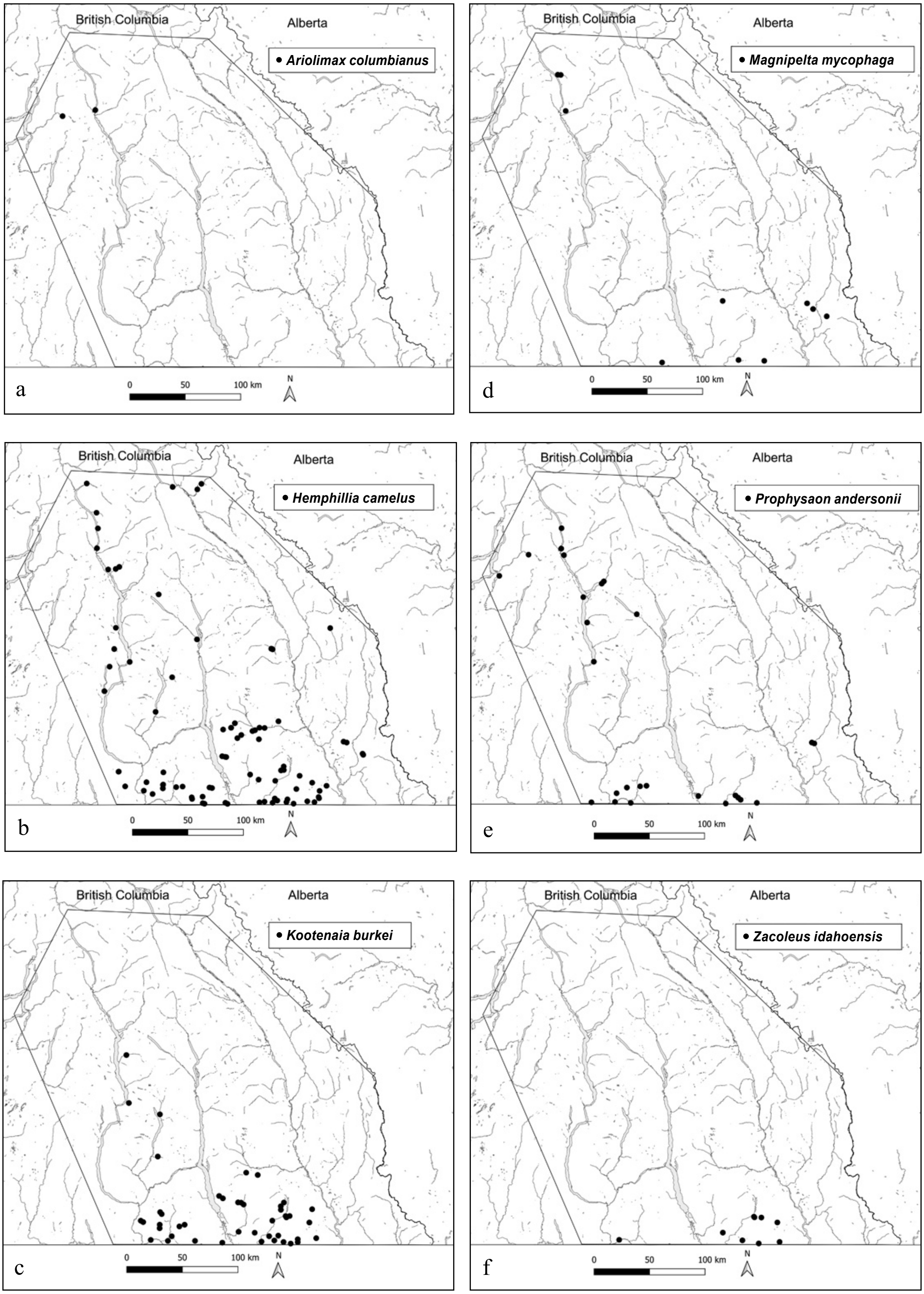


FIGURE 2. Comparison of the distributions of selected species of slugs, a–f, and large snails, g–l, detected in the study area in southeastern British Columbia.

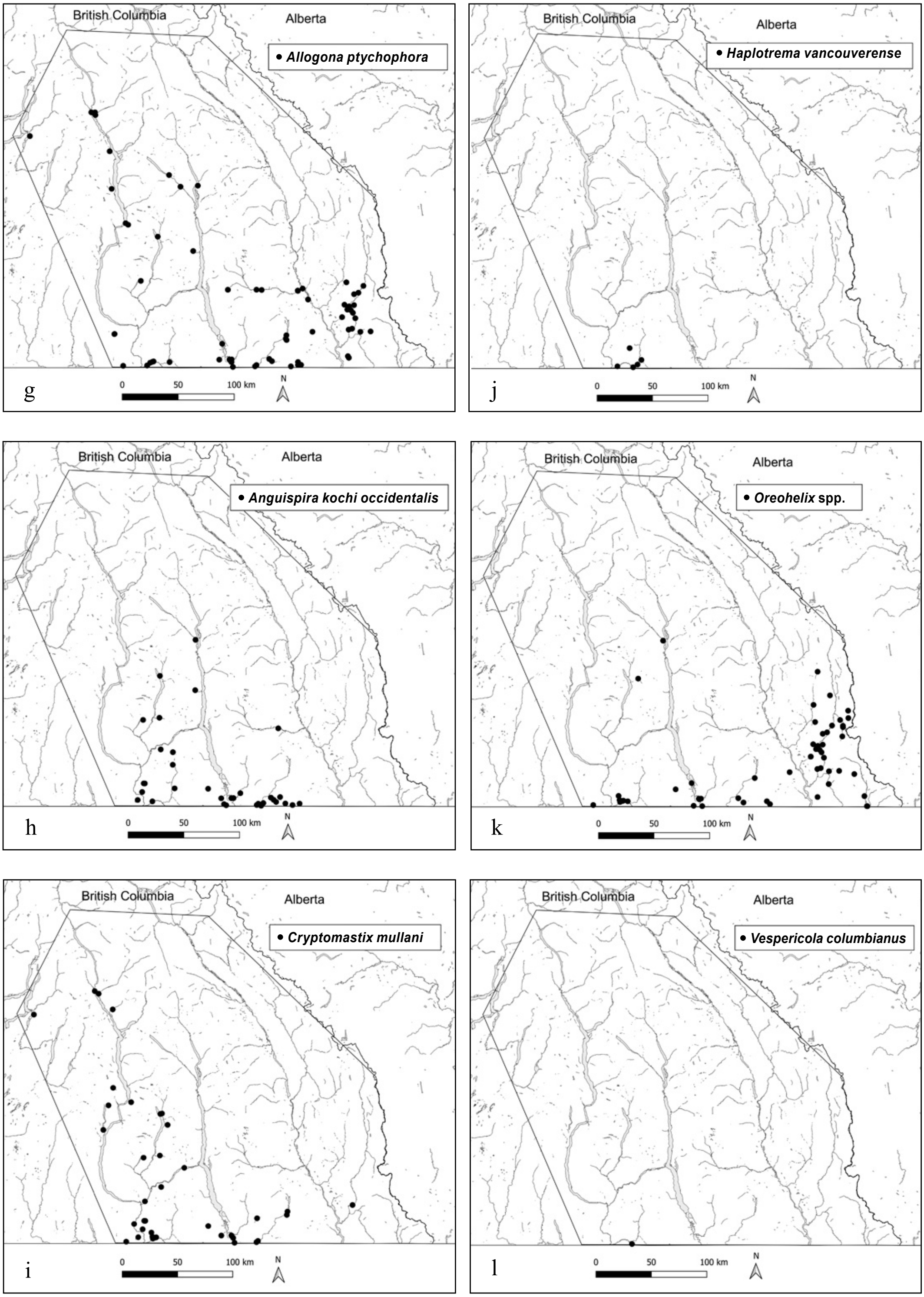


FIGURE 2. *Continued.*

FIGURE 3. Selected species detected during surveys in the Kootenay region, 2007–2015. a. Sheathed Slug, *Zacoleus idahoensis* (September 2013, site 158, 25 mm, *in situ*); b. Pygmy Slug, *Kootenaia burkei* (September 2014, site 230, 12 mm, *in situ*); c. Pale Jumping-slug, *Hemphillia camelus* (September 2014, site 83, juvenile 35 mm, *in situ*); d. Magnum Mantleslug, *Magnipelta mycophaga* (July 2007, site 267, 65 mm, *in situ*); e. Coeur d'Alene Oregonian, *Cryptomastix mullani* (September 2007, site 142, 15 mm); f. Rocky Mountainsnail, *Oreohelix strigosa* (September 2007, site 142, 20 mm); g. Western Banded Tigersnail, *Anguispira kochi occidentalis* (3 September 2008, site 78, 25 mm, *in situ*); h. Idaho Forestsnail, *Allogona ptychophora* (September 2010, site 14, 22 mm). Size is extended length for slugs, shell width for snails. Photos: Kristiina Ovaska.

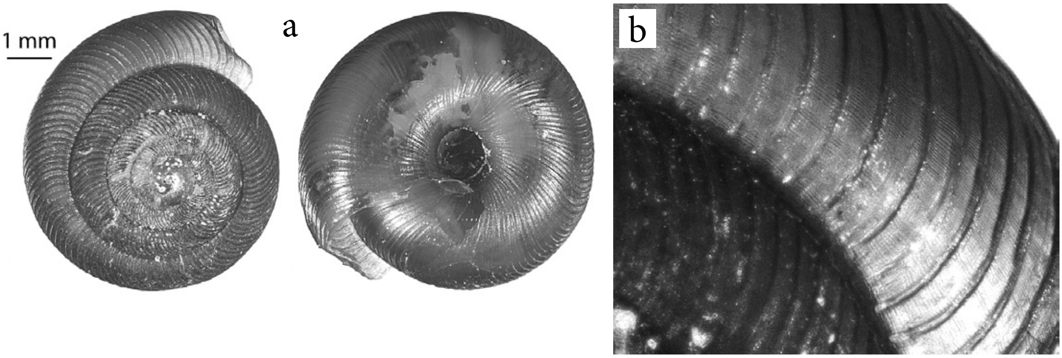


FIGURE 4. a. Fir Pinwheel, *Radiodiscus abietum* (23 September 2013, site 85) from the Kootenay region. b. Detail of shell with diagnostic fine spiral striae. Photos: Kristiina Ovaska and Heidi Gartner.

of these species represents natural distribution or resulted from recent introductions by humans from the coast remains unknown.

Non-native species encountered during the surveys include the snails Iroquois Vallonia (*Vallonia excentrica*) at one site, adjacent to hot springs at a recreational site, and Grovesnail (*Cepaea nemoralis*) at three lower elevation sites, two of them in provincial parks. Introduced slugs of three families (Agriolimacidae, Arionidae, Limacidae) were widespread within the study area and occurred at 51 sites (16.2%), distributed across all five biogeoclimatic zones sampled and often associated with human-modified habitats.

This study contributes to a growing body of information on distributions of terrestrial gastropods of southeastern BC. Most of the sampling sites were in the ICH biogeoclimatic zone, which was expected to provide suitable habitat for most of the focal species. Higher elevation sites in the ESSR and MS zones, in particular, merit further surveys, but pose logistic challenges because of difficulties of access. Yet, these habitats may contain unique species and faunas that might be particularly vulnerable to climate change impacts, as reported in other areas (Müller *et al.* 2009).

Author Contributions

Writing – Original draft: K.O. and L.S.; Writing – Review & editing: K.O., L.S., and J.H.; Conceptualization: K.O., L.S., and J.H.; Surveys & specimen identification: K.O. and L.S.; Logistics & landowner contacts: J.H.; Funding acquisition: J.H.

Acknowledgements

We are grateful to all individuals and organizations who partnered with us and helped make this project possible, including landholders and managers who allowed us on their lands. We particularly acknowledge Ktunaxa First Nations representatives on Aqam and Akisqnuk Reserves, Ted Antifeau, Lindsay Anderson, Kari Stewart-Smith, Ian Adams, Darren Komonoski, Zehnder Farms, Wayne Stetski, and Nancy Newhouse, for their assistance in selecting and accessing survey sites. Laura Parkinson, Kyle Shottanana, and Christian Engelstoft provided able field assistance during parts of the study. Lyle Chichester performed dissections of *Hemphillia* specimens. Heidi Gartner diligently and expediently catalogued voucher specimens at Royal British Columbia Museum. Robert Forsyth and Dwayne Lepitzki provided helpful comments, which greatly improved the manuscript. Funding was provided by the BC Ministry of Environment and Climate Change Strategy and BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Additional funding came from Environment Canada through the Habitat Stewardship Program for surveys in 2010 and through the Committee on the Status of Endangered Wildlife in Canada for field verification associated with the preparation of status reports in 2013 and 2014. The Royal British Columbia Museum and BC Parks Enhancement Fund contributed to travel expenses associated with the surveys.

Literature Cited

BECP (Biogeoclimatic Ecosystem Classification Program). n.d. Zone and provincial classification reports. Research Branch, Ministry of Forestry, Victoria, British Columbia, Canada. Accessed April 2019. https://www.for.gov.bc.ca/HRE/becweb/resources/classificationreports/provincial/index.html.

Bouchet, P., J.-P. Rocroi, B. Hausdorf, A. Kaim, Y. Kano, A. Nützel, P. Parkhaev, M. Schrödl, and E.E. Strong. 2017. Revised classification, nomenclator and typification of gastropod and monoplacophoran families. Malacologia 61: 1–526. https://doi.org/10.4002/040.061.0201

Brunsfeld, S.J., J. Sullivan, D.E. Soltis, and P.S. Soltis. 2001. Comparative phylogeography of northwestern North America: a synthesis. Pages 319–339 *in* Integrating Ecology and Evolution in a Spatial Context. *Edited by* J. Silvertown and J. Antonovics. Blackwell Science, Oxford, United Kingdom.

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

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2016a. COSEWIC assessment and status report on the Pygmy Slug *Kootenaia burkei* in Canada. COSEWIC, Ottawa, Ontario, Canada.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2016b. COSEWIC assessment and status report on the Sheathed Slug *Zacoleus idahoensis* in Canada. COSEWIC, Ottawa, Ontario, Canada.

Forsyth, R.G. 1999. Terrestrial malacology in the Columbia Basin, British Columbia. Living Landscape project, Royal British Columbia Museum, Victoria, British Columbia. Accessed March 2019. https://royalbcmuseum.bc.ca/exhibits/living-landscapes/cbasin/molluscs/introduction2.html.

Forsyth, R.G. 2004. Land Snails of British Columbia. Royal British Columbia Museum, Victoria, British Columbia, Canada.

Horsáková, V., J.C. Nekola, and M. Horsák. 2019. When is a "cryptic" species not a cryptic species: a consideration from the holarctic micro-landsnail genus *Euconulus* (Gastropoda: Stylommatophora). Molecular Phylogenetics and Evolution 132: 307–320. https://doi.org/10.1016/j.ympev.2018.12.004

Leonard, W.P., L. Chichester, J. Baugh, and T. Wilke. 2003. *Kootenaia burkei*, a new genus and species of slug from northern Idaho, United States (Gastropoda: Pulmonata: Arionidae). Zootaxa 355: 1–16. https://doi.org/10.11646/zootaxa.355.1.1

MacKillop, D., A. Ehman, K. Iverson, and E. McKenzie. 2018. A Field Guide to Ecosystem Classification and Identification for Southeast British Columbia: the East Kootenay. Land Management Handbook 71. Government of British Columbia, Victoria, British Columbia, Canada. Accessed 14 January 2020. https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/LMH71.pdf.

Müller, J., C. Bässler, C. Strätz, B. Klöcking, and R. Brandl. 2009. Molluscs and climate warming in a low mountain range national park. Malacologia 51: 89–109. https://doi.org/10.4002/040.051.0106

Nekola, J.C., S. Chiba, B.F. Coles, C.A. Drost, T. von Proschwitz, and M. Horsák. 2018. A phylogenetic overview of the genus *Vertigo* O. F. Müller, 1773 (Gastropoda: Pulmonata: Pupillidae: Vertigininae). Malacologia 61: 21–161. https://doi.org/10.4002/040.062.0104

Nekola, J., B. Coles, and M. Horsak. 2011. Land snail biodiversity assessment for the Selkirk Mountains Park region in southeastern British Columbia. Unpublished report. Valhalla Wilderness Society, New Denver, British Columbia, Canada.

Pilsbry, H.A. 1939. Land Mollusca of North America (north of Mexico). Monograph 3, 1(1): i–xvii, 1–573, i–ix. Academy of Natural Sciences of Philadelphia, Philadelphia, USA.

Pilsbry, H.A. 1940. Land Mollusca of North America (north of Mexico). Monograph 3, 1(2): 575–994, i–ix. Academy of Natural Sciences of Philadelphia, Philadelphia, USA.

Pilsbry, H.A. 1946. Land Mollusca of North America (north of Mexico). Monograph 3, 2(1): i–iv, 1–520, i–ix, frontispiece. Academy of Natural Sciences of Philadelphia, Philadelphia, USA.

Pilsbry, H.A. 1948. Land Mollusca of North America (north of Mexico). Monograph 3, 2(2): i–xlvii, 521–1113. Academy of Natural Sciences of Philadelphia, Philadelphia, USA.

Reise, H., J.M.C. Hutchinson, S. Schunack, and B. Schlitt. 2011. *Deroceras panormitanum* and congeners from Malta and Sicily, with a redescription of the widespread pest slug as *Deroceras invadens* n. sp. Folia Malacologica 19: 201–233. https://doi.org/10.2478/v10125-011-0028-1

Received 15 May 2019
Accepted 27 December 2019

SUPPLEMENTARY MATERIAL:

Appendix S1. List of sites surveyed for terrestrial gastropods in the Kootenay region, British Columbia, 2007–2015.

Appendix S2. List of voucher specimens deposited to collections at Royal British Columbia Museum, Victoria, British Columbia.

The Canadian Field-Naturalist

Conspecific cues encourage Barn Swallow (*Hirundo rustica erythrogaster*) prospecting, but not nesting, at new nesting structures

Andrew J. Campomizzi[1,*], **Zoé M. Lebrun-Southcott**[1], and **Kristyn Richardson**[2]

[1]Bird Ecology and Conservation Ontario, 114 Vaughan Road, Suite 307, Toronto, Ontario M6C 2M1 Canada
[2]Bird Studies Canada, P.O. Box 160, 115 Front Street, Port Rowan, Ontario N0E 1M0 Canada
[*]Corresponding author: andy@beco-birds.org

Campomizzi, A.J., Z.M. Lebrun-Southcott, and K. Richardson. 2019. Conspecific cues encourage Barn Swallow (*Hirundo rustica erythrogaster*) prospecting, but not nesting, at new nesting structures. Canadian Field-Naturalist 133(3): 235–245. https://doi.org/10.22621/cfn.v133i3.2233

Abstract

Shed-like structures are being built to provide Barn Swallow (*Hirundo rustica erythrogaster*) nesting habitat in response to population declines. However, Barn Swallow use of these structures is unavailable in the literature. We conducted three manipulative experiments to test if adding conspecific cues (i.e., vocalizations and decoys) to newly-built structures affected prospecting visits by Barn Swallows (1) during pre-breeding, (2) during post-breeding, and (3) during or after broadcasts of vocalizations compared to before broadcasts. Additionally, we monitored nesting following pre- and post-breeding cues. We built one nesting structure with and one without conspecific cues at each of 10 study sites in southern Ontario, Canada where nesting habitat was recently lost. We detected about twice as many Barn Swallows immediately after conspecific broadcasts compared to before. We did not find substantial differences in abundance and interactions with new nesting structures for other comparisons involving conspecific cues. Following pre-breeding cues at 10 sites, six nests were built in three of 10 structures treated with conspecific cues, compared to five nests in four of 10 structures without cues. In the subsequent breeding season following post-breeding cues at eight sites, four nests were built in two of eight structures treated with conspecific cues, compared to four nests in three of eight structures without cues. Conspecific vocalizations appeared to increase prospecting behaviour, but not the number of nests, at new nesting structures. The paucity of nests on new structures suggests that building shed-like structures may not be an effective method of mitigating loss of nesting habitat.

Key words: Aerial insectivore; conspecific attraction; habitat restoration; nesting habitat; Ontario; prospecting; public information; social cues

Introduction

Social cues provide inadvertent information from an animal engaged in its activities and convey information about a species' habitat that can be observed by other animals (Danchin *et al.* 2004). There is empirical evidence that territorial and colonial-nesting migratory birds can be attracted to nesting areas by experiments that introduce conspecific cues (e.g., Ahlering and Faaborg 2006; Hahn and Silverman 2006; Farrell *et al.* 2012). Thus, conspecific cues have potential application in conservation of various species to attract nesting birds to restored or protected habitat.

Previous research has shown that migratory songbirds can be attracted with conspecific cues to locations that do not provide typical conditions of a species' breeding habitat (Nocera *et al.* 2006). Such circumstances could produce an ecological trap, in which individuals identify a location as breeding habitat because of artificial conspecific cues, but the location negatively affects breeding (Schlaepfer *et al.* 2002). Alternatively, if conspecific cues increase the size of a breeding colony, there may be increases in reproductive success through various mechanisms such as predator dilution, group vigilance, or extra-pair paternity (Parrish and Edelstein-Keshet 1999; Danchin *et al.* 2000). Prospecting behaviour to visit potential nesting areas can occur before, during, or after the breeding season for adults and late in the breeding season for hatch-year birds, after they are independent from parents (Reed *et al.* 1999; Doligez *et al.* 2004; Ward 2005).

Conspecific cues could potentially aid conservation of Barn Swallow (*Hirundo rustica erythrogaster*), an aerial insectivore. Populations of birds that forage on flying insects while in flight have declined markedly over the last several decades in North America (Nebel *et al.* 2010; Sauer *et al.* 2013, 2017; Smith *et al.* 2015), leading to conservation concern and recovery efforts. These aerial insectivores include species from four taxonomic families:

nighthawks and nightjars (Caprimulgidae), swifts (Apodidae), tyrant flycatchers (Tyrannidae), and swallows (Hirundinidae). Barn Swallow is the most abundant and widespread swallow species worldwide (Brown and Brown 1999) and considered least concern by the International Union for Conservation of Nature (BirdLife International 2016). Although still common in many rural areas, the Barn Swallow population declined by 80% in Canada and 66% in Ontario between 1970 and 2012 (Heagy *et al.* 2014), leading to its listing as threatened by the governments of Canada (Government of Canada 2017) and Ontario (MECP 2012). The reasons for its population decline are not well understood, but potential causes include: (1) loss of nesting habitat; (2) loss or degradation of foraging habitat impacting prey insects; (3) climate change and mortality from extreme cold weather events on breeding grounds; (4) pollution and pesticides; (5) reduced fecundity because of predation, ectoparasites, and persecution by humans; and (6) loss of, and human disturbance at, roosts (COSEWIC 2011; Heagy *et al.* 2014).

In Ontario, Barn Swallows breed predominantly south of the Canadian Shield in the Mixedwood Plains ecozone (Lepage 2007). They breed in various non-forested areas and are typically associated with human-built structures that provide nesting opportunities, such as barns, bridges, and sheds (Brown and Brown 1999). Recently, structures specifically designed as Barn Swallow nesting habitat have been built. In Ontario, most nesting structures are built as mitigation for habitat loss as required by the Ontario Ministry of Environment, Conservation and Parks (e.g., due to building or bridge demolition or renovation; MECP 2013); others are built to provide new nesting habitat. There are reports providing information about nesting in these structures (e.g., Heagy *et al.* 2014; K.R. unpubl. data), but we were unable to find information in the literature. Overall, the frequency of use of these structures for nesting by Barn Swallows is unclear because few results are available. Although loss of nesting habitat is only one potential factor contributing to Barn Swallow population declines, it is important for conservation efforts that address habitat loss to make the best use of funds and opportunities by providing nesting habitat that is most likely to be used productively by the species.

Barn Swallows often nest colonially (Brown and Brown 1999), suggesting they may use conspecific cues (e.g., the presence of adults at a nesting structure) when selecting nest sites. There is some evidence of success in using conspecific cues to attract Purple Martin (*Progne subis*; another swallow species) to nest in previously unoccupied martin houses (Kostka 2000). We hypothesized that introducing conspecific cues (i.e., decoys and vocalizations), to make it appear that a structure was already being used by nesting Barn Swallows, would increase the likelihood of nesting at a new structure.

There is evidence that the presence of old nests influences the use of a nest site by Barn Swallows. Safran (2004) found that removing old nests before birds arrived on the breeding grounds reduced the proportion of immigrant female Barn Swallows at sites in New York. Additionally, birds that reused old nests had higher seasonal fecundity than those that built new nests (Safran 2004). Settlement patterns of females breeding at a site for the first time were associated with the number of old nests, rather than the prevalence of colourful males or opportunities for extra-pair copulations (Safran 2007). Ringhofer and Hasegawa (2014) found that the number of old undamaged nests was associated with the spring arrival date of male Barn Swallows at nest sites. Thus, both conspecific cues and the presence of old nests likely influence the use of nest sites by Barn Swallows.

Barn Swallows likely gather information about numerous potential nest sites before selecting one for breeding, as occurs with other migratory songbirds (Brown and Brown 1999; Reed *et al.* 1999). Visits to nesting structures by Barn Swallows likely indicate that individuals are gathering information about the structure for potential future use for nesting. Attracting Barn Swallows to new nesting structures could positively or negatively influence reproductive success. Breeding success of Barn Swallows can decrease with increasing number of proximate nests (Shields and Crook 1987); however, it is unknown how the use of conspecific cues might influence the reproductive success of the species.

Our goal was to test the influence of conspecific cues on the use of newly built nesting structures by Barn Swallows to inform conservation efforts that include the creation of nesting structures. In experiment one, we monitored pre-breeding prospecting visits by Barn Swallows to assess if birds visited structures with conspecific cues (i.e., vocalizations and decoys) more frequently than structures without cues. In experiment two, we monitored post-breeding prospecting visits to assess if birds visited structures with conspecific cues more frequently than structures without cues. In experiment three, we further investigated the immediate response to conspecific vocalizations by assessing if Barn Swallows visited structures more frequently during or after vocalization broadcasts compared to before broadcasts. Additionally, we monitored nesting following pre- and post-breeding cues to assess if conspecific cues influenced the number and success of Barn Swallow nests at nesting structures.

Study Area

We located study sites where an old structure with nesting Barn Swallows was removed or made unavailable to the birds. This situation enabled us to simulate the circumstances under which many new nesting structures are being built in Ontario (i.e., mitigation for loss of nesting habitat under the *Endangered Species Act* [MECP 2013]). We coordinated the construction of two new nesting structures at each site, during the fall or spring, prior to the breeding season. The result was a paired design, with two new nesting structures on each study site, one treatment with conspecific cues and one control without conspecific cues, thus allowing us to assess the influence of the cues on Barn Swallow use of the new nesting structures. We flipped a coin to randomly select one of the two structures on each of the 10 study sites to have conspecific cues (i.e., decoys and a broadcast box).

We established 10 study sites in southern Ontario between Erin (43.766°N, 80.058°W) in the north and Port Rowan (42.626°N, 80.452°W) in the south. We opportunistically identified study sites through existing contacts and by directly contacting landowners. Barn Swallow nesting habitat was lost at study sites prior to our study because structures were demolished or access to structures was blocked due to building renovation, nesting deterrents, or a need to keep doors closed (Table 1). The number of Barn Swallow nests in structures where habitat was lost varied, from one to ~50, across study sites (Table 1). We were unable to estimate the number of nests that were used in the year before habitat was lost, which would have provided better information about the number of nesting pairs compared to the number of nests. To the best of our knowledge, Barn Swallows nested at ≥8 of the 10 study sites in the year prior to our experiment.

We used the following criteria to guide where to place new nesting structures. We placed structures in non-forested areas with foraging habitat for Barn Swallows (i.e., grassland, cropland; Brown and Brown 1999). Additionally, we attempted to build new structures ≤1 km from the previous nesting location to meet mitigation guidelines (MECP 2013) and so that Barn Swallows returning to the site could easily encounter the new structures. We attempted to place the two new structures equal distances from the location of the demolished, renovated, or closed structure and about 400 m apart from each other to minimize the effects of the conspecific cues on the control structure (i.e., to ensure that broadcasted vocalizations were inaudible at control structures). Additionally, we attempted to place structures >100 m from forest edges to maximize availability of proximate foraging habitat. Because of constraints on study sites, we placed nesting structures 81–1220 m (mean = 427 m) from the location where Barn Swallows nested previously, 265–589 m (mean = 378 m) apart from each other, and 16–474 m (mean = 167 m) from the nearest forest edge based on land cover data from the Southern Ontario Land Resource Information System (MNRF 2000).

Methods

Structures

We designed nesting structures using the best available information about what Barn Swallows would most likely use (Brown and Brown 1999). However, information about structures built for Barn Swallow nesting is limited and not in the literature. The best available information suggested building

TABLE 1. Reason for habitat loss, number of Barn Swallow (*Hirundo rustica erythrogaster*) nests in lost habitat in year before monitoring (number of previously-active nests unknown), number of new nests in structures with and without pre-breeding conspecific cues built to replace lost habitat, and the year each study site was monitored.

Site	Old structure		No. nests in new structure		Year monitored
	Habitat lost	No. nests	Conspecific cues	No cues	
AN	Barn demolished	~12	2	2	2014
CH	Barn access denied	Unknown*	0	0	2015
DA	Barn access denied	1 to 2†	0	0	2015
DR	Barn access denied	~6 pairs‡	0	0	2015
GU	Barn access denied	1§	0	0	2015
LA	Barn demolished	6	0	1	2014
LE	Barn demolished	20 to 50	2	1	2015
RA	Eaves access denied	1	2	0	2015
WA	Barn access denied	4 to 5	0	1	2015
WI	3 buildings demolished	~15	0	0	2015

*Landowner observed several nesting pairs previously using structure, but structure was inaccessible to confirm presence of nests.

†Nests active in 2012.

‡Number of nests unknown, landowner estimated six nesting pairs.

§Unknown if nest active in 2014.

structures with similar characteristics to bridges and barns that are used for nesting, including rough vertical surfaces on which birds can build nests, shelter from wind and rain, visual barriers between nests, and a structure large enough to support several nesting pairs (MECP 2013; L. Sarris pers. comm. 13 February 2014; K.R. unpubl. data). We designed a wooden structure with a metal roof, 4.9 m long, 1.3 m wide at the nesting compartments, and 3.7 m tall at the peak of the roof (Figure 1). The structure included 16 nesting compartments, two rows of eight compartments along the 4.9-m length of the structure. In each row of eight compartments, we alternated available nest supports by providing a wooden nest cup (i.e., a wooden replica of a nest) in one compartment and bridging in the shape of the letter X, as found in some old barns, in the next compartment. Each compartment was bordered by 5 × 25 cm lumber along the center and along the outside of the structure and 5 × 15 cm lumber between compartments on the inside of the structure to provide a visual barrier between nests. Compartments had a flat ceiling above and no obstructions below. To provide shelter from weather, we added 40 cm of lumber along the outside of the structure below the nesting compartments.

FIGURE 1. One of the nesting structures built to test the impact of conspecific cues on prospecting and nesting by Barn Swallows (*Hirundo rustica erythrogaster*) in southern Ontario, Canada. Photo: A.J. Campomizzi.

Each structure was equipped with nest cups, perches, and predator deterrents to encourage use by Barn Swallows and decrease risk of nest predation. We placed nest cups on all structures because they are required for mitigation projects in Ontario (MECP 2013). Although the presence of old nests may increase the chance of nesting, Barn Swallow response to nest cups is unknown. We placed 16 nest cups on each structure, eight on the inside and eight on the outside of the structure. We placed nest cups far enough from ceilings (6.4 cm) and roofs (6.4 cm under roof peaks and 10.8 cm under sloped roofs) to allow the birds to build a mud rim along the top of the cup. The distance between the top of the nest cup and the ceiling or roof above was based on instructions provided by a nest cup supplier (American Artifacts, Taneytown, USA) and Barn Swallow nest placement (i.e., typically 2.5 to 6.0 cm from a ceiling; Brown and Brown 1999). We attached four perches to each structure; two on the inside and two on the outside. We included perches on the structures because there is evidence that adults lead juveniles from the nest to a perch, fledglings frequently perch after leaving the nest, and fledglings are initially fed by parents while perched (Brown and Brown 1999). To deter mammalian nest predators from accessing and preying on nests, we covered each support post with galvanized sheet metal (Figure 1).

Experiment one: pre-breeding prospecting

We monitored structures at 10 study sites (two sites in 2014 and eight in 2015). We placed seven carved Barn Swallow decoys (Olde World Carvings, Spartanburg, South Carolinia, USA; Starr Decoys, Weybridge, Vermont, USA) at each treatment structure on perches and nests to make it appear as though the structure was being used, but not fully occupied, by nesting Barn Swallows.

We attached the broadcast box to a small shelf about 1.5 m from the ground on a post that supported each treatment structure. We largely followed Farrell and Campomizzi (2011) for the design of the broadcast box, resulting in a plastic box containing a compact disc player, amplified speaker, battery, and timer that broadcasted Barn Swallow vocalizations periodically throughout the day. We made a 30-min audio track of Barn Swallow songs, non-alarm calls, and periods of silence to simulate an active Barn Swallow nesting colony. To assemble the 30-min track, we obtained eight audio recordings made in Ontario and adjacent US states from the Cornell Lab of Ornithology (2014). To provide vocalizations throughout the day, we programmed the timer to turn the broadcast box on for 30 min at 0600, 0700, 0800, 1000, 1200, 1500, 1700, and 1900. We used the literature about Barn Swallow vocalizations to guide our selection of songs and calls to include, when to broadcast the vocalizations during the day, and the number of vocalizations interspersed with silence (Samuel 1971; Brown 1985; Brown and Brown 1999). We installed conspecific cues for the return of Barn Swallows to the study area for breeding in the spring. We continued broadcasting vocalizations for the duration of the nesting season, until late August in 2014 and early September in 2015.

Across 2014 and 2015, we monitored 10 treatment and 10 control structures for pre-breeding prospecting visits by Barn Swallows to assess if birds visited structures with conspecific cues more frequently than structures without cues and to record their behaviour. We conducted prospecting surveys at a designated survey location 50 m from each structure twice per week, between sunrise and sunset. Pre-breeding prospecting surveys occurred from 24 April to 14 June. This period corresponds to Barn Swallow arrival in the study area and the beginning of nesting. Seven to 21 days pass between pair formation and egg laying (Brown and Brown 1999) and the earliest egg date for Ontario is 10 May (Peck and James 1987).

During each 10-min survey, we recorded each Barn Swallow detected within 50 horizontal m of the structure. During each 2-min interval of the 10-min survey, we recorded each individual detected, its distance from the structure, if it behaviourally interacted with the structure (perched on, flew under, or flew into or out of the structure). We also recorded if we detected an individual carrying nest material during the 10-min survey and if birds interacted with, perched next to, or attempted to copulate with decoys. We recorded a conservative estimate of the number of individuals to avoid counting one individual multiple times during a survey. We conducted surveys during weather conducive to Barn Swallow activity and detection (i.e., not during rain or strong wind). We noted if nest predators were on or attempting to get on the structure. After each survey, we walked to the structure to see if birds were inside and to monitor nests, as described below.

Experiment two: post-breeding prospecting

Following the pre-breeding prospecting experiment at each study site, we monitored 10 treatment and 10 control structures for post-breeding prospecting visits by Barn Swallows to assess if birds visited structures with conspecific cues more frequently than structures without cues, and to record their behaviour. Using the same broadcast schedule of Barn Swallow vocalizations and bird survey methods described above, we conducted post-breeding surveys from 20 July to 5 September, a range that includes when pairs not attempting second broods are finishing caring for dependent fledglings to when we no longer saw birds in breeding areas. The latest egg date for Ontario is 21 August (Peck and James 1987).

Experiment three: prospecting before, during, and after

In 2016, we placed conspecific vocal cues at three structures that were randomly selected as treatments in 2015 but were not used for nesting by Barn Swallows in 2015. In 2016, each of the three study sites had a pair of structures, one with and one without conspecific vocal cues. We did not use decoys for experiment three.

We changed the frequency and duration of vocalizations played on each day at each treatment structure compared to 2015 to enable assessment of Barn Swallow visits before, during, and after broadcasts of vocalizations. Vocalizations played for 20 min at the start of each hour between 0600 and 2100. Broadcasts began on 19 April and ceased on 6 June.

In 2016, we surveyed the three nesting structures for pre-breeding prospecting visits by Barn Swallows. We designed surveys to document Barn Swallows searching for nest sites (particularly behavioural interactions with structures) and if conspecific cues influenced the frequency of detections. We visited treatment structures twice per week, once in the morning and once in the afternoon or evening, for a one hour survey. We scheduled the majority of surveys during the morning and evening because, in 2014 and 2015, we observed more Barn Swallow activity during these times compared to other times. The survey hour consisted of 20 min before the broadcast, 20 min of broadcast, and 20 min after the broadcast. We observed treatment structures from a designated survey location 50 m away, recording all individual Barn Swallows that came within 50 horizontal m. Survey periods were broken into 5-min intervals to record possible variation in bird abundance and behaviour throughout the survey. During each 5-min interval, we recorded detections of each individual. For each Barn Swallow detected, we recorded its horizontal distance from, and interactions with, the nesting structure. We conducted surveys during weather conducive to Barn Swallow activity and detection.

After each survey, we approached the treatment structure to look for signs of nesting and check active nests. We did not conduct prospecting surveys of the control structures on the three study sites because we were testing Barn Swallow response to broadcasts at treatment structures only (prospecting surveys at control structures were conducted for the pre-breeding and post-breeding prospecting experiments, see above). We checked for nesting activity at control structures after surveys were completed at treatment structures.

Nest monitoring

We monitored nests to assess differences in the number of nests and nest success of Barn Swallows between structures with and without conspecific cues. We monitored 10 study sites across 2014 and 2015 following pre-breeding conspecific cues. Additionally, we monitored nesting at eight study sites in 2016 following post-breeding conspecific cues applied in 2015. Nest monitoring occurred from 12 May to 22 August. We followed nest monitoring protocols for Barn Swallows provided on Bird Studies Canada's Project NestWatch website (http://www.birdscanada.org/volunteer/pnw/index.jsp?targetpg=barsmonitor), with minor modifications. We looked for evidence of nest building while conducting bird surveys early in the breeding season. At the five study sites without bird surveys in 2016, the frequency of nest monitoring visits varied based on whether there were active nests at the site. We checked active nests approximately once per week until nesting activity ceased. Sites without active nests were checked periodically throughout the season.

We began monitoring nests with a mirror to observe nest contents on the visit after a nest appeared fully built, to minimize the chance of nest abandonment. We checked nest contents with a mirror once every five to seven days. During each nest check, we recorded the number of eggs, number and age of young, brood parasitism, adult activity, and condition of the nest. We did not check nest contents with a mirror if nestlings were >10 days old, to avoid potentially causing young to fledge prematurely; instead, we observed the nest from a distance with binoculars. We continued to check nesting structures for active nests throughout the breeding season.

Analyses

We did not use statistical analyses for nest data because sample size of nests was too small. Instead, we described nesting activity. For bird survey data, we first explored data through graphs and descriptive statistics. We excluded survey data collected while Barn Swallow nests were active at a structure to ensure that detections were of prospecting birds, not adults attending to nests. We used means and CI to assess the direction, magnitude, and precision of effects (Johnson 1999; Wasserstein and Lazar 2016), and interpreted their biological importance (Guthery *et al.* 2001; Nakagawa and Cuthill 2007; Nuzzo 2014). We calculated means and CI for the difference in Barn Swallow detections and interactions with structures from spatially and temporally paired surveys described below. We conducted analyses using R (version 3.4.1, R Core Team 2017).

Experiment one: pre-breeding prospecting: We separately compared the abundance of Barn Swallows detected and interacting with structures during pre-breeding surveys. We compared the difference in abundance of Barn Swallows detected between (1) broadcast and non-broadcast times at treatments, (2) broadcast and non-broadcast times at controls, and (3) all surveys at treatments compared to controls. We made the same three comparisons in the difference in the abundance of Barn Swallows interacting with structures. For comparisons during broadcast and non-broadcast times at treatments and controls, we paired surveys conducted during the same week for each structure. For example, to calculate the difference in abundance between broadcast and non-broadcast times at each treatment structure for each week of surveys, we subtracted the number of Barn Swallows detected during the non-broadcast time from the number of individuals detected while conspecific vocalizations were broadcasted. For comparisons between treatments and controls, we paired surveys conducted on the same day for each pair of treatment and control structures at each study site. These analyses resulted in three estimates of the difference in abundance of Barn Swallows detected at structures (Figure 2a) and another three estimates of the difference in abundance of individuals interacting with structures (Figure 2b) during pre-breeding surveys. Estimated means greater than zero indicate more Barn Swallows detected or interacting with structures during broadcast compared to non-broadcast or treatment compared to control.

Experiment two: post-breeding prospecting: For post-breeding surveys, we made the same comparisons as pre-breeding surveys with one exception. We used surveys at treatments during broadcast and controls during non-broadcast only because mean abundance at treatments was more than twice as high during broadcast compared to non-broadcast times, suggesting a potential numerical response by the birds. These analyses resulted in an additional three estimates of the difference in abundance of Barn Swallows detected at structures (Figure 2a) and three estimates of the difference in abundance of individuals interacting with structures (Figure 2b) during post-breeding surveys.

Experiment three: prospecting before, during, and after: We compared the difference in abundance of Barn Swallows detected at treatment structures during broadcast versus before broadcast and after broadcast versus before. We paired data for surveys conducted on the same day for each structure. We were unable to make comparisons of the abundance of Barn Swallows interacting with structures because we did not detect interactions during these surveys. These analyses resulted in two estimates of the difference in abundance of Barn Swallows detected at structures (Figure 3). Estimated means greater than zero indicate more Barn Swallows detected during broadcast compared to before broadcast or after broadcast compared to before.

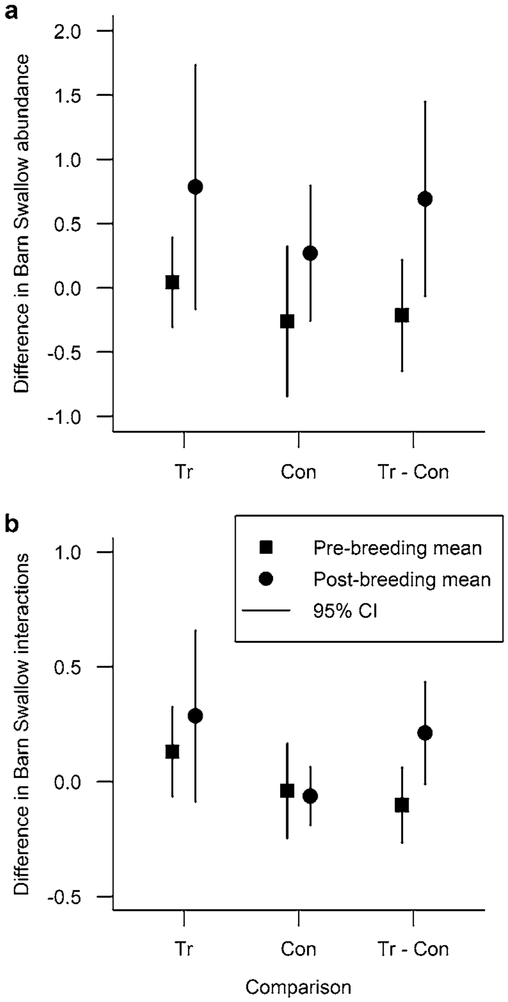


FIGURE 2. Mean and 95% CI of the difference in abundance of Barn Swallows (*Hirundo rustica erythrogaster*) a. detected and b. interacting with nesting structures (i.e., perched on, flew under, or flew into or out of the structure) with and without conspecific cues in southern Ontario, Canada in 2014 and 2015. Comparisons during pre-breeding are for structures treated with conspecific cues during broadcast minus non-broadcast surveys (Tr), control structures during broadcast minus non-broadcast surveys (Con), and all treatment minus control surveys (Tr - Con). Comparisons during post-breeding are the same for Tr and Con; the third comparison is of treatment during broadcast minus control during non-broadcast surveys only (Tr - Con).

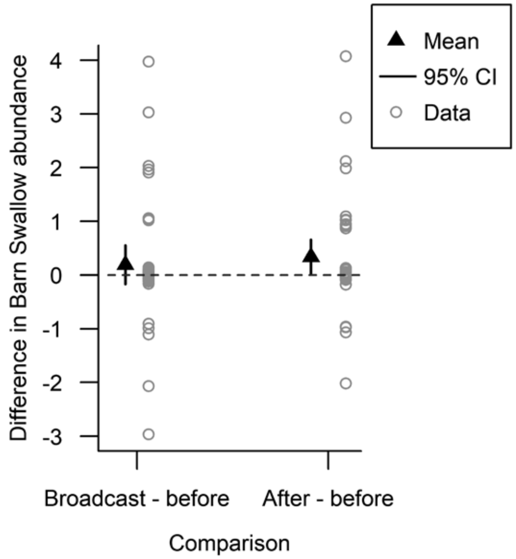


FIGURE 3. Mean, 95% CI, and observed data of the difference in abundance of Barn Swallows (*Hirundo rustica erythrogaster*) detected on one hour surveys conducted for 20 min before, during, and after conspecific vocalizations at three nesting structures in southern Ontario, Canada in 2016.

Results

Across all surveys in 2014 and 2015, we detected Barn Swallows on 33% (*n* = 263) of surveys at structures with conspecific cues and 38% (*n* = 263) of surveys at structures without cues. Across surveys with Barn Swallow detections, we detected 279 Barn Swallows on 88 surveys at structures with conspecific cues and 299 Barn Swallows on 99 surveys at structures without cues. These results include data from surveys of structures with active nests. As noted above, we reduced the dataset for the comparisons below.

Experiment one: pre-breeding prospecting

During pre-breeding, the mean difference in Barn Swallow abundance during broadcast compared to non-broadcast times at treatments was 0.04 (*n* = 46) and not substantially different from zero (Figure 2a). Similarly, the mean difference in Barn Swallow abundance during broadcast compared to non-broadcast times at controls (−0.26, *n* = 50) and at treatments compared to controls (−0.21, *n* = 98) was not substantially different from zero (Figure 2a).

Experiment two: post-breeding prospecting

During post-breeding, all three mean differences in Barn Swallow abundance were larger than during pre-breeding and greater than zero. The mean difference in Barn Swallow abundance during broadcast compared to non-broadcast times was 0.78 (*n* = 42) at treatments, 0.27 (*n* = 48) at controls, and 0.69 (*n* = 52) at treatments compared to controls. These differences suggest an effect of ~0.5 individuals per survey, but 95% CI included zero, although marginally for treatments compared to controls (lower 95% CI: −0.06; Figure 2a).

The largest differences in abundance of Barn Swallows interacting with structures was during post-breeding. The mean difference in Barn Swallows interacting with structures during broadcast compared to non-broadcast was 0.28 (*n* = 42) at treatments and 0.21 (*n* = 52) for treatments compared to controls (Figure 2b). Both CI marginally included zero (lower 95% CI: −0.09 for treatments and −0.01 for treatments compared to controls), indicating some lack of confidence in an effect of ~0.2 individuals per survey interacting with structures (Figure 2b).

Experiment three: prospecting before, during, and after

We detected 40 individual Barn Swallows on prospecting surveys in 2016 and 45% (*n* = 42) of surveys for this experiment had Barn Swallow detections. We detected 12, 20, and 26 individuals before, during, and after conspecific broadcast, respectively. Mean difference in abundance of Barn Swallows detected at treatment structures was higher both during broadcast compared to before broadcast (0.19, *n* = 42) and after broadcast compared to before (0.33, *n* = 42; Figure 3). The CI for after broadcast compared to before was greater than zero (95% CI: 0.01, 0.65; Figure 3). We did not observe Barn Swallows behaviourally interacting with structures (i.e., perching on or flying inside of a structure) in 2016.

Nesting

Experiment one: pre-breeding prospecting: Across 2014 and 2015, there were six nests on three structures with conspecific cues and five nests on four structures without cues (Table 1). All nests observed with eggs eventually fledged young. Two additional nests were built on structures without cues; however, we never observed eggs in these nests. All three nesting pairs at structures with conspecific cues appeared to fledge a second clutch, compared to one of four pairs nesting at structures without cues. The earliest nest initiation date (i.e., first egg date) was 20 May at structures with conspecific cues and 21 May at structures without cues.

All nests were built in wooden nest cups in the interior of the structures. For all 11 nests monitored following pre-breeding cues, Barn Swallows added a mud rim to the top of the wooden nest cup, making the top of the nest look similar to a typical Barn Swallow nest.

Experiment 2: post-breeding prospecting: In 2016, four nests were built in two of eight structures treated with post-breeding conspecific cues in 2015, compared to four nests in three of eight structures without post-breeding cues in 2015. All eight nests were in nest cups in the interior of the structure and fledged young. One additional nest was initiated on the exterior of a structure but was abandoned after some addition of mud to a nest cup; we did not observe eggs in this nest. Two nests from 2015 were reused in 2016. Three of the eight nests appeared to be second clutches.

Experiment 3: prospecting before, during, and after: Barn Swallows did not nest at the three sites used for the experiment comparing prospecting before, during, and after broadcasts of vocalizations in 2016.

Discussion

To our knowledge, this is the first evaluation of Barn Swallow use of new nesting structures specifically built for the species. Our study provides some evidence to link prospecting behaviour by Barn Swallows at new nesting structures to broadcasts of conspecific vocalizations. During pre-breeding, Barn Swallow abundance was higher immediately after conspecific broadcasts compared to before broadcasts. However, we did not find substantial differences in Barn Swallow abundance and interactions with new nesting structures for other comparisons involving conspecific cues. Most importantly, Barn Swallows did not nest more frequently on structures treated with pre- or post-breeding conspecific cues; they nested on and fledged young from structures with and without cues, albeit in low numbers.

Our results provide some evidence that Barn Swallows can be attracted to at least investigate new nesting structures by introducing conspecific cues. On several occasions, we observed Barn Swallows approaching nesting structures immediately after the broadcast started, anecdotally suggesting a response to the start of the vocalizations. On a few occasions, we observed Barn Swallows interacting with decoys by perching on, singing at, and attempting to copulate with decoys. Previous research in the literature has not documented Barn Swallow prospecting behaviour in response to simulated conspecific cues at nesting sites. A study on Chimney Swift (*Chaetura pelagica*; another aerial insectivore species) showed that introducing conspecific vocalizations and decoys increased the length of time that the birds spent near new nesting towers (Finity and Nocera 2012). Additionally, conspecific cues introduced during post-breeding have been shown to influence habitat selection in the next breeding season for migratory songbirds (Nocera *et al.* 2006, Betts *et al.* 2008). In our study, however, Barn Swallows did not build more nests in 2016 at structures treated with conspecific cues during post-breeding in 2015, compared to structures without cues. Future research to explore the impacts of broadcasted conspecific vocalizations on prospecting behaviour and nesting may help inform future efforts to create nesting habitat for various species.

Some of the structures included in this project provided nesting habitat for Barn Swallows and all nests observed with eggs fledged young. We did not observe a difference in the number of nests built on structures with and without conspecific cues that were provided during pre-breeding or post-breeding. Although nesting structures provided opportunities for birds to nest on X-shaped bridging in addition to nest cups, all nests were built in nest cups. Nest cups may be an important feature of new nesting structures because they provide a nesting substrate and essentially a partially-built nest. The nest cups may attract Barn Swallows to new structures if they function similarly to old nests (*sensu* Safran 2004, 2007; Ringhofer and Hasegawa 2014) and enable birds to begin nesting earlier in the season because the birds do not need to build an entire nest. Re-using old nests can increase reproductive success (Safran 2007; but see Barclay 1988). Therefore, nest cups could be important for conservation because they may enable Barn Swallow pairs to raise a second brood, thus increasing fecundity. Combining conspecific cues and the presence of old nests (perhaps by providing wooden nest cups) may maximize the number of Barn Swallows that prospect at new nesting structures but may not lead to more nests at new structures.

It is possible that the structures with and without cues were not far enough apart to completely separate the effect of the conspecific cues. Although the distance Barn Swallows travel to prospect for nest sites is unknown, adults will forage up to 500 m from nesting colonies (Møller 1987), suggesting individuals encountering one structure on a study site could encounter the other structure. Future research to assess if conspecific cues at one structure can affect prospecting at multiple structures, or if prospecting is greater at structures with conspecific cues compared to structures without cues (at greater distances than we tested), may be helpful for understanding nest site selection and guiding conservation efforts. Additionally, most of our study sites had few nests in the nesting habitat that was lost. With few Barn Swallows returning to nest at these sites, there may have been few Barn Swallows within hearing distance of the vocalizations. The number of philopatric Barn Swallows may impact the magnitude of the effect of conspecific cues on prospecting birds.

We are uncertain how many nesting pairs could nest simultaneously on the structures used for our experiment. However, building a few of these new structures is unlikely to replace the lost nesting habitat provided by bridges or old barns with large nesting colonies (e.g., 50 breeding pairs). Building one nesting structure cost ~$2500 to $3500 (CAD). Regulators and land managers should consider if this expense is worth the benefit or if funds could be used in more effective ways to support Barn Swallow nesting habitat. A potential alternative is to provide incentives for landowners to repair and maintain aging barns that can provide nesting habitat for larger colonies of Barn Swallows and for more years than new structures (Heagy *et al.* 2014). It may also be beneficial for future research to investigate the relationship between colony size and characteristics of nesting structures and the surrounding landscape. Building new nesting structures may be an option for creating new Barn Swallow nesting habitat in locations with appropriate foraging habitat (i.e., grassland, cropland; Brown and Brown 1999), where no structure currently exists and there is an interest in contributing to Barn Swallow conservation. When structures are built for Barn Swallow nesting habitat, we recommend including wooden nest cups in the interior of the structure, which was the location of all nests in our experiment. However, more research is needed to assess if loss of nesting habitat is limiting the Barn Swallow population to determine if creating or maintaining nesting habitat is likely to have a positive impact on the population or if resources should be directed to addressing other threats to the species.

Our results confirm that new structures can provide nesting habitat for Barn Swallows but providing conspecific cues may not enhance this conservation strategy. The paucity of nests built on structures raises questions about the efficacy and efficiency of building new nesting structures to mitigate the loss of nesting habitat.

Author Contributions

Conceptualization: Z.M.L., A.J.C., and K.R.; Data Curation: A.J.C. and Z.M.L.; Formal Analysis: A.J.C.; Funding Acquisition: K.R., Z.M.L., and A.J.C.; Investigation: Z.M.L., A.J.C., and K.R.; Methodology: A.J.C., Z.M.L., and K.R.; Project Administration: Z.M.L., K.R., and A.J.C.; Resources: Z.M.L. and K.R.; Supervision: Z.M.L. and K.R.; Validation: A.J.C. and Z.M.L.; Visualization: A.J.C. and Z.M.L.; Writing – Original Draft: A.J.C. and Z.M.L.; Writing – Review & Editing: A.J.C., Z.M.L., and K.R.

Acknowledgements

Funding for this project was provided by the Government of Ontario, TD Friends of the Environment Foundation, The City of Waterloo, Colleges and Institutes Canada Clean Tech Internship program, Echo Foundation, the Government of Canada (Canada Summer Jobs Program), Ontario Soil and Crop Improvement Association through the Species at Risk Farm Incentive Program (SARFIP), and individual donors. We are grateful for assistance with field monitoring from Betty Chanyi, Timothy Fernandes, Rebecca Howe, Jaelyn Kloepfer, Katherine Robbins, Gail Tako, Bob Wood, Graham Wood, Karen Wood, and Carolyn Zanchetta. Thanks to Becky Stewart, Bird Studies Canada, for the opportunity to undertake this project. We also thank the Nature Conservancy of Canada, *rare* Charitable Research Reserve, The Arboretum at the University of Guelph, The City of Waterloo, and several private landowners for allowing construction and monitoring of nesting structures on their properties. Richard Van Vleck (American Artifacts) and Larry Sarris (Ontario Ministry of Transportation) provided substantial helpful information about structures for Barn Swallows. Thanks to Jeff Sauder (for assistance designing structures and leading construction) and the other builders. Mike Cadman, Tara Imlay, and two anonymous reviewers provided helpful comments on previous versions of this manuscript. The views expressed herein are those of the authors, not funders or other entities.

Literature Cited

Ahlering, M.A., and J. Faaborg. 2006. Avian habitat management meets conspecific attraction: if you build it, will they come? Auk 123: 301–312. https://doi.org/10.1642/0004-8038(2006)123[301:ahmmca]2.0.co;2

Barclay, R.M.R. 1988. Variation in the costs, benefits, and frequency of nest reuse by Barn Swallows (*Hirundo rustica*). Auk 105: 53–60. https://doi.org/10.1093/auk/105.1.53

Betts, M.G., A.S. Hadley, N. Rodenhouse, and J.J. Nocera. 2008. Social information trumps vegetation structure in breeding-site selection by a migrant songbird. Proceedings of the Royal Society of London B: Biological Sciences 275: 2257–2263. https://doi.org/10.1098/rspb.2008.0217

BirdLife International. 2016. *Hirundo rustica*. The IUCN Red List of Threatened Species 2016: e.T22712252A87461332. http://doi.org/10.2305/iucn.uk.2016-3.rlts.t22712252a87461332.en

Brown, C.R. 1985. Vocalizations of Barn and Cliff Swallows. Southwestern Naturalist 30: 325–333. https://doi.org/10.2307/3671263

Brown, C.R., and M.B. Brown. 1999. Barn Swallow (*Hirundo rustica*), The Birds of North America Online. *Edited by* A. Poole. Cornell Lab of Ornithology, Ithaca, New York, USA. Accessed 1 February 2014. https://birdsna.org/Species-Account/bna/species/barswa/introduction.

Cornell Lab of Ornithology. 2014. Macaulay Library. Accessed 14 April 2014. https://www.macaulaylibrary.org/.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2011. COSEWIC assessment and status report on the Barn Swallow *Hirundo rustica* in Canada. COSEWIC, Ottawa, Ontario, Canada.

Danchin, E., L.A. Giraldeau, T.J. Valone, and R.H. Wagner. 2004. Public information: from nosy neighbors to cultural evolution. Science 305: 487–491. https://doi.org/10.1126/science.1098254

Danchin, E., R.H. Wagner, J.K. Parrish, and L. Edelstein-Keshet. 2000. Benefits of membership. Science 287: 804–807. https://doi.org/10.1126/science.287.5454.803e

Doligez, B., T. Pärt, and E. Danchin. 2004. Prospecting in the collared flycatcher: gathering public information for future breeding habitat selection? Animal Behaviour 67: 457–466. https://doi.org/10.1016/j.anbehav.2003.03.010

Farrell, S.L., and A.J. Campomizzi. 2011. A component system for broadcasting sound for research and management. Journal of Wildlife Management 75: 463–466. https://doi.org/10.1002/jwmg.45

Farrell, S.L., M.L. Morrison, A.J. Campomizzi, and R.N. Wilkins. 2012. Conspecific cues and breeding habitat selection in an endangered woodland warbler. Journal of Animal Ecology 81: 1056–1064. https://doi.org/10.1111/j.1365-2656.2012.01995.x

Finity, L., and J.J. Nocera. 2012. Vocal and visual conspecific cues influence the behavior of Chimney Swifts at provisioned habitat. Condor 114: 323–328. https://doi.org/10.1525/cond.2012.110145

Government of Canada. 2017. Species profile: Barn Swallow. Accessed 20 March 2019. https://wildlife- species.canada.ca/species-risk-registry/species/speciesDetails_e.cfm?sid=1147.

Guthery, F.S., J.J. Lusk, and M.J. Peterson. 2001. The fall of the null hypothesis: liabilities and opportunities. Journal of Wildlife Management 65: 379–384. https://doi.org/10.2307/3803089

Hahn, B.A., and E.D. Silverman. 2006. Social cues facilitate habitat selection: American redstarts establish breeding territories in response to song. Biology Letters 2: 337–340. https://doi.org/10.1098/rsbl.2006.0472

Heagy, A., D. Badzinski, D. Bradley, M. Falconer, J. McCracken, R.A. Reid, and K. Richardson. 2014. Recovery Strategy for the Barn Swallow (*Hirundo rustica)* in Ontario. Ontario Recovery Strategy Series. Accessed 20 March 2019. http://files.ontario.ca/environment-and-energy/species-at-risk/mnr_sar_rs_brn_swl_en.pdf.

Johnson, D.H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63: 763–772. https://doi.org/10.2307/3802789

Kostka, K. 2000. Social attraction: a new technique for establishing a Purple Martin colony site. Purple Martin Conservation Association. Accessed 1 December 2015. http://www.purple-martin.org/PMArticles/SocialAttractionPMPA.htm.

Lepage, D. 2007. Barn Swallow. Pages 398–399 *in* Atlas of the breeding birds of Ontario, 2001–2005. *Edited by* M.D. Cadman, D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, Ontario Nature, Toronto, Ontario, Canada.

MECP (Ministry of Environment, Conservation and Parks. 2012. Species at risk in Ontario. Accessed 21 March 2019. https://www.ontario.ca/page/species-risk-ontario.

MECP (Ministry of Environment, Conservation and Parks). 2013. Alter a structure (habitat for Barn Swallow). Accessed 21 March 2019. https://www.ontario.ca/page/alter-structure-habitat-barn-swallow.

MNRF (Ministry of Natural Resources and Forestry). 2000. Southern Ontario Land Resource Information System (SOLRIS). Accessed 21 March 2019. https://data.ontario.ca/dataset/southern-ontario-land-resource-information-system-solris-20.

Møller, A.P. 1987. Advantages and disadvantages of coloniality in the swallow, *Hirundo rustica*. Animal Behaviour 35: 819–832. https://doi.org/10.1016/S0003-3472(87)80118-5

Nakagawa, S., and I.C. Cuthill. 2007. Effect size, confidence interval and statistical significance: a practical guide for biologists. Biological Reviews 82: 591–605. https://doi.org/10.1111/j.1469-185X.2007.00027.x

Nebel, S., A. Mills, J.D. McCracken, and P.D. Taylor. 2010. Declines of aerial insectivores in North America follow a geographic gradient. Avian Conservation and Ecology 5(2): 1. http://doi.org/10.5751/ACE-00391-050201

Nocera, J.J., G.J. Forbes, and L.A. Giraldeau. 2006. Inadvertent social information in breeding site selection of natal dispersing birds. Proceedings of the Royal Society of London B: Biological Sciences 273: 349–355. https://doi.org/10.1098/rspb.2005.3318

Nuzzo, R. 2014. Statistical errors: *P* values, the "gold standard" of statistical validity, are not as reliable as many scientists assume. Nature 506: 150–152. https://doi.org/10.1038/506150a

Parrish, J.K., and L. Edelstein-Keshet. 1999. Complexity, pattern, and evolutionary trade-offs in animal aggregation. Science 284: 99–101. https://doi.org/10.1126/science.284.5411.99

Peck, G.K., and R.D. James. 1987. Breeding Birds of Ontario: Nidiology and Distribution Volume 2: Passerines. The Royal Ontario Museum, Toronto, Ontario, Canada. https://doi.org/10.5962/bhl.title.60694

R Core Team. 2017. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reed, J.M., T. Boulinier, E. Danchin, and L.W. Oring. 1999. Informed dispersal: prospecting by birds for breeding sites. Current Ornithology 15: 189–259. https://doi.org/10.1007/978-1-4757-4901-4_5

Ringhofer, M., and T. Hasegawa. 2014. Social cues are preferred over resource cues for breeding-site selection in Barn Swallows. Journal of Ornithology 155: 531–538. https://doi.org/10.1007/s10336-013-1035-3

Safran, R.J. 2004. Adaptive site selection rules and variation in group size of barn swallows: individual decisions predict population patterns. American Naturalist 164: 121–131. https://doi.org/10.1086/422198

Safran, R.J. 2007. Settlement patterns of female barn swallows *Hirundo rustica* across different group sizes: access to colorful males or favored nests? Behavioral Ecology and Sociobiology 61: 1359–1368. https://doi.org/10.1007/s00265-007-0366-6

Samuel, D.E. 1971. Vocal repertoires of sympatric Barn and Cliff Swallows. Auk 88: 839–855. https://doi.org/10.2307/4083842

Sauer, J.R., W.A. Link, J.E. Fallon, K.L. Pardieck, and D.J. Ziolkowski, Jr. 2013. The North American Breeding Bird Survey 1966–2011: summary analysis and species accounts. North American Fauna 79: 1–32. https:// doi.org/10.3996/nafa.79.0001

Sauer, J.R., K.L. Pardieck, D.J. Ziolkowski, Jr., A.C. Smith, M.R. Hudson, V. Rodriguez, H. Berlanga, D.K. Niven, and W.A. Link. 2017. The first 50 years of the North American Breeding Bird Survey. Condor 119: 576–593. https://doi.org/10.1650/condor-17-83.1

Schlaepfer, M.A., M.C. Runge, and P.W. Sherman. 2002. Ecological and evolutionary traps. Trends in Ecology & Evolution 17: 474–480. https://doi.org/10.1016/S0169-5347(02)02580-6

Shields, W.M., and J.R. Crook. 1987. Barn Swallow coloniality: a net cost for group breeding in the Adirondacks? Ecology 68: 1373–1386. https://doi.org/10.2307/1939221

Smith, A.C., M.R. Hudson, C.M. Downes, and C.M. Francis. 2015. Change points in the population trends of aerial-insectivorous birds in North America: synchronized in time across species and regions. PLoS ONE 10: e0130768. https://doi.org/10.1371/journal.pone.0130768

Ward, M.P. 2005. Habitat selection by dispersing yellow-headed blackbirds: evidence of prospecting and the use of public information. Oecologia 145: 650–657. https://doi.org/10.1007/s00442-005-0179-0

Wasserstein, R.L., and N.A. Lazar. 2016. The ASA's statement on *p*-values: context, process, and purpose. American Statistician 70: 129–133. https://doi.org/10.1080/00031305.2016.1154108

Received 27 March 2019
Accepted 18 December 2019

The Canadian Field-Naturalist

Seasonal movements of White-tailed Deer (*Odocoileus virginianus*) in the Rocky Mountains of British Columbia

Trevor A. Kinley

Parks Canada Agency, P.O. Box 220, Radium Hot Springs, British Columbia V0A 1M0 Canada; email: trevor.kinley@canada.ca

Kinley, T.A. 2019. Seasonal movements of White-tailed Deer (*Odocoileus virginianus*) in the Rocky Mountains of British Columbia. Canadian Field-Naturalist 133(3): 246–252. https://doi.org/10.22621/cfn.v133i3.2201

Abstract

Nineteen adult female White-tailed Deer (*Odocoileus virginianus*), fitted with very high frequency or global positioning system collars in the Rocky Mountains of southeast British Columbia, exhibited straight-line seasonal movements ranging from <4 km to 109 km. Movement was almost entirely along the floor of both low- and high-elevation valleys, although there was some use of mid-elevation mountainsides during early winter. Spatial locations of deer spanned 891–2234 m above sea level. Seasonal movements of these deer from a single winter range extended to two provinces, three national parks, one provincial park, non-park provincial Crown land, and private land. Deer populations with similar movement patterns may be most effectively managed by considering their extensive movements and coordinating approaches across jurisdictions.

Key words: Kootenay National Park; *Odocoileus virginianus*; seasonal movement; summer range; White-tailed Deer; winter range

Introduction

White-tailed Deer (*Odocoileus virginianus*) inhabit a range of ecosystems across North and South America. Some individuals and populations exhibit migration (round-trip movements between distinct seasonal ranges, *sensu* Berger 2004) of tens of kilometres, with greater movements typical in northern or mountainous locations (Baumeister 1992; Demarais *et al.* 2000; Robinson *et al.* 2002; Nelson *et al.* 2004; Brinkman *et al.* 2005; Stewart *et al.* 2011). In some study areas, individuals may be sedentary, facultative migrators, or obligate migrators (Sabine *et al.* 2002; Brinkman *et al.* 2005; Fieberg *et al.* 2008; Grovenburg *et al.* 2011). Deer on low-quality winter range may be more likely to migrate as a result of density-dependent competition (Henderson *et al.* 2018). During spring and summer, an advancing line of greening vegetation offers ungulates in the Rocky Mountains the opportunity to follow high-quality habitat up slope (Merkle *et al.* 2016; Middleton *et al.* 2018).

Based on long-term roadside surveys and incidental observations, White-tailed Deer in Kootenay National Park (KNP), British Columbia (BC), Canada, are common from spring through fall, but absent or nearly so during winter (S. Wrazej unpubl. data). Considering those observations in the context of the strong elevation gradient in the area, seasonal elevation differences reported for nearby deer populations (Robinson *et al.* 2002; Hoekman *et al.* 2006), and an expectation of generally low-quality winter ranges for deer in snowy, mountainous areas in the northern part of their range, I speculated that deer summering in the park overwintered at lower elevations south of the park. I collared adult female White-tailed Deer south of the park and within the park, and investigated their movement patterns. Deer were monitored for variable periods and could not all be confirmed to make return movements (migrations); thus, I use the more general term "seasonal movement". I report on seasonal movements and elevation-use patterns of these collared deer, including in relation to jurisdictional boundaries potentially affecting management regimes.

Study Area

The Beaverfoot and upper Kootenay Rivers are part of the Columbia River watershed of southeast BC (Figure 1). Their headwaters rise in the same valley in the Rocky Mountains. From there, the Beaverfoot River flows generally north by northwest into Yoho National Park where it joins the Kicking Horse River, which eventually exits the Rocky Mountains and flows into the Columbia River in the Rocky Mountain

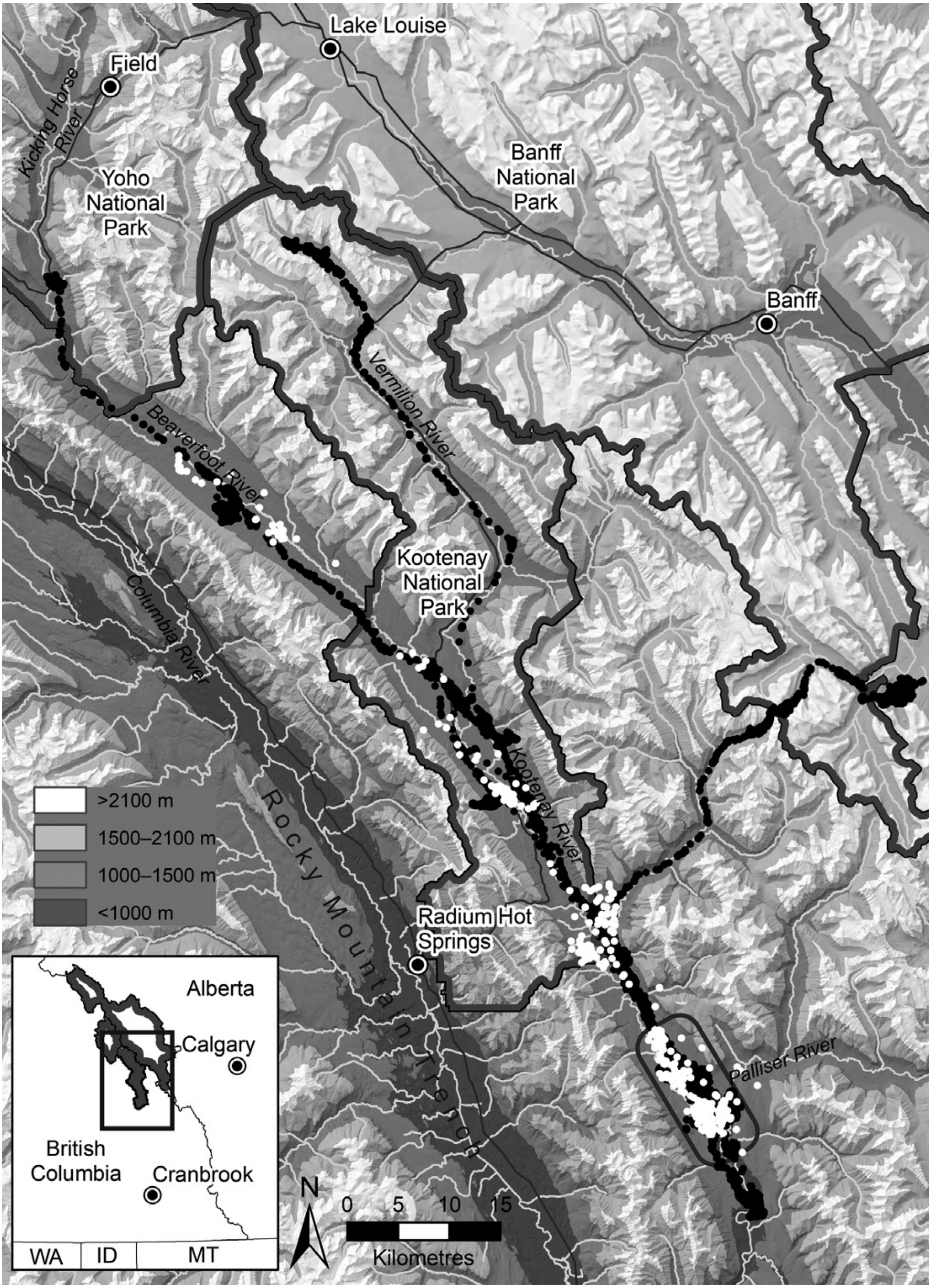


FIGURE 1. Pooled location data from 19 female White-tailed Deer (*Odocoileus virginianus*) fitted with global positioning system (black dots) or very high frequency (white dots) collars in the upper Kootenay River valley of British Columbia, 2011–2016. Winter range is oval in lower right.

Trench (hereafter "Trench"). The Kootenay River flows south by southeast, passing through and beyond KNP before exiting the Rockies into the Trench. The elevation of the valley bottom is ~1250 m at the headwaters and ~1050 m at the downstream ends of the parks. Mountains adjacent to the rivers reach a maximum elevation of 2400–3000 m.

Leading tree species vary with elevation and location, but along the valley bottoms are primarily Lodgepole Pine (*Pinus contorta* Douglas ex Loudon), Engelmann Spruce (*Picea engelmannii* Engelmann), Trembling Aspen (*Populus tremuloides* Michaux), Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), Western Larch (*Larix occidentalis* Nuttall), and, locally, Western Red Cedar (*Thuja plicata* Donn ex D. Don). At higher elevations, leading tree species are Engelmann Spruce and Subalpine Fir (*Abies lasiocarpa* (Hooker) Nuttall). Vegetation is dominated by mixed-age, mixed-species stands of those conifers interspersed with burns, wetlands, cutblocks from past logging (outside of parks), and non-forested areas on the highest peaks. This variety includes the range of grass, shrub, and open forest cover types normally selected by deer nearby and also the greater canopy cover selected under deep snow conditions (Hoekman *et al.* 2006). There is no agriculture within the study area.

Methods

Deer were captured in Clover traps (VerCauteren *et al.* 1999) baited with either hay and liquid and dried commercial deer attractants or hay, salt, apple, and dried molasses. One deer was immobilized by free-range darting (Dan-Inject APS, Børkop, Denmark) using a medetomidine–ketamine mixture (Caulkett *et al.* 2000). Deer captures were undertaken primarily in February 2014 on a winter range 15–20 km south of the southern boundary of KNP (Figure 1). This was at the confluence of the Kootenay and Palliser Rivers, at an elevation of 950–1100 m. Capture also occurred during November 2011, April 2012, and November–December 2015 within or beside anthropogenic forest openings in KNP, at ~1160 m elevation.

Females <11 months old and all males were released. All other females were fitted with collars, either global positioning system (GPS; G2110D, Advanced Telemetry Systems, Isanti, Minnesota, USA) or very high frequency (VHF; LMRT-2, Lotek Wireless, Newmarket, Ontario, Canada). One female originally fitted with a VHF collar was later recaptured and fitted with a GPS collar. GPS collars attempted fixes hourly, were programmed to detach about 10 months after collaring, and were downloaded on retrieval. VHF-collared deer were relocated on an approximately two-week schedule through ground monitoring. Aerial monitoring was undertaken twice in late winter of the first year, when only one deer was collared and snow depth prevented ground access, and once for all deer in another year as they left the winter range when not all deer could be located from the ground.

Maximum straight-line movements were determined for each deer monitored from at least January or February to July or August or the reverse for one or more years, i.e., for those with potential to demonstrate seasonal movements. Universal Transverse Mercator coordinates were used to calculate Euclidean distances between the most distant points. Elevations reported here are only as recorded onboard GPS collars because, in the mountainous study area, relatively small horizontal errors would translate into considerable elevation errors if extracted via a geographic information system, especially for VHF collar data. All maximum and minimum elevation records were confirmed to be within clusters of sequential locations and, hence, unlikely to reflect significant GPS error. To represent movement vectors at an appropriate scale, sequential records of deer locations were manually approximated graphically. Where overlapping individuals were not distinguishable, these representations were further linearized for visual clarity.

Results

Time from date of collaring to death, collar drop, or cessation of monitoring ranged from 299 to 1417 days for the 10 VHF-collared deer ($\bar{x}$ = 667, SD 295) and from 166 to 320 days for the nine GPS-collared deer ($\bar{x}$ = 286, SD 56) for which seasonal movements were calculated. Maximum straight-line movements (Figure 2) ranged from 6.1 to 82.4 km for VHF-collared deer ($\bar{x}$ = 33.0 km, SD 27.3) and from 3.4 to 109.2 km for deer with GPS collars ($\bar{x}$ = 48.7 km, SD 40.0). Among GPS-collared deer, maximum elevations ranged from 1199 m to 2234 m and minimum elevations from 891 m to 997 m (pooled sample: 10% < 1010 m, 10% > 1382 m). Variation in elevation use was evident during summer, with two deer occurring at maximum elevations (>1900 m) at a time when all others were below 1500 m, and during early winter when two deer used elevations above 1600 m while others were below 1300 m (Figure 3).

Seventeen deer were not recorded outside the contiguous Kootenay–Beaverfoot–Kicking Horse valley (Figures 1 and 2), but two moved into a major tributary valley or crossed the Continental Divide into Alberta. All 19 occurred for at least part of the year on provincial Crown land in BC, of which at least nine also made use of Kootenay, Yoho, or Banff national parks, one of Spray Valley Provincial Park,

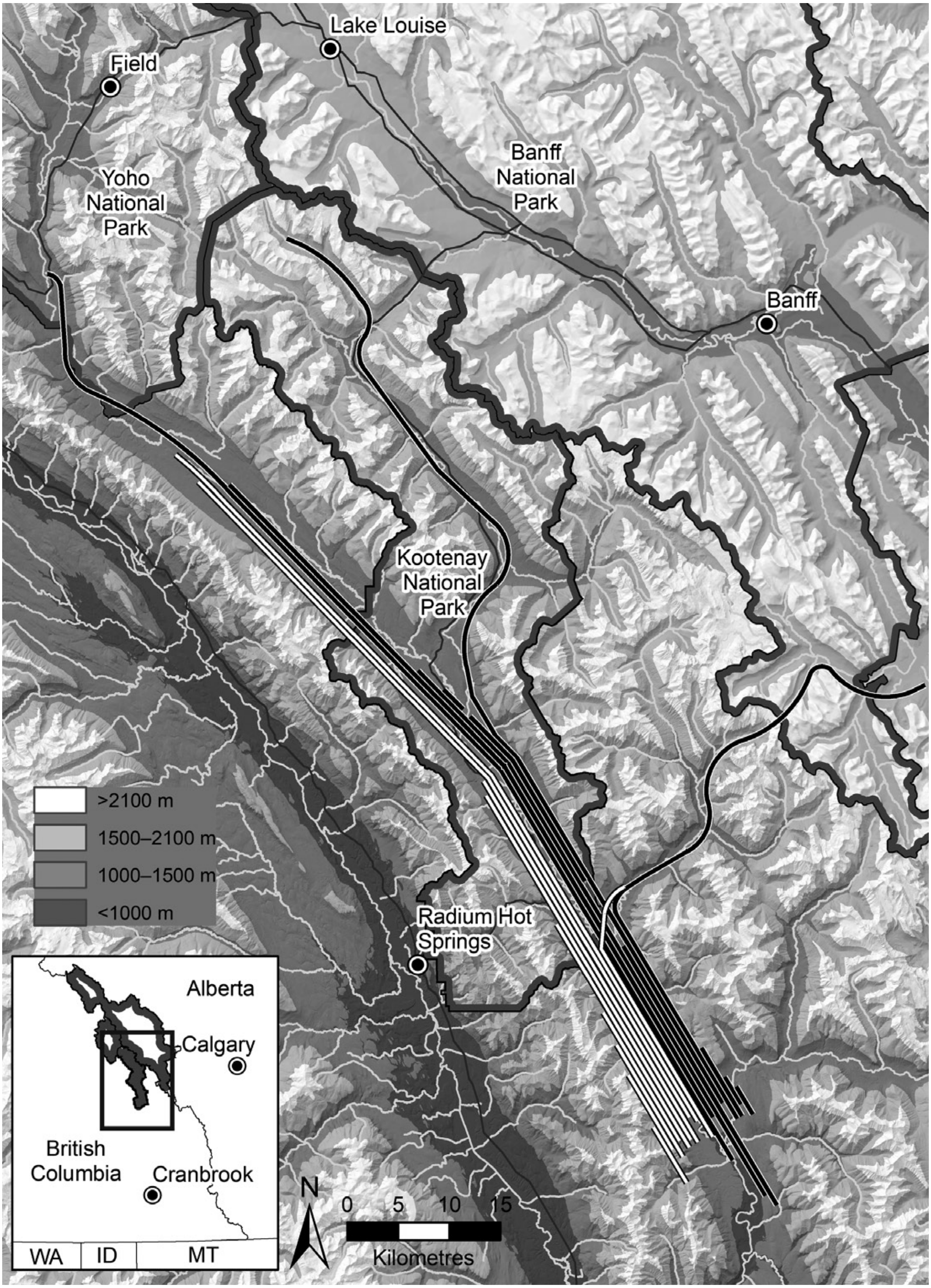


FIGURE 2. Maximum extent of movements of 19 female White-tailed Deer (*Odocoileus virginianus*) fitted with global positioning system (black lines) or very high frequency (white lines) collars in the upper Kootenay River valley of British Columbia, 2011–2016. Movements are presented as linear vectors for visual clarity.

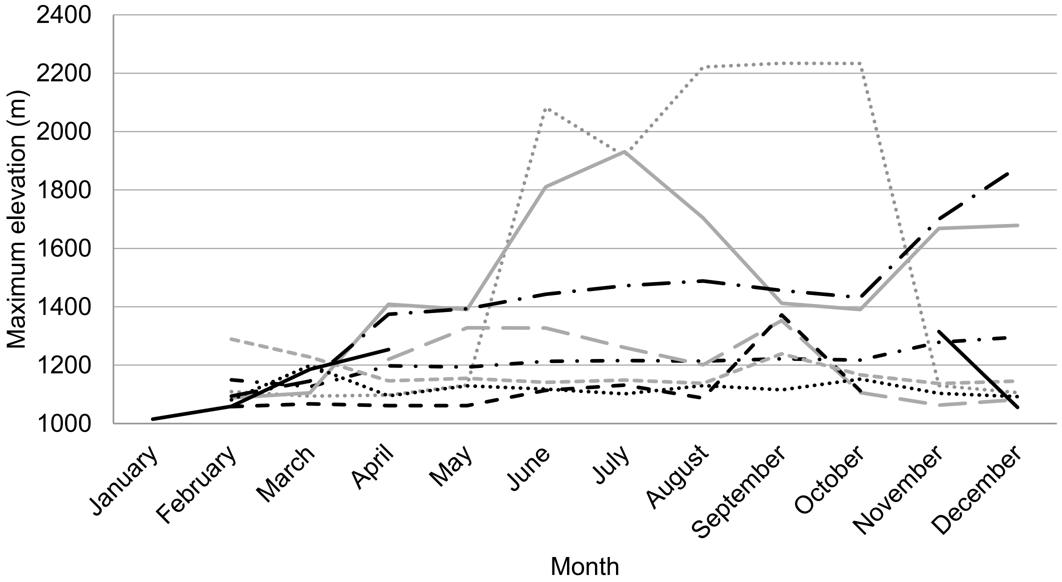


FIGURE 3. Maximum elevation per month of nine White-tailed Deer (*Odocoileus virginianus*) captured in the upper Kootenay River valley of British Columbia and fitted with global positioning system collars, 2012–2016.

Alberta, and five of private land in BC. Of the nine using one or more national parks for part of the year, at least eight were on Crown or private land in BC during part or all of the current regular, youth, or bow-only "antlerless" hunting seasons from October through December (MFLNRORD 2018). One collared deer summered south of the winter range; all others were generally north.

Discussion

Given the lower frequency of monitoring of VHF collars and potential effects of limited access on manual monitoring, data from VHF collars likely underrepresent deer movements and use of high elevations relative to GPS collars. The apparently shorter maximum movements of VHF-collared deer despite longer duration of monitoring may reflect that. However, for both collar types, a wide range and broadly similar distribution of maximum movements was recorded. Even with the possibility that some deer movements reported in other studies may have represented dispersals, mean and maximum seasonal movements reported here are greater than values reported from nearby studies in the mountains of BC and northwest United States (Morgan 1993; Secord 1994; Robinson *et al.* 2002; Hoekman *et al.* 2006) and in 10 earlier studies from the same region summarized by Baumeister (1992: 56) and similar to those observed by Baumeister (1992). Compared with the findings of most of those authors and Henderson *et al.* (2018), maximum movements of the deer in my study were an order of magnitude greater.

A range of elevation-use strategies was apparent. Use of minimum elevations was similar among individuals, but maximum elevations varied considerably. Most deer activity was along the floor of the main valley in which they wintered. When deer left that valley, movements typically followed the floors of the tributary valleys in which they travelled. However, the higher elevations of those tributaries, along with some limited forays from the main valley to adjacent mountain slopes, were associated with several other patterns of elevation use. Some deer occurred at high elevations for at least part of the summer, and some moved to relatively high elevations during early winter.

Relatively long-distance movement by deer in this study area may have reflected the abundance and broad distribution of moderate- to high-elevation summer habitats and the limited elevation gradient at valley-floor positions, such that any deer gaining the advantage of following the wave of greening vegetation upslope (Mysterud 2013; Merkle *et al.* 2016, Middleton *et al.* 2018) without leaving valley floors would be obliged to move considerable distances in this landscape. The existence of a wintering population in an elevated valley proximal to the Trench is notable. The Trench is as close as 15 km to summer and winter activity (Figure 1), is accessible via several passes or downstream movement, is at lower elevations with less snow and warmer winter temperatures, includes agricultural fields and extensive riparian areas, and is notable for an abundant large-mammal fauna and high-quality winter range (Benson 1970) including for deer. Delaying movement to winter ranges is advantageous to some ungulates (Mysterud 2013), yet White-tailed Deer are poorly adapted to snow (Stelfox and Taber 1969; Telfer and Kelsall 1984). For deer in my study, further travel through snow to reach the Trench may be prohibitive late in the season despite apparently higher-quality habitat used by other deer in the Trench. Alternatively, the shorter return distance to summer habitats and the ability to more precisely gauge the initiation of green-up may offer advantages to remaining within the mountains during winter. Additional collaring on summer ranges within this region of the Rocky Mountains would indicate whether some White-tailed Deer summering there do seasonally join other deer in the Trench.

Deer wintering in the upper Kootenay River valley occurred in Kootenay and Yoho national parks in BC, Banff National Park and Spray Valley Provincial Park in Alberta, and both private land and non-park Crown land in BC. For a species as resilient as White-tailed Deer (Halls 1978), a lack of protective management across jurisdictions is unlikely to have the severe population effects experienced by many migratory ungulates (Bolger *et al.* 2008). However, management goals for resource extraction, fire, deer hunting, predator hunting and trapping, ecological integrity, and recreation have the potential to constrain or enhance deer populations and movements. Cross-jurisdictional differences may influence the ability of any agency to achieve its wildlife or ecosystem objectives. For example, managing predators or enhancing habitat to benefit deer would have less effect if done only on a portion of the population's annual range, and maintaining a naturally functioning system may be affected by activities on other land bases, such as hunting during the "antlerless" deer season on provincial and private land. It would be prudent for resource managers to coordinate their efforts with nearby jurisdictions or at least consider the effect of extensive seasonal movements when managing White-tailed Deer in the Rocky Mountains.

Acknowledgements

Many Parks Canada Agency staff, students, and volunteers helped capture, monitor, retrieve collars, or manage data. I thank Jenny Burrows, Blair Fyten, Matt Kennedy, Justin Kinnersley, Isabel McFetridge, Sonia Nicholl, Tom Niddrie, Margaret Pak, Darren Quinn, Adam Sherriff, Geoff Skinner, Brian Spreadbury, Natalie Stafl, Kate Williams, Shelagh Wrazej, and Anna Yuill. I particularly appreciate the cheerful company and dedicated cold-weather trapping of Laura Kroesen and Patrick Langan, the provision of roadside survey data by Shelagh Wrazej, and the geomatics talent of Dan Teleki, all of Parks Canada in Radium Hot Springs, British Columbia. Alan Dibb and two anonymous reviewers provided helpful comments on earlier drafts. Permits were issued by the British Columbia Ministry of Natural Resource Operations and by Parks Canada's animal care committee. Capture and handling protocols were approved under research permit KOONP-2011-7812 (and subsequent renewals) and animal care permit 8979 for work conducted in Kootenay National Park, and under *Wildlife Act* permit CB12-76585 and CB13-92061 for work on provincial land. Project funds were provided by Parks Canada Agency through its Conservation and Restoration Program.

Literature Cited

Baumeister, T.R. 1992. Ecology of white-tailed deer on summer-fall range in northcentral Idaho. M.Sc. thesis, Montana State University, Bozeman, Montana, USA.

Benson, W.A. 1970. The land capability analysis of the East Kootenay area (annotated map). Queen's Printer, Ottawa, Ontario, Canada.

Berger, J. 2004. The last mile: how to sustain long-distance migration in animals. Conservation Biology 18: 320–331. https://doi.org/10.1111/j.1523-1739.2004.00548.x

Bolger, D.T., W.D. Newmark, T.A. Morrison, and D.F. Doak. 2008. The need for integrative approaches to understand and conserve migratory ungulates. Ecology Letters 11: 63–77. https://doi.org/10.1111/j.1461-0248.2007.01109.x

Brinkman, T.J., C.S. DePerno, J.A. Jenks, B.S. Haroldson, and R.G. Osborn. 2005. Movement of female white-tailed deer: effects of climate and intensive row-crop agriculture. Journal of Wildlife Management 69: 1099–1111. https://doi.org/10.2193/0022-541X(2005)069[1099: mofwde]2.0.co;2

Caulkett, N.A., P.H. Cribb, and J.C. Haigh. 2000. Comparative cardiopulmonary effects of carfentanil–xylazine and medetomidine–ketamine used for immobilization of mule deer and mule deer/white-tailed deer hybrids. Canadian Journal of Veterinary Research 64: 64–68.

Demarais, S., K.V. Miller, and H.A. Jacobson. 2000. White-tailed deer. Pages 601–628 *in* Ecology and Management of Large Mammals in North America. *Edited by* S. Demarais and P.R. Krausman. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Fieberg, J., D.W. Kuehn, and G.D. DelGiudice. 2008. Understanding variation in autumn migration of northern white-tailed deer by long-term study. Journal of Mammalogy 89: 1529–1539. https://doi.org/10.1644/07-mamm-a-277.1

Grovenburg, T.W., C.N. Jacques, R.W. Klaver, C.S. DePerno, T.J. Brinkman, C.C. Swanson, and J.A. Jenks. 2011. Influence of landscape characteristics on migration strategies of white-tailed deer. Journal of Mammalogy 92: 534–543. https://doi.org/10.1644/09-mamm-a-407.1

Halls, L.K. 1978. White-tailed deer. Pages 43–65 *in* Big Game of North America: Ecology and Management. *Edited by* J.L. Schmidt and D.L. Gilbert. Stackpole Books, Harrisburg, Pennsylvania, USA.

Henderson, Jr., C.R., M.S. Mitchell, W.L. Meyers, P.M. Lukacs, and G.P. Nelson. 2018. Attributes of seasonal home range influence choice of migratory strategy in white-tailed deer. Journal of Mammalogy 99: 89–96. https://doi.org/10.1093/jmammal/gyx148

Hoekman, S.T., G.L. Dusek, and A.K. Wood. 2006. Spatial relationships and resource selection. Pages 109–186 *in* Ecology of White-tailed Deer in the Salish Mountains, Northwest Montana. Montana Fish, Wildlife & Parks, Wildlife Division, Helena, Montana, USA.

Merkle, J.A., K.L. Monteith, E.O. Aikens, M.M. Hayes, K.R. Hersey, A.D. Middleton, B.A. Oates, H. Sawyer, B.M. Scurlock, and M.J. Kauffman. 2016. Large herbivores surf waves of green-up during spring. Proceedings of the Royal Society B 283: 20160456. https://doi.org/10.1098/rspb.2016.0456

MFLNRORD (Ministry of Forests, Lands, Natural Resource Operations and Rural Development). 2018. 2018–2020 hunting and trapping regulations synopsis. Black Press Media, Victoria, British Columbia, Canada.

Middleton, A.D., J.A. Merkle, D.E. McWhirter, J.G. Cook, R.C. Cook, P.J. White, and M.J. Kauffman. 2018. Green-wave surfing increases fat gain in a migratory ungulate. Oikos 127: 1060–1068. https://doi.org/10.1111/oik.05227

Morgan, J.T. 1993. Summer habitat use of white-tailed deer on the Tally Lake Ranger District, Flathead National Forest. Ph.D. thesis, Montana State University, Bozeman, Montana, USA.

Mysterud, A.T. 2013. Ungulate migration, plant phenology, and large carnivores: the times they are a-changin'. Ecology 94: 1257–1261. https://doi.org/10. 1890/12-0505.1

Nelson, M.E., L.D. Mech, and P.F. Frame. 2004. Tracking of white-tailed deer migration by global positioning system. Journal of Mammalogy 85: 505–510. https://doi.org/10.1644/bos-120

Robinson, H.S., J.C. Gwilliam, and I. Parfitt. 2002. Movements, survival and mortality of white-tailed deer in the Pend d'Oreille River valley. Columbia Basin Fish and Wildlife Compensation Program, Nelson, British Columbia, Canada.

Sabine, D.L., S.F. Morrison, H.A. Whitlaw, W.B. Ballard, G.J. Forbes, and J. Bowman. 2002. Migration behavior of white-tailed deer under varying winter climate regimes in New Brunswick. Journal of Wildlife Management 66: 718–728. https://doi.org/10.2307/3803137

Secord, M.L. 1994. Winter habitat use, migration, and spring and summer use of clearcuts by white-tailed deer in the Priest Lake watershed of northern Idaho. M.Sc. thesis, University of Montana, Missoula, Montana, USA.

Stelfox, J.G., and R.D. Taber. 1969. Big game in the northern Rocky Mountain coniferous forest. Pages 197–222 *in* Coniferous Forests of the Northern Rocky Mountains: Proceedings of the 1968 Symposium. *Edited by* R.D. Taber. University of Montana Foundation, Missoula, Montana, USA.

Stewart, K.M., R.T. Bowyer, and P.J. Weisberg. 2011. Spatial use of landscapes. Pages 181–218 *in* Biology and Management of White-tailed Deer. *Edited by* D.G. Hewitt. CRC Press, Boca Raton, Florida, USA. https://doi.org/10.1201/9781482295986

Telfer, E.S., and J.P. Kelsall. 1984. Adaptation of some large North American mammals for survival in snow. Ecology 65: 1828–1834. https://doi.org/10.2307/1937779

VerCauteren, K., J. Beringer, and S.E. Hyngstrom. 1999. Use of netted cage traps for capturing white-tailed deer. Pages 155–164 *in* Mammal Trapping. *Edited by* G. Proulx. Alpha Wildlife Research and Management Ltd., Sherwood Park, Alberta, Canada.

Received 7 January 2019
Accepted 18 December 2019

The Canadian Field-Naturalist

Sharp-tailed Grouse (*Tympanuchus phasianellus*) population dynamics and restoration of fire-dependent northern mixed-grass prairie

Robert K. Murphy[1,2,*] **and Karen A. Smith**[1,3]

[1]United States Fish and Wildlife Service, Des Lacs National Wildlife Refuge Complex, Kenmare, North Dakota 58746 USA
[2]Current address: Eagle Environmental, Inc., 12 Longview Road, Sandia Park, New Mexico 87047 USA
[3]Current address: 8210 88th Street NW, Kenmare, North Dakota 58746 USA
[*]Corresponding author: murph@eagleenvironmental.net

Murphy, R.K., and K.A. Smith. 2019. Sharp-tailed Grouse (*Tympanuchus phasianellus*) population dynamics and restoration of fire-dependent northern mixed-grass prairie 133(3): 253–262. https://doi.org/10.22621/cfn.v133i3.2115

Abstract

Case studies of Sharp-tailed Grouse (*Tympanuchus phasianellus*) population dynamics before and during re-introduction of fire to northern mixed-grass prairies that lacked fire for multiple decades are unavailable. At a 108-km^2 northern mixed-grass prairie refuge in North Dakota, fire was suppressed from the early 1900s through late 1970s. Nine management units (total area 16.8 km^2, 15.7% of the refuge) received initial prescribed fire treatments during 1979–1984. The mean annual density of male Sharp-tailed Grouse attending leks on these units during 1981–1985 (9.0 males/km^2) was twice that on the same units during 1961–1965 (4.2 males/km^2), amid the fire exclusion era; nonoverlap of 90% CIs encompassing the means suggested a significant treatment effect. However, densities of males on units managed without prescribed fire during 1961–1965 and 1981–1985 did not change between the two periods. By 1987, fire had been re–introduced to >50% of the refuge overall. Mean annual abundance (i.e., total numbers) of lekking males on the entire refuge did not differ between 1961–1965 and 1981–1985 but was significantly greater during 1989–1993 than during 1961–1965 and 1981–1985. Changes in density and abundance of lekking males coincided with fire-induced reductions in woody cover and increases in herbaceous cover. Our study illustrates the marked capacity of Sharp-tailed Grouse to respond to reductions of tree and shrub cover resulting from prescribed fire in northern mixed-grass prairie and the species' attraction to habitat disturbance in general.

Key words: Sharp-tailed Grouse; *Tympanuchus phasianellus*; northern mixed-grass prairie; prairie management; prescribed fire; North Dakota

Introduction

During the 1900s, tree and shrub cover increased markedly on present-day national wildlife refuges in the northern mixed-grass prairie (NMGP) region of North America's Great Plains, mainly due to fire suppression (Grant and Murphy 2005). Fire-intolerant Trembling Aspen (*Populus tremuloides* Michaux), Silverberry (*Elaeagnus commutata* Bernhardi ex Rydberg), and Western Snowberry (*Symphoricarpos occidentalis* Hooker) were common tree and shrub species that proliferated. Some species of grassland-dependent passeriform birds that bred on the refuges became rare or absent in areas invaded by trees and shrubs (Madden *et al.* 1999; Grant *et al.* 2004; Murphy and Smith 2007). Sharp-tailed Grouse (*Tympanuchus phasianellus*), a conspicuous member of the NMGP breeding bird community, may abandon landscapes that become invaded by trees and shrubs in the absence of fire, e.g., in Aspen Parkland (Caldwell 1976; Moyles 1981; Berger and Baydack 1992). However, there are no published reports of changes in numbers of the species during years encompassing prescribed fires to restore grassland landscapes invaded by woody vegetation in the NMGP region.

While compiling a case study on the management of 108-km^2 Lostwood National Wildlife Refuge (LNWR), centred in the NMGP region, we found that data on annual counts of Sharp-tailed Grouse and concurrent records of fire re-introduction to the area after roughly 60 years of fire exclusion could contribute to the knowledge of fire's role in Sharp-tailed Grouse management. Moreover, the case study could be supported by published data on changes in dominance of woody versus herbaceous vegetation associated with prescribed fire on the refuge (Madden *et al.* 1999; Murphy and Smith 2007; Smith and Murphy 2007) given a major refuge management objective: to restore the historic (before settlement by Euro-

American peoples) balance of woody versus herbaceous vegetation to favour native grassland bird species and other native wildlife (U.S. Fish and Wildlife Service 1998). Our first study objective, carried out at a local spatial scale, was to compare the density (i.e., number/km^2) of lekking male Sharp-tailed Grouse on prairie management units during 1961–1965, amid the fire exclusion era, to the density of lekking males on the same units under initial prescribed fire treatments during 1981–1985. Our second study objective, pursued at a landscape scale, was to compare overall abundance (i.e., total number) of lekking male Sharp-tailed Grouse on all of LNWR among three 5-yr periods: (1) 1961–1965, amid the fire exclusion era; (2) 1981–1985, the initial fire re-introduction period; and (3) 1989–1993, after >50% of the refuge had been treated by prescribed fire at least once. As part of this objective, we also examined relationships between abundance or density of lekking male Sharp-tailed Grouse and fire history, i.e., number of fires conducted, across management areas of the entire refuge.

Methods

LNWR, in Burke and Mountrail counties, northwestern North Dakota (48.617°N, 102.450°W), is rolling to hilly native prairie (55% of refuge area) and tame grasslands (21%) interspersed with about 4000, 0.1- to 224-ha wetlands (20%; Murphy 1993). Before settlement by Euro-Americans in the early 1900s, the upland landscape was mixed-grass prairie dominated by needlegrasses (*Nassella viridula* [Trinius] Barkworth, *Hesperostipa comata* Oldham and Brinker, *Heterostipa spartea* [Trinius] Barkworth), Western Wheatgrass (*Pascopyrum smithii* [Rydberg] Á. Löve), Blue Grama (*Bouteloua gracilis* [Kunth] Lagasca ex Griffiths), and a variety of native forb species (Barker and Whitman 1988). Shrubs probably covered ~5% of the uplands and trees were rare (U.S. Soil Conservation Service 1975). Patches of tree-size Trembling Aspen began to appear by the 1930s (as detected in aerial photos) after 10–20 years of active fire suppression (Murphy 1993). The density and mean size of aspen patches on LNWR increased from 1.5 patches/km^2 and 0.13 ha in the mid–1930s, when the refuge was established, to 4.8 patches/km^2 and 0.36 ha in the early 1980s, respectively. Shrub cover dominated by Western Snowberry increased from ~25% in the mid–1930s to >50% by the early 1980s.

Counts of lekking male Sharp-tailed Grouse can yield reliable population indices if done within narrow constraints with bias accounted for (Drummer *et al.* 2011). All Sharp-tailed Grouse leks on LNWR were located systematically in early spring annually during 1961–1965 and 1981–1993, following standard guidelines (Kirsch 1956). Each lek had at least two males by definition. To maximize accuracy, males were counted two to four times on each lek between 0.5 h before sunrise to 2 h after sunrise during mid-April through early-May, encompassing the peak period of lek attendance by breeding hens in the region (Connelly *et al.* 1998). Males on some leks could be counted by observation with binoculars from nearby hilltops. Most leks, however, were higher than their surroundings such that some or most males could not be viewed directly from any single location. In such a case, the observer crept to within ~3–10 m of the lek's edge and listened to determine whether females were present; acoustic displays by male Sharp-tailed Grouse on leks are distinctly more intense when females are there (Connelly *et al.* 1998). If females were present, they would flush immediately when the observer stood slowly. In contrast, males typically hesitated to flush for several seconds after all females flushed, then flushed and flew together in a cohesive flock. The flocked males typically could be counted by the observer at least twice before landing or flying from view. The same procedure would be followed at the respective lek on at least one other morning until counts of total males on the lek were consistent among mornings.

To address our first objective of comparing the density of lekking male Sharp-tailed Grouse on management units during 1961–1965 to the density of lekking males on the same units during initial prescribed fire treatments ~20 years later, we used concurrent changes in densities of lekking males on units not prescribe-burned as a baseline for comparison. Relying on refuge records, we categorized the 1940–1985 management history of units as either (1) grazed by cattle <19 years; (2) grazed by cattle >29 years; (3) prolonged rest; (4) treated by prescribed fire during 1979–1984; or (5) burn perimeter (Table 1, Figure 1). Prescribed fires at LNWR were conducted by using a surround technique, described in Murphy and Smith (2007). Most fires consumed >80% of aboveground vegetation (Table 2). We categorized the area within 0.8 km of burn units as burn perimeter (a mix of grazed <19 years, grazed >29 years, and prolonged rest categories; Figure 1) because prescribed fires could indirectly influence densities of lekking male Sharp-tailed Grouse on adjacent management units, and 0.8 km approximates the mean distance between the species' leks and nest sites (reviewed in Connelly *et al.* 1998).

We could not formally test for differences in density of lekking male Sharp-tailed Grouse among management history categories because management treatment types were not assigned randomly to the various units, and prolonged rest and burn perimeter categories were represented by only one and

TABLE 1. Management history of prairie management units at Lostwood National Wildlife Refuge in northwestern North Dakota during 1940–1985.

Unit category	Number of units	Total area (km^2)	Management history description
Grazed <19 years*	3	13.8	Grazed by cattle at light stocking rates (0.4–0.6 Animal Unit Months/ha) during July–October every 1–4 years during 1940–1979 and rested during 1980–1985
Grazed >29 years†	3	16.0	Grazed by cattle at light stocking rates (0.4–0.6 Animal Unit Months/ha) during July–October every 1–2 years during 1940–1979 and rested during 1980–1985
Prolonged rest	1	7.1	Not grazed or prescribe-burned
Burned 1979–1984	9	16.8	Rested and periodically grazed 1940–1978 then prescribe-burned one, two, or three times in late spring or summer during 1979–1984, with 2–3 years between prescribed fires on units burned two or three times‡
Burn perimeter	2	19.2	Not prescribe-burned; a mix of grazed <19, grazed >29, and prolonged rest categories

*Range 11–18 years.

†Range 30–36 years.

‡Table 2 presents detailed 1979–1984 fire treatment history for each unit.

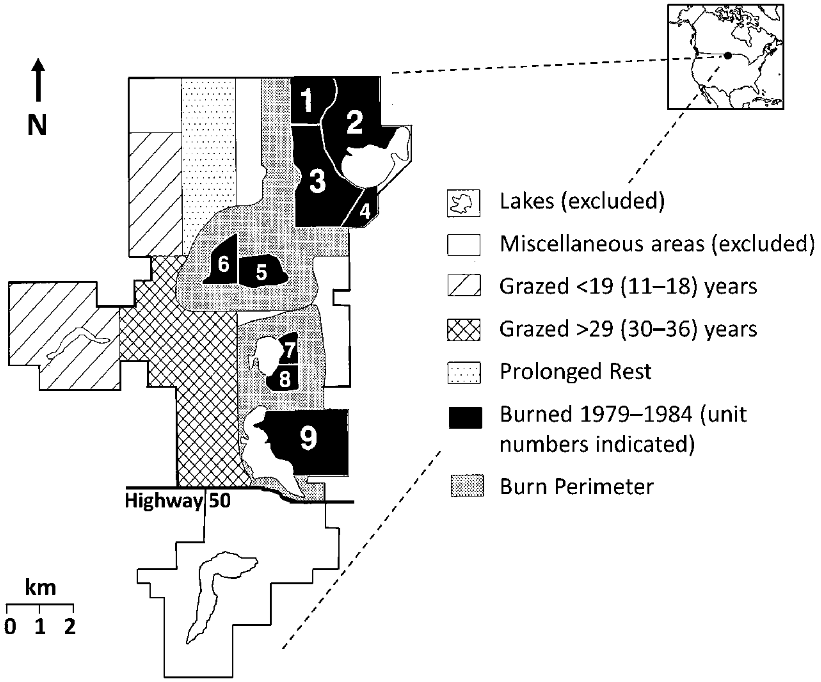


FIGURE 1. Location and management history of prairie management units on Lostwood National Wildlife Refuge in northwestern North Dakota as of 1981–1985, when density (individuals/km^2) of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) displaying on leks in spring was documented annually on units of five management categories. These were compared to densities of lekking males documented on the respective units during 1961–1965. The refuge area south of Highway 50 was excluded from the comparison of densities as it was open to hunting of Sharp-tailed Grouse. Inset map (upper right) indicates the study area (black dot) in relation to North America's northern mixed-grass prairie region (grey shaded).

two units, respectively (Table 1). Our conclusions were thus limited. We considered, however, that tentative evidence of a treatment effect might be implied for a given management history category if 90% CIs around the respective 1961–1965 and 1981–1985 mean densities did not overlap. Moreover, our approach to assessing male Sharp-tailed Grouse density in relation to prescribed fire included counts of lekking males on all prescribed fire units each spring, such that in a given spring, residual vegetation was

TABLE 2. Size, year of treatment, and thoroughness of burns on prairie management units treated by prescribed fire on Lostwood National Wildlife Refuge in northwestern North Dakota during June, July, or August, 1979–1984.

Unit number	Area (km^2)	Year					
		1979	1980	1981	1982	1983	1984
1	1.0	c*		c		c	
2	3.7		b		c		
3	5.0			c		c	
4	0.5	a		b		c	
5	0.9	c			a	b	
6	1.0				c		b
7	0.4				c		
8	0.5				c		c
9	3.8				c		

*Approximate percentage of above-ground live and residual vegetation removed by prescribed fire: (a) 35–50%; (b) 51–80%; (c) >80%.

limited on units that had been burned the previous summer. This provides for a conservative picture of the species' response to prescribed fire because in the first spring after summer fires, vegetation on LNWR is relatively short and sparse (Madden *et al.* 1999), less than optimal for females seeking nest sites. Because male Sharp-tailed Grouse compete for space on leks near areas frequented by females seeking ideal nesting cover (Gratson 1988), lek attendance by males is likely to be reduced during the first spring after summer fires. We acknowledge that small numbers of male Sharp-tailed Grouse may not attend leks in some years or do so infrequently (Gratson *et al.* 1991) but believe this possibility would negligibly influence our conclusions.

During 1986–1993, following the initial prescribed fires, incrementally greater proportions of LNWR were treated by prescribed fire such that units lacking prescribed fire histories including burn perimeter became less and less available. This change hindered longer-term comparison of male Sharp-tailed Grouse density among management history categories. We could, however, assess landscape-level changes in abundance (i.e., total numbers) of lekking male Sharp-tailed Grouse across all of LNWR in relation to prescribed fire. For our second objective, we sought to examine abundance of lekking males in the first five-year period after 1985 during which >50% of the refuge was treated with prescribed fire. We also sought a five-year period during which mean annual precipitation, from one year before the start to one year before the end of the period, was similar to that in the 1961–1965 baseline (40.2 cm) and 1981–1985 initial prescribed fire periods (41.7 cm). For a given year, we considered precipitation level in the previous year as a key potential confounding factor in our comparison because it can markedly influence survival of Sharp-tailed Grouse in general (Cartwright 1944). The years 1989–1993 met these two criteria (55–64% of refuge burned; 40.0 cm mean annual precipitation during 1988–1992), except that an unnaturally severe wildfire burned a 22.7-km^2 unit of the refuge in August 1988. We considered the wildfire an anomaly because it occurred when there was an abnormally high buildup of residual vegetation combined with ambient temperature, relative humidity, fuel moisture, and windspeed conditions far exceeding bounds for conducting prescribed fires (U.S. Fish and Wildlife Service unpubl. data). The wildfire burned into the humus layer and in many places to mineral soil, removing all residual and live, above-ground herbaceous and woody vegetation except for ~40% of tree-size Trembling Aspen and scant patches of Western Snowberry. Therefore, we replaced the following spring's (1989) count of lekking males with like data from spring 1987, the only year following prescribed fire treatment (July 1986) of the area, although total precipitation in the previous year (1986) was slightly greater (45.7 cm) than the 1988–1992 mean. Last, we considered the August 1988 wildfire to be, in effect, a 1989 prescribed fire with regard to its influence on residual vegetation and numbers of lekking male grouse the following spring.

We therefore consider the 1989–1993 period as a landscape-level prescribed fire period (hereafter the Landscape Fire period). In a similar vein, we hereafter refer to the 1961–1965 period, that neared the end of ~60 years of fire suppression, as the Fire Exclusion period, and the 1981–1985 years associated with initial prescribed fire treatments as the Initial Fire period.

During the mid-1980s, LNWR was partitioned into 20 "management blocks" (MBs) averaging 4.7 km^2 in area (SE = 1.0, range = 0.6–22.7). To assess whether total abundance of lekking male Sharp-tailed Grouse on LNWR changed between any two of the three time periods, we first combined small (<5 km^2), adjoining MBs into five MB groups composed of two to four MBs each. Each of five other "groups" were represented by one large MB. Thus, a total of 10 MB groups were available to provide adequate sample sizes for a matched-pairs analyses of temporal change in abundance of lekking male grouse. We next summed the total number of lekking males in each MB group, for each year in each of the three time periods, then calculated the mean annual abundance of lekking males for each MB group by period. To test for a difference in total abundance between two given periods, we paired the periods' annual means for each MB group and used the non-parametric Wilcoxon matched-pairs signed-ranks test (Daniel 1990) to assess whether overall means of the paired observations differed. Specifically, we used a two-tailed version of the test with α set at 0.1 to determine whether total abundance of lekking male Sharp-tailed Grouse differed between (1) the Fire Exclusion and Initial Fire periods, (2) Initial Fire and Landscape Fire periods, and (3) Fire Exclusion and Landscape Fire periods. A one-tailed test would seem appropriate based on knowledge that Sharp-tailed Grouse abundance can increase when prescribed fire is incorporated into the habitat disturbance regime (Kirsch and Kruse 1972; Kirsch *et al.* 1973). However, one-tailed Wilcoxon tests performed with small sizes, as in our case (10 matched pairs), can result in incorrect *P*-values (Mundry and Fischer 1998), so we used the more conservative two-tailed approach. Before conducting the tests, we plotted distributions of the differences between pairs and found the distributions to be reasonably symmetrical, an assumption of the Wilcoxon signed-ranks test (Daniel 1990).

Finally, we categorized each MB by the number of prescribed fires (i.e., fire history) applied to it during 1979–1992, from none up to four (Figure 2). However, most area covered by two MBs in a three or four burns category also was treated with intensive, prolonged grazing by cattle during two and three (respectively) late spring-early summer seasons of the Landscape Fire period. So, we placed them in a unique fire history category named "3 or 4 Burns plus Grazing" (3+G in Figure 2). The 22.7-km^2 unit that experienced a severe wildfire in August 1988 was placed in its own MB category, named "1 Burn plus 1 Wildfire" (1+W), because the wildfire event distinguished it from other MBs; this MB also was unique due to its large size, nearly four times larger than any other. We used non-overlap of 90% CIs encompassing means as tentative evidence of differences in abundance of lekking male Sharp-tailed Grouse among fire history categories in different periods. We also calculated period-specific densities of lekking male Sharp-tailed Grouse for each fire history category.

Results

Based on non-overlapping 90% CIs (Figure 3), the mean annual density of lekking male Sharp-tailed Grouse on prairie management units that were treated by prescribed fire during the Initial Fire period was more than double what it was on the same units ~20 years earlier, during the Fire Exclusion period. Meanwhile, densities of lekking males did not differ between the periods on rested, grazed, and burn perimeter units, based on substantial overlap among 90% CIs (Figure 3).

Across all of LNWR, the mean annual abundance of lekking male Sharp-tailed Grouse did not differ be-

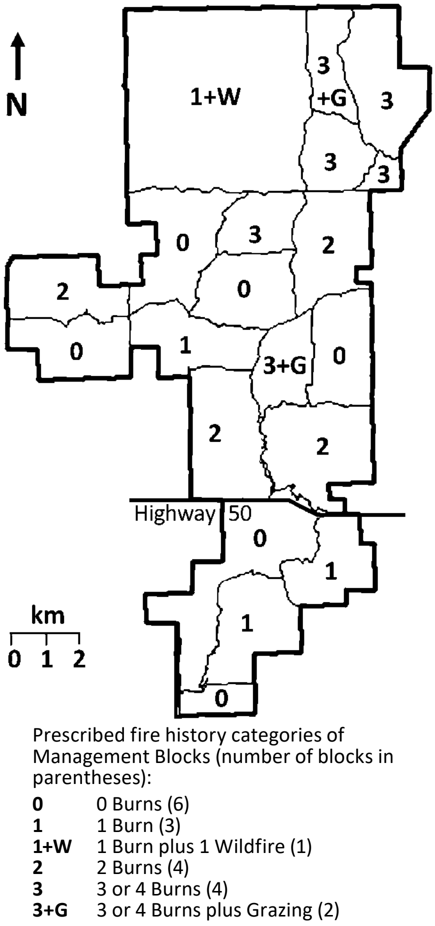


Figure 2. Number of prescribed fires applied during 1979–1992 on management blocks at Lostwood National Wildlife Refuge in northwestern North Dakota. Wildfires had been effectively suppressed on the area before 1979. Management block boundaries were designated during the mid-1980s.

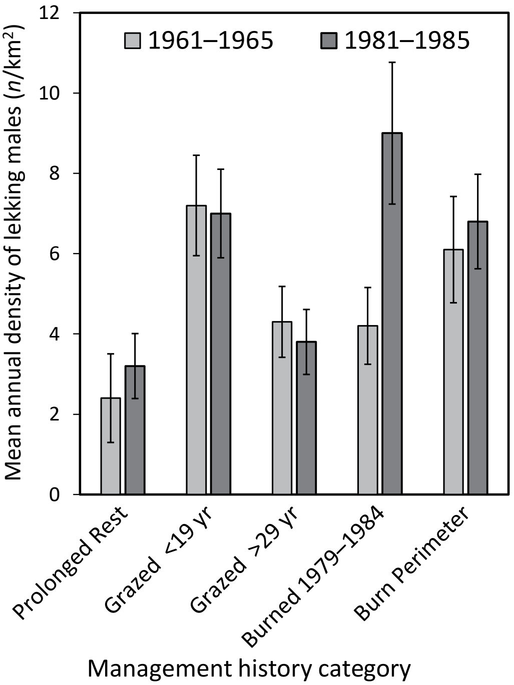


FIGURE 3. Mean annual densities (individuals/km^2) of lekking male Sharp-tailed Grouse (*Tympanuchus phasianellus*) at Lostwood National Wildlife Refuge in northwestern North Dakota during 1961–1965 and 1981–1985 on multiple prairie management units of each of five management history categories (see Table 1); density was assessed on the same units of each category during both time periods. After ~60 years of fire suppression, prescribed fire was re-introduced to the refuge during 1979–1984, specifically on units in the Burn 1979–1984 category. Error bars are 90% CIs.

tween the Fire Exclusion and Initial Fire periods ($W^+ = 23.5$, $n = 10$, $P = 0.70$; Figure 4). However, mean annual abundance of lekking male Sharp-tailed Grouse across all of LNWR was significantly greater during the Landscape Fire period than during the Fire Exclusion ($W^+ = 7$, $n = 10$, $P = 0.04$) and Initial Fire periods ($W^+ = 2$, $n = 10$, $P = 0.006$; Figure 4). A 32% increase in mean annual abundance from the Initial Fire to Landscape Fire periods coincided with a substantial rise in the percentage of LNWR treated by prescribed fire at least once, from 6.0–15.7% during 1979–1984 to 53.4–63.1% during 1987–1992 (Figure 4). Up to 1185 lekking males were recorded in one year (1992), representing an overall density of 12.6 males/km^2 (based on 94.2 km^2 total refuge area excluding major lakes). Most of the increase in total numbers arose from MBs burned once or twice between 1979 and 1992 (Figure 5a). During this period, density of lekking males seemed consistently high across all categories of number of fires experienced (range of means = 9.7 to 10.7 males/km^2; range of CIs, ± 1.7 to ± 2.7), except for the "3 or 4 Burns plus Grazing" category, where no lekking males were detected, and the "0 Burns" category (Figure 5b).

Discussion

Our case study of the re-introduction of fire to a large tract of NMPG deprived of fire for >60 years and associated changes in density and abundance of lekking male Sharp-tailed Grouse is unique for the NMGP region. It may well illustrate the species' marked capacity to respond to the reduction of trees and shrubs by prescribed fires in a prairie ecosystem, and to major perturbations in general. During the 1981–1985 Initial Fire period, the mean annual density of lekking males was about two-fold greater on prairie management units receiving initial prescribed fire treatments than on the same units during the Fire Exclusion period two decades earlier, when the units had been managed by prolonged rest or rest and grazing. This increase occurred even though the Initial Fire dataset included many counts of males on units treated by prescribed fire in previous summers. Scattered unburned patches of vegetation may have attracted nesting females to such areas; unburned "skips" comprised a mean of 14.5% of three units burned during 1982–1984 (Kruse and Piehl 1984). Moreover, the lack of change in male densities between the Fire Exclusion and Initial Fire periods on all but the burn units suggests that the increased density of lekking male Sharp-tailed Grouse on burn units can be attributed to the general growth in bird numbers on those units rather than just shifts in locations of males from other units.

In contrast with the markedly increased density of male Sharp-tailed Grouse between the Fire Exclusion and Initial Fire periods on management units in the burn category, we found no evidence of concurrent change in male density on units categorized as either prolonged rest, <19 years grazed, or >29 years grazed. Under the latter management regimes, however, densities likely would have declined during time intervals exceeding two decades, as trees and shrubs continued to displace grass- and forb-dominated prairie. Indeed, in the absence of fire for roughly six decades, much of the NMGP refuge had become aspen parkland, with some 2.59-km^2 sections having >15 aspen tree patches (Murphy 1993). In southern Manitoba, Berger and Baydack (1992) documented a severe decline in the number of Sharp-tailed Grouse leks as prairie gradually transformed into Trembling Aspen-dominated forest during only 21 years of fire suppression; on average, the birds abandoned a given lek if forest cover within 1 km exceeded 56%. Tree-size Trembling Aspen cover at LNWR averaged far less, only about 0.6% in 1969 and 0.7% in

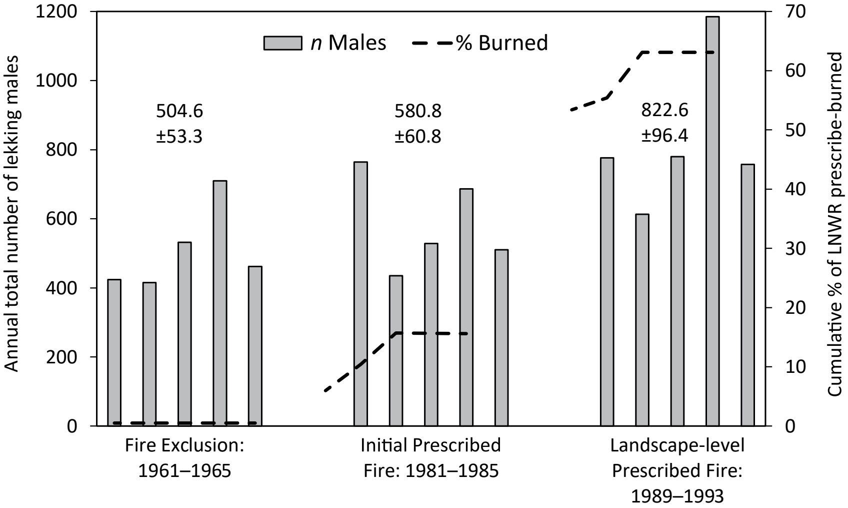


FIGURE 4. Change in annual abundance, i.e., total number, of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) attending leks in spring at Lostwood National Wildlife Refuge, northwestern North Dakota during three historic time periods in relation to percentage of the refuge treated by prescribed fire at least once beginning in 1979, after ~60 years of fire suppression. Prescribed fires were conducted during late spring through summer. Due to an artificially severe wildfire on a 22.7-km^2 management block in August 1988, the 1989 count of lekking males was replaced by like data from 1987, following the management block's first prescribed fire in 1986 (see text). Above each five-year group of columns is the respective group mean ± 1 SE.

1985 (Figure 4 in Grant and Murphy [2005]). Thus, the near-complete removal of aspen trees at LNWR via burning or combinations of grazing and burning (Smith and Murphy 2007) probably contributed less to increases in male Sharp-tailed Grouse abundance than did the conversion of much shrub cover (mainly Western Snowberry and Silverberry) to grass-forb cover types via prescribed fire (Madden *et al.* 1999). Such a conversion has been critical in restoring other key members of the refuge's grassland bird community. For example, the endemic Sprague's Pipit (*Anthus spragueii*) and Baird's Sparrow (*Ammodramus bairdii*) were absent and rare, respectively, on two 90-ha tracts rested and lightly grazed for >40 years but reappeared and increased after four prescribed fires were conducted during a ~16-year period. These changes coincided with a shift in grass-dominated cover from 45% to 84% and a 33% reduction in overall vegetation height and density (Murphy and Smith 2007).

The increase in Sharp-tailed Grouse density on management units undergoing initial prescribed fire treatments in our case study was consistent with a 32% increase in total abundance of males at the landscape scale during the Landscape Fire period, when >50% of the refuge had been burned at least once. Historically, the fire return interval for the eastern, more mesic part of the NMGP that encompasses LNWR averaged roughly six years (Bragg 1995; Madden *et al.* 1999). A mosaic of management units under short (2–4 years) and moderate (5–7 years) fire return intervals seems optimal for most native grassland bird species at LNWR (Madden *et al.* 1999). The heterogenous structure and general composition of vegetation in units managed under these fire return intervals (Madden *et al.* 1999, 2000) may be ideal for Sharp-tailed Grouse as well. Indeed, the mean annual density of lekking males during the Initial Fire period was high on units treated by prescribed fire even though most units were burned two to three times with only 1–2 years between treatments. Although Sharp-tailed Grouse have a general affinity for frequent disturbance and early successional stages (Kirsch *et al.* 1973; Connelly *et al.* 1998), the consistently high mean annual densities of lekking males across MBs of all fire history categories (excluding MBs that also were intensively grazed; Figure 5b) during the Landscape Fire period, suggest that the bird's abundance in NMGP does not necessarily increase with increasing "fire experience" (*sensu* Madden *et al.* 1999), at least during 10- to 15-year periods.

Conclusions about effects of a given fire return interval on the structure and general composition of NMGP—and thus on attractiveness of the habitat for Sharp-tailed Grouse—should be considered tentative, particularly if other types of defoliation treatments are applied between prescribed fires. The type, frequency, duration, and intensity of any such treatments likely influence effects of a given fire return

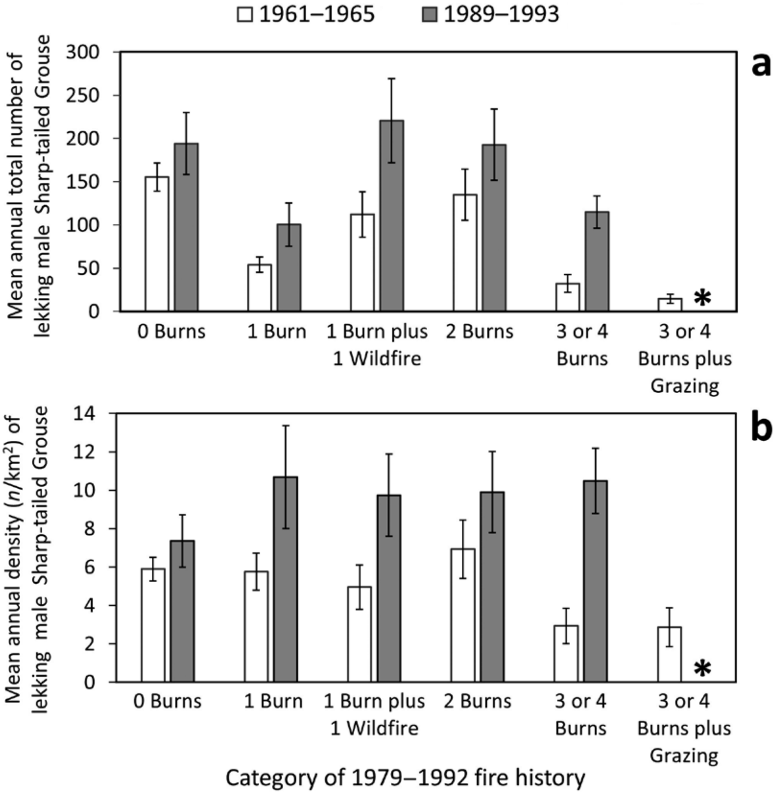


FIGURE 5. Mean annual abundance (i.e., total number of individuals, a) and density (i.e., number of individuals/km^2, b) of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) attending leks in spring at Lostwood National Wildlife Refuge, northwestern North Dakota: (1) during 1961–1965, amid ~60 years of fire suppression; and (2) during 1989–1993, by which time >50% of the refuge area had been prescribe-burned at least once, beginning in 1979. The refuge is divided into six categories of management blocks based on numbers of fires experienced during 1979–1992. Thus, values during 1961–1965 reflect abundance and density before fire was re-introduced to the refuge. Each category of fire history is represented by two to six management blocks except the "1 Burn plus 1 Wildfire" (1+W) category, which is represented by a single but very large (22.7 km^2) management block. Due to an artificially severe wildfire on this latter area in August 1988, the 1989 count of lekking males was replaced by like data from 1987, following the management block's first prescribed fire in 1986 (see text). In addition to having multiple prescribed fires, management blocks in the "3 or 4 Burns plus Grazing" (3+G) category received intensive, prolonged grazing by cattle in spring and early summer for 2–3 years during 1988–1992, leaving little residual nesting cover for Sharp-tailed Grouse in subsequent springs. Error bars are 90% CIs. Asterisks indicate no lekking males detected.

interval on prairie vegetation in general, e.g., by reducing fuel loads (Engle and Bidwell 2001). Also, influences of various fire return intervals on vegetation structure and composition may be confounded by the presence of Smooth Brome (*Bromus inermis* Leysser) and Kentucky Bluegrass (*Poa pratensis* L.), two introduced, cool-season grass species that have become pervasive in much of the NMGP (Romo *et al.* 1990; Murphy and Grant 2005). These grasses appear to be increasing regardless of prairie management treatment history (Ellis-Felege *et al.* 2013; but see Kobiela *et al.* 2017), a change that may reduce the availability and attractiveness of cover for Sharp-tailed Grouse.

Our comparisons of Sharp-tailed Grouse density and abundance among the Fire Exclusion, Initial Fire, and Landscape Fire periods included some basic components of a before-after-control-impact (BACI) study design, but our overall case study was observational in nature and lacked robust replication. Ideally, a statistically valid experimental design with replication across a more extensive landscape would be used to distinguish effects of habitat management on Sharp-tailed Grouse from confounding, non-management, factors, e.g., precipitation extremes. Aldridge *et al.* (2004) attempted this in an aspen parkland landscape. Regardless, long-term monitoring of Sharp-tailed Grouse abundance at LNWR enables passive adaptive management of the species' NMGP habitat (Aldridge *et al.* 2004).

Acknowledgements

We dedicate this paper to the memory of three northern prairie and prairie grouse management experts: Michael Gratson, Leo Kirsch, and Arnie Kruse. During 1961–1965, counts of lekking male Sharp-tailed Grouse at Lostwood National Wildlife Refuge were conducted by Merrill Hammond, Ned Peabody, and Don White. Bob Danley and Ken Maruskie assisted us with lek counts during the 1990s. Discussions with Ryan Nielson (Eagle Environmental Inc.) enhanced our approach to data analyses. We thank Todd Grant, two anonymous reviewers, and Associate Editor Jenn Foote for many comments that markedly improved our manuscript. Findings and conclusions in this article are those of the authors and do not necessarily represent views of the United States Fish and Wildlife Service.

Literature Cited

Aldridge, C.L., M.S. Boyce, and R.K. Baydack. 2004. Adaptive management of prairie grouse: how do we get there? Wildlife Society Bulletin 32: 92–103. https://doi.org/10.2193/0091-7648(2004)32[92:amopgh]2.0.co;2

Barker, W.B., and W.C. Whitman. 1988. Vegetation of the Northern Great Plains. Rangelands 10: 266–272. Accessed 13 May 2019. https://journals.uair.arizona.edu/index.php/rangelands/article/viewFile/10975/10248.

Berger, R.P., and R.K. Baydack. 1992. Effects of aspen succession on Sharp-tailed Grouse, *Tymphanuchus phasianellus*, in the interlake region of Manitoba. Canadian Field-Naturalist 106: 185–191. Accessed 13 May 2019. https://biodiversitylibrary.org/page/34347405.

Bragg, T.B. 1995. Climate, soils and fire: the physical environment of North American grasslands. Pages 49–81 *in* The Changing Prairie. *Edited by* K.H. Keeler and A. Joern. Oxford University Press, New York, New York, USA.

Caldwell, P.J. 1976. Energetic and population consideration of Sharp-tailed Grouse in the Aspen Parkland of Canada. Ph.D. thesis, Kansas State University, Manhattan, Kansas, USA.

Cartwright, B.W. 1944. The "crash" decline in Sharp-tailed Grouse and Hungarian Partridge in western Canada and the role of the predator. Transactions of the North American Wildlife Conference 9: 324–329.

Connelly, J.W., M.W. Gratson, and K.P. Reese. 1998. Sharp-tailed Grouse (*Tympanuchus phasianellus*), version 2.0. *In* The Birds of North America. *Edited by* A.F. Poole and F.B. Gill. Cornell Lab of Ornithology, Ithaca, New York, USA. https://doi.org/10.2173/bna.354

Daniel, W.W. 1990. Applied Non-parametric Statistics. PWS-Kent, Boston, Massachusetts, USA.

Drummer, T.D., R.G. Corace, and S.J. Sjogren. 2011. Sharp-tailed Grouse lek attendance and fidelity in upper Michigan. Journal of Wildlife Management 75: 311–318. https://doi.org/10.1002/jwmg.42

Ellis-Felege, S.N., C.S. Dixon, and S.D. Wilson. 2013. Impacts and management of invasive cool-season grasses in the Northern Great Plains: challenges and opportunities for wildlife. Wildlife Society Bulletin 37: 510–516. https://doi.org/10.1002/wsb.321

Engle, D.M., and T.G. Bidwell. 2001. The response of central North American prairies to seasonal fire. Journal of Range Management 54: 2–10. https://doi.org/10.2458/azu_jrm_v54i1_engle

Grant, T.A., E. Madden, and G.B. Berkey. 2004. Tree and shrub invasion in northern mixed-grass prairie: implications for breeding grassland birds. Wildlife Society Bulletin 32: 807–818. https://doi.org/10.2193/0091-7648(2004)032[0807:tasiin]2.0.co;2

Grant, T.A., and R.K. Murphy. 2005. Changes in woodland cover on prairie refuges in North Dakota, USA. Natural Areas Journal 25: 359–368.

Gratson, M.W. 1988. Spatial patterns, movements, and cover selection by Sharp-tailed Grouse. Pages 158–192 *in* Adaptive Strategies and Population Ecology of Northern Grouse. *Edited by* A.T. Bergerud and M.W Gratson. University of Minnesota Press, Minneapolis, Minnesota, USA.

Gratson, M.W., G.K. Gratson, and A.T. Bergerud. 1991. Male dominance and copulation disruption do not explain variance in male mating success on Sharp-tailed Grouse (*Tympanuchus phasianellus*) leks. Behaviour 118: 187–213. https://doi.org/10.1163/156853991x00283

Kirsch, L.M. 1956. Spring grouse census and habitat inventory methods. U.S. Fish and Wildlife Service, Wildlife Management Series Number 13.

Kirsch, L.M., A.T. Klett, and H.W. Miller. 1973. Land use and prairie grouse population relationships in North Dakota. Journal of Wildlife Management 37: 449–453. https://doi.org/10.2307/3800307

Kirsch, L.M., and A.D. Kruse. 1972. Prairie fires and wildlife. Tall Timbers Fire Ecology Conference 12: 289–303.

Kobiela, B., J. Quast, C. Dixon, and E.S. DeKeyser. 2017. Targeting introduced species to improve plant community composition on USFWS-managed prairie remnants. Natural Areas Journal 37: 150–161. https://doi.org/10.3375/043.037.0204

Kruse, A.D., and J.L. Piehl. 1984. The impact of prescribed burning on ground-nesting birds. Proceedings of the North American Prairie Conference 9: 153–156. Accessed 13 May 2019. http://digicoll.library.wisc.edu/cgi-bin/EcoNatRes/EcoNatRes-idx?type=article&did=EcoNatRes.NAPC09.AKruse&id=EcoNatRes.NAPC09&isize=M.

Madden, E.M., A.J. Hansen, and R.K. Murphy. 1999. Influence of prescribed fire history on habitat and abundance of passerine birds in northern mixed-grass prairie. Canadian Field-Naturalist 113: 627–640. Accessed 13 May 2019. https://biodiversitylibrary.org/page/34235497.

Madden, E.M., R.K. Murphy, A.J. Hansen, and L. Murray. 2000. Models for guiding management of prairie bird habitat in northwestern North Dakota. American Midland Naturalist 144: 377–393. https://doi.org/10.1674/0003-0031(2000)144[0377:mfgmop]2.0.co;2

Moyles, D.L.J. 1981. Seasonal and daily use of plant communities by Sharp-tailed Grouse (*Pedioecetes phasianellus*) in the parklands of Alberta. Canadian Field-Naturalist 95: 287–291. Accessed 13 May 2019. https://www.biodiversitylibrary.org/page/28061990.

Mundry, R., and J. Fischer. 1998. Use of statistical programs for nonparametric tests of small samples often leads to incorrect values: examples from animal behavior. Animal Behavior 6: 256–259. https://doi.org/10.1006/anbe.1998.0756

Murphy, R.K. 1993. History, nesting biology, and predation ecology of breeding raptors in the Missouri Coteau of northwestern North Dakota. Ph.D. thesis, Montana State University, Bozeman, Montana, USA. Accessed 13 May 2019. https://scholarworks.montana.edu/xmlui/bitstream/handle/1/7252/31762102084736.pdf;sequence=1.

Murphy, R.K., and T.A. Grant. 2005. Land management history and floristics in mixed-grass prairie, North Dakota, USA. Natural Areas Journal 25: 351–358.

Murphy, R.K., and K.A. Smith. 2007. Long-term trends in abundance of breeding songbirds during restoration of northern mixed-grass prairie. Transactions of the North American Prairie Conference 20: 359–370. Accessed 13 May 2019. https://digitalcommons.unl.edu/usfwspubs/79/.

Romo, J.T., P.L. Grilz, and E.A. Driver. 1990. Invasion of the Canadian prairies by an exotic perennial. Blue Jay 48: 131–135.

Smith, K.A., and R.K. Murphy. 2007. Burning and grazing regime decimates Quaking Aspen in a northern mixed-grass prairie (North Dakota). Ecological Restoration 25: 63–64.

U.S. Fish and Wildlife Service. 1998. Lostwood National Wildlife Refuge Comprehensive Conservation Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region, Denver, Colorado, USA. Accessed 13 May 2019. https://www.fws.gov/mountain-prairie/refuges/completedPlanPDFs_F-L/lst_1998_ccpfinal_all.pdf.

U.S. Soil Conservation Service. 1975. Field technical guide. U.S. Department of Agriculture, Soil Conservation Service, Bismarck, North Dakota, USA.

Received 27 August 2018
Accepted 8 December 2019

The Canadian Field-Naturalist

Humpback Whale (*Megaptera novaeangliae*) observations in Laskeek Bay, western Hecate Strait, in spring and early summer, 1990–2018

Anthony J. Gaston[1,*], **Neil G. Pilgrim**[1], **and Vivian Pattison**[2]

[1]Laskeek Bay Conservation Society, P.O. Box 867, Queen Charlotte City, British Columbia V0T 1S0 Canada
[2]Department of Geography, University of Victoria, 3800 Finnerty Road, Victoria, British Columbia V8P 5C2 Canada
[*]Corresponding author: tonygastonconsult@gmail.com

Gaston, A.J., N.G. Pilgrim, and V. Pattison. 2019. Humpback Whale (*Megaptera novaeangliae*) observations in Laskeek Bay, western Hecate Strait, in spring and early summer, 1990–2018. Canadian Field-Naturalist 133(3): 263–269. https://doi.org/10.22621/cfn.v133i3.2231

Abstract

We describe observations of Humpback Whales (*Megaptera novaeangliae*) made along the west side of central Hecate Strait, British Columbia, during the spring and summer of 1990–2018. From none in March, the frequency of sightings increased from early April to a peak in May, then fell in June with few in July. The frequency of sightings during the peak period (1 May–20 June) increased over the course of the study at a mean rate of 6% a year, similar to increases recorded elsewhere in British Columbian waters. The frequency of sightings was highest in years when the Oceanic Niño Index for January–March was low and peaked earlier in years when the Oceanic Niño Index was high. Both of these relationships suggest a connection between Humpback Whale sightings in western Hecate Strait and the larger oceanographic context, with sightings more frequent in years of lower water temperatures.

Key words: Humpback Whale; *Megaptera novaeangliae*; Hecate Strait; seasonal occurrence; population trends; oceanography

Introduction

Humpback Whale (*Megaptera novaeangliae*) is the most common rorqual along the west coast of Canada during the spring and summer, occurring in northern British Columbia (BC) waters principally from May to September (COSEWIC 2011; Ford 2014). Most of the population that occurs in summer in northern BC waters winters around the Hawaiian Islands (Calambokidis *et al.* 2001). Whales sighted in spring in BC waters may remain for the whole summer or may pass through *en route* to summering grounds farther north (Ashe *et al.* 2013; Ford 2014). Most Humpback Whales are believed to be faithful to their summering areas, with the same individuals identified in particular parts of the summer range over several years (Rambeau 2008; Gabriele *et al.* 2017).

Humpback Whale populations were heavily impacted by commercial whaling that took place along the BC coast between 1905 and 1967 (Trites *et al.* 2007). Since then, detailed observations between 1985 and 2014 in Glacier Bay, Alaska, showed that a humpback population summering there increased over that period at a mean 5% annually. A similar estimate, but based on fewer years, has been obtained for the population summering in inlets along the mainland coast of Hecate Strait (Ashe *et al.* 2013), while an assessment of trends in BC waters by COSEWIC (2011) suggested an annual rate of increase in adult numbers of 4%. These trends reflect a population recovery after severe reductions by commercial whaling in the period before 1970 (COSEWIC 2011).

Since 1990, the Laskeek Bay Conservation Society, a citizen science non-governmental organization based on the archipelago of Haida Gwaii, BC, has conducted observations of marine mammals in western Hecate Strait, in one of the three important Humpback Whale areas in BC waters identified by Dalla Rosa *et al.* (2012). Observations were made from a seasonal camp on East Limestone Island, a 40-ha island off the southeast corner of the much larger Louise Island, on the east coast of Haida Gwaii (Figure 1).

In this paper, we summarize observations of Humpback Whales made over the period 1990–2018 from March to July. We analyze seasonal and inter-annual variation and compare our observations with those made elsewhere in the northeast Pacific. Given the large amount of inter-annual variation in our data, we compare them with variations in oceanographic

---

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

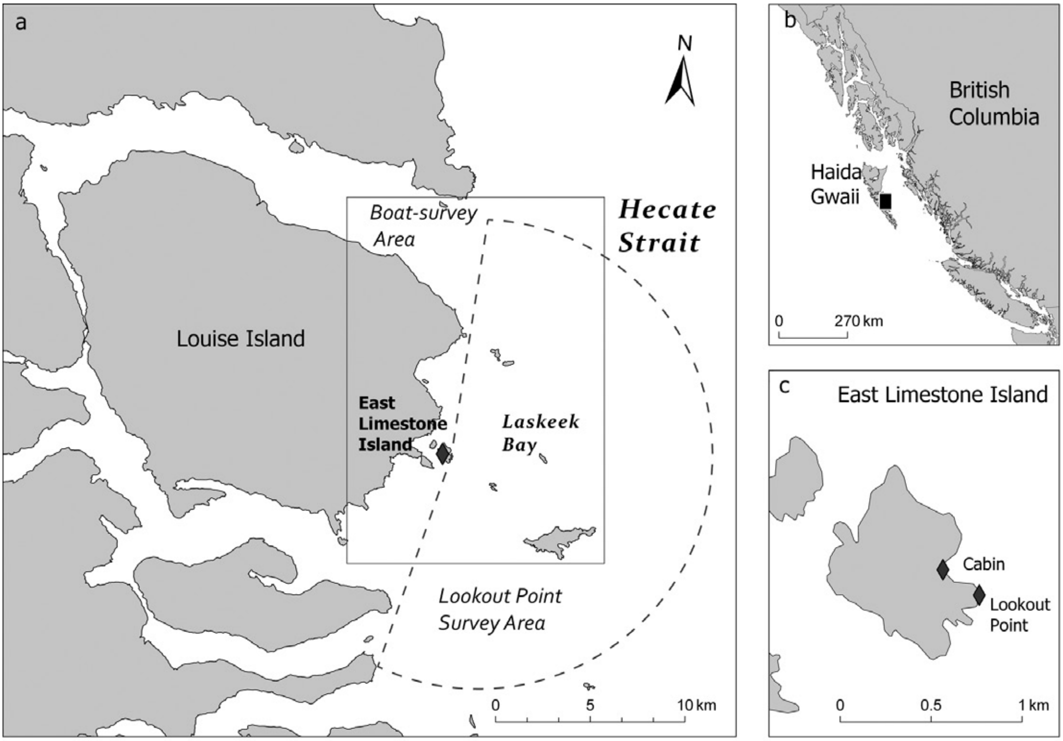


FIGURE 1. Map of the study area showing: a. the arc of view from Lookout Point (dashed line) and the area within which boat surveys were conducted regularly (rectangle); b. the location of Haida Gwaii; c. detail of East Limestone Island.

conditions, both in the northeast Pacific and more locally in BC waters, to improve our understanding of the factors influencing Humpback Whale occurrence in western Hecate Strait.

Methods

Fieldwork

The Laskeek Bay Conservation Society camp on East Limestone Island (Figure 1a–c) has been active in spring and early summer since 1990. Marine mammals were noted both systematically and incidentally throughout the period when camp was occupied, for periods between 56 and 126 days (mean 88 days/year). Starting dates varied from 15 March to 5 May. In 1990, the first year of operations, camp was open 25 April–5 June, but thereafter, in all years up to 2004, camp opened before 10 April and closed between 3 and 25 July. From 2005 to 2018, camp opened later, with starting dates between 21 April and 5 May and closure between 8 and 22 July (Table 1).

Systematic timed observations of marine mammals were made for several hours each week from a point ~20 m above sea level (asl; maximum tidal range 4 m; Fisheries and Oceans Canada 2019) at the southeastern tip of the island. If two or three observers were present, they watched together for 30 or 60 min, continuously, scanning waters within sight (an area of ~120 km^2 shown approximately in Figure 1a). When marine mammals were sighted, they were observed through a 25×60 spotting scope. Single observers scanned the area by dividing it into three sectors and spent 10 min on each sector in rotation. Watches were conducted during good visibility (usually >15 km), with sea conditions reflecting a Beaufort sea state of 3 or less (defined by World Meteorological Office as waves <1.25 m; National Oceans and Atmosphere Administration 2002).

Incidental observations were made from several locations. The camp is located on the east shore of the island (Figure 1c), from which an arc of ~120° is visible in an east-northeast direction. Most observations from camp were made from the cabin, ~5 m asl. People were present in camp for several hours each day. Incidental observations were made from other parts of the island shores and additional observations were also made from a small boat, used to survey for marine birds for 6–8 h every 10–15 days (area of rectangle in Figure 1a), as well as while travelling between islands for other fieldwork.

Analysis

To investigate seasonal variation in whale num-

TABLE 1. Period during which the East Limestone Island camp was active in each year of the study.

Year	Start date	End date	Days of observation
1990	25 April	19 June	56
1991	26 March	14 June	81
1992	9 April	3 July	86
1993	9 April	10 July	98
1994	5 April	15 July	102
1995	25 March	15 July	113
1996	20 March	11 July	114
1997	15 March	11 July	119
1998	3 April	9 July	98
1999	2 April	25 July	115
2000	1 April	20 July	111
2001	22 March	25 July	126
2002	20 March	7 July	102
2003	20 March	4 July	99
2004	30 April	22 July	84
2005	22 April	22 July	92
2006	28 April	20 July	84
2007	28 April	13 July	77
2008	5 May	16 July	73
2009	1 May	14 July	75
2010	1 May	9 July	70
2011	29 April	9 July	71
2012	4 May	12 July	70
2013	3 May	12 July	71
2014	1 May	11 July	72
2015	1 May	10 July	71
2016	30 April	22 July	84
2017	4 May	22 July	80
2018	4 May	20 July	78

bers, we used three statistics: (a) the proportion of observation days on which whales were seen, (b) the monthly sums of the number of whales seen each day (whales × days), and (c) the average number of whales seen on days when at least one was recorded. We included all years in this analysis, although no observations were made in July 1990 and 1991 and, after 2003, no observations were made before 21 April. Because of variation in observing dates each year, only records from the 50-day period 1 May–20 June were used for inter-year trend analysis. Observations were made daily in every year during this period. We used the proportion of days on which one or more whales were seen during this 50-day period as our index of whale frequency (whale index, WI) for time-trend analysis.

To examine the possible influence of large-scale oceanographic variation on the occurrence of Humpback Whales in Laskeek Bay, we corrected the number of whales observed assuming an increasing population trend of 4% annually, as suggested by COSEWIC (2011). The resulting adjusted index of whale abundance is referred to as the "corrected whale index" (CWI):

$$\mathrm{CWI} = (D_w / D_t) \times 1.04^{(2018-y)}$$

where D_w = days on which whales were sighted in a given year; D_t = total days camp was occupied during 1 May–20 June; and y = year of observations.

This index was compared with the following ocean climate indices:

As a measure of the El Niño/Southern Oscillation (ENSO), the Oceanic Niño Index (ONI) for January–March, the three-month running mean of ERSST.v5 (extended reconstructed sea surface temperature anomalies in the Niño 3.4 region; 5°N–5°S, 120–170°W), based on centred 30-year base periods updated every five years (National Weather Service n.d.). Sea surface temperatures in the northeast Pacific tend to be closely correlated with indices of the ENSO cycle (e.g., Niño 3.4 index; Tseng *et al.* 2017).

As a measure of the Pacific Decadal Oscillation (PDO), the H300-based PDO index (HPDO), defined as the projections of monthly mean H300 anomalies from the National Centers for Environmental Prediction's Global Ocean Data Assimilation System onto their first empirical orthogonal function vector in the North Pacific (20°–60°N), based on the 30-year period from 1981 to 2010 (GODAS n.d.).

Years in which the ONI was −0.5 or lower for the first three months of the year were classified as "cold" (as defined at National Weather Service n.d.) and the CWI for these years was compared with the CWI for warmer years. Comparisons among days with and without whale sightings were made using the Fisher exact probability test. Tests for time trends were made using linear regression and the Pearson correlation coefficient. Statistics were performed using Statistica v. 7.1 (Statsoft, Inc., Tulsa, Oklahoma, USA). Mean values are given ± 1 SE.

Results

Humpback Whales were seen in all but three years of the study, with sightings from early April to late July. They were recorded on 14% of the 2572 days that camp was occupied and on 20% of the 1673 days during the period 1 May–20 June. No humpbacks were seen in March and the frequency of sightings built up during April, with the buildup continuing longer in cold than in warmer years (Figure 2). The highest sighting frequency occurred in May, peaking 21–31 May in cold years (when whales were seen on 36% of days) and 1–10 May in other years (recorded on 21% of days). WIs were significantly higher in cold years than in others during 21–31 May and 1–10 June (Fisher exact test, $P < 0.001$ for both periods).

No humpbacks were seen in 1990, 1991, or 1996. The highest frequencies for 1 May–20 June occurred in 2007 (WI = 56% of days), 2008 (63%),

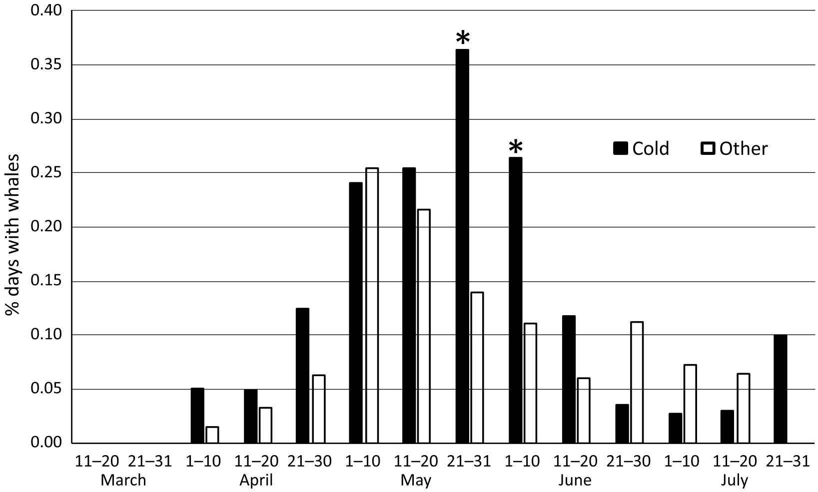


FIGURE 2. Proportion of days when Humpback Whales (*Megaptera novaeangliae*) were seen in Laskeek Bay in relation to date, for years when the Oceanic Niño Index was less than −0.5 during January–March (cold) and other years (1990–2018). *Proportion of days with whales was significantly greater in cold years than in other years (Fisher exact $P < 0.001$).

2016 (39%), and 2018 (41%). Six of the 10 lowest years occurred before 1999 (Figure 3). There was a significant positive correlation between year and the proportion of days with whales during 1 May–20 June (r_{27} = 0.48, P = 0.009). A similar positive correlation was found for non-cold years (r_{17} = 0.48, P = 0.04) when analyzed separately. The correlation coefficient was similar, but non-significant for cold years (r_8 = 0.41, P = 0.24). The linear regression slope for the proportion of days with whales over time was consistent with an annual rate of increase of 6%. Slopes were similar for cold and non-cold years when analyzed separately, but were closer to a 4% rate of annual increase (Figure 4).

Number of whales per day

Summing daily counts, 1750 humpback sightings were recorded, 1602 during the period 1 May–20 June. Probably many of these involved the same animals on different days, but we think it unlikely that many involved the same animal seen more than once on a given day. The highest number was recorded during May (1304, 75% of all sightings). Highest numbers of whales × days were recorded in 2003 (142), 2007 (213), and 2014 (233). The number sighted on days when at least one whale was seen aver-

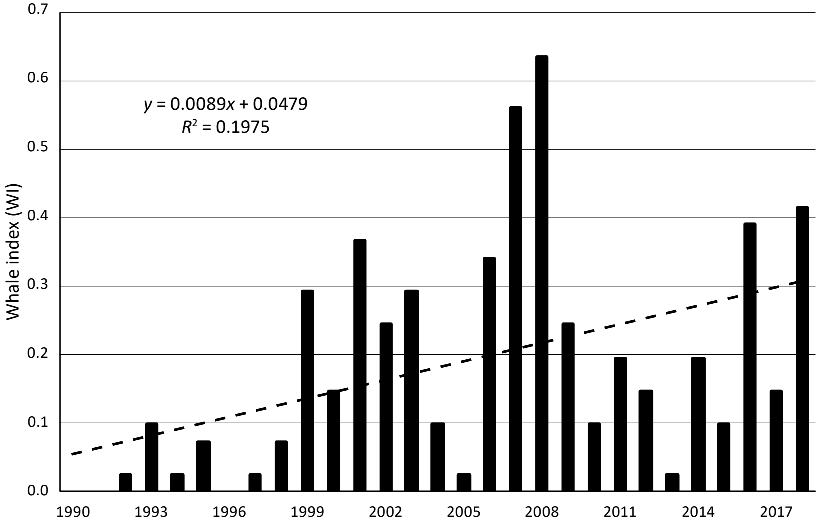


FIGURE 3. Whale index (WI), i.e., days when Humpback Whales (*Megaptera novaeangliae*) were seen in Laskeek Bay (11 May–20 June) as a proportion of all days, during 1990–2018, showing linear regression.

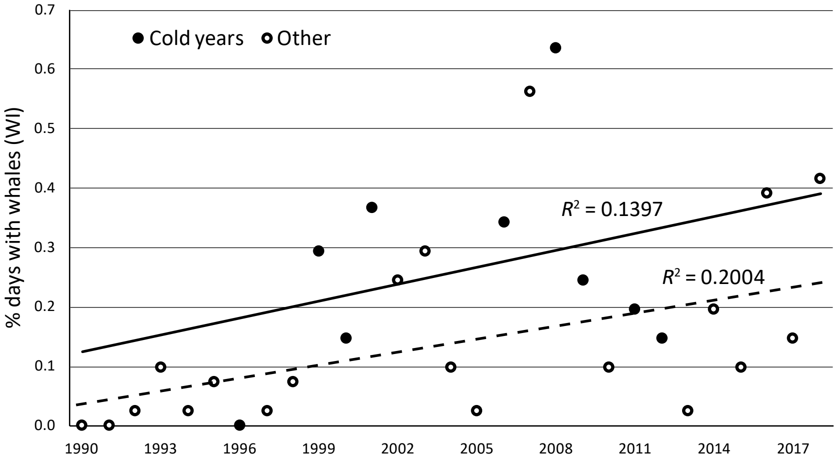


FIGURE 4. Proportion of days with whales (WI) in Laskeek Bay (11 May–20 June) separated into years with Oceanic Niño Index below −0.5 during January–March (cold years) and warmer years (other).

aged 5.6 whales/day during 1 May–20 June and 2.3 whales/day outside that period (Figure 5). The number of whales seen per day on days when at least one whale was seen did not differ significantly between cold years (4.5 ± 1.8 whales/day) and other years (4.3 ± 0.9 whales/day, $t_{24} = 0.11$, $P = 0.9$).

Effects of oceanography

The proportion of days with whales was generally higher in years with negative ONI (cold years, 28% ± 5%) than others (15% ± 4%, $t_{28} = 2.02$, $P = 0.05$). CWI was negatively correlated with ONI for January–March ($r_{27} = 0.37$, $P = 0.037$; Figure 6), but did not show any relation to the HPDO index ($P > 0.10$). The ONI accounted for 17% of variation in CWI ($F_{1,27} = 4.82$, adjusted $R^2 = 0.17$, beta = −0.41).

Discussion

Despite substantial variation in the amount of effort devoted to whale observations and the inevitable fluctuations in viewing conditions created by weather, our results show a clear increasing trend in the frequency of Humpback Whale sightings in Laskeek Bay since 1990. The complete set of annual indices has a regression coefficient consistent with a 6% annual rate of increase, while dividing the years into those displaying colder relative oceanic conditions and others (average or warmer conditions), based on the ONI, suggests a rate of increase closer to 4% for both samples. Observations of marine mammals from nearby Reef Island (5 km ESE of East Limestone Island) during April–June of 1984–1989

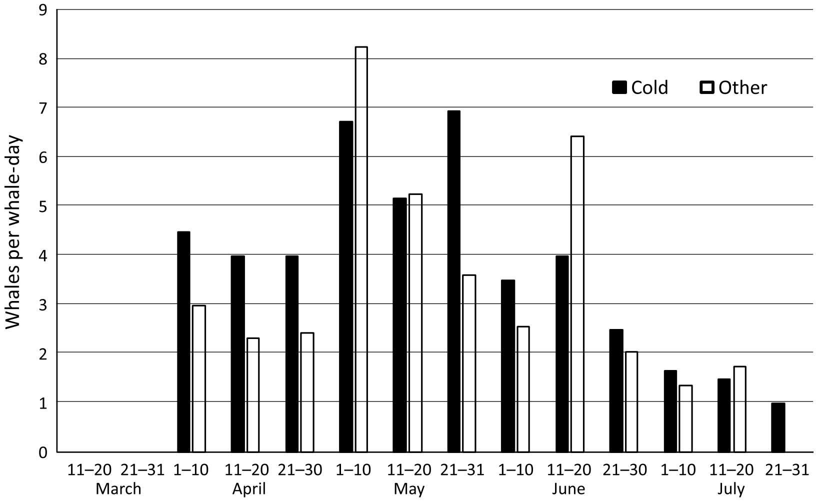


FIGURE 5. Number of whales seen per day in Laskeek Bay (11 May–20 June) on days when at least one was recorded (1990–2018).

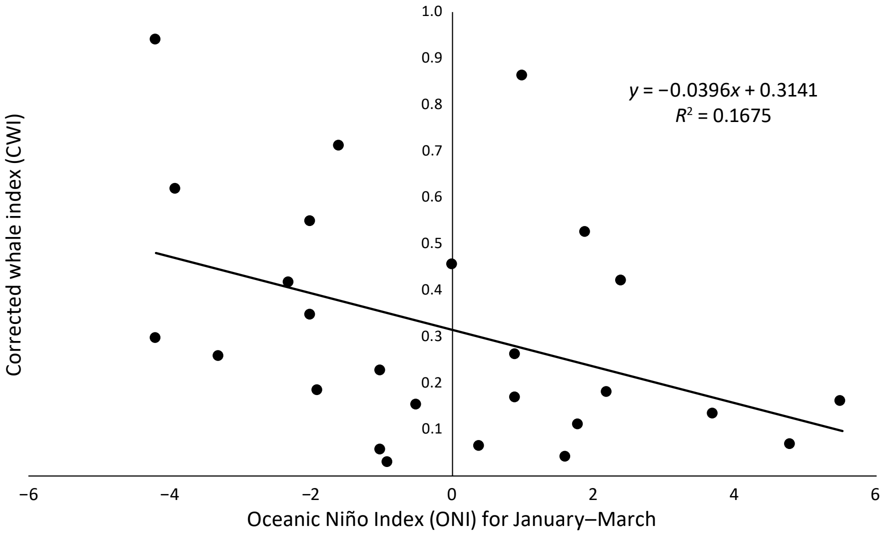


FIGURE 6. The corrected whale index (assumes a 4% annual rate of population increase) compared with El Niño/Southern Oscillation conditions, represented by the Oceanic Niño Index (ONI). Negative ONI is associated with colder than average ocean conditions, while positive ONI is associated with warmer than average conditions (Laskeek Bay, 1990–2018).

included sightings of Humpback Whales only in 1985 (up to three on 17 days), 1987 (one on a single day), and 1989 (up to five on six days; Gaston and Jones 1991). In all years, these observations extended from early April to mid-June, but all sightings fell between 2 May and 6 June (Gaston and Jones 1991). The paucity of sightings during the 1980s supports the idea that numbers have increased substantially since then. Our results are consistent with those obtained elsewhere in BC waters (COSEWIC 2011; Ashe *et al.* 2013). An estimate by Fisheries and Oceans Canada (2009) suggested a mean rate of increase for the BC population of 4.1% a year, identical with ours once warm and cold years are separated. The appearance of large numbers of Humpback Whales in Queen Charlotte Strait and the inside passage off Vancouver Island since the early 2000s (Nichol *et al.* 2017) is also consistent with our findings.

The absence of humpbacks in March and low numbers in the first 20 days of April may be partly accounted for by lower population size in the early years of the study, when most observations in March and April occurred. However, the number of days of observations after 10 July was biased toward recent years; thus, the decrease in number of sightings after mid-June is unlikely to have been influenced by the population trend.

Some of the humpbacks recorded in Laskeek Bay may be migrating to summering areas farther north. The timing of peak numbers reported in Laskeek Bay fits well with data from Glacier Bay, Alaska, ~750 km by sea to the north of Laskeek Bay, where the peak arrival of humpbacks occurs in June (Gabriele *et al.* 2017), about three weeks after the peak in Laskeek Bay. This rate of travel (about 36 km/day) is comfortably within the migration speed of 48 km/day observed for humpbacks by satellite telemetry (Lagerquist *et al.* 2008). However, it is possible that some or all of the whales seen in Laskeek Bay shift to other BC waters in July. Animals were frequently observed feeding in Laskeek Bay, both lunging at the surface and "flick feeding" (A.J.G. unpubl. data), which Ford (2014) mentions as common in waters off Moresby Island. It seems likely that most whales observed were feeding in the vicinity, causing them to pause in the area for a period.

Inter-year variability in sighting frequency was high, with the proportion of days with humpback sightings during the period 1 May–20 June, varying from 0 to 60%. Part of this variation can be explained by oceanographic processes, with the Oceanic Niño Index accounting for 17% of variation in the trend-corrected proportion of whale sightings. Seasonal trends in sightings, with sightings in cold years peaking later than those in other years, suggests that ocean conditions, influenced by large-scale processes, such as ENSO, may affect the suitability of inshore waters along the western side of Hecate Strait for humpback foraging. A similar effect of large-scale oceanographic forcing on Humpback Whales (in that case on diet) was reported by Fleming *et al.* (2016). The fact that numbers seen on a given day were not affected by ONI suggests that much of the variation in observation frequency probably relates to the rate at which the whales pass through the area, rather than being accounted for by fluctuations in the number of individuals using the area. Given the much greater frequency of whale sightings in Laskeek Bay in recent years, we may be able to make more detailed observations in future, perhaps with greater emphasis on photo-identification, giving us better understanding of the importance of Laskeek Bay waters to individual Humpback Whales.

Acknowledgements

We thank past staff and volunteers of the Laskeek Bay Conservation Society for their contributions to the observations we catalogue here. Useful comments on the manuscript were provided by Christie McMillan and Jackie Hildering of the Marine Education and Research Society and by an anonymous reviewer. For permission to maintain the field camp at East Limestone Island, we thank British Columbia Parks and the Council of the Haida Nation.

Literature Cited

Ashe, E., J. Wray, C.R. Picard, and R. Williams. 2013. Abundance and survival of Pacific Humpback Whales in a proposed critical habitat area. PLoS ONE 8: e75228. https://doi.org/10.1371/journal.pone.0075228

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urbán-Ramirez, J.K. Jacobsen, O. Von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P. Ladron de Guevara, M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T.J. Quinn. 2001. Movements and population structure of Humpback Whales in the North Pacific. Marine Mammal Science 17: 769–794. https://doi.org/10.1111/j.1748-7692.2001.tb01298.x

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2011. COSEWIC assessment and status report on the Humpback Whale *Megaptera novaeangliae* in Canada. COSEWIC, Ottawa, Ontario, Canada.

Dalla Rosa, L., J.K.B. Ford, and A.W. Trites. 2012. Distribution and relative abundance of humpback whales in relation to environmental variables in coastal British Columbia and adjacent waters. Continental Shelf Research 36: 89–104. https://doi.org/10.1016/j.csr.2012.01.017

Fisheries and Oceans Canada. 2009. Recovery potential assessment of the Humpback Whale, Pacific Population. Canadian Science Advisory Secretariat Science Advisory Report 2009/048. Fisheries and Ocean Canada, Ottawa, Ontario, Canada.

Fisheries and Oceans Canada. 2019. Copper Islands (#9724): 2019 tide tables. Fisheries and Oceans Canada, Ottawa, Ontario, Canada. Accessed 1 January 2019. https://www.tides.gc.ca/eng/data/table/2019/wlev_sec/9724.

Fleming, A.H., C.T. Clark, J. Calambokidis, and J. Barlow. 2016. Humpback whale diets respond to variance in ocean climate and ecosystem conditions in the California Current. Global Change Biology 22: 1214–1224. https://doi.org/10.1111/gcb.13171

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

Gabriele, C.M., J.L. Neilson, J.M. Straley, C.S. Baker, J.A. Cedarleaf, and J.F. Saracco. 2017. Natural history, population dynamics, and habitat use of humpback whales over 30 years on an Alaska feeding ground. Ecosphere 8: e01641. https://doi.org/10.1002/ecs2.1641

Gaston, A.J., and I.L. Jones. 1991. Seabirds and marine mammals recorded in western Hecate Strait, British Columbia, in spring and early summer, 1984–1989. Canadian Field-Naturalist 105: 550–560. Accessed 16 January 2020. https://biodiversitylibrary.org/page/34349068.

GODAS (Global Ocean Data Assimilation System). n.d. Monthly HC300-based PDO. Climate Prediction Center, National Weather Service, College Park, Maryland, USA. Accessed 1 January 2019. http://www.cpc.ncep.noaa.gov/products/GODAS/PDO_body.html.

Lagerquist, B.A., B.R. Mate, J.G. Ortega-Ortiz, M. Winsor, and J. Urbán-Ramirez. 2008. Migratory movements and surfacing rates of humpback whales (*Megaptera novaeangliae*) satellite tagged at Socorro Island, Mexico. Marine Mammal Science 24: 815–830. https://doi.org/10.1111/j.1748-7692.2008.00217.x

National Oceans and Atmospheric Administration. 2002. WOCE Upper Ocean Data. Accessed 8 January 2020. https://www.nodc.noaa.gov/woce/woce_v3/wocedata_1/woce-uot/document/wmocode.htm.

National Weather Service. n.d. Cold & warm episodes by season. Climate Prediction Center, National Weather Service, College Park, Maryland, USA. Accessed 1 January 2019. http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php.

Nichol, L.M., S.P. Majewski, B.M. Wright, C.J. McMillan, J. Hildering, E.U. Rechsteiner, and J.K.B. Ford. 2017. Humpback whales, harbor seals, and Steller sea lions in British Columbia: population trends of formerly harvested marine mammals. Pages 115–121 *in* State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2016. Canadian Technical Report of Fisheries and Aquatic Sciences 3225. *Edited by* P.C. Chandler, S.A. King, and J. Boldt. Fisheries and Oceans Canada, Sidney, British Columbia, Canada.

Rambeau, A.L. 2008. Determining abundance and stock structure for a widespread migratory animal: the case of humpback whales (*Megaptera novaeangliae*) in British Columbia, Canada. M.Sc. thesis, University of British Columbia, Vancouver, British Columbia, Canada.

Trites, A.W., V.B. Deecke, E.J. Gregr, J.K.B. Ford, and P.F. Olesiuk. 2007. Killer whales, whaling, and sequential megafaunal collapse in the North Pacific: a comparative analysis of the dynamics of marine mammals in Alaska and British Columbia following commercial whaling. Marine Mammal Science 23: 751–765. https://doi.org/10.1111/j.1748-7692.2006.00076.x

Tseng, Y.H., R. Ding, and X. Huang. 2017. The warm Blob in the northeast Pacific—the bridge leading to the 2015/16 El Niño. Environmental Research Letters 12: 054019. https://doi.org/10.1088/1748-9326/aa67c3

Received 16 March 2019
Accepted 23 December 2019

The Canadian Field-Naturalist

A Tribute to Rudolph Frank Stocek, 1937–2018

Donald F. McAlpine[1,*] and **Graham J. Forbes**[2]

[1]New Brunswick Museum, 227 Douglas Avenue, Saint John, New Brunswick E2K 1E5 Canada
[2]University of New Brunswick, Fredericton, New Brunswick E3B 5A3 Canada
*Corresponding author: email: donald.mcalpine@nbm-mnb.ca

McAlpine, D.F., and G.J. Forbes. 2019. A Tribute to Rudolph Frank Stocek, 1937–2018. Canadian Field-Naturalist 133(3): 270–275. https://doi.org/10.22621/cfn.v133i3.2435

Rudolph (Rudy) Frank Stocek, aged 81, "the eagle man" of New Brunswick (Figure 1), passed away on 2 December 2018 at the Dr. Everett Chalmers Hospital, Fredericton, New Brunswick following a stroke. Rudy was born 5 June 1937 in Woodside, New York, just south of the Bronx, even then one of the most densely populated regions of the United States. However, summers at his grandparent's farm in Millhurst, New Jersey, left Rudy with a deep love of the outdoors and a fascination with the natural history of the trees, fish, birds, and other wildlife that populated the surrounding waterways and woodlands.

The north woods beckoned, and Rudy set off to the University of Maine at Orono, graduating in 1959 with a B.Sc. in Wildlife Management and a minor in Forestry. During his undergraduate summers he worked for the Maine Department of Inland Fisheries and Game, undertaking stream and lake surveys, tagging fish, and reading fish scales. Athletic and active, Rudy played football and boxed in university. His athleticism would serve him well as both a field biologist and an instructor in wildlife management.

Figure 1. Rudy Frank Stocek, 1937–2018. Photograph taken as part of a composite for the 1997 Maritime Forest Ranger School graduating class. Photo: J. Cummings.

With a solid, practical, introduction to fisheries management during his summers, it probably seemed natural to pursue fisheries science at the Ontario Agricultural College in Guelph, Ontario, then affiliated with the University of Toronto. Rudy completed his M.Sc. in 1962 under the supervision of Dr. Hugh R. McCrimmon, a committed fish culturist, now remembered for his volume on carp in Canada (McCrimmon 1968). Although Rudy later became best known for his work on raptors, his interest in freshwater fish never left him. He designed and taught the first ichthyology course offered at the University of New Brunswick, and he reported the addition of Muskellunge (*Esox masquinogy*) to the Saint John River system. Even as he approached 70, he documented the occurrence of Fat Head Minnow (*Pimephales promelas*) in New Brunswick.

Brief stints as a wildlife biologist with the Metropolitan Toronto and Region Conservation Authority (1960–1961), and as Manager of the Tinicum Wildlife Preserve, Philadelphia (1961–1965), followed his M.Sc. In 1965 Rudy entered a Ph.D. program at the University of Western Ontario to study growth and development in young Canada Geese (*Branta canadensis*). However, his marriage in 1960 (to Arlene, *nee* Wellhauser), and the two children that followed (Rudy Jr. born 1963, Lehanne born 1964), made a 1968 job opportunity in New Brunswick simply

---

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

too good to pass up. Rudy and family moved east to the Maritimes, where Rudy took a position as an Instructor and Fish and Wildlife Biologist with the Maritime Forest Ranger School (MFRS; since 2003 the Maritime College of Forest Technology). Opened in 1946 as a co-operative venture of the New Brunswick–Nova Scotia governments and the forest industry, at its establishment the role of the MFRS was to re-train and integrate returning World War II veterans. However, by the time Rudy arrived in New Brunswick, MFRS was catering to students from wide and varied backgrounds.

By 1973, Rudy's ability to inspire students interested in pursuing careers that required a knowledge of fish and wildlife biology had become evident. From then until his retirement in 2002, Rudy designed, directed, and with other instructors, delivered, the MFRS wildlife technology program as his "day job" to hundreds of young men and women intent on becoming forest rangers, wildlife protection officers, fish and wildlife technicians, park rangers, and wardens. But for one with Rudy's energy and curiosity, teaching alone was not enough. As an independent fish and wildlife biologist, he also accepted contracts from various federal and provincial government departments and private environmental consulting firms to investigate a variety of wildlife-related issues in the Maritimes. A 1982 contract from the New Brunswick Environmental Assessment Branch that identified and assessed more than 90 environmentally sensitive areas in southern New Brunswick was an important precursor to current work by government and land trusts now intent on setting aside habitat in New Brunswick for conservation purposes. In the broader context, and in a province dominated by industrial forestry, Rudy's research and teaching can be seen as part of a rising tide of concern for North American wildlife and the environment that became evident in the 1970s. Until 1968, New Brunswick was one of the heaviest DDT (Dichlorodiphenyltrichloroethane) users in North America, a pesticide identified as a major cause of raptor declines across the continent and one that appears to have had impacts on aquatic ecosystems in the province that are still evident (Kurek *et al.* 2019).

With the establishment of the *New Brunswick Endangered Species Act* in 1976 (superseded by the *New Brunswick Species at Risk Act* in 2012) a short list of species was accorded protection. Although Bald Eagle (*Haliaeetus leucocephalus*) was assigned regionally endangered status, there were limited data to work from.

There are two sources of Bald Eagles occupying New Brunswick. A resident population breeds in the province (*Haliaeetus leucocephalus washingtoniensis*), while immature birds fledged in the southeastern United States (*Haliaeetus leucocephalus leucocephalus*) disperse northward into New Brunswick in the late summer. In the early 1970s the impact of pesticide use in the United States was evident in New Brunswick, with a reduced number of southern birds available to disperse northward. Although legendary New Brunswick wildlife biologist Bruce Wright (1912–1975) had identified the Saint John River estuary as critical summer habitat for Bald Eagles fledged south of the province (Wright 1953), historically the species was never a common breeding bird in New Brunswick. A mere 12–15 pairs nested in the province by the early 1970s.

Accordingly, Rudy was contracted by the New Brunswick Department of Natural Resources to undertake regular Bald Eagle surveys in New Brunswick. This was not Rudy's first foray into raptor research. In 1973 Rudy had been engaged by the Canadian Wildlife Service to assess the status and reproductive success of Peregrine Falcon (*Falco peregrinus)* and Osprey (*Pandion haliaetus*), along with Bald Eagle, across the Maritimes. Rudy would continue annual New Brunswick Bald Eagle surveys for the next 25 years. When funds for aerial surveys became difficult to secure, undeterred, Rudy was able to take advantage of members of the Fredericton Flying Club and the 422nd Tactical Helicopter Squadron out of Canadian Forces Base Gagetown. In addition to determining numbers of breeding pairs in New Brunswick, Rudy also collected information on distribution, nesting success, habitat requirements, and winter feeding patterns and developed management guidelines for individual Bald Eagle nesting sites (Figure 2).

With a growing interest in the problems of raptor conservation in North America, Rudy soon found himself presenting his findings, both for Bald Eagles and Ospreys, at meetings of raptor specialists across North America. As an experienced educator and an engaging speaker, Rudy also lectured widely on Bald Eagle in the Maritimes to regional audiences. For the media, he became the go-to-guy for expert opinion on a bird with a high public profile, and huge significance to the Indigenous community. Rudy went on to write the Bald Eagle account for the iconic federal government Hinterland Who's Who series (Stocek 1992) and in 2006 summarized his decades of research on the bird in a book that ultimately received an independent publishers book award.

While best known for his work on raptors, Bald Eagles in particular, Rudy also found time to work and publish on other Maritime wildlife, including Common Loon (*Gavia immer*), the elusive Cougar (*Felis concolor*), and Tree Swallows (*Tachycineta bi-*

FIGURE 2. Rudy banding a Bald Eagle (*Haliaeetus leucocephalus*) nestling in southwestern New Brunswick, *circa* 1978. Photo: unknown.

color). A useful and well-received field guide to New Brunswick trees and shrubs in winter helped fulfil his commitment to teaching, but was also made available to a wider general audience (Figure 3). A mainstay of provincial government committees dealing with species of conservation concern, in 1995 Rudy received the Career Achievement Award of the Atlantic Society of Fish and Wildlife Biologists and in 2010 an Award of Professional Excellence from the University of Maine Wildlife Program. Outgoing and gregarious, Rudy somehow still found time to play tuba and accordion in five local bands, stay active as a judge and organizer for the New Brunswick and Canadian gymnastics communities (including judging at the 1976 Olympics in Montreal), and help manage the local curling club!

Today, as the biodiversity crisis deepens, there is a growing chorus calling for the revitalization of natural history (Schmidly 2005; Nature News 2014; Tewksbury *et al.* 2014). In the best possible way, Rudy was an "old school" wildlife biologist who never left natural history behind, even as he upped his game after graduate school with courses in computer programming, teaching and administration, and media communications. A first-rate field naturalist, Rudy could identify trees and shrubs, and knew his fish, his birds, and his mammals. But his second love, after Arlene, his wife of 58 years, was the Bald Eagle. Although recent research has documented precipitous declines in numbers of birds of many species in North America (Rosenberg *et al.* 2019), Rudy had the satisfaction of watching New Brunswick's Bald Eagle populations, both migratory and resident, recover and rise dramatically, and know that his work played a role in this. By the time the 1986–1990

FIGURE 3. Rudy with a Maritime Forest Ranger School dendrology class in 2000, two years before his retirement. His 1991 winter field guide to trees and shrubs continues to be used in wildlife and forestry programs. Photo: Maritime School of Forest Technology.

Maritimes Breeding Bird Atlas had been completed, 40 pairs of Bald Eagles were confirmed nesting in New Brunswick (Erskine 1992), and numbers have continued to rise. An astounding 92 pairs of Bald Eagles nested in New Brunswick during the second atlas period (2006–2010; Stewart *et al.* 2015). Bald Eagle populations in New Brunswick are now recognized as secure. There have been few success stories for North American wildlife since Europeans arrived on the continent over 400 years ago, but the recovery of the Bald Eagle is one of them. That recovery is testament to the vision and the hard work of many, Rudy among them.

Acknowledgements

We are grateful to Lehanne Knowlton and Arlene Stocek for providing access to Rudy's papers and for help filling in details related to Rudy's life and scientific contributions. Lehanne Knowlton, Peter Pearce, and Arlene Stocek kindly commented on an early draft of the manuscript.

Literature Cited

Erskin, A.J. 1992. Atlas of breeding birds of the Maritime Provinces. Nimbus Publishing Limited and the Nova Scotia Museum, Halifax, Nova Scotia, Canada.

Kurek, J., P.W. MacKeigan, S. Veinot, A. Mercer, and K.A. Kidd. 2019. Ecological legacy of DDT archived in lake sediments from eastern Canada. Environmental Science Technology 53: 7316–7325. https://doi.org/10.1021/acs.est.9b01396

McCrimmon, H.R. 1968. Carp in Canada. Fisheries Research Board of Canada, Ottawa. Bulletin 165.

Nature News. 2014. Natural decline. Few biology degrees still feature natural history. Is the naturalist a species in decline? Nature 508: 7–8. https://doi.org/10.1038/508 007b

Rosenberg, K.V., A.M. Dokte, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J.C. Stanton, A. Panjabi, L. Helft, M. Parr, and P.P. Marra. 2019. Decline of North American avifauna. Science 366: 120–124. https://doi.org/10.1126/science.aaw1313

Schmidly, D.J. 2005. What it means to be a naturalist and the future of natural history at American universities. Journal of Mammalogy 89: 449–456. https://doi.org/10.1644/1545-1542(2005)86[449:wimtba]2.0.co;2

Stewart, R.L.M., K.A. Bredin, A.R. Couturier, A.G. Horn, D. Lepage, S. Makepeace, P.D. Taylor, M.A. Villard, and R. Mm. Whittam. 2015. Second atlas of breeding birds of the Maritime Provinces. Bird studies Canada, Environment Canada, Natural History Society of Prince Edward Island, Nature New Brunswick, New Brunswick Department of Natural Resources, Nova Scotia Bird Society, Nova Scotia Department of Natural Resources, and Prince Edward Island Department of Agriculture and Forestry, Sackville, New Brunswick, Canada.

Stocek, R.F. 1992. Bald Eagle. Hinterland Who's Who. Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, Canada. Accessed 19 January 2020. http://www.hww.ca/en/wildlife/birds/bald-eagle.html. (also issued in French under the title: Le pygargue à tête blanche).

Tewksbury, J.J., J.G.T. Anderson, J.D. Bakker, T.J. Billo, P.W. Dunwiddie, M.J. Groom, S.E. Hampton, S.G. Herman, D.J. Levey, N.J. Machnicki, C. Martinez del Rio, M.E. Power, K. Rowell, A.K. Solomon, L. Stacey, S.C. Trombulak, and T.A. Wheeler. 2014. Natural history's place in science and society. BioScience 64: 300–310. https://doi.org/10.1093/biosci/biu032

Wright, B.S. 1953. The relation of Bald Eagles to breeding ducks in New Brunswick. Journal of Wildlife Management 17: 55–62.

Bibliography of Rudolph Frank Stocek

Stocek, R.F. 1962. Some aspects of the ecology of the Rainbow Trout (*Salmo gairdneri*) and the Largemouth Bass (*Micropterus salmoides*) in a small lake. M.Sc. thesis, University of Toronto (Ontario Agricultural College), Guelph, Ontario, Canada.

Stocek, R.F. 1965. Tinicum—A City Preserve. Frontiers 29: 136–141.

Stocek, R.F., and H.R. McCrimmon. 1965. The co-existence of Rainbow Trout (*Salmo gairdneri* Richardson) and Largemouth Bass (*Micropterus salmoides* Lacepede) in a small Ontario lake. Canadian Fish Culturist 35: 37–58.

Stocek, R.F. 1970. Observations on the breeding biology of the Tree Swallow. Cassinia 52: 3–20.

Stocek, R.F. 1972a. Copulation in the Tree Swallow. Eastern Bird Banding News 35: 163–165.

Stocek, R.F. 1972b. The occurrence of Osprey on electric power lines in New Brunswick. N.B. Naturalist 3: 19–27.

Stocek, R.F. 1972c. Technical in service training for fish and wildlife personnel. Canadian Society of Wildlife and Fish Biologists, Atlantic Chapter Newsletter 2: 3–5.

Stocek, R. 1973. The Tree Farm: there's a lot [of wildlife]. The Maritime Farmer and Co-operative Dairyman, Sussex, New Brunswick, Canada. 20 March, No 12: 2, 17.

Stocek, R.F. 1976a. A dwarf Tree Swallow egg. Canadian Field-Naturalist 90: 183–184. Accessed 26 January 2020. https://biodiversitylibrary.org/page/28045666.

Stocek, R.F. 1976b. The 1975 North American Peregrine Falcon Survey—The Maritime Provinces. Canadian Field-Naturalist 90: 248. Accessed 26 January 2020. https://biodiversitylibrary.org/page/28045735.

Stocek, R.F., and P.A. Pearce. 1978a. The Peregrine Falcon in the Maritime Provinces. Manuscript Report. No. 36. Canadian Wildlife Service, Wildlife Toxicology Division, Ottawa, Ontario, Canada.

Stocek, R.F., and P.A. Pearce. 1978b. The Bald Eagle and Osprey in the Maritime Provinces. Manuscript Report. No. 37. Canadian Wildlife Service, Wildlife Toxicology Division, Ottawa, Ontario, Canada.

Stocek, R.F. 1979. Decline of summering Bald Eagles in central New Brunswick. Canadian Field-Naturalist 93: 443–445. Accessed 26 January 2020. http://biodiversitylibrary.org/page/28063770.

Stocek, R.F. 1981. Bird Related Problems on Electric Power Systems in Canada. Report 110-T-210. Canadian

Electrical Association Research, Montreal, Quebec, Canada.

Stocek, R.F., and P.A. Pearce. 1981. Status and breeding success of New Brunswick Bald Eagles. Canadian Field-Naturalist 35: 428–433. Accessed 26 January 2020. https://biodiversitylibrary.org/page/28062135.

Stocek, R.F. 1982. Environmentally Significant Areas in the Saint John Planning Region of New Brunswick. Environmental Services Branch, Environment New Brunswick, Fredericton, New Brunswick, Canada.

Patch, J.R., and R.F. Stocek. 1983. Introduction. Pages 1–2 *in* Wildlife Habitat Management and Small Woodlots. Proceedings of the 14 June 1983 DNR Workshop. Fish and Wildlife Branch, New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada.

Stocek, R. 1983a. The Bald Eagle. New Brunswick Natural Resources. Department of Natural Resources, Fredericton, New Brunswick, Canada. Spring 1983: 14.

Stocek, R.F. 1983b. Non-Game Birds and Woodlot Management. Pages 49–73 *in* Wildlife Habitat Management and Small Woodlots. Proceedings of the 14 June 1983 DNR Workshop. Fish and Wildlife Branch, New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada.

Stocek, R.F., and P.A. Pearce. 1983. Distribution and reproductive success of Ospreys in New Brunswick, 1974–1980. Pages 215–221 *in* Biology and Management of Bald Eagles and Ospreys. Proceedings of the 1st Symposium on Bald Eagles and Ospreys. *Edited by* D.M. Bird, N.R. Seymour, and J.M. Gerrard. McDonald Raptor Research Centre and Raptor Research Foundation, McGill University, Montreal, Quebec, Canada.

Stocek, R.F. 1984. Snags and woodpeckers in the University of New Brunswick forest. Technical Bulletin No. 117. Environment Canada, Canadian Forestry Service, Martimes Forest Research Centre, Fredericton, New Brunswick, Canada.

Stocek, R.F. 1985a. The Bald Eagle in New Brunswick in the 80's. Pages 44–47 *in* The Bald Eagle in Canada: Proceedings of Bald Eagle Days, 1983. *Edited by* J.M. Gerrard and T.N. Ingram. White Horse Palins Publishers, Headingly, Manitoba, Canada.

Stocek, R. 1985b. Bald Eagles and winter feeding. N.B. Naturalist 14: 138–140.

Stocek, R.F., and D. Cartwright. 1985. Birds as non-target catches in the New Brunswick furbearer harvest. Wildlife Society Bulletin 13: 314–317.

Stocek, R.F. 1986a. Spring weather and the local movement of Tree Swallows. Canadian Field-Naturalist 100: 134–136. Accessed 26 January 2020. https://biodiversitylibrary.org/page/28072209.

Stocek, R. 1986b. Notes on Tree Swallow breeding biology I—Aggression directed towards human disturbance. N.B. Naturalist 15: 87–89.

Stocek, R. 1987. Notes on Tree Swallow breeding biology II—Ageing nestlings. N.B. Naturalist 16: 19–20.

Stocek, R. 1988a. Notes on Tree Swallow breeding biology III—Nest building and breeding success. N.B. Naturalist 16: 50–51.

Stocek, R. 1988b. The Bald Eagle in New Brunswick. N.B. Naturalist 16: 81–82.

Stocek, R. 1989a. An unusual Mourning Dove breeding record. N.B. Naturalist 16: 116.

Stocek, R.F. 1989b. The Common Loon in New Brunswick. Status Report prepared for the World Wildlife Fund (Canada), Toronto, Ontario, Canada.

Stocek, R. 1990. The rise and fall of *Passer domesticus*. N.B. Naturalist 17: 60.

Stocek, R. 1991a. The abundance of wintering Bald Eagles in New Brunswick. N.B. Naturalist 18: 4–5.

Stocek, R.F. 1991b. New Brunswick trees and shrubs in winter: a field guide. New Brunswick Maritime Forest Ranger School, and Canada/New Brunswick Cooperation Agreement on Forestry Development, Fredericton, New Brunswick, Canada.

Stocek, R.F. 1992a. Bald Eagle. Hinterland Who's Who. Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, Canada. Accessed 19 January 2020. http://www.hww.ca/en/wildlife/birds/bald-eagle.html. (also issued in French under the title: Le pygargue à tête blanche).

Stocek, R. 1992b. Book Review. Fishes of the Atlantic Coast of Canada (W.B. Scott and M.G. Scott. University of Toronto Press and Canadian Bulletin of Fisheries and Aquatic Sciences 219, 1988, 731 pages). N.B. Naturalist 19: 23.

Stocek, R.F. 1993. Book Review: Ecology and Management of the Eastern Coyote (A.H. Boer [Editor]. Wildlife Research Unit, University of New Brunswick, Fredericton, 1992, 194 pages). The Daily Gleaner, Fredericton. January 8, 113(6): 8.

Stocek, R.F. 1994. Importance of riparian zones as wildlife habitat. Horizons (newsletter of the Fundy Model Forest Network) 1(2): 3.

Stocek, R.F. 1995a. Book Review: Common sense wildlife management: discourses on personal experiences (N.R. Dickinson. Settle Hills Publishing, 1993, 107 pages). Atlantic Society of Fish and Wildlife Biologists Newsletter 11(1): 4.

Stocek, R.F. 1995b. The Cougar, *Felis concolor*, in the Maritime Provinces. Canadian Field-Naturalist 109: 19–22. Accessed 26 January 2020. https://biodiversitylibrary.org/page/35456881.

Stocek, R.F., P. Cronin, and P.D. Seymour. 1999. The Muskellunge, a recent addition to the ichthyofauna of New Brunswick. Canadian Field-Naturalist 113: 230–234. Accessed 26 January 2020. https://biodiversitylibrary.org/page/34235092.

Stocek, R.F. 2000a. Diet of wintering Bald Eagles in New Brunswick. Canadian Field-Naturalist 114: 605–611. Accessed 26 January 2020. https://biodiversitylibrary.org/page/34237111.

Stocek, R. 2000b. Nest utilization by Bald Eagles in New Brunswick. N.B. Naturalist 26: 107–110.

Stocek, R. 2000c. The Bald Eagle: A species at risk in New Brunswick? Éléments (Online Environmental Magazine) New Brunswick Environment Network. December 2000. Accessed 19 January 2020. http://www.elements.nb.ca/theme/endangeredspecies/bald/eagle.htm.

Stocek, R. 2002. An Eagle-Eyed Odyssey. N.B. Naturalist 28: 99.

Stocek, R.F. 2003a. The Bald Eagle population in New Brunswick. Bird Trends: a report on results of National Ornithological Surveys in Canada. No. 9: 21–24.

Stocek, R.F. 2003b. Fifty forestry-focused frivolities: perplexing problems for the restless mind. Privately Printed, R.F. Stocek, Fredericton, New Brunswick, Canada.

Hood D.J., and R.F. Stocek. 2005. The Fathead Minnow in New Brunswick. Canadian Field-Naturalist 119: 351–354. https//doi.org/10.22621/cfn.v119i3.144

Stocek, R. 2005. The Bald Eagle in the St. John River Watershed. The River (Newsletter of the St. John River Society). Summer 2005: 1–2.

Stocek, R. 2006. Through the Eye of an Eagle: The Bald Eagle in New Brunswick. Rudy Stocek and Taylor Printing Group, Fredericton, New Brunswick, Canada.

Stocek, R., and R. Eldridge. 2009. Fall and winter diet of coastal Bald Eagles in New Brunswick. NB Naturalist 36: 69–71.

Received 19 December 2019
Accepted 29 January 2020

The Canadian Field-Naturalist

Book Reviews

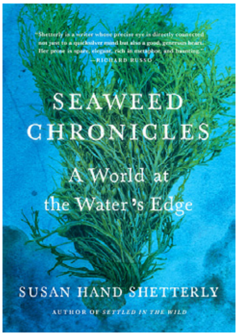
Book Review Editor's Note: *The Canadian Field Naturalist* is a peer-reviewed scientific journal publishing papers on ecology, behaviour, taxonomy, conservation, and other topics relevant to Canadian natural history. In line with this mandate, we review books with a Canadian connection, including those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

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

BOTANY

Seaweed Chronicles

By Susan Hand Shetterly. 2018. Algonquin Books of Chapel Hill. 271 pages, 27.59 CAD, Cloth.



Seaweed Chronicles is a blend of engaging popular science and interview-based narrative. It is highly place-based—the Gulf of Maine and surrounding area is the main geographic focus—but the nature of the subject matter means that connections are made between ocean coasts of all kinds. Shetterly has been involved in the regulatory and research communities for decades, and although her knowledge of the subject matter is apparent and the book is clearly well researched, this is not a treatise on the biology of seaweed. Several species of seaweed and the creatures that depend on them are highlighted and sufficient background is provided to inform the uninitiated, but this is primarily a book of stories, lives lived in a relationship with algae.

Each chapter focusses on one or a few related subjects, typically presented from the experience of a topic specialist via direct quotes and background information. The writing is usually conversational in tone and covers integrated topics such as the cod fishery collapse, island sheep farming, potato gardening, invasive species, and eider ducks. I started reading this book while living in landlocked Ontario, but after living on the East Coast for a month, I found it significantly more engrossing. That is not to say that those without a coastal context will not enjoy *Seaweed Chronicles*, but I suspect having at least casual contact with the ocean will only improve the reading experience. Shetterly does provide a short primer in the front matter on the algal species that feature prominently, but it would benefit from a measure of visual context—if you don't know the species in question, it may help to start your reading with a quick Internet image search. While the author does refer to specific facts and findings, the book itself does not contain references.

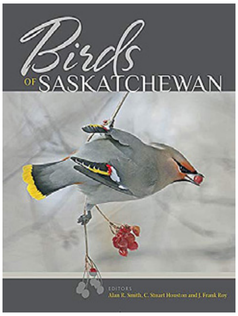
What *Seaweed Chronicles* does exceptionally well is tell the stories of individual people. Perspectives represented include those of researchers, farmers, harvesters, policymakers, and conservationists, and their lived experiences are the foundation of the book's content and structure. In this relatively short work, Shetterly delves into more dimensions of seaweed than you ever knew existed—as habitat, foodstuffs, artisanal martini decoration, animal forage, restoration tool, fertilizer, and so on. Some stories will probably grip you more than others depending on your personal context, but the writing is accessible and there is almost certainly something within that will pique your interest. For those with a coastal upbringing or fond place-based memories, *Seaweed Chronicles* provides an enjoyable stroll along the water with a good teacher to reveal new layers of understanding. For those less familiar, it offers a window into a macroalgae world that is foundational to the health of our oceans. Either way, it is worth the read.

HEATHER A. CRAY
Halifax, NS, Canada

ORNITHOLOGY

Birds of Saskatchewan

Edited by Alan R. Smith, C. Stuart Houston, and J. Frank Roy. 2019. Nature Saskatchewan. 765 pages, 79.95 CAD, Cloth.



For over three-quarters of a century, Nature Saskatchewan (formerly the Saskatchewan Natural History Society) has promoted investigation of the natural history of the province and surrounding areas by both amateurs and professionals. Many of the results have appeared in the quarterly *Blue Jay*, and in the Society's many Special Publications. Birds have been the focus of much of this work. *Birds of Saskatchewan* is the culmination of these efforts. It began as the dream of the late Manley Callin (1911–1985). His bequest helped fund its production and his dream is fulfilled by more than a decade of effort by the three editors, 107 authors of one or more species accounts, 69 photographers, and 24 reviewers.

Readers will find much of interest and value on every page of this large book (30 × 23 cm; 3 kg). The 437 accounts cover all species occurring regularly in the province, plus extinct, accidental, and hypothetical species. There is much more than just species accounts in this book. The first section is an "Introduction to the Province". It begins with a presentation of the seven "Natural Vegetation Zones in Saskatchewan", describing their natural flora and listing their typical and special bird species. One or more beautiful photos illustrate each zone and give lie to the common belief that the province has nothing but flat wheat fields. "Human History and the Flora and Fauna of Saskatchewan" reviews the influence of humans on the plants and animals, especially since the beginning of European settlement in 1872. It describes the negative impacts of human activity such as agriculture and resource extraction on many avian species, and the positive effects on species that have invaded or prospered in response to such activity. Efforts to protect and sustain bird populations are described, from the establishment of the first bird sanctuary in North America at Last Mountain Lake in 1887 to recent concerns about the federal government's divestiture of the Prairie Farm Rehabilitation Administration pastures and its impact on populations of threatened grassland bird species. "The Ornithological History of Saskatchewan" begins with Henry Kelsey's 1690 observation of Passenger Pigeons and Sir John Richardson's ornithological collections in 1827. A "who's who" of professional ornithologists (John Macoun, A.C. Bent, Francis Harper, W.E. Clyde Todd, George M. Sutton, W. Earl Godfrey, and J. Dewey Soper, among others) visited the province between 1880 and 1947. Their specimens are found in many of the major museums in North America. The roles of resident naturalists, bird banders, and institutions and organizations such as the Royal Saskatchewan Museum and Nature Saskatchewan are reviewed briefly. The section ends with a description of a century of "citizen science" which has contributed greatly to this book through Christmas Bird Counts (CBC), the Prairie Nest Records Scheme (PNRS), Breeding Bird Surveys (BBS), and through recent electronic activities such as Saskbirds (https://twitter.com/hashtag/saskbirds) and eBird (https://ebird.org/home).

Accounts for species that occur regularly in the province are about four pages in length, and packed with information. Each begins with a brief introduction to the species and a description of the North American range. A small map of the province is colour-coded to indicate seasonal distribution. "History" summarizes records prior to extensive settlement (1924). "Status" reviews relative abundance and population trends based on BBS data and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designation, where appropriate. Sections on "Spring", "Breeding", "Fall", and "Winter" summarize information on migration dates and breeding records. The final sections describe "Saskatchewan Research" and "Banding" (including names of banders with the number banded and recoveries). One to five photos showing plumages, nests, young, and, in many cases, behaviour, illustrate each account. Accounts for permanent residents and winter visitors include a table summarizing CBCs for different vegetation zones. Accounts for common waterfowl species include maps illustrating the recoveries of birds banded in the province, clearly demonstrating the role of Saskatchewan as the "duck factory" of North America. Accounts for accidental (44) and hypothetical (42) species are a half-page or less in length. They summarize records for accidentals and available evidence for species whose occurrence in

Saskatchewan has not been documented with photographs or sound recordings.

Most of the accounts include a shaded "Interest Box". Some provide special information (e.g., a short biography of Bernard Rogan Ross, for whom Ross's Goose and Gull were named) or give taxonomic information (e.g., the convoluted history of the scientific name for the Olive-sided Flycatcher). However, most recount specific experiences that contributors have had with the species in question. The late L.B. Potter describes (in the 1922 volume of *The Canadian Field-Naturalist*) the abundance of Sage-grouse in southwestern Saskatchewan in the first decades of the 20th century. He notes a tameness which led them to trespass into the garden and eat the lettuce plants. Editor Alan Smith remembers a night in the 1960s that he spent sleeping on the prairie wool at the Matador Field Station, only to be woken in the early morning by a Vesper Sparrow who landed on his hip and used him as a song perch. Such vignettes capture the pleasures, rewards, and memories that we all derive from our activities in the natural world.

Special mention must also be made of the photographs that grace almost every page of this book. Many of these are nothing short of spectacular—it would be impossible to select a favourite! The Bohemian Waxwing on the cover is a good example. The photographers and the Photo Selection Committee deserve congratulations for their efforts.

Eight appendices follow the species accounts and cover various topics, including a list of bird banders mentioned in the accounts, a summary of results of CBCs from 1913 to 2016, a map of BBS localities (none in the northern third of the province), and a useful gazetteer of place names mentioned in the accounts. Appendix B includes biographical sketches of 168 now-deceased individuals who contributed to our knowledge of Saskatchewan ornithology. It includes explorers, early collectors, and professional ornithologists who have worked in the province. But most contributors were farmers, ranchers, teachers, physicians, accountants, homemakers, etc. who shared a common love of natural history and birds. On almost every page, I found the name of someone who encouraged or supported a bird-crazy teenager on my path to a career in ornithology. I know that many others of my cohort (including the senior editor) shared this experience, and that it continues today, guaranteeing that Saskatchewan ornithology will thrive in the 21st century.

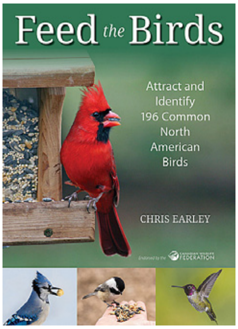
The book ends with a "Literature Cited" section spanning 49 pages and including approximately 2500 entries (my estimate)! I suspect that there few (if any) publications relevant to the avifauna of Saskatchewan that have been overlooked. Future researchers now have a single place to access relevant citations covering information on observations and research from 1690 to 2016.

Birds of Saskatchewan is an important record of the history and current state of the avian fauna of the province. It brings together a wealth of information that will be useful to both bird enthusiasts and future scholars. Beyond that, it is a delight to move through the pages, sampling both the data and the biological details contained. Its price is well worth the rewards of exploring a remarkable book.

M. ROSS LEIN
University of Calgary, Calgary, AB, Canada

Feed the Birds: Attract and Identify 196 Common North American Birds

By Chris Earley. 2019. Firefly Books. 296 pages, 29.95 CAD / 24.95 USD, Paper.



Chris Earley's book, *Feed the Birds: Attract and Identify 196 Common North American Birds*, couldn't have come at a better time. In October 2019, a landmark paper was published documenting the catastrophic decline in North American avifauna. Rosenberg *et al.* (2019: 120) wrote that their analyses indicate "a net loss approaching 3 billion birds, or 29% of 1970 abundance". With an overall decline of avian species, even common species, we need to do everything we can to help our feathered friends.

Feed the Birds is an easy-to-use book geared toward aiding in bird observation and study. The book begins with a brief introduction, asking questions like "why feed birds?" and delving into possible answers, such as citizen science, involving kids in birding, and photography. After the introduction, the book is divided into two major sections: (1) attracting and feeding birds and (2) identifying birds. The first section has four chapters: "Feeding Wild Birds" (what and how to feed); "Creating a Bird Friendly Backyard" (natural foods, water, shelter, nesting boxes, predators, etc.); "Bird Feeder Building Plans"; and "Bird Behavior and Biology" (recognizing individual birds, nature's predators, predator detectors, adaptions). The second section (comprising half the book) is focussed on bird identification, from hummingbirds and woodpeckers to grosbeaks and orioles. The book ends with a blank "birds at my feeder list", works cited, further reading, photo credits, and an index.

The first section is a joy to read. The writing is not long-winded and gets to the point. The paragraphs are packed with information, and each page is loaded with colour photos to support the text. For example, feeding wild birds is much more than tossing out a simple hardware store seed mix. Certain birds require certain kinds of food; different types of seeds attract different species of birds and some bird food types aren't even seeds, like suet, fruits and jellies, nectar, and mealworms. What do you do with these foods? Toss them on the ground? Not always. There is a whole philosophy behind bird feeders and dispensers and, depending on what you want to attract to your yard, these feeders are critical. Creating a bird-friendly yard can also enhance the avian biodiversity in your area. Supplying a water source, nesting areas, shelters, and bird-attracting plants will no doubt increase the number of birds in your yard. There are many things one needs to consider such as native versus non-native plants, berry-bearing shrubs and trees, plants that support invertebrates, and flowers that attract hummingbirds and other nectar feeders. Other must-read sections include how cats impact birds and the balance between enjoying the squirrels in your yard and when they become too much of a pest at the expense of your bird friends. Birds crashing into windows is another issue, and the book addresses this as well.

As you watch the birds in your yard, you will begin to take note of various behaviours that may seem baffling at first, but with careful study, the mysteries of bird interactions, aggressive displays, and courtship begin to tease out and demystify. Chapter 4, "Bird Behavior and Biology", is a fascinating and welcome addition to your reading adventure. Various topics are covered, including feather maintenance, feeding behaviour, threat displays, nestling care, and bird intelligence. It's always a joy to watch jays and crows figure out bird feeders as well as harass pesky squirrels.

Of course, the biggest draw to attracting birds to your yard is bird identification. It's an incredible thrill to keep a tally of bird species (life lists) and to add a rare bird from time to time. One huge reward is knowing that the bird likely arrived in your yard simply because of the extra effort made to convert a once barren space into a bird paradise. The book discusses tips on how to identify birds, from size and shape, to beak morphology, bird movement, and field marks. The book includes a bird quick-find guide that assists in figuring out bird species, even if you only see the bird for a few moments. The guide will then direct you to a general bird group that will help with further identification. The general groups make up the last half of the book. Each group has species accounts, typically a page each, that provide additional information about the bird. Account topics include a general introduction to the bird, what natural foods they prefer, what feeds should be available in your yard, size comparisons, field identification marks, and a range map. All accounts are supported by several full colour photos of the bird species and sometimes additional side-by-side photo comparisons of closely related or resembling species. Along the bottom of each account is a small call-out box with a photo and natural history tidbit or anecdote about the bird. For example, in the American Robin account, the author discusses his observation of a robin "anting", that is, allowing ants to crawl on its feathers, crushing them, and rubbing the ants through the feathers. Anting is thought to be a form of chemical application to help repel external parasites.

Overall, *Feed the Birds* is a must-read for those interested in attracting birds to their yard. With the general decline in bird species in North America and elsewhere, now is the time to create as many bird friendly spaces as possible. Chris Earley's book is a one-stop shop for all you need to know to move forward with this wildlife enhancing concept. It's easy to do and, with minimal effort, we can enjoy bird watching without even leaving the house. Be sure to participate in citizen science projects, like iNaturalist or eBird, and let's do our part to conserve and preserve avian biodiversity.

Acknowledgement: I thank Susan Hagen for improving the review manuscript.

Literature Cited

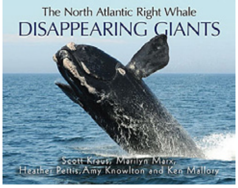
Rosenberg, K.V., A.M. Dokter, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J.C. Stanton, A. Panjabi, L. Helft, M. Parr, and P.P. Marra. 2019. Decline of the North American avifauna. Science 366: 120–124. https://doi.org/10.1126/science.aaw1313

Howard O. Clark, Jr.
Colibri Ecological Consulting, LLC,
Fresno, California, USA

ZOOLOGY

The North Atlantic Right Whale: Disappearing Giants. Revised and Updated Edition

By Scott Kraus, Marilyn Marx, Heather Pettis, Amy Knowlton, and Kenneth Mallory. 2019. Fitzhenry & Whiteside. 140 pages, 24.95 USD, Paper.



North Atlantic Right Whales (NARW; *Eubalaena glacialis*) have been in the news quite a bit over the last three years in Canada, beginning in 2017 with the deaths of 12 NARW in the Gulf of St. Lawrence. This may not seem like a huge number, but with around 400 individuals left, mortality events like this are noteworthy. The Government of Canada acted surprisingly quickly, enacting vessel slowdown measures and fisheries closures to reduce the risk of ship strikes and entanglements, respectively. This management strategy apparently worked, with no NARW found dead in Canadian waters in 2018. But 2019 was a dire season again, with eight or nine NARW found dead in Canadian waters. The National Oceanic and Atmospheric Administration of the United States have even labelled these mortalities as Unusual Mortality Events. *Disappearing Giants* outlines the plight of NARW, paying particular attention to the recent Unusual Mortality Event that the population underwent. This book provides a useful, relatively concise overview of the conservation issues surrounding this species, and could be especially interesting for Canadian readers who want to learn more about this species following the recent deaths in the Gulf of St. Lawrence.

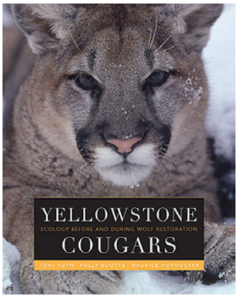
Disappearing Giants is a clearly written, nontechnical overview of NARW, filled with wonderful photos of the whales. Close to 50% of the book is filled with photos, so beyond the interesting content, it would be a great book to leave out on a coffee table. This book is written by researchers from the New England Aquarium, some of whom, including main author Kraus, have been studying NARW since the 1970s. The book educates readers about NARW, with a brief chapter on evolution, followed by their history with humans, starting with centuries of whaling that devastated the population, to current research and threats to the species. While all of the 14 species of baleen or great whales (Mysticetes) were target species for whalers, the 'right whales' to hunt were the three species of right whales (*Eubalaena* spp., including NARW) and Bowhead Whales (*Balaena mysticetus*; Family Balaenidae) because they were easier to recover after they were killed: when they die, they tend to float on the surface, unlike rorqual whales (Family Balaenopteridae) that typically sink once they die. The commercial hunt for NARW ended in 1935 and, at that point, it was thought that only 100 whales were left. The population has recovered since then, but not as well as other right whale species, such as Southern Right Whales (*Eubalaena australis*). A main reason for this difference is that NARW live along the Atlantic coast of North America, where they are constantly exposed to ship traffic and active fishing grounds, leading to continued human-caused mortality.

Disappearing Giants doesn't just focus on the bleak history of NARW. It ends on a chapter called "Hope for the Future", where the authors describe reasons why we shouldn't give up on NARW, and should continue working towards helping this species recover. The authors outline recent management initiatives that have been quite effective in reducing mortalities of NARW and, perhaps most importantly, describe the collaborative nature of NARW conservation initiatives, where like-minded people have come together to address conservation issues surrounding NARW. These collaborations are a crucial aspect of the recovery of this species, and do indeed give me hope that the conservation issues surrounding NARW are solvable, which will hopefully lead to recovery.

WILLIAM D. HALLIDAY
Wildlife Conservation Society Canada,
Whitehorse, YT, and
Department of Biology, University of Victoria,
Victoria, BC

Yellowstone Cougars: Ecology Before and During Wolf Restoration

By Toni K. Ruth, Polly C. Buotte, and Maurice G. Hornocker. 2019. University Press of Colorado. 336 pages, 65.00 USD, Cloth, 53.00 USD, E-book.



Yellowstone Cougars is an academic-style book written primarily for biologists and wildlife managers. It contains a treasure trove of data on Cougar (*Puma concolor*) and is the first book written on an apex carnivore to examine their ecology before and after the recovery of another keystone predator—in this case, Gray Wolf (*Canis lupus*). Given its scientific focus, the reading is very dense and time consuming with an impressive amount of data within its 300+ pages. The 8.25 × 10.25 inch (20.8 × 26.1 cm) hardcover contains small font and double columns per page so the book really felt like over 500 pages! Each chapter took me a couple hours to read given the length along with the technical information on each page. However, everything you want to know about Cougars in the world's first national park is told here. This book and *Cougar: Ecology and Conservation* (2010, University of Chicago Press) are now the two reference books for this animal to which other works will be compared.

Ruth and her colleagues conducted a 14-year study—seven years before wolves returned to Yellowstone National Park (1987–1994) and seven years (1998–2005) covering the tail end of wolf reintroduction to the beginning of a recovered population. The book is broken into five main sections, the first consisting of three introductory chapters discussing their methods and the study area, followed by three middle sections on Cougar diet and their competition with wolves (five chapters), landscape use (four chapters), and Cougar population characteristics pre- and post-wolf recovery (four chapters), and the final section contains two synthesis chapters on carnivores and humans. Each of the three middle sections has an introductory chapter which frames where the next three to four chapters will take us. Each chapter ends with a convenient summary of the most pertinent information from that section, making it easier to digest the scientific information presented in that chapter—I often read those sections first before starting each chapter, then re-read it after I finished a given chapter.

The authors spent an amazing amount of time in the field, marking 87–94% of the adult Cougars annually with 80 total Cougars radio-collared and ear-tagged (including all age classes) during pre-wolf studies and 88–93% post-wolf adult Cougars collared annually with 83 total tagged post-wolf (pp. 28, 69). Cougars were treed by hounds and then darted by biologists to sedate them. They were then followed so their movements and predation patterns could be recorded, with 40–50 kills found annually (p. 34). The researchers collected about 12 000 VHF (very high frequency) radio locations and over 19 500 GPS (global positioning system) points on these animals over 14 years. Their study area consisted mainly of the Northern Range of Yellowstone because Cougars only seasonally lived in the remaining 75–80% of the park due to deep snow and ungulates leaving those areas in winter, except for Bison (*Bison bison*) which they did not prey on (p. 58).

We learned that Cougars were at the bottom of the large carnivore hierarchy, with wolves and Grizzly Bears (*Ursus arctos*) dominating them (pp. 93, 116), wolves most commonly, though rarely, killing them and bears most frequently usurping their kills (p. 244). Elk (*Cervus canadensis*) were the staple prey for Cougars and wolves throughout both study periods, with Mule Deer (*Odocoileus hemionus*) second for Cougars (p. 50). Calf Elk were the most important prey class throughout the study for Cougars (p. 52). This remained the case even when Elk decreased at the end of the study owing to recovery of carnivore populations, including bears, causing the system to change from bottom-up regulation of Elk before wolves to top-down post-wolf (p. 117). In general, wolves were superior at exploiting Elk adults and Cougars at exploiting Elk calves. Given their high niche overlap (82%, pp. 243–244), the sympatric carnivores were unwittingly engaged in exploitation competition for a common food source (pp. 119, 244).

Cougars survived by avoiding competitors, mainly wolves, by living in more forested and rougher terrain (p. 62), which contained a lower density of prey (p. 66). When prey Cougars killed was not taken over by competitors, Cougars often spent two to five days at a carcass before moving on to travel and eventually kill again, usually three to four days after leaving their previous food cache (pp. 71–73). The authors believed that Cougars benefited from using areas of lower densities of prey as this reduced potentially fatal encounters with wolves (pp. 179, 240, 242). Even so, wolves killed at least three adult Cougars and five kittens during the study (pp. 180, 208, 212).

Interestingly, Cougar home ranges and core areas were more stable after wolf restoration compared to before (pp. 134–136). While Cougars used less area (females 10–46% and males 43–65%) on the landscape when wolves were back, they overlapped with more conspecifics sharing non-defended areas (i.e., females and philopatric daughters; pp. 137–138). In avoiding open and flat areas when wolves were back on the landscape, the authors repeatedly stressed the importance of forested and rough terrain for Cougars (e.g., pp. 159, 176, 181, 235). The heterogenous habitats of northern Yellowstone likely makes carnivore coexistence possible as each species used different areas (pp. 181, 242).

Some unexpected findings of the study were, despite wolves engaging in exploitation (eating similar prey) and interference (direct killing) competition with Cougars, the cats had similar litter sizes (averaging 2.9 cubs) throughout the study (p. 216) and kitten survival actually increased post-wolf (pp. 216, 202, 205) with less infanticide by adult male Cougars (p. 212). Because territories were more stable post-wolf, kittens actually stayed with their mothers for five months longer (12–14 versus 17–19 months) than before wolves came back (pp. 204, 220, 240), and living in small groups of adult-sized Cougars likely offered enhanced protection, intimidation, and vigilance from other predators (p. 230). In addition, the Cougar population increased post-wolf with about 30–40 total Cougars living in northern Yellowstone despite using a smaller percentage of overall habitat in the park (pp. 226, 230). Part of this can be explained by Cougars recolonizing the area in the 1980s (p. 21) and then becoming saturated on the landscape as wolves came back. Densities of Cougars of two adults and 3.9 total per 100 km^2 in the study area were actually on the high end compared to other Cougar populations (p. 225). With this fully occupied area, females—with no room to stay near their mothers—averaged the same dispersal distance as young males (70 km; p. 221) and females moved more home range diameters away than did males (pp. 224, 254). Similarly, while 35% of females before wolves were philopatric only 11% were so post-wolf (p. 220). These young dispersers contributed to Yellowstone being a source population to nearby areas (pp. 255–256). Source populations are helping Cougars recover and colonize long vacant areas like the midwestern and even eastern United States (Way 2017: 249).

Yellowstone Cougars is comparable to the incredibly detailed and well-researched books *Desert Puma* (2001, Island Press) and *Mountain Lions of the Black Hills* (2018, Johns Hopkins University Press; Way 2018) in that it does a superb job of describing an in-depth long-term study on Cougars in a specific region. *Yellowstone Cougars* includes: 10 pages of Appendices explaining their study variables; 10 pages of "Notes" which are detailed statistics described in the chapters but shown at the end of the book to avoid too much detail in each section; an impressive 30 pages of double-columned references; and a seven-page index. It takes six pages at the beginning of the book to list the titles of the illustrations, including 118 figures and 60 tables. Many of those figures are black and white pictures of wild Cougars from the study, impressive because Cougars are notoriously difficult to photograph. My only complaint was that there was no map displaying dispersal distances from the source population when the authors discussed emigration (pp. 219, 221). Also, I did notice a few errors on some of the figures, including wrong labels in the charts (e.g., Figure 11.1 on p. 155, Figure 11.14 on p. 173, Figure 15.4 on p. 207, and Figure 16.4 on p. 230).

The reading material is labourious to go through thoroughly but is vital to understanding Cougar ecology in Yellowstone. I found Part 5, *Carnivores and Humans: Competition and Coexistence*, to be particularly important because it provided a synthesis of the book and offered management and conservation recommendations for the big cats. I was a little disappointed with the last chapter (18) in that it described management and conservation of Cougars but did not actually offer any concrete management options for state agencies. For instance, their data (see Figure 18.1, p. 253) showed that many female Cougars killed by hunters left orphaned offspring that died via starvation (p. 250). The authors do suggest management regimes where non-parklands also include areas closed to hunting to mimic natural populations (p. 250). These areas can be managed adaptively through rest rotation, whereby periods of hunting alternate with periods of rest (p. 248). However, without any specific suggestions of where these could occur, my experience with carnivore management suggests that even with involving citizens in a bottom-up approach (p. 258) it is difficult to envision state wildlife agencies doing anything other than continuing with killing the maximum sustainable amount of a species—even an ecologically important predator.

For enthusiasts of Yellowstone or carnivores, this is an important book. Unfortunately, and like many academic-style texts, *Yellowstone Cougars* is expensive. However, the book is truly a benchmark in detailing the life history of an elusive and difficult to study species.

Literature Cited

Way, J.G. 2017. [Book Review] Heart of a Lion: A Lone Cat's Walk Across America. Canadian Field-Naturalist 131: 82–84. https://doi.org/10.22621/cfn.v131i1.1972

Way, J.G. 2018. [Book Review] Mountain Lions of the Black Hills: History and Ecology. Canadian Field-Naturalist 132: 200–201. https://doi.org/10.22621/cfn.v132i2.2189

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

OTHER

How to Give Up Plastic: A Guide to Changing the World, One Plastic Bottle at a Time

By Will McCallum. 2018. Penguin Random House. 224 pages, 15.00 USD, Paper.

Plastic. No matter where we look, it is everywhere, whether we see it or not. The impact that plastic has been having on wildlife and ecosystems has extended past the environmental field and has exploded into mainstream media. It can almost feel like we are bombarded by the various ways to become more eco-friendly and adopt a zero-waste lifestyle, leaving many people feeling like their contributions will be minimal at best. As someone who is always trying to reduce their footprint and encouraging others to do the same, this book was one I was particularly excited to check out.

How to Give Up Plastic begins with a wake-up call. The first two chapters focus entirely on the plastic problem and include many astonishing statistics and research that I was unfamiliar with. It was very interesting to learn the history of how plastics became so prevalent in our lives, how they have evolved, and how our recycling systems are not what we, as regular consumers, believe them to be. These chapters paint a somewhat glum picture of where our reliance on plastic has brought us, countered in the next chapter, "Stories of Hope and Success", showing how one person or one group created a huge difference in their community and beyond. Throughout the book you can find mini interviews relating the experiences of people leading the charge in the fight against plastics. I thoroughly enjoyed reading their views, tips, and reasons for doing the work that they do.

The next five chapters take us through different areas in our homes and lives. Each chapter breaks its area down into the most common items one might use (for example, the bathroom chapter includes sections on lip balm, shampoo, make-up, and hair removal). Some of the categories mention businesses that are targetting certain waste forms by creating alternatives. This information is very helpful in giving you a place to begin searching for items that suit your lifestyle; however, it could go quickly out of date as businesses come and go. While most of this advice is available through internet searches, having it all in one location to read through puts the bigger picture together and allows you to see where you want your plastic-free life to begin. As someone who has begun changing my lifestyle to lessen my waste and use of single-use plastics, I was happy to find many items that weren't on my radar and a few new blog suggestions! Many of the chapters end with a work page where you can list your plastic-free plan based on the topics covered.

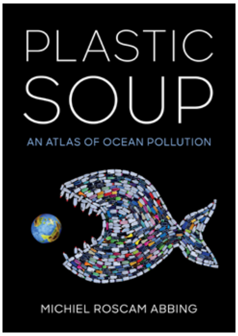
Chapters 10 and 11 take you from targetting your individual plastic use to your workplace and community. They are full of ideas, from getting people motivated to using your vocabulary to engage others to join the cause. The chapter on community gives a step-by-step guide to running your own clean-up, writing an effective letter to your members of government, and hosting a protest. These are activities that I think many people would like to be involved in and this allows them to take the next step in the actual planning process.

This is a great book for those who are relatively new to being plastic-free. It has tips and tricks for your everyday life and acts as an easy access, easy-to-read guide to start making your plastic-free plan. What felt like almost a blog-type format kept the content engaging and easy to read. I appreciated that the author consistently highlighted the need for systemic change, beginning with the industry, and an understanding that different realities exist for different people and can inhibit their ability to fully give up plastics. I typically expect books like this to be relatively preachy, but I also appreciated the fact that the author did a good job of being non-judgemental while still giving solid advice and statistics on the repercussions of plastic use. I would recommend this book to anyone interesting in beginning to reduce the amount of plastic in their life or anyone currently on the plastic-free journey as it may provide some topics they haven't thought of yet.

TIANNA BURKE
Conservation Biologist, Georgian Bay Biosphere
Reserve, Parry Sound, ON

Plastic Soup: An Atlas of Ocean Pollution

By Michiel Roscam Abbing. 2019. Island Press. 136 pages, 27.00 CAD, Cloth or E-book.



Plastic is in almost every item we use and own. Its convenience as a relatively cheap and durable material has become rather inconvenient from an environmental standpoint. For a few years now I have personally tried to make my household less reliant on plastic and am continuously surprised at just how difficult it is. Whether it is purchasing food, soap, pet products, or craft supplies, it has been incredibly difficult to manoeuver in a world where things are not individually wrapped or contain plastic.

Plastic Soup: An Atlas of Ocean Pollution is a short book with a lot of impact, both by the written content and the visual content. Author Michiel Roscam Abbing is a political scientist actively working on the plastic soup problem since 2011 alongside the Plastic Soup Foundation. Trying to put an end to increasing amount of plastic pollution, the Plastic Soup Foundation works to tackle plastic issues at the source, something that is focussed on in this book.

Plastic Soup is separated into two distinct parts; the first, "On the Map", focusses on the plastic crisis: its creation, the effects plastic has on ecosystems and wildlife, and some of the major items contributing to the plastic problem. The second half of the book, "Off the Map", focusses on solving the plastic crisis, highlighting research and initiatives around the world, the introduction of laws, and even how art is bringing this issue into the forefront.

More than just an atlas of pollution, this book is also an atlas of hope. I found it so interesting to learn how many different stakeholders across the world are reducing the use of plastic. Being someone who loves food, the idea of lasered food to reduce packaging and stickers was especially of interest. This book also challenged the optics of plastic itself and some of the plastic solutions that are becoming popular. I found it interesting to read that, technically, plastic reduces food waste because it helps to extend the shelf life of many items. Similarly, it takes fewer emissions and less water to produce than paper does, another common packaging item. However, while this may seem like plastic is an obvious solution, the total lifecycle of the product says otherwise, emphasizing the need to think critically and in terms of lifecycles.

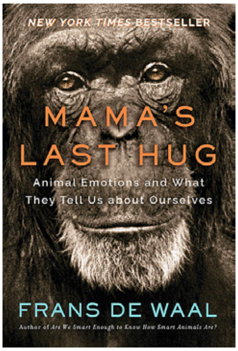
Critical thinking came up again in Chapter 7, "Between Belief and Hope", which tackles subjects such as recycling, bioplastics, and creating products out of ocean plastic. While these ideas may seem brilliant, they may be better than the actual results. Many books tend to focus on what you can do at an individual level and, while this book points out the roles our purchasing and lifestyle choices play, I was impressed by the author's emphasis on change at a level greater than a household. It helped me realize what more I can be doing at home and provided ideas I can push through to my local municipality and government.

I really enjoyed how in this first section the topics moved from obvious plastics, such as balloons, to plastics that we cannot see, such as microplastics. The author did a great job informing the reader of the problems and delivering the scientific evidence in a way that reaches all audiences. It was easy to understand, and the written content was enhanced by stunning photography and infographics. The format of the book makes it easy to read, providing a valuable tool for people seeking to learn more about the plastics issue. Throughout, heart-wrenching images bring home very effectively the message of the damage plastic has done to our planet and wildlife. Even if you don't read the book, the images alone will make you want to change your habits! I would recommend this book to anyone who is interested in learning more about plastics or for those, like me, who are trying to teach others and could use a resource jam-packed with information.

TIANNA BURKE
Conservation Biologist, Georgian Bay Biosphere Reserve, Parry Sound, ON

Mama's Last Hug: Animal and Human Emotions

By Frans de Waal. 2019. W.W. Norton. 336 pages, 36.95 USD, Paper.



Humans have held themselves superior to all other life forms for millennia. Dating back to Aristotle, this attitude in Western cultures was crystalized in the biblical notion that 'man will have dominion over the earth and all the creatures therein'. The consequences of this belief, and the subsequent actions over succeeding millennia, have been disastrous for the animals, as well as the earth itself. While ecologists, environmentalists, and most students of the life sciences are increasingly recognizing, defining, and warning us of these consequences, the notion of human supremacy is one that still remains strong. Why this should be so is a key question that primatologist Frans de Waal addresses in this, his 12th book, a "companion" to his *Are We Smart Enough to Know How Smart Animals Are?*, published by Norton in 2016. As de Waal explains in his Acknowledgments, "[e]ven though these two books treat emotions and cognition separately, in real life they are fully integrated" (p. 279). The arguments for animal intelligence and emotional lives presented by de Waal are compelling, supported by the increasing research in these areas and the rich anecdotal evidence gathered during his own long experience with primates and from other primatologists.

Mama's Last Hug begins with just such a story. We meet Mama as a 50-year-old Chimpanzee on her death bed. A researcher who had spent much time with her but who had not seen her in several years appeared for a final visit. On seeing him, Mama was transformed, from a listless animal on its way out to an excited, expressive creature that greeted her old friend effusively. How this could be seen in any other way as an emotional response is the mystery that de Waal seeks to unravel.

After a brief Prologue, the book continues for seven chapters. The first, "Mama's Last Hug", relates the story noted above; the next three discuss various emotions. Many of us conflate emotions with feelings, but de Waal distinguishes between them, defining feelings as interior states that we can describe using language and emotions as the deeply rooted, initially subconscious states that emerge into consciousness during various situations. The distinction is helpful, allowing him to address the idea that because animals don't have words to express emotion, they do not feel emotion; they simply react behaviourally to various stimuli in instinctual ways. This idea is not to be underestimated in its force—centuries of animal research have been premised on it. Chapters 2 and 3 present evidence of positive emotions in animals—laughter, empathy, sympathy—while Chapter 4, "Emotions That Make Us Human", deals with negative emotions, including disgust, guilt, and shame. These chapters contain many instances, observed in the wild or concluded from ingenious experiments, demonstrating the reality of animal emotional lives. Two themes running through these chapters, and indeed the book, are the continuity between the behavioural responses of apes and humans, and the continuing, though diminishing, resistance of scientists to accept or, more accurately, to write as though they accept, that apes have emotions just as humans do.

These chapters are the foundation for the more difficult, controversial discussions in the next three, Chapter 5, "Will to Power – Politics, Murder, Warfare", Chapter 6, "Emotional Intelligence – On Fairness and Free Will", and Chapter 7, "Sentience – What Animals Feel". If you cannot accept that animals have emotions, then it will be next to impossible to accept, as argued in Chapters 5 and 6, that animals have complex political relations, can engage in murder and warfare, or choose to act with fairness, and have the capacity to think through the consequences presented at times decisions are required. But the evidence is strong, the stories compelling. If one accepts evolutionary continuity between apes and humans, de Waal's conclusions are inescapable.

Chapter 7 is the capstone of the book. It begins by exploding the long-held belief that human superiority is based on the size of our brains and number of neurons therein. Recent research has shown that elephants have more of both than we do! And the related myth that consciousness is a property of humans alone gets similar treatment. Not only that, but instinct as sole explainer of animal actions is itself relegated to the dustbin of historical ideas. In the process of making these remarkable conclusions, de Waal discusses "three reasons (apart from pressing ecological ones) that humans should respect all forms of life: the inherent *dignity* of all living things, the *interest* every form of life has in its own existence and survival, and *sentience* and the capacity for suffering" (p. 245; italics in the original). He admits that assigning dignity to all forms of life is based on our subjective evaluations, the danger we must guard against is falling back into the ancient concept of what the Elizabethans called the great chain of being.

It is more readily seen that living things have an interest in remaining alive. While this is obvious from the reactions of animals, from mammals to arthropods, it remains true of plants, which, science is discovering, have incredibly complex defensive systems.

The big reason for respecting all forms of life, however, is sentience, the idea, impossible to confirm with scientific certainty, that animals have conscious experience of their emotions. Surely this must be an essentially human capacity. Well, not so surely, it turns out. All creatures, from cells to fungi, plants, and animals, have some capacity for sentience, or the ability to adjust their experienced conditions. But "[s]entience in the narrow sense implies subjective feeling states, such as pain and pleasure" (p. 248). It is de Waal's view that all living creatures, with and without brains and central nervous systems, should be considered as "sentient in the sense of having subjective feeling states" (p. 249). And this form of sentience resulted, de Waal believes, in the development of consciousness "relatively early in evolution" (p. 255).

The acceptance of these ideas is still ongoing, although science has come a long way from the early days of research into "affective neuroscience", a discipline founded by Jaak Panksepp, who "was ahead of his time…" (p. 256). In Panksepp's day, relates de Waal, funding for such research was difficult to come by, so strong was the opposition to animal emotions and intelligence, particularly in the field of psychology, dominated by Skinnerian behaviourism. My first degree was in psychology during the heyday of this movement, which I rejected instinctively. I took a personal delight in reading de Waal's description of the movement's demise. Unfortunately, its lingering legacy is the "gap between humans and all other species, which only widened with time" (p. 260). The results of that gap are still being promulgated in books celebrating human exceptionalism, but meanwhile, "[b]ehaviourism is dying a slow death" (p. 262). And about time. As noted in my review (Cottam 2018) of *Through a Glass Brightly*, people who reject the notion that humans are animals need to elevate their concepts of what animals are. Personally, I find it comforting to think that rather than dwelling on some fictional peak, we humans are connected with all living matter, part of the great natural cycle of life and death, the only 'eternity'—should we manage not to destroy the earth—that we can know.

Much of the evidence in this book is derived from field experience, whether in the jungles and other habitats where the animals live, or in the humane environments in which many research animals now reside, relatively free to interact in their normal social ways. It's highly readable 'popular' science at its best, but the topics are huge and critically important, the concepts revolutionary if we accept them. Thus it provides some hope that we humans will realize that continuing to consider ourselves superior to all other forms of life is just what it takes to destroy our own.

Editor's note: I used an advance reading copy to review this book. The final publication will differ somewhat—it will be indexed, for example, and has a different cover—so page numbers for quotations in this review may not exactly match those in the published version.

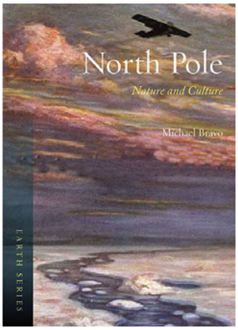
Literature Cited

Cottam, B. 2018. [Book review] Through a Glass Brightly: Using Science to See Our Species as We Really Are. Canadian Field-Naturalist 132: 202–203. https://doi.org/10.22621/cfn.v132i2.2191

BARRY COTTAM
Corraville, PE, and Ottawa, ON

North Pole: Nature and Culture

Michael Bravo. 2019. Reaktion Books. 254 pages and 111 illustrations, 62 in colour. 24.95 USD, Cloth or E-book.



Michael Bravo, Head of Circumpolar History and Public Policy Research at the Scott Polar Research Institute, Cambridge, United Kingdom, has written a rather unusual book. As the title suggests, it deals with the North Pole, but it is extraordinarily eclectic, ranging from classical writings on the polar regions, through the speculations of renaissance geographers, to accounts of polar exploration in the 18th through 20th centuries, and includes diversions into different sorts of poles (astronomical, geographical, magnetic) and polar exploration in cartoons and satirical writing. We meet Madame Blavatsky, Scipio Africanus, Herakles, and Baron Munchausen, among many others. Some are characters we might expect to see at the North Pole (Peary, Amundsen, Nansen), while others come as a total surprise (Mary Shelley and Frankenstein, Ptolemy, Bal Gangadhar Tilak).

This is not a book for those who primarily want factual information about the North Pole, although some of that is included. It is more likely to appeal to those who enjoy a ramble through miscellaneous polar ‘factoids’. Among the great names of polar travel, Peary gets quite a bit of space, although the controversy about where he actually got to is referenced but not described in detail, and Cook only gets passing mention. Steffanson, although never attempting to approach the pole, gets fairly extensive treatment, but I felt that Nansen got rather short shrift.

There is much in the book to be cherished regarding the impact of the pole on literature and art, and there are some lovely and, I suspect, little-known, images. However, I was constantly asking myself whether the book is really serious or a very well-disguised send-up of arcane scholarship. For example, after mentioning the section in Winnie-the-Pooh where Pooh finds a pole (he “just found it”) and Christopher Robin announces that it must be the North Pole, Bravo makes the following suggestion (p. 158):

> Milne, diverging from ethnonationalists who elevated the status of the North Pole to that of an ur-site of Aryan origins, recognised it for what it was, the essential point of origin in a mathematical projection but philosophically no more special than anywhere else …

The book is very attractively produced and illustrated on wonderful glossy paper. It is very entertaining to thumb through and browse and only the most diligent student of things polar is likely to be familiar with all the material covered. However, the Pooh excerpt given above is just a rather extreme example of the book’s generally over-erudite and, to my mind, over-elaborate, approach to the topic. Recommended for generalists and romantics. Not recommended for those only wanting information on polar exploration.

TONY GASTON
Ottawa, ON

NEW TITLES

Prepared by Barry Cottam

Please note: Only books marked † or * have been received from publishers. All other titles are listed as books of potential interest to subscribers. Please send notice of new books to the Book Review Editor.

†Available for review *Assigned

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

BIOLOGY

Biodiversity and Evolution. Edited by Philippe Grandcolas and Marie-Christine Maurel. 2018. ISTE Press–Elsevier. 284 pages, 127.50 USD, Cloth, 97.75 USD, E-book.

The Biology of Parasites. By Richard Lucius, Brigitte Loos-Frank, Richard P. Lane, Robert Poulin, Craig W. Roberts, and Richard K. Grencis. Translated by Renate FitzRoy and Ron Shankland. 2017. Wiley-Blackwell. 472 pages, 118.75 CAD, Cloth.

Biology of Sex. By Alex Mills. 2018. University of Toronto Press. 432 pages, 170.00 CAD, Cloth, 77.00 CAD, Paper, 62.00 CAD, E-book.

Is That a Bat? A Guide to Non-Bat Sounds Encountered During Bat Surveys. By Neil Middleton. 2020. Pelagic Publishing. 288 pages, 59.39 CAD, Paper.

The Evolutionary Biology of Species. Oxford Series in Ecology and Evolution. By Timothy G. Barraclough. 2019. Oxford University Press. 288 pages, 90.00 CAD, Cloth, 45.95 CAD, Paper. Also available as an E-book.

Field and Laboratory Methods in Animal Cognition: A Comparative Guide. Edited by Nereida Bueno-Guerra and Federica Amici. 2018. Cambridge University Press. 456 pages, 137.95 CAD, Cloth, 62.95 CAD, Paper, 44.00 USD, E-book.

Fundamentals of Microbiome Science: How Microbes Shape Animal Biology. By Angela E. Douglas. 2018. Princeton University Press. 248 pages, 39.50 USD, Cloth. Also available as an E-book.

Mate Choice: The Evolution of Sexual Decision Making from Microbes to Humans. By Gil G. Rosenthal. 2017. Princeton University Press. 648 pages, 55.00 USD, Cloth. Also available as an E-book.

Quantitative Biology: Theory, Computational Methods, and Models. Edited by Brian Munsky, William S. Hlavacek, and Lev S. Tsimring. 2018. MIT Press. 728 pages, 70.00 USD, Cloth.

Social Evolution and Inclusive Fitness Theory: An Introduction. James A.R. Marshall. 2019. Princeton University Press. 216 pages, 27.95 USD, Paper. Cloth and E-book editions published in 2015.

BOTANY

Applied Tree Biology. By Andrew D. Hirons and Peter A. Thomas. 2018. Wiley Blackwell. 432 pages, 62.00 CAD, Paper, 49.99 CAD, E-book.

The Great Fen: A Journey Through Time. By Alan Bowley. Illustrated by Oliver Bowley. Foreword by Tony Juniper. 2019. Nature Bureau Pisces Publications. 194 pages, 27.50 GBP, Cloth.

The Nature of Plants: An Introduction to How Plants Work. By Craig N. Huegel. 2019. University Press of Florida. 288 pages, 24.95 USD, Paper.

The Sphagnum Species of the World. Bibliotheca Botanica Series, Volume 162. By Dierk Michaelis. 2019. Schweizerbart Science Publishers. 435 pages and 219 plates, 159.00 EUR, Cloth.

Sprout Lands: Tending the Everlasting Gift of Trees. By William Bryant Logan. 2019. W.W. Norton. 384 pages, 27.95, Cloth, 17.95 USD, Paper.

Trees of Life. By Max Adams. 2019. Apollo. 256 pages, 9.99 GBP, Paper.

Witness Tree: Seasons of Change with a Century-Old Oak. By Lynda V. Mapes. 2017. Bloomsbury USA. 240 pages, 27.00 USD, Cloth, 18.90 USD, E-book.

CLIMATE CHANGE

Biodiversity and Climate Change: Transforming the Biosphere. Edited by Thomas E. Lovejoy and Lee Hannah. Foreword by Edward O. Wilson. 2019. Yale University Press. 416 pages, 40.00 USD, Paper.

Floating Coast: An Environmental History of the Bering Strait. By Bathsheba Demuth. 2019. W.W. Norton. 416 pages, 27.95 USD, Cloth, 17.95 USD, Paper.

Invasive Species and Global Climate Change. Edited by Lewis Ziska and Jeffery Dukes. 2019. CABI. 366 pages, 70.00, Paper. Cloth edition published in 2014.

Living in the Anthropocene: Earth in the Age of Humans. Edited by W. John Kress and Jeffrey K. Stine. Foreword by Elizabeth Kolbert. Afterword by Edward O. Wilson. 2017. Smithsonian Books in association with Smithsonian Institution Scholarly Press. 208 pages, 34.95 USD, Cloth.

Losing Earth: A Recent History. By Nathaniel Rich. 2019. Farrar, Strauss and Giroux. 224 pages, 25.00 USD, Cloth, 16.00 USD, Paper.

Structures of Coastal Resilience. By Catherine Seavitt Nordenson, Guy Nordenson, and Julia Chapman. 2018. Island Press. 248 pages, 80.00 USD, Cloth, 45.00 USD, Paper or E-book.

When The Seas Rise: Global Changes and Local Impacts. By Heather Dewar. 2016. University Press of Florida. 120 pages, 14.95 USD, Paper.

CONSERVATION & ECOLOGY

Abundant Earth: Toward an Ecological Civilization. By Eileen Crist. 2020. University of Chicago Press. 288 pages, 105.00 USD, Cloth, 35.00 USD, Paper. Also available as an E-book.

Climate Change Impacts on Urban Pests. CABI Climate Change Series 10. Edited by Partho Dhang. 2017. CABI. 200 pages, 132.80 USD, Cloth.

Community-Based Control of Invasive Species. Edited by Paul Martin, Theodore R. Alter, Donald W. Hine, and Tanya M. Howard. 2019. CABI. 288 pages, 105.00 USD, Cloth.

Complex Ecology: Foundational Perspectives on Dynamic Approaches to Ecology and Conservation. Edited by Charles G. Curtin and Timothy F.H. Allen. 2018. Cambridge University Press. 594 pages, 140.00 USD, Cloth, 54.99 USD, Paper.

Conservation Biology. By Bradley Cardinale, Richard Primack, and James Murdoch. 2019. Sinauer Associates, an imprint of Oxford University Press. 672 pages, 114.95 CAD, Cloth. Also available as an E-book.

Ecological Effects of Electricity Generation, Storage and Use. By Peter Henderson. 2018. CABI. 240 pages, 45.00 USD, Paper.

Ecoviews Too: Ecology for All Seasons. By Whit Gibbons and Anne R. Gibbons. 2017. University of Alabama Press. 224 pages, 24.95 USD, Paper or E-book.

Evolutionary Community Ecology. **Monographs in Population Biology, Volume 58**. By Mark A. McPeek. 2017. Princeton University Press. 324 pages, 60.00 USD, Cloth.

The Fall of the Wild: Extinction, De-Extinction, and the Ethics of Conservation. By Ben A. Minteer. 2018. Columbia University Press. 192 pages, 28.00 USD, Cloth, 27.99 USD, E-book.

Forests Adrift: Currents Shaping the Future of Northeastern Trees. By Charles D. Canham. 2020. Yale University Press. 240 pages, 28.00 USD, Paper.

Marine Conservation. By P. Keith Probert. 2017. Cambridge University Press. 517 pages, 99.99 USD, Cloth, 54.99 USD, Paper.

Open Ecosystems: Ecology and Evolution Beyond the Forest Edge. By William J. Bond. 2019. Oxford University Press. 192 pages. 75.00 CAD, Cloth. Also available as an E-book.

The Rights of Nature: A Legal Revolution That Could Save the World. By David R. Boyd. 2017. ECW Press. 312 pages, 12.95 CAD, Paper, 14.99 CAD, E-book.

ENTOMOLOGY

Bees of Australia: A Photographic Exploration. By James Dorey. 2018. CSIRO Publishing. 222 pages, 49.99 AUD, Paper.

Courtship and Mating in Butterflies. By R.J. Cannon. 2020. CABI. 384 pages and 242 colour photographs, 160.00 USD, Cloth.

The Dark Side of the Hive: The Evolution of the Imperfect Honey Bee. By Robin Moritz and Robin Crewe. 2018. Oxford University Press. 203 pages, 80.00 CAD, Cloth. Also available as an E-book.

The Discovery of a Visual System—The Honeybee. By Adrian Horridge. 2019. CABI. 296 pages, 120.00 USD, Cloth.

Dragonflies & Damselflies: A Natural History. By Dennis Paulson. 2019. Princeton University Press. 224 pages, 29.95 USD, Paper.

The Economics of Integrated Pest Management of Insects. Edited by David W. Onstad and Philip Crain. 2019. CABI. 232 pages, 120.00 USD, Cloth.

Forest Insect Population Dynamics, Outbreaks, and Global Warming Effects. By A.S. Isaev, V.G. Soukhovolsky, O.V. Tarasova, E.N. Palnikova, and A.V. Kovalev. 2017. Wiley and Scrivener Publishing. 304 pages, 281.00 CAD, Cloth.

Insects and Society. By Timothy D. Schowalter. 2019. CRC Press. 306 pages and 157 colour illustrations, 87.99 GBP, Cloth, 43.99 GBP, Paper. Also available as an E-book.

Insect Behavior: From Mechanisms to Ecological and Evolutionary Consequences. Edited by Alex Córdoba-Aguilar, Daniel González-Tokman, and Isaac González-Santoyo. 2018. Oxford University Press. 404 pages, 100.00 USD, Cloth, 49.95 USD, Paper.

Insect Collection and Identification: Techniques for the Field and Laboratory. By T.J. Gibb and C. Oseto. 2019. Academic Press. 342 pages, 76.95 GBP, Paper.

Insect Conservation: A Global Synthesis. By Michael J. Samways. 2019. CABI. 600 pages, 205.00 USD, Cloth, 90.00 USD, Paper.

Insects Did It First. By Gregory S. Paulson and Eric R. Eaton. 2018. Xlibris Corporation. 156 pages, 29.99 USD, Cloth, 19.99 USD, Paper, 3.99 USD, E-book.

Insect Mouthparts: Form, Function, Development and Performance. Edited by Harald W. Krenn. 2019. Springer Nature. 695 pages, 159.99 USD, Cloth, 119.99 USD, E-book.

Life Cycles of British & Irish Butterflies. By Peter Eeles. Foreword by Chris Packham. 2019. NatureBureau. 400 pages and 1300 colour photos and maps, 35.00 GBP, Cloth.

True Bugs of the World (Hemiptera: Heteroptera): Classification and Natural History. Monograph Series Volume 8. By Randall T. Schuh and Christine Weirauch. 2020. Siri Scientific Press. 800 pages, 129.99 GBP, Cloth.

Stingless Bees of Mexico: The Biology, Management and Conservation of an Ancient Heritage. By José Javier G. Quezada-Euán. 2018. Springer International Publishing. 304 pages, 169.99 USD, Cloth, 159.99 USD, Paper, 119.00 USD, E-book.

Urban Landscape Entomology. By David Held. 2019. Academic Press. 224 pages, 79.96 USD, Paper or E-book.

Wasp. By Richard Jones. 2019. Reaktion Books. 208 pages and 114 illustrations, 12.95 GBP, Paper.

HERPETOLOGY

Fossil Frogs and Toads of North America. **Life of the Past**. By J. Alan Holman. 2018. University of Indiana Press. 261 pages, 30.00 USD, Paper. Originally published in 2013.

Salamanders: Habitat, Behavior and Evolution. Edited by Rashid Gerasimov. 2019. Nova Science Publishers. 154 pages, 82.00 USD, Paper.

ICHTHYOLOGY

Age and Growth of Fishes: Principles and Techniques. Edited by Michael C. Quist and Daniel A. Isermann. 2017. American Fisheries Society. 359 pages, 79.00 USD, Cloth.

The Behavior and Ecology of Pacific Salmon and Trout. Second Edition. By Thomas P. Quinn. 2018. University of Washington Press in association with the American Fisheries Society. 554 pages, 60.00 USD, Paper.

From Catastrophe to Recovery: Stories of Fishery Management Success. Edited by Charles C. Krueger, William W. Taylor, and So-Jung Youn. 2019. American Fisheries Society. 530 pages, 79.00 USD, Paper.

Fishes of the Salish Sea. **Volume One: Puget Sound and the Straits of Georgia and Juan de Fuca**. By Theodore Pietsch and James Wilder Orr. Illustrated by Joseph R. Tomelleri. 2019. Heritage House. 1032 pages, 179.00 CAD, Cloth.

Managing Centrarchid Fisheries in Rivers and Streams. Edited by Michael J. Siepker and Jeffrey W. Quinn. 2019. American Fisheries Society. 270 pages, 79.00 USD, Paper.

The Ocean Ecology of Pacific Salmon and Trout. Edited by Richard J. Beamish. 2018. American Fisheries Society. 1090 pages, 98.00 USD, Cloth.

Paddlefish: Ecological, Aquacultural, and Regulatory Challenges of Managing a Global Resource. Edited by Jason D. Schooley and Dennis L. Scarnecchia. 2019. American Fisheries Society. 290 pages, 79.00 USD, Paper.

Trout and Char of the World. Edited by Jeffrey L. Kershner, Jack E. Williams, Robert E. Gresswell, and Javier Lobón-Cerviá. 2019. American Fisheries Society. 800 pages, 79.00 USD, Paper.

ORNITHOLOGY

Kingfisher. By Ildiko Szabo. 2019. Reaktion Books. 208 pages and 90 colour plates, 19.95 USD, Paper.

Owls of the World: A Photographic Guide. **Second Edition**. By Heimo Mikkola. 2019. Firefly Books. 528 pages, 49.95 CAD, Flexibound Cloth, 44.95 CAD, Flexibound Paper.

Red Coats and Wild Birds: How Military Ornithologists and Migrant Birds Shaped Empire. Flows, Migrations, and Exchanges Series. By Kirsten A. Greer. 2020. University of North Carolina Press. 190 pages, 90.00 USD, Cloth, 29.95 USD, Paper, 22.99 USD, E-book.

A Season on the Wind: Inside the World of Spring Migration. By Kenn Kaufman. 2019. Houghton

Mifflin Harcourt. 288 pages, 26.00 USD, Cloth, 14.99 USD, E-book.

White Feathers: The Nesting Lives of Tree Swallows. 2020. By Bernd Heinrich. Houghton Mifflin Harcourt. 256 pages, 27.00 USD, Cloth.

ZOOLOGY

Bat Surveys for Professional Ecologists: Good Practice Guidelines. Third Edition. Edited by Jan Collins. Foreword by Julia Hanmer and Kit Stoner. 2016. Bat Conservation Trust. 103 pages, Paper. Non-printable PDF available at https://cdn.bats.org.uk/pdf/Resources/Bat_Survey_Guidelines_2016_NON_PRINTABLE.pdf?mtime=20181115113931.

Black Bears: A Natural History. Second Edition. By Dave Taylor. 2020. Fitzhenry and Whiteside. 288 pages, 40.00 USD, Paper.

Biodemography: An Introduction to Concepts and Methods. By James R. Carey and Deborah A. Roach. Foreword by James W. Vaupel. 2020. PUP. 480 pages, 60.00 USD, Cloth.

Biology and Conservation of Musteloids. Edited by David W. Macdonald, Chris Newman, and Lauren A. Harrington. 2018. Oxford University Press. 672 pages, 137.50 CAD, Cloth, 115.95 CAD, Paper.

The Champions of Camouflage. By Jean-Philippe Noël. 2019. Firefly Books. 160 pages and 110 colour photographs, 35.00 CAD, Cloth.

Extinction and Evolution: What Fossils Reveal about the History of Life. By Niles Eldredge. 2019. Firefly Books. 256 pages and 160 colour plates, 29.95 CAD, Paper. Originally published in 2014.

Guide to Venomous and Medically Important Invertebrates. By David E. Bowles, James A. Swaby, and Harold J. Harlan. 2018. CSIRO Publishing. 237 pages, 59.99 AUD, Paper.

Handbook of Whales, Dolphins and Porpoises of the World. By Mark Carwardine. 2020. Princeton University Press. 528 pages, 1000 colour illustrations, and 90 maps, 35.00 CAD, Paper.

Narwhal: Revealing an Arctic Legend. Edited by William W. Fitzhugh and Martin T. Nweeia. 2017. IPI Press and Arctic Studies Center, National Museum of Natural History (Smithsonian Institution). 261 pages, 30.00 USD, Paper. This book is the companion to the exhibit "Narwhal: Revealing an Arctic Legend" at the Smithsonian Institution's National Museum of Natural History.

***Voices of Marine Mammals: William E. Schevill and William A. Watkins: Pioneers in Bioacoustics**. 2019. New Bedford Whaling Museum. 125 pages and flexi-disc insert of audio recordings, 29.99 USD, Paper.

OTHER

All Things Harmless, Useful, and Ornamental: Environmental Transformation through Species Acclimatization, from Colonial Australia to the World. By Pete Minard. 2019. University of North Carolina Press. 208 pages, 90.00 USD, Cloth, 32.95 USD, Paper, 25.99 USD, E-book.

Animal Welfare in a Changing World. Edited by Andrew Butterworth. 2018. CABI. 320 pages, 140.00 USD, Cloth, 75.00 USD, Paper.

Being a Scientist: Tools for Science Students. By Michael H. Schmidt. 2019. University of Toronto Press. 320 pages, 63.75 CAD, Cloth, 36.95 CAD, Paper, 26.95 CAD, E-book.

That Wild Country: An Epic Journey through the Past, Present, and Future of America's Public Lands. By Mark Kenyon. 2019. Little A [Amazon Publishing imprint]. 300 pages, 31.12 CAD, Cloth, 14.42 CAD, Paper.

Extinction Studies: Stories of Time, Death, and Generations. Edited by Deborah Bird Rose, Thom van Dooren, and Matthew Chrulew. Foreword by Cary Wolfe. 2017. Columbia University Press. 256 pages, 90.00 USD, Cloth, 30.00 USD, Paper or E-book.

The Fruitful City: The Enduring Power of the Urban Food Forest. By Helena Moncrieff. 2018. ECW Press. 224 pages, 22.95 CAD, Paper, 16.99 CAD, E-book.

Geology of New Brunswick and Prince Edward Island Field Guide. 2019. Boulder Books. 300 pages, 34.95 CAD, Paper.

Modern Plant Hunters: Adventures in Pursuit of Extraordinary Plants. By Sandy Primrose. 2020. Pimpernel Press. 272 pages, 30.00 GBP, Cloth.

North America's Galapagos: The Historic Channel Islands Biological Survey. By Corinne Heyning Laverty. 2019. University of Utah Press. 384 pages, 29.95 USD, Paper, 24.00 USD, E-book.

Overrun: Dispatches from the Asian Carp Crisis. By Andrew Reeves. 2019. ECW Press. 384 pages, 22.95 CAD, Paper, 16.99 CAD, E-book.

Phylogenetic Diversity: Applications and Challenges in Biodiversity Science. Edited by Rosa A.

Scherson and Daniel P. Faith. 2018. Springer International Publishing. 224 pages, 159.99 USD, Cloth or Paper, 119.00 USD, E-book.

Sampling Theory for the Ecological and Natural Resource Sciences. By David G. Hankin, Michael S. Mohr, and Kenneth B. Newman. 2019. Oxford University Press. 368 pages, 105.00 CAD, Cloth, 55.00 CAD, Paper. Also available as an E-book.

Smitten by Giraffe: My Life as a Citizen Scientist. **Footprints Series, No. 22**. By Anne Innis Dagg. 2016. McGill-Queen's University Press. 256 pages, 34.95 CAD, Cloth. Also available as an E-book.

Swamp: Nature and Culture. By Anthony Wilson. 2017. Reaktion Books. 248 pages, 14.95 GBP, Paper.

Synergistic Selection: How Cooperation Has Shaped Evolution and the Rise of Humankind. By Peter Corning. 2018. World Scientific. 304 pages, 78.00 USD, Cloth, 29.95 USD, Paper, 19.95 USD, E-book.

The Theory of Evolution: Principles, Concepts, and Assumptions. Edited by Samuel M. Scheiner and David P. Mindell. 2020. UCP. 464 pages, 120.00 USD, Cloth, 45.00 USD, Paper. Also available as an E-book.

Why Study Biology by the Sea? Edited by Karl S. Matlin, Jane Maienschein, and Rachel A. Ankeny. 2019. University of Chicago Press. 344 pages, 135.00 USD, Cloth, 45.00 USD, Paper or E-book.

The Canadian Field-Naturalist

News and Comment

Upcoming Meetings and Workshops

Alberta Chapter of The Wildlife Society Conference

The Alberta Chapter of The Wildlife Society Conference to be held 13–15 March 2020 at The Norsemen Inn, Camrose, Alberta. The theme of the conference is: 'Species on the Move'. Registration is currently open. More information is available at https://www.actws.ca/conference/.

Entomological Society of America, Joint North Central & Southwestern Branch Meeting

The 2020 Joint North Central & Southwestern Branch Meeting of the Entomological Society of America to be held 15–18 March 2020 at The Skirvin Hilton Oklahoma City, Oklahoma City, Oklahoma. Registration is currently open. More information is available at https://www.entsoc.org/2020-joint-northcentral-southwestern-branch-meeting.

Eastern Bird Banding Association Meeting

The 97th meeting of the Eastern Bird Banding Association to be held 27–29 March 2020 at the Hilton Garden Inn Mystic/Groton, Groton, Connecticut. The theme of the conference is: 'Using Bird Science to Inform Conservation'. Registration is currently open. More information is available at https://ebba2020.org/.

Entomological Society of America, 2020 Joint Eastern & Southeastern Branch Meeting

The 2020 Joint Eastern & Southeastern Branch Meeting of the Entomological Society of America to be held 29 March–1 April 2020 at the Sheraton Atlanta Hotel, Atlanta, Georgia. Registration is currently open. More information is available at https://www.entsoc.org/2020-joint-eastern-southeastern-branch-meeting.

American Fisheries Society, Western Division and Washington-British Columbia Chapters Annual Meeting

The annual meeting of the Western Division and Washington-British Columbia Chapters of the American Fisheries Society to be held 13–17 April 2020 at the Pinnacle Harbourfront Hotel, Vancouver, British Columbia. The theme of the conference is: 'Crossing Boundaries and Navigating Intersections'. Registration is currently open. More information is available at https://wa-bc.fisheries.org/2020-meeting/.

Northeast Natural History Conference

The 20th Northeast Natural History Conference to be held 17–19 April 2020 at the Hilton Stamford Hotel, Stamford, Connecticut. Registration is currently open. More information is available at https://www.eaglehill.us/NENHC_2020/NENHC2020.shtml.

Northeast Fish & Wildlife Conference

The 76th annual Northeast Fish & Wildlife Conference, hosted by the New Jersey Division of Fish and Wildlife, to be held 19–21 April 2020 at the Ocean Place Resort, Long Branch, New Jersey. The theme of the conference is: 'The Power of Partnerships'. Registration is currently open. More information is available at http://www.neafwa.org/conference.html.

Biodiversity Without Boundaries 2020 (NatureServe)

Biodiversity Without Boundaries 2020 to be held 19–22 April 2020 at the Richmond Marriott, Richmond, Virginia. Registration is currently open. More information is available at https://www.natureserve.org/news-events/events/biodiversity-without-boundaries-2020.

Entomological Society of America, Pacific Branch Meeting

The 104th annual meeting of the Pacific Branch of the Entomological Society of America to be held 19–22 April 2020 at The Centennial Hotel, Spokane, Washington. Registration is currently open. More information is available at https://www.entsoc.org/pacific/2020-branch-meeting.

Wild *Canis* spp. of North America: a pictorial representation

There has been considerable discussion of hybridization in the genus *Canis* in North America with the general consensus that the western Coyote (*Canis latrans*), Eastern Timber Wolf (*Canis lycaon*), and Gray Wolf (*Canis lupus*) hybridized to produce the Eastern Coyote/Coywolf (*Canis latrans* var. or *Canis latrans* × *lycaon*) and Great Lakes Wolf (*Canis lupus* × *lycaon*) in eastern North America (Rutledge *et al.* 2012, 2015; Way 2013; Way and Lynn 2016; Heppenheimer *et al.* 2018). Way (2013) described the five types of wild canids (*Canis* spp.; foxes excluded) in North America and noted that these canid groups were useful even with the few studies that claim that the Eastern Timber Wolf is not a distinct species but rather a hybrid between western Coyotes and Gray Wolves (von Holdt *et al.* 2011, 2016), despite the lack of field evidence that these two species mate and produce viable offspring (e.g., see Mech *et al.* 2014).

A comprehensive review of the taxonomy of wolves in North America supports the Eastern Timber Wolf as a distinct taxon (Chambers *et al.* 2012) as has most of the research on canids in eastern North America (see references in Rutledge *et al.* 2015, but see vonHoldt 2011 countering this). With this "*Canis* soup" of different, but closely related, species (there is gene flow from *C. lycaon* to *C. lupus* and from *C. lycaon* to *C. latrans* [Way 2013; Heppenheimer *et al.* 2018]), distinct species status for any canid complicates conservation efforts (including *C. lupus* in eastern North America). Furthermore, the degree of hybridization and terminology associated with these hybrids can be confusing for the layperson, for example, Way and Lynn's (2016) use of the term Coywolf versus Wheeldon and Patterson's (2017) use of the term Eastern Coyote.

Accordingly, we created a pictorial representation of *Canis* spp. in North America showing the six main types of canids: western Coyotes, Eastern Coyotes/Coywolves, Red Wolves, Eastern Timber Wolves, Great Lakes Wolves, and Gray Wolves (Figure 1). Because of the frequent separation of Red Wolf (*Canis rufus*), Eastern Timber Wolf, and Gray Wolf in analyses (e.g., von Holdt *et al.* 2011; Chambers *et al.* 2012) we show these canids separately even though others believe Red Wolf and Eastern Timber Wolf are the same species at opposite ends of their range (Wilson *et al.* 2000). This drawing represents average body sizes of one canid compared to another; however, it is important to realize the limitations of these average depictions. Even within a given type, males and females differ in size and there is considerable variation—where the size of one might be similar or even larger than the one adjacent. They may be difficult to tell apart in the field, not only from a distance, but even when captured, especially where their ranges overlap (e.g., in and around Algonquin Provincial Park, Ontario). This is further exemplified by Newsome *et al.* (2015) noting that even larger western Gray Wolves and smaller western Coyotes (which share no size overlap; Figure 1) are often difficult to tell apart from a distance and someone 'shooting a coyote can sometimes result in a dead wolf'. Natural expansion or recolonization of a range is a confounding factor (e.g., Eastern Timber Wolves or Great Lakes Wolves dispersing into southern Canada and the northeastern USA are just claimed to be

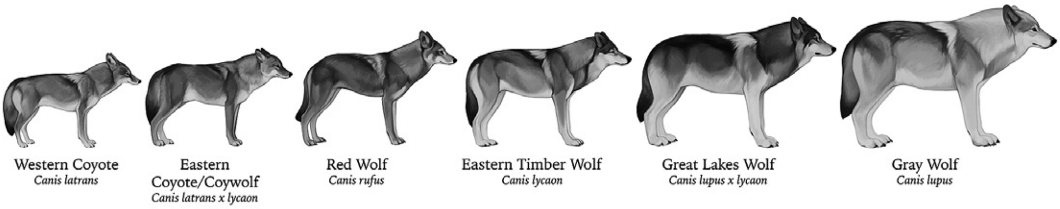


FIGURE 1. Wild *Canis* of North America. These drawings are intended to represent average body sizes of one canid compared to another. But within a given type, males and females differ in size and there is considerable variation such that the size of one might be similar or even larger than the one adjacent making them difficult to tell apart in the field, especially where ranges overlap. Also, while Red and Eastern Timber Wolf are considered separate here, many studies have indicated that they are possibly the same species (*Canis lycaon*) living on opposite ends of their eastern North American range. Drawings: J.L. Hirten.

heavy Eastern Coyotes). Often genetic testing is the only way to differentiate among *Canis* spp. in eastern North America (Rutledge *et al.* 2012).

Recent research acknowledges the importance of hybridization among closely related species and in the case of eastern wolves there is a need for managed introgression that focusses on preserving any eastern wolf genetic material in any genome regardless of their potential mosaic ancestry composition (Heppenheimer *et al.* 2018). If such an effort prioritizes and maintains individuals that carry admixed genomes, as Heppenheimer *et al.* (2018) suggest, then more common animals like the Eastern Coyote would be an important source of greater genetic variation and potential adaptive capacity. It is our hope that this diagram (Figure 1) is a useful guide to show the variation and types of *Canis* spp. in North America with a specific focus in eastern North America.

Literature Cited

Chambers, S.M., S.R. Fain, B. Fazio, and M. Amaral. 2012. An account of the taxonomy of North American wolves from morphological and genetic analyses. North American Fauna 77: 1–67. https://doi.org/10.3996/nafa.77.0001

Heppenheimer, E., R.J. Harrigan, L.Y. Rutledge, K.-P. Koepfli, A.L. DeCandia, K.E. Brzeski, J.F. Benson, T. Wheeldon, B.R. Patterson, R. Kays, P.A. Hohenlohe, and B.M. von Holdt. 2018. Population genomic analysis of North American eastern wolves (*Canis lycaon*) supports their conservation priority status. Genes 9: 606: 1–18. https://doi.org/10.3390/genes9120606

Mech, L.D., B.W. Christensen, C.S. Asa, M. Callahan, and J.K. Young. 2014. Production of hybrids between western gray wolves and western coyote. PLoS ONE 9(2): e88861. https://doi.org/10.1371/journal.pone.0088861

Newsome, T.M., J.T. Bruskotter, and W.J. Ripple. 2015. When shooting a coyote kills a wolf: mistaken identity or misguided management? Biodiversity and Conservation 24: 3145–3149.

Rutledge, L.Y., S. Devillard, J.Q. Boone, P.A. Hohenlohe, and B.N. White. 2015. RAD sequencing and genomic simulations resolve hybrid origins within North American *Canis*. Biology Letters 11: 20150303. https://doi.org/10.1098/rsbl.2015.0303

Rutledge, L.Y., P.J. Wilson, C.F.C. Klutsch, B.R. Patterson, and B.N. White. 2012. Conservation genomics in perspective: a holistic approach to understanding *Canis* evolution in North America. Biological Conservation 155: 186–192. https://doi.org/10.1016/j.biocon.2012.05.017

von Holdt, B.M., J.A. Cahill, Z. Fan, I. Gronau, J. Robinson, J.P. Pollinger, B. Shapiro, B.J. Wall, and R.K. Wayne. 2016. Whole-genome sequence analysis shows that two endemic species of North American wolf are admixtures of the coyote and gray wolf. Science Advances 2: e1501714. https://doi.org/10.1126/sciadv.1501714

von Holdt, B.M., J.P. Pollinger, D.A. Earl, J.C. Knowles, A.R. Boyko, H. Parker, E. Geffen, M. Pilot, W. Jedrzejewski, B. Jedrzejewska, V. Sidorovich, C. Greco, E. Randi, M. Musiani, R. Kays, C.D. Bustamante, E.A. Ostrander, J. Novembre, and R.K. Wayne. 2011. A genome-wide perspective on the evolutionary history of enigmatic wolf-like canids. Genome Research 21: 1294–1305. https://doi.org/10.1101/gr.1163 01.110

Way, J.G. 2013. Taxonomic implications of morphological and genetic differences in Northeastern Coyotes (Coywolves) (*Canis latrans* × *C. lycaon*), Western Coyotes (*C. latrans*), and Eastern Wolves (*C. lycaon* or *C. lupus lycaon*). Canadian Field-Naturalist 127: 1–16. https://doi.org/10.22621/cfn.v127i1.1400

Way, J.G., and W.S. Lynn. 2016. Northeastern coyote/coywolf taxonomy and admixture: a meta-analysis. Canid Biology and Conservation 19: 1–7. Accessed 11 October 2019. http://canids.org/CBC/19/Northeastern_coyote_taxonomy.pdf.

Wheeldon, T.J., and B.R. Patterson. 2017. Comment on "northeastern coyote/coywolf taxonomy". Canid Biology and Conservation 20: 14–15. Accessed 11 October 2019. https://canids.org/CBC/20/Comment%20_on_Way_and_Lynn_2016.pdf.

Wilson, P.J., S. Grewal, I.D. Lawford, J.N.M. Heal, A.G. Granacki, D. Pennock, J.B. Theberge, M.T. Theberge, D.R. Voigt, W. Waddell, R.E. Chambers, P.C. Paquet, G. Goulet, D. Cluff, and B.N. White. 2000. DNA profiles of the eastern Canadian wolf and the red wolf provide evidence for a common evolutionary history independent of the gray wolf. Canadian Journal of Zoology 78: 2156–2166. https://doi.org/10.1139/z00-158

JONATHAN G. WAY
Eastern Coyote Research, Osterville, MA, USA

JUSTINE LEE HIRTEN
Fairfield, CT, USA

In Memoriam: Francis Cook (3 March 1935–3 January 2020)

Francis Cook was the longest serving editor of *The Canadian Field-Naturalist*. He was editor of the journal for 34 years, from 1962 to 1966 and from 1981 to 2010. In total, Francis edited 35 volumes of *The Canadian Field-Naturalist*. He helped hundreds of researchers publish their work in the journal.

In addition to his work on *The Canadian Field-Naturalist,* Francis Cook was the Curator of Herpetology at what is now the Canadian Museum of Nature from 1960 to 1993, aside from a two-year educational leave to work on a Ph.D. at the University of Manitoba. Francis had a passion for herpetofauna that lasted a lifetime. He spent decades gathering data on the natural history of local amphibians near his home.

In 2018, Francis was awarded the Order of Canada for his research on amphibians and reptiles and for being the long-time editor of *The Canadian Field-Naturalist*. He was also honoured by the Ottawa Field-Naturalists' Club. He was selected as Member of Year in 1990 and 2010 for his efforts editing *The Canadian Field-Naturalist*, and he was made an Honorary Member of the Club in 1998 "For service to the Club and herpetological work". Francis's exceptional contributions to our understanding of the natural history of amphibians and reptiles (detailed in Halliday and Seburn 2018; Seburn and Halliday 2018) were honoured in special issues (volume 132, issues 1 and 2) of *The Canadian Field-Naturalist*, with the content of those issues dedicated to studies on Canadian amphibians and reptiles.

Francis Cook died in Kemptville on 3 January 2020. Memorial donations may be made to *The Canadian Field-Naturalist* if desired; you may direct an e-transfer to treasurer@ofnc.ca with a note "Re: The Canadian Field Naturalist in Memory of Francis Cook".

Literature Cited

Halliday, W.D., and D.C. Seburn. 2018. Introduction to the Special Issue on herpetology in Canada. Canadian Field-Naturalist 132: 1–3. https://doi.org/10.22621/cfn.v132i1.2113

Seburn, D.C., and W.D. Halliday. 2018. The publications of Francis Cook. Canadian Field-Naturalist 132: 99–102. https://doi.org/10.22621/cfn.v132i2.2169

OFNC PUBLICATIONS COMMITTEE

The Canadian Field-Naturalist

Editors' Report for Volume 132 (2018)

Mailing dates for the four issues in volume 132 were: 24 October 2018, 31 January 2019, 2 May 2019, and 31 July 2019. Summaries of the distribution of paid subscribers to *The Canadian Field-Naturalist* for 2018 are provided in Table 1, along with comparison numbers for volume 131. This list does not include free copies distributed to Honorary Ottawa Field Naturalists' Club (OFNC) members or online access, which is included in OFNC membership dues. Institutional subscribers potentially represent many thousands of users. The number of articles published in volume 132 increased by 10 over the number published in volume 131 while the number of notes decreased by 10, with the same number of manuscripts published both years (Table 2). Not surprisingly, 25/45 (56%) of the manuscripts in 132 were on amphibians and reptiles, given the first two issues of 132 were Special Issues: studies on Canadian amphibians and reptiles in honour of Dr. Francis Cook. The three manuscripts in the "other" category were on alvars, Arctic slumps, and fungi (Table 2). The number of book reviews and new titles published in volume 132 were slightly up and down, respectively, over the numbers in volume 131 (Table 3). The total number of pages published increased by 36 for volume 132 over volume 131 (Table 4) with articles contributing 69% to the page count and 76% of manuscripts published (Table 2). There were no thematic collections (editor-selected compilations of previously published contributions in both *The Canadian Field-Naturalist* and the regional OFNC publication, *Trail & Landscape*, on a central theme with internet links to each article) nor articles on Greatest Canadian Field Naturalists, the latter of which were included in News and Comment in 131.

Table 2. Number of research articles and notes published in *The Canadian Field-Naturalist*, Volume 132 (Volume 131), by major field of study.

Subject	Articles	Notes	Total
Mammals	3 (3)	0 (8)	3 (11)
Birds	3 (10)	2 (6)	5 (16)
Amphibians and Reptiles	19 (3)	6 (2)	25 (5)
Fishes	0 (1)	1 (2)	1 (3)
Plants	4 (3)	1 (2)	5 (5)
Insects	1 (1)	0 (0)	1 (1)
Non-insect invertebrates	1 (2)	1 (1)	2 (3)
Other	3 (1)	0 (0)	3 (1)
Total	34 (24)	11 (21)	45 (45)

Table 3. Number of reviews and new titles published in the Book Review section of *The Canadian Field-Naturalist*, Volume 132 (Volume 131), by topic.

	Reviews	New Titles
Zoology	26 (15)	148 (155)
Botany	7 (7)	24 (43)
Miscellaneous	9 (18)	122 (111)
Total	42 (40)	294 (309)

Table 1. The 2018 (2017) circulation of *The Canadian Field-Naturalist*. Compiled by Eleanor Zurbrigg from the subscription list for 132(4). This list does not include copies distributed to Honorary Members or online access which is included in OFNC membership fees.

Subscriber Type	Canada		USA		Other		Total	
OFNC Members	43	(51)	1	(4)	0	(0)	44	(55)
Subscriptions:								
Individual	26	(26)	7	(7)	0	(0)	33	(33)
Institutional	66	(73)	90	(106)	12	(12)	168	(191)
Total	135	(150)	98	(117)	12	(12)	245	(279)

Sixty-five manuscripts were submitted to *The Canadian Field-Naturalist* in 2018, eight more than in 2017; there were also two initial enquiries about suitability of topics for submission, one of which submitted formally in 2019. All except one manuscript was submitted using the Online Journal System, some (n = 9) after an initial email submission. Thirteen of the 65 were for the Special Issues on Canadian amphibians and reptiles. Only 11 of the 65 submitted manuscripts were not accepted for publication upon initial submission or review or were insufficiently revised to warrant publication. The remainder, 83.1%, were accepted or are undergoing revision and review. In 2017,

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist*, volume 132 (131), by issue.

	Issue				Total
	1	2	3	4	
Editorials/Editors' Report*	3 (0)	4 (0)	3 (2)	0 (1)	10 (3)
Articles	51(67)	86 (47)	74 (47)	94 (42)	305 (203)
Notes	12 (7)	2 (17)	11 (30)	12 (27)	37 (81)
Thematic Collections	0 (5)	0 (8)	0 (0)	0 (0)	0 (13)
Tributes	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Book Reviews†	18 (14)	18 (15)	18 (15)	8 (13)	62 (57)
News and Comment	2 (2)	2 (1)	2 (6)	2 (12)	8 (21)
Reports‡	12 (19)	0 (0)	0 (0)	0 (0)	12 (19)
Erratum	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Index	– (–)	– (–)	– (–)	8 (9)	8 (9)
Total	98 (114)	112 (88)	108 (100)	124 (104)	442 (406)

*Includes introductions to Special Issue Parts I and II.
†Includes reviews and new titles.
‡Includes Annual Business Meeting Minutes, Annual Committee Reports, and Awards, including the James Fletcher Award for best paper published in the volume; Financial Statements are only available online beginning with 132.

89.5% of the 57 submissions were accepted for publication and either published or underwent further revision and review.

Guest Editors William Halliday and Dave Seburn received the manuscripts submitted for the Special Issues, assigned reviewers, handled the review process, and passed the accepted manuscripts to Dwayne Lepitzki, *Editor-in-Chief*, and Amanda Martin, the *Assistant Editor*, for the rest of the publication process. Amanda edited content, proofread galleys, and sent and received author order and transfer of copyright forms; she also prepared the News and Comment. Sandra Garland and John Wilmshurst proof-read and copy edited manuscripts. Wendy Cotie typeset galleys, provided corrections for page proofs, and created pdfs. Barry Cottam, *Book Review Editor*, requested books for review, selected reviewers, edited submitted reviews, and prepared the new titles listings. Ken Young sent page charge invoices to authors and tracked the budget while Eleanor Zurbrigg managing subscriptions and mailed printed copies. William Halliday, *Online Journal Manager* and *Webmaster*, provided digital content to subscribers, posted tables of contents, abstracts, and pdfs on *The Canadian Field-Naturalist* website, and prepared the Index. Our *Associate Editors* managed manuscripts, provided reviews and recommendations, and guided authors through the revisions process. Dave Seburn, our *Map Editor*, reviewed and provided suggestions for all the maps. The Publication Committee, chaired by Jeff Saarela and consisting of Annie Bélair, Dan Brunton, Carolyn Callaghan, Paul Catling, Barry Cottam, William Halliday, Diane Kitching, Dwayne Lepitzki, Amanda Martin, Karen McLachlan Hamilton, Dave Seburn, Ken Young, and Eleanor Zurbrigg effectively guided the operation of the journal. We are indebted to our very dedicated team.

The following *Associate Editors* managed, assessed, and reviewed manuscripts published in volume 132: R. Brooks, University of Guelph, emeritus, Guelph ON (2 manuscripts); P.M. Catling, Agriculture and Agri-Food Canada, retired, Ottawa ON (6); F. Chapleau, University of Ottawa, Ottawa ON (1); J. Foote, Algoma University, Sault St. Marie ON (4); W. Halliday, University of Victoria, Victoria BC (18); D. Lepitzki, Banff AB (1); D.F. McAlpine, New Brunswick Museum, Saint John NB (1); J. McCracken, Bird Studies Canada, Port Rowan ON (1); G. Mowat, Government of British Columbia, Nelson BC (1); D.W. Nagorsen, Mammalia Biological Consulting, Victoria BC (2); J.M. Saarela, Canadian Museum of Nature, Ottawa ON (1); D. Seburn, Canadian Wildlife Federation, Ottawa ON (6); J. Skevington, Agriculture and Agri-Food Canada, Ottawa ON (1).

As with many other journals, *Associate Editors* are at times having difficulty finding suitable reviewers; without dedicated *Associate Editors* and reviewers there would be no journal. As such, a heart-felt thanks and gratitude is extended to the following who reviewed manuscripts published in volume 132 (number of manuscripts reviewed >1 in parentheses): Carl Anthony, John Carroll University; Andréanne Beardsell, Université du Québec à Rimouski; Christine Bishop, Environment and Climate Change Canada; Sean Blaney, Atlantic Canada Conservation Data Centre (2); Ernie Brodo, Research Associate, Canadian Museum of Nature; Ron Brooks, University of Guelph (2); Dan Brunton, Brunton Consulting (2); Jacob Burkhart, University of Missouri; William Busby, Kansas Biological Survey; Rob Cannings, Royal British Columbia Museum; Pauline Catling, North-South Environmental Inc.; Tony Chubbs, Department of National Defence; Stephen Clayton, New Brunswick Museum; Justin Congdon, University of

Georgia; Joe Crowley, Ontario Ministry of Natural Resources and Forestry; David Cundall, Lehigh University; Christina Davy, Ontario Ministry of Natural Resources and Forestry; Kendra Driscoll, New Brunswick Museum; Marco Festa-Bianchet, University of Sherbrooke (2); Neil Ford, University of Texas at Tyler; Robert Forsyth, Kamloops BC; Roseanna Gamlen-Greene, University of British Columbia; Scott Gillingwater, Upper Thames River Conservation Authority (2); Peter Gogan, US Geological Survey; Patrick Gregory, University of Victoria (2); Gareth Griffith, Aberystwyth University; Samuel Hache, Environment and Climate Change Canada; Gavin Hanke, Royal British Columbia Museum; Allan Harris, Northern Bioscience Ecological Consulting; Virgil Hawkes, LGL Ltd.; Tim Haxton, Ontario Ministry of Natural Resources and Forestry (2); Stephen Hecnar, Lakehead University (2); Eric Hellquist, New York Botanical Garden; Tom Herman, Acadia University (2); Bob Inman, Montana Fish, Wildlife and Parks; Gregory Jongsma, New Brunswick Museum; Karl Larsen, Thompson Rivers University (2); Jackie Litzgus, Laurentian University; Eric Lofroth, BC Conservation Data Centre, retired; Teresa Lorenz, US Department of Agriculture Forest Service; Stephen MacFarlane, University of Toronto; John Maunder, The Rooms Provincial Museum; David McCorquondale, Cape Breton University; Liam McGuire, Texas Tech University; David Mifsud, Herpetological Resource Management; Joseph Mitchell, Florida Museum of Natural History; Steve Mockford, Acadia University; Patrick Moldowan, University of Toronto (2); Mason Murphy, Miami University; Jeff Nekola, University of New Mexico; Annegret Nicolai, Université de Rennes; Michael Oldham, Ontario Natural Heritage Information Centre (2); Martin Ouellet, Amphibia-Nature; Brittany Ousterhout, National Great Rivers Research and Education Center; Kristiina Ovaska, Biolinx Environmental Research Ltd.; Steve Paiero, University of Guelph; James Paterson, University of Ottawa (2); Cynthia Paszkowski, University of Alberta; Ray Poulin, Royal Saskatchewan Museum; George Powell, University of Calgary; Tanya Pulfer, Ontario Nature; Jennie Rausch, Environment and Climate Change Canada; Don Reid, Wildlife Conservation Society Canada; Scott Redhead, Agriculture and Agri-Food Canada; Matt Reudink, Thompson Rivers University; Anton Reznicek, University of Michigan; Tony Roberts, US Fish and Wildlife Service; Pamela Rutherford, Brandon University; Taza Schaming, Cornell University; Fred Schueler, Fragile Inheritance; Cory Sheffield, Royal Saskatchewan Museum; Brian Slough, Whitehorse YT; Brian Smith, Black Hills State University; Chris Somers, University of Regina; Duane Stevenson, National Oceanic Atmospheric and Administration, National Marine Fisheries Service; David Swanson, University of South Dakota; Carl Taylor, American Museum of Natural History.

The journal was printed at Gilmore Printers, Ottawa. Thanks to Guylaine Duval of Gilmore Printers for overseeing production and printing. We are grateful to The Ottawa Field-Naturalists' Club President Diane Lepage and the club's Board of Directors for their support of the journal. We are also grateful to all of the individual subscribers and authors who support our team as we strive to provide a high-quality scientific journal on natural history, field biology, and ecology. Finally, we thank our families/partners for being patient and supportive throughout many long days, evenings, and weekends of working on the journal.

DWAYNE LEPITZKI, *Editor-in-Chief*
AMANDA MARTIN, *Assistant Editor*

Tributes

Book Reviews

News and Comment

Mailing date of the previous issue 133(2): 5 December 2019

THE CANADIAN FIELD-NATURALIST **Volume 133, Number 3** **2019**

(continued inside back cover)

ISSN 0008-3550