

# The CANADIAN FIELD-NATURALIST

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Special Issue honouring Donald F. McAlpine:  
contributions to the natural history of the Canadian Maritimes



Ottawa Field-Naturalists' Club  
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COVER: Fruiting bodies of Wasp's Nest Slime Mould (*Metatrachia vesparia*), with clusters of shiny blue-black ~1.5 mm tall sporangia on orange stalks. Specimen collected by Eleni Hines, August 2017, Spednic Lake Protected Natural Area, New Brunswick. This species is widespread on rotting wood and bark in forests. The old sporangia resemble miniature paper wasp's nests. See Zoll *et al.* (pages 64–86). Photo (created with focus-stacking): Amanda Bremner and Gayathri Sreedharan.

# The Canadian Field-Naturalist

## Foreword to the Special Issue honouring Donald F. McAlpine: contributions to the natural history of the Canadian Maritimes

It is a great pleasure to dedicate this double Special Issue of *The Canadian Field-Naturalist* (CFN) to Dr. Donald F. McAlpine, Research Curator of Zoology and Head of the Department of Natural History at the New Brunswick Museum. Although New Brunswick encompasses <1% of the area of Canada and <2% of its population, Don has made outsize contributions to Maritime and Canadian natural history. He is a distinguished researcher, curator, and science communicator; an influential mentor of students and citizen scientists; and an organizer and leader of collaborative projects that have done much to further knowledge and conservation of biodiversity. He is also a longtime contributor to this journal. More than 40 of his research articles and notes have appeared in CFN since 1976, and he has served as an Associate Editor of the journal since 2003.

Don began hinting a few years ago at retirement. We hasten to add that it isn't our intention to nudge him in that direction (!), but to celebrate and honour his many contributions over a long and continuing career. The range of taxonomic groups and research methodologies represented in this issue attests in part to the unusual breadth of his interests and collaborations. Several of the papers originate partly or largely from opportunities that he created through BiotaNB—a long-term biodiversity survey in New Brunswick's protected natural areas. From our outreach to colleagues and students, we know that many others would like to have contributed. Inevitably, time constraints shaped the content of the issue. We are grateful to the manuscript reviewers for their critical input, and we also thank the New Brunswick Museum for financial and other assistance.

The issue begins with a sketch of Don's career (Clayden). The 12 research articles and notes which follow are by 32 authors, not including Don, who is also a co-author on one of the manuscripts. Several deal with the dynamics of vertebrate species' populations that have been much-affected by human activity: River Otter (*Lontra canadensis*) in Prince Edward Island (Gregory *et al.*); Moose (*Alces alces*) in mainland Nova Scotia (Scott *et al.*); and occurrences in urban settings in New Brunswick of Gray Treefrog

(*Hyla versicolor*; Wallace *et al.*) and two turtle species (Browne and Sullivan), Eastern Painted Turtle (*Chrysemys picta picta*) and non-native, potentially problematic Red-eared Slider (*Trachemys scripta elegans*). Other zoological contributions include a survey of the diversity of terrestrial molluscs in a protected natural area and adjoining provincial park in north-central New Brunswick (Forsyth); the first report for New Brunswick of Seaside Dragonlet (*Erythrodiplax berenice*), a dragonfly species restricted to saline habitats (Sabine *et al.*); and a study of the diversity and frequency of parasitic subcutaneous mites occurring on Northern Gannet (*Morus bassanus*) in Atlantic Canadian waters (Proctor *et al.*). Four other contributions deal with species diversity and/or range extensions among myxomycetes (slime moulds), fungi, lichens, and flowering plants in New Brunswick. Eighty myxomycete species are reported, greatly increasing the known diversity of this group in the province (Zoll *et al.*). The occurrence and identities of 10 species in the mushroom-forming genus *Cortinarius* are confirmed by molecular evidence, with morphological and habitat descriptions provided for each (Malloch *et al.*). A synopsis of the lichen genus *Rinodina* details the distributions and habitats of 15 species (Clayden *et al.*). And a widely disjunct occurrence of the native annual Douglas' Knotweed (*Polygonum douglasii*) is documented (Blaney *et al.*).

We thank CFN for the opportunity to celebrate Don's productive and diverse career in natural history, and we wish him good health and happiness in his continuing adventures.

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# The Canadian Field-Naturalist

## Notes on the natural history of Donald F. McAlpine

In the high schools of New Brunswick in the early 1970s, a standard textbook for students of French as a second language featured the adventures of a fictional 15-year-old speleologist and aspiring scientist living in southwestern France (Dale and Dale 1964). Little did most of those students (myself among them) know that, in Donald McAlpine, we had a real-life teenaged investigator of local caves and cave life in our midst. By his early 20s, when he graduated with a B.A. in biology from the University of New Brunswick (UNB), Don had already authored several peer-reviewed scientific papers and other articles, mostly on the physical structure and fauna of solution caves in the province.

He reported a hibernating Tricoloured Bat (*Perimyotis subflavus*), the first provincial record of this

species (McAlpine 1976); examined the diversity and ecology of cave-dwelling earthworms with Dr. John Reynolds, who was then a professor at UNB (McAlpine and Reynolds 1977); documented cave-use by American Beaver (*Castor canadensis*; McAlpine 1977); and assessed the state of faunistic and ecological knowledge of these habitats in New Brunswick, emphasizing the need for further research (McAlpine 1979; see also McAlpine 1983a).

His curiosity and productivity are perennial. Dr. Donald F. McAlpine (Figure 1) is the long-time Research Curator of Zoology and Head of the Department of Natural History at the New Brunswick Museum (NBM). He is an unusually versatile biodiversity scientist who has made prolific contributions to knowledge, conservation, and public appreciation of Canada's terrestrial, freshwater, and marine biota, focussing on the Atlantic region. His published works include more than 160 peer-reviewed papers, 20 book chapters, a major edited book on the biodiversity of the Atlantic Maritime Ecozone (McAlpine and Smith 2010a), a co-authored volume on the mammals of Prince Edward Island (Curley *et al.* 2019), flashcard guides to freshwater mussels (McAlpine *et al.* 2021b) and freshwater fishes of conservation significance (McAlpine and Karstad *in press*) in the Maritimes, and many more natural history articles written for magazines, newsletters, and other forums. Don is, equally, and has long been, a generous mentor of students and citizen scientists; an instigator and genial leader of collaborative projects; and a tireless advocate for the key role of natural history museums in documenting and conserving biodiversity (McAlpine 1986, 1993, 2011, 2018a, 2022).

Growing up, Don lived in the city of Saint John, a few kilometres across town from the NBM. But every summer, after school was out, his family would move to their small cottage on the bank of the Wolastoq (Saint John River) at Grand Bay, about 15 km upriver from the city and the Bay of Fundy. By all indications, it was here that he emerged as a naturalist, with a special fondness for frogs, turtles, and their kin. With supportive parents, he soon found his way to the museum, and by his early teens was volunteering after school and on weekends in the NBM natural history collections. At the time, zoologist-curator



**FIGURE 1.** Donald McAlpine, in Kennedy Lakes Protected Natural Area (PNA), New Brunswick, 14 August 2022. Photo: Mathieu Léger.

Dr. Stan Gorham (1917–1984) was deeply engaged in building the NBM's systematic research collections of vertebrates (Gorham 1978; McAlpine 1986; Cook 1991). As a specialist in herpetology, with local, national, and international experience in field and museum work and scientific writing, he was an influential early mentor to Don. Others were David Christie—ornithologist, all-round naturalist, and at the time the head of the NBM science department—and Dr. Francis Cook (1935–2020)—curator of herpetology at the Canadian Museum of Nature, and long-serving Editor-in-Chief of *The Canadian Field-Naturalist* (CFN).

Don's early and continuing contributions to herpetology illustrate his uncommon ability to parlay opportunity and experience into diverse and evolving outcomes. Three of those early opportunities took him outside Canada: to Panama in 1979, Iceland in 1980, and the island of Jersey in the English Channel in 1981.

In Panama, on a student expedition, he enlisted the help of fellow participants in a study of nesting behaviour in Leatherback Sea Turtle (*Dermochelys coriacea*; McAlpine 1980). Years later (2002–2004) he would serve on the Atlantic Leatherback Turtle Recovery Team of Fisheries and Oceans Canada and assess the status and conservation of marine turtles in British Columbia (McAlpine *et al.* 2004) and Canadian waters (McAlpine *et al.* 2007). Through his outreach to Maritime fishermen and colleagues at the Atlantic Veterinary College and Canadian Sea Turtle Network, the NBM has assembled important research collections of leatherbacks and other sea turtles. These include tissue samples, carapaces, and skeletal material salvaged from animals that were found dead on beaches or drowned in fishing gear. For many years, a whole-body mount of one such leatherback featured prominently in an exhibition on marine biodiversity conservation seen by thousands of visitors to the NBM. Meanwhile, a series of educational leaflets on endangered species in New Brunswick (conceived and written largely by Don) included the leatherback (McAlpine and Heward 1993) among the 20 numbers produced by the museum.

On Jersey, during an internship at what is now the Durrell Wildlife Conservation Trust, Don initiated and completed a study of activity patterns and correlated colour changes in captive individuals of Keel-scaled Boa (*Casarea dussumieri*), an at-risk snake species (IUCN Red Listed as Vulnerable; Cole *et al.* 2018) endemic to a single small island in the archipelago of Mauritius (McAlpine 1981, 1983b). In recent years, he and colleagues have examined several aspects of the biology and variability of Maritime Canadian populations of Common Gartersnake (*Thamnophis*

*sirtalis pallidulus*). The latest in this series of studies examines the multiple colour morphs occurring in these populations (McAlpine *et al.* 2022c). Although these are genetic variants of a polymorphic and widespread species, not analogous to physiological colour changes, the topic hints at a long-held interest. The spring and summer of 1981 were momentous for Don in quite another happily enduring way. It was on Jersey that he met his wife, Lynne.

Don's first scientific study of amphibians examined the status of Gray Treefrog (*Hyla versicolor*; recognized by Frost [2023] as *Dryophytes versicolor*) at what was then its only known locality in New Brunswick, a marsh within the city of Fredericton (McAlpine *et al.* 1980). This work contributed to protection of the site by the Nature Trust of New Brunswick as Hyla Park, the first area in Canada set aside expressly for amphibian conservation and related public education (McAlpine and Vail 2005; Wallace *et al.* 2023 [this CFN issue]). Hyla Park was also the setting of Don's M.Sc. research at UNB, in which he compared microhabitats and prey sizes among three family Ranidae frog species (McAlpine and Dilworth 1989). He has subsequently shown that the treefrog is expanding its range in the province, largely in anthropogenic habitats (McAlpine *et al.* 1991a, 2009; McAlpine 2023). Positing that losses or alteration of habitats might have caused historical declines of other amphibian species in the province, he found instead that the low degree of habitat specialization of most of these species appears to have offset such possible impacts (McAlpine 1997a, 2010). On the other hand, a study of Mink Frog (*Lithobates septentrionalis*; recognized by Frost [2023] as *Aquarana septentrionalis*) population numbers during an Eastern Spruce Budworm (*Choristoneura fumiferana*) outbreak in the 1970s–1990s showed adverse responses in areas sprayed with the insecticide fenitrothion (McAlpine *et al.* 1998).

For his Ph.D., also at UNB, Don investigated another dimension of amphibian biology that had received little previous attention in Canada. Under the direction of parasitologist Dr. Michael Burt (1938–2014), he carried out taxonomic and ecological studies of helminth communities in several species of New Brunswick frogs (e.g., McAlpine 1997b; McAlpine and Burt 1998a,b). His interest in parasitology has extended to host-groups as varied as whales (McAlpine *et al.* 1997), sharks (Adams *et al.* 1998; Pratt *et al.* 2010), and crayfish (Gelder *et al.* 2009). He also completed the editing of a major work on the nematodes of Canadian fishes (Arai and Smith 2016), following the death of co-editor Michael Burt.

Some of Don's colleagues, and many museum-goers and others, know him mainly in connection

with whale research and conservation. His trip to Iceland in 1980 gave him a visceral introduction to large cetaceans. From June to September of that year, he was employed as the Canadian observer of the Icelandic commercial whale hunt, reporting to the International Whaling Commission. Dividing his time between the deck of a whaling ship and an onshore processing station, he was able to retrieve and prepare skeletal material from several individuals of the targeted species: Sei Whale (*Balaenoptera borealis*), Fin Whale (*Balaenoptera physalus*), and Sperm Whale (*Physeter macrocephalus*). He also measured organ weights in a larger sample of the harvested animals, and reported his findings as a contribution to understanding the comparative physiology of these species (McAlpine 1985).

The skeletal material that he salvaged in Iceland became part of the NBM zoological collections. Over the ensuing years, through his wide collaboration and networking, and with the support of other NBM zoology staff (strong constitutions a job prerequisite), these collections have come to include the most comprehensive research holdings in any museum of the marine mammal fauna of Atlantic Canada (Figure 2a). As with the collections of sea

turtles, this material originates largely from animals that died after strandings or entanglements (see Nemiroff *et al.* 2010). Don has taken part in necropsies of a number of these individuals. Besides assessing the causes of death, these studies have yielded knowledge of the reproductive status and pathology of various cetaceans (e.g., McAlpine *et al.* 1999a; Daoust *et al.* 2022). Their broader goal is to contribute to reducing mortality resulting from human activities (see Van der Hoop *et al.* 2013). Don developed a particular interest in Pygmy Sperm Whale (*Kogia breviceps*) and Dwarf Sperm Whale (*Kogia sima*) after a Pygmy Sperm Whale washed ashore dead, in fresh condition, in Saint John in December 1992 (McAlpine *et al.* 1997). He has contributed authoritative accounts of these two rarely observed toothed whales, which are phylogenetic cousins of the much larger Sperm Whale, to standard international reference works on marine mammals (McAlpine 2014, 2018b).

The “Hall of the Great Whales” was among the centrepiece attractions of the NBM exhibition centre on the Saint John waterfront from 1996 to 2022. Conceived and developed by Don and the museum’s design and exhibition staff, it included the articulated skeleton and a life-size model of an adult female



**FIGURE 2.** Donald McAlpine. a. In the mammal collections storage area at the New Brunswick Museum, Saint John, New Brunswick (NB), 25 August 2020. b. At the entrance to a bat hibernaculum, White Cave, near Hillsborough, NB, 21 April 2015. Photo a: Julia Wright. Photo b: Karen Vanderwolf.

Northern Right Whale (*Eubalaena glacialis*), nicknamed Delilah, that died near Grand Manan in the Bay of Fundy in 1992 following a ship strike. The salvage of Delilah was facilitated by Laurie Murison (1959–2022), marine conservationist, long-time director of the Grand Manan Whale and Seabird Research Station, and a close colleague of Don. The model was created by noted whale biologist Dr. Paul Brodie, who Don first met in Iceland in 1980. The exhibition heightened public awareness of the threats faced by the North Atlantic Right Whale (listed as Critically Endangered by IUCN [Cooke 2020] and Endangered by the Canadian federal government [SARA Registry 2023]) and other large marine vertebrates in Atlantic Canadian waters. In so doing, it probably also contributed indirectly to the successful rerouting of a major shipping lane away from the area frequented by right whales near Grand Manan (Vanderlaan *et al.* 2008). In 2022, the NBM embarked on a comprehensive renewal of its exhibition and collections/research facilities. Although the exhibition centre will be closed during this process, the model of Delilah has been given a fitting new home in the Fundy Discovery Aquarium at the Huntsman Marine Science Centre in St. Andrews, New Brunswick.

The scope of Don's original research on the distribution, biology, and conservation of other vertebrates and invertebrates defies easy summary. He has also published, in some cases extensively, on fishes, birds, bats, shrews, rodents, seals, canids, felids, earthworms, freshwater and terrestrial molluscs, crayfish, woodlice, millipedes, and several orders of insects. Even this list is incomplete. The astonishing range is partly a reflection of the mandate of a curator of diverse collections, working in a region with few resident taxonomic specialists. It also illustrates Don's keen motivation to document and understand, across taxonomic groups, species' responses to environmental variation and change (McAlpine and Smith 2010b). His collaboration with many other biodiversity scientists and students, and the diversification and growth of the NBM natural history collections over the past several decades, can be seen in a similar light. For an example, see his and Dr. Aaron Fairweather's accounts of the history and development of the NBM insect collections (Fairweather and McAlpine 2011; McAlpine 2011, 2018c), and Don's tribute to odonatologist and NBM research associate Paul Brunelle (1952–2020; McAlpine 2020).

About a third of Don's research publications report new provincial, regional, national, or North American species-occurrence records. Invariably, these are meticulously researched papers providing historical and ecological context and, increasingly, the results of genetic and stable isotope analyses. Nearly

all are co-authored with colleagues and students. A few examples, in chronological order, are papers on American Mud Earthworm (*Sparganophilus tamesis*; synonym *Sparganophilus eiseni*), one of only two native species among the 21 earthworm species that have been found in New Brunswick to date (McAlpine *et al.* 2001, 2022a); Pickerel Frog (*Rana palustris*; recognized by Frost [2023] as *Lithobates palustris*) on Prince Edward Island (McAlpine *et al.* 2006); Ocean Pout (*Zoarces americanus*) and Ocean Sunfish (*Mola mola*) in the Saint John River system (McAlpine 2013); a wild-origin Gray Wolf–Eastern Wolf hybrid (*Canis lupus* × *Canis lycaon*) in New Brunswick (McAlpine *et al.* 2015); Spring Field Cricket (*Gryllus veletis*) in the Maritime provinces (Lewis *et al.* 2019); and island and mainland populations of White-Footed Deer Mouse (*Peromyscus leucopus*) in New Brunswick (Huyhn *et al.* 2021a,b).

Complementing these studies, Don has paid close attention to non-native and potentially invasive species, and native species undergoing what are or may be anthropogenic changes in distribution, abundance, or breeding status. Examples fitting these broad categories include Gray Treefrog, noted above; gulls (Astle and McAlpine 1985; McAlpine *et al.* 2005); seals (e.g., McAlpine *et al.* 1999b; Lucas and McAlpine 2002); Gray Fox (*Urocyon cinereoargenteus*; McAlpine *et al.* 2008, 2016a); a wild-origin Greylag Goose (*Anser anser*; McAlpine *et al.* 2020b); and Silver-haired Bat (*Lasionycteris noctivagans*; McAlpine *et al.* 2021a). Among invertebrates, examples include Spinycheek Crayfish (*Faxonius* [formerly *Orconectes*] *limosus*; McAlpine *et al.* 1991b; Lambert *et al.* 2007), Southern White River Crayfish (*Procambarus zonangulus*; McAlpine *et al.* 2020a), Common Freshwater Jellyfish (*Craspedacusta sowerbyi*; McAlpine *et al.* 2002), Common Ridgeback woodlouse (*Haplophthalmus mengii*; McAlpine and Fairweather 2016), Chinese Mystery Snail (*Cipangopaludina chinensis*; McAlpine *et al.* 2016b; Kingsbury *et al.* 2021), millipedes (McAlpine and Shear 2018; McAlpine 2019), and earthworms (McAlpine *et al.* 2022a,b).

One of the most severely consequential invasive organisms in North America in recent decades has been the fungus *Pseudogymnoascus destructans* (*Pd*), the causal agent of white-nose syndrome (WNS) in bats. When the disease was first detected in upstate New York in 2006, Don realized that a narrow window of time remained in New Brunswick during which the pre-white-nose status of hibernating bat populations and co-occurring biota could be documented. His previous caving experience and bat research put him in a good position to undertake the work, but it would be physically and logistically challenging. By good fortune, an intrepid student of mammalogy, Karen

Vanderwolf, embraced the opportunity to work on the project for her M.Sc. thesis at UNB, with Dr. Graham Forbes and Don as co-supervisors. They were joined by mycologist and NBM research associate Dr. David Malloch, who guided the study of fungi originating from Karen's and Don's intensive sampling efforts in caves and mines (Figures 2b and 3c).

Beginning their surveys in early 2009, Karen and Don found the first New Brunswick bats infected and killed by *Pd* in March 2011 (McAlpine *et al.* 2011; Vanderwolf *et al.* 2012). By 2015, more than 99% of Little Brown Bat (*Myotis lucifugus*) and Northern Long-eared Bat (*Myotis septentrionalis*) in the known hibernacula in the province had succumbed, and no Tricoloured Bats have been observed in New Brunswick since 2013 (Vanderwolf and McAlpine 2021). Karen, Don, David, and colleagues have published nearly 20 research papers to date on the environmental characteristics and biota of the New Brunswick

hibernacula, before and after the arrival of *Pd*. These deal with the cave microclimates (e.g., Vanderwolf *et al.* 2012; Vanderwolf and McAlpine 2021), their fungal diversity (e.g., Vanderwolf *et al.* 2013, 2019; Malloch *et al.* 2016), and potential vectors and reservoirs of *Pd* (e.g., Vanderwolf *et al.* 2016). This work has yielded the most comprehensive findings currently available on the fungal biota of the affected bat species and for any caves in Canada—backed up by live cultures deposited in the UAMH Center for Global Microfungal Biodiversity at the University of Toronto, and dried specimens in the NBM herbarium (Vanderwolf *et al.* 2019). From this solid foundation, Karen extended her WNS research widely beyond New Brunswick and completed her Ph.D. thesis at Trent University in 2022 on aspects of the “mycobiome” of bats, with Don as a member of her supervisory committee.

Given his broad interests and expertise, it was natural that Don would take the lead in organizing and



**FIGURE 3.** Donald McAlpine (DFM) with students and colleagues. a. Left to right: Howard Huynh, Aaron Fairweather, Laura Hill, DFM, and Derek Durston, in Caledonia Gorge Protected Natural Area (PNA), New Brunswick (NB), 23 August 2012. b. Left to right: DFM, Jake Lewis, Madelaine Empey, and Rachel Fullerton-Quin, in Spednic Lake PNA, NB, 19 August 2017. c. Left to right: Karen Vanderwolf, David Malloch, and DFM, en route to bat hibernaculum in Markhamville Mine, NB, 11 March 2011. d. Botany and mycology field lab at BiotaNB, DFM in foreground, Kennedy Lakes PNA, NB, 27 June 2019. e. Sign on entrance-door to zoology field lab, Kennedy Lakes PNA, NB, 6 July 2019. Photos a and b: Karen Vanderwolf. Photo c: Randall Miller. Photos d and e: Stephen Clayden.

editing the book *Assessment of Species Diversity in the Atlantic Maritime Ecozone* (McAlpine and Smith 2010a). Ten years in the making, this includes 31 chapters by 51 researchers from across Canada and elsewhere. It is one of only a few such works, and the only one formally published, that synthesizes knowledge of the biodiversity of an entire Canadian ecozone. Fifteen terrestrial ecozones are recognized nationally. Among these, the Atlantic Maritime Ecozone comprises the Maritime Provinces of New Brunswick, Nova Scotia, and Prince Edward Island; the Appalachian region of eastern Quebec and Gaspésie; and the Îles-de-la-Madeleine (McAlpine and Smith 2010a). In a review of the book published in CFN, Dr. Paul Catling called it “a great achievement” and “a major source for anyone interested in Canada’s biodiversity as well as that of northeastern North America” (Catling 2012: 71). He added: “It will provide a basis for research and teaching and a vast source of general information [...] Naturally we hope that its example and standard can be followed” (Catling 2012: 74).

The most ambitious project conceived and led by Don is BiotaNB. Every year since 2009—with a two-year hiatus during the COVID-19 pandemic—BiotaNB has brought together a group typically including 40 to 60 taxonomic experts, students, volunteers, and several artists-in-residence for two weeks of intensive field studies in New Brunswick’s larger protected natural areas (PNAs). Its primary goal is to build a base of knowledge supporting conservation of species and ecosystem diversity in the province. It also provides opportunities for students to work with experienced biodiversity specialists, and for interaction among scientists and artists as they explore the PNAs (Figures 3a,b,d,e and 4). A student-led project during BiotaNB was the first to examine the incidence of the chytrid fungus, *Batrachochytrium dendrobatidis*, in a range of amphibian species in New Brunswick (Jongsma *et al.* 2019).

Through open house events, BiotaNB has enabled community members near the protected areas to engage with researchers and artists, learn about their discoveries and creative work, and share local knowledge. In addition to its research findings, reported in more than 60 peer-reviewed papers to date, the project has yielded a substantial body of artworks in diverse media, a book of poetry, and a feature film (see McAlpine 2022). On a practical level, its success has hinged on Don’s skill and hard work as an organizer and fund-raiser, and on the technical and logistic prowess of other NBM natural history staff and volunteers. (Many participants would note the camaraderie and delicious evening meals as further keys to the success of the field program.)

BiotaNB has been a formative multi-year experience for a number of students who acknowledge Don as an influential mentor. Among the BiotaNB “alumni” are Aaron Fairweather (Ph.D., 2023, University of Guelph; ant diversity and ecology), Madeline Empey (current Ph.D. candidate, University of Ottawa; amphibian ecotoxicology), Howard Huynh (Ph.D., 2018, Texas Tech University; mammal systematics, morphology, and biogeography), Gregory Jongsma (Ph.D., 2022, University of Florida; frog systematics and phylogeography), Jake Lewis (M.Sc., 2022, University of Ottawa; beetle systematics), and Karen Vanderwolf (Ph.D., 2022, see above). As a member of supervisory or examining committees, Don has mentored three other doctoral students and more than 20 M.Sc. students. Many others who have worked as undergraduate summer students in the NBM zoology section have pursued careers in wildlife and conservation biology, health sciences, and teaching.

Don’s service on scientific panels, steering committees, and other organizations has also been extensive. Groups in which he has been especially active include the Canadian Herpetological Society (including the Canadian Amphibian and Reptile Conservation Network, CARCNET); the Alliance of Natural History Museums of Canada; the New Brunswick Scientific Advisory Committee on Protected Natural Areas; the New Brunswick Committee on the Status of Species-at-Risk; and the Stonehammer UNESCO Global GeoPark. He has also served on the editorial boards of several research journals, including CFN, of which he has been an Associate Editor since 2003.

His accomplishments in biodiversity research and conservation, collections development, and public education have been recognized by national awards from the Canadian Council on Ecological Areas (1997), the Canadian Museums Association (1997), the Canadian Wildlife Federation (2015), and the Canadian Herpetological Society (2022). Also, the NBM received a Visionary Award in 1996 from the Gulf of Maine Council on the Marine Environment for its “provision of scientific advice to governments and the private sector on the natural history and conservation of the Bay of Fundy and Gulf of Maine” and “long commitment to promoting public awareness of marine science”.

It was Don’s advocacy that led to the creation of a curatorial position in geology and palaeontology at the NBM in 1986 and another in botany and mycology in 1987. Dr. Randall (Randy) Miller and I were hired in turn in those years, and the two of us and Don worked closely together for the next 30 years. It often felt like we were channeling the spirits of our early counterparts—the small group of geologists, zoologists, and botanists who pursued the scientific work of



**FIGURE 4.** The BiotaNB “lab” in the Queens County Courthouse Museum, Gaagetown, New Brunswick during the Grand Lake Protected Natural Area bioblitz, 12 August 2014. From left to right: Virginia Zoll (foreground/below), David Malloch (above), Bruce Malloch, Amanda Bremner, Karen Vanderwolf (below window), Kendra Driscoll (looking into microscope), Greg Jongsma (almost hidden behind table at back), Annegret Nicolai, Robert Forsyth, Bianca Langille (wearing a ballcap), Don McAlpine, and Howie Huynh. Photo: Dwayne Lepitzki.

the Natural History Society of New Brunswick, forerunner of the NBM, in the mid to late 1800s and early 1900s. Randy retired in 2016 and I followed in 2018. Happily, the work continues, with new curators joining experienced technicians and bringing fresh expertise and ambitions to the NBM, while keeping the doors open to old-timers. Don, too, just might “retire” one of these years. That surely won’t mean putting away his collecting net or setting down his pen. He seems bound to stay closely engaged in the NBM and wider natural history communities that he has done so much to foster.

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## Recent records of telamonioid species of *Cortinarius* (Agaricales: Cortinariaceae) in New Brunswick, Canada

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### Abstract

Eight species of *Cortinarius* (webcaps) subgenus *Telamonia* and two other telamonioid *Cortinarius* species are reported from New Brunswick, Canada. Internal transcribed spacer sequences of these were used to build a phylogenetic tree confirming species identifications and relationships to relevant material, especially types and other Canadian collections. Descriptions and photographs of fresh material and microscopic features are provided. Habitat details, particularly potential mycorrhizal partners and dominant bryophytes, were recorded for each collection and compared with published records. Seven species, *Cortinarius caninoides*, *Cortinarius cicindela*, *Cortinarius fulvescens*, *Cortinarius harvardensis*, *Cortinarius plumulosus*, *Cortinarius pseudobiformis*, and *Cortinarius valgus* are new distribution records for New Brunswick, and *C. plumulosus* is apparently a first record for North America. Because these species have rarely been reported, they have yet to be given common names.

Key words: Fungi; Agaricales; mushroom; *Cortinarius*; *Telamonia*; New Brunswick; Bay of Fundy; Canada; new distribution record

### Introduction

The mushroom-forming genus *Cortinarius* (Basidiomycota: Agaricomycetes: Agaricales: Cortinariaceae) is considered to be one of the largest of all fungal genera, as it is estimated to include several thousand species (Bhunjun *et al.* 2022). In the past, many authors have expressed doubts about the taxonomic uniformity of *Cortinarius* and have treated parts of this group as separate genera. Some of these segregates, such as *Dermocybe* and *Phlegmacium*, attained a limited level of acceptance by mycologists, but never came into wide usage.

Recent studies using genomic analyses have led to a reconsideration of how we view *Cortinarius*. The family Cortinariaceae, long thought to contain several genera, was shown by Matheny *et al.* (2015) to contain only *Cortinarius*, with other genera, such as *Crepidotus*, *Gymnopilus*, *Inocybe*, distributed in several other families. However, using multi-locus genomic data, Liimatainen *et al.* (2022) presented a phylogenetic analysis dividing *Cortinarius* into 10 genera: *Cortinarius*, *Phlegmacium*, *Thaxterogaster*, *Calonarius*, *Aureonarius*, *Cystinarius*, *Volvanarius*,

*Hygronarius*, *Mystinarius*, and *Austrocortinarius*, all included in the Cortinariaceae. Species of seven of these genera (*Cortinarius*, *Phlegmacium*, *Thaxterogaster*, *Calonarius*, *Aureonarius*, *Cystinarius*, and *Hygronarius*) have been shown to occur in Quebec (Landry *et al.* 2021) and probably occur throughout North America.

In spite of its relatively small size, the province of New Brunswick is ecologically diverse and contains a variety of habitats favourable to Cortinariaceae. It is within the Atlantic Maritime Ecozone and contains seven ecoregions (McAlpine and Smith 2010). Of the seven genera of Cortinariaceae reported from Quebec, only members of *Calonarius* and *Hygronarius* have yet to be reported in New Brunswick.

As part of an ongoing effort to catalogue the fungi of New Brunswick, species of Cortinariaceae are currently being collected and studied. One of the taxonomically most difficult groups within the genus *Cortinarius* is the subgenus *Telamonia* and the superficially similar taxa referred to as “telamonioid”. Traditionally these have been characterized as having basidiomata with dry pilei and stipes and generally

lacking brightly coloured lamellae. Here we report on eight species of *Cortinarius* subgenus *Telamonia* and two additional telamonioid species. We have included descriptions, illustrations, and habitat information for these species, based on genetically verified voucher specimens.

## Methods

All collections were made in New Brunswick. They were photographed in the field and later scanned on a flatbed scanner. Notes were taken on the fresh material and spore prints were made by placing pieces of basidiomata over glass microscope slides. Colours were recorded from a cellphone using a handbook with the HSV/HSB (Hue, Saturation, Value or Hue, Saturation, Brightness) colour system, an alternative representation of the RGB (Red, Green, Blue) model commonly used in computer graphics (Malloch 2021). The basidiomata were then dried in a food drier for 24 h at 60°C. All collections were deposited in the herbarium of the New Brunswick Museum (NBM).

### Microscopic studies

Microscopic features of sections of the pileipellis and lamellae were examined in Windex window cleaner (S.C. Johnson & Son, Racine, Wisconsin, USA) and in 3% KOH. Basidia and other hymenial structures were examined in 3% KOH after presoaking and clearing in aqueous Congo Red.

Basidiospores from spore prints were suspended in a drop of Melzer's solution on a microscope slide and examined with a 100× objective using bright field illumination. When spore prints were not available (e.g., *Cortinarius evernius* (Fr.) Fr., Silky Webcap), basidiospores deposited on the universal veil were examined.

The slides were scanned along parallel transect lines and basidiospores lying in profile were photographed. The photographs were viewed using an open-source image editor (Gnu Image Manipulation Program, v. 2.10, <https://www.gimp.org>). Basidiospores lying in profile were rotated so that the apiculus was at the left and oriented to approximately 225°. Rotated basidiospores were then cut from the photograph and placed side by side on a new and separate image. The aligned basidiospores were measured using ImageJ (National Institutes of Health, Bethesda, Maryland, USA) and the results transformed using a spreadsheet. Measurements are expressed as the full size range and aspect ratio (Q) of the sample followed by the mean and SD of length, width, and Q. Sample size is shown in square brackets.

### Molecular studies

DNA was extracted from dried herbarium specimens following standard procedures for mushroom-

forming fungi. The fungal barcode, nrITS region (nrITS1-5.8S-nrITS2), was targeted for amplification, using the primer pair ITS1F-ITS4 (White *et al.* 1990; Gardes and Bruns 1993). DNA extraction, polymerase chain reaction (PCR), and sequencing were carried out at ALVALAB (Oviedo, Spain).

Raw chromatogram data were edited and assembled using ChromasPro (Technelysium DNA Sequencing Software, South Brisbane, Australia). A total of 11 new sequences were generated in our study. We assembled a molecular dataset that includes all type specimens of the species studied here and representatives of those species from Eurasia and North America (if available). The final dataset consisted of 38 nrITS sequences, including two species of *Cortinarius* subgenus *Dermocybe* (*Cortinarius neosanguineus* Ammirati, Liimat. & Niskanen and *Cortinarius sierraensis* (Ammirati) Ammirati, Niskanen & Liimat.) that were used as outgroup taxa.

Sequences were aligned using MAFFT version 7 (Katoh *et al.* 2019) with the strategy FFT-NS-i. The alignment was inspected and manually corrected in AliView (Larsson 2014). We ran a maximum likelihood analysis using RAxML 8.2.10 under a GTRGAMMAI model as recommended (Stamatakis 2014), with 100 rapid bootstrap replicates. The analysis was run using resources at the CIPRES Science Gateway (Miller *et al.* 2010). A phylogenetic tree was visualized in FigTree v. 1.4.4 (University of Edinburgh, Edinburgh, United Kingdom), then exported as an SVG file and edited in Adobe Illustrator (Adobe, San Jose, California, USA) for final presentation.

## Results

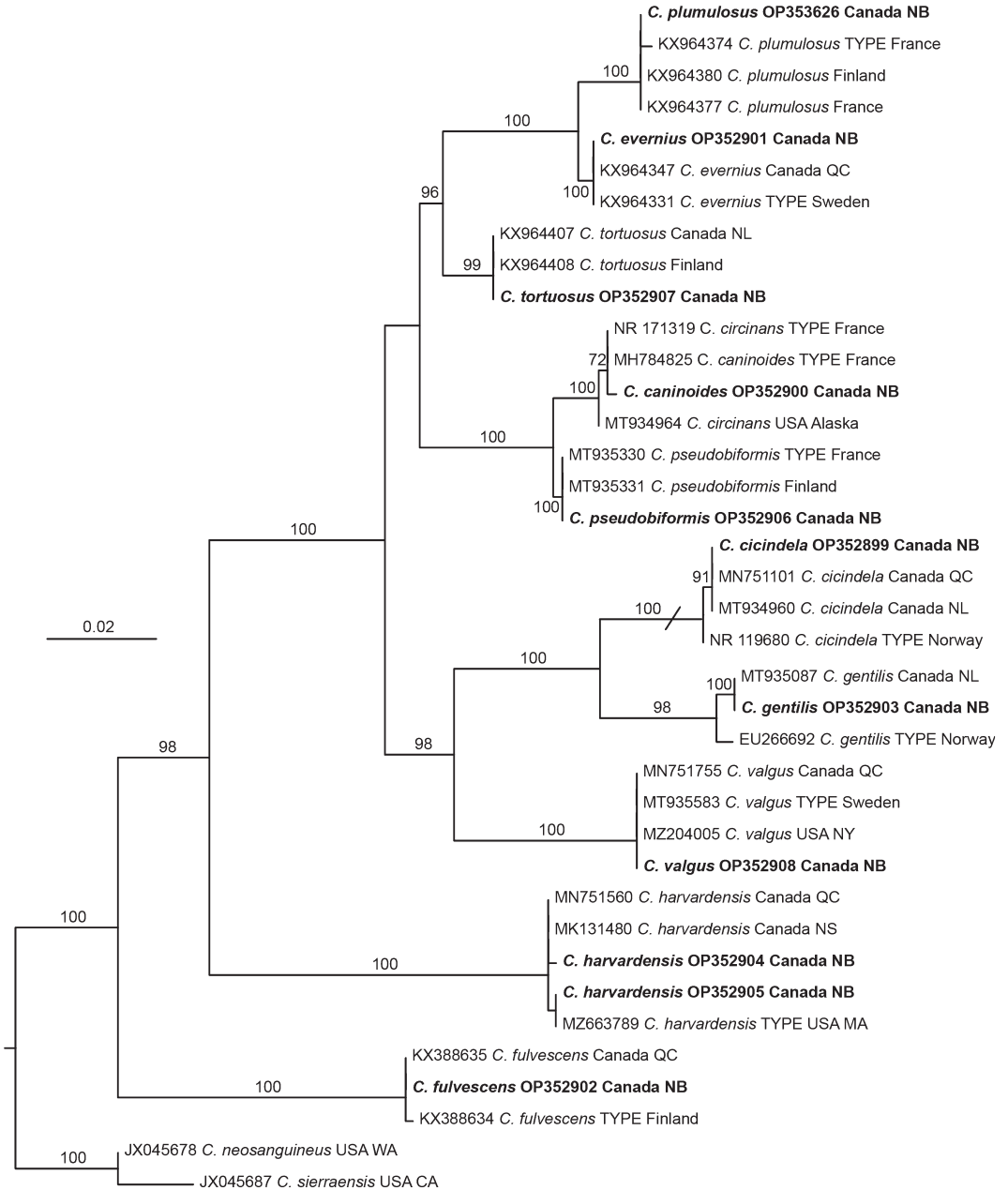
The best tree from the maximum likelihood analysis of the sequences we studied is presented in Figure 1. The internal transcribed spacer (ITS) sequences of the New Brunswick collections grouped in all cases with their respective type collections and/or reference sequences from North America and Eurasia. The species-level clades recovered in the analyses get full bootstrap support (100%), with the exception of *Cortinarius tortuosus* (Fr.) Fr. (99%) and *Cortinarius gentilis* (Fr.) Fr. (Conifer Webcap; 98%). This is consistent with previous phylogenies of these two species (Landry *et al.* 2021; Liimatainen *et al.* 2022).

### Annotated Checklist

#### *Cortinarius* subgenus *Telamonia*, section *Bicolores*

##### *Cortinarius plumulosus* Rob. Henry (Figures 2a, 3a)

*Pileus* conic-turbinate at first, not seen when fully expanded, with a large rounded umbo, glabrous, light orange brown (HSV30:20–30:90) but probably hygrophanous and faded, slightly paler at the margin, dry, 43 mm in diameter. *Stipe* equal, dry, pale violet



**FIGURE 1.** Best tree from maximum likelihood analysis of the nrITS sequences of *Cortinarius*. Bootstrap values  $\geq 70\%$  are shown on or below the branches. The symbol / indicates that the branch length has been reduced to facilitate graphic representation. All sequences of New Brunswick specimens were newly generated for this study and are shown in bold. The scale bar represents number of nucleotide substitutions per site.

(HSV250:30–40:90), with universal veil present as a white annular band and irregular streaks below the annular zone,  $75 \times 13$  mm. *Lamellae* dark brown (HSV20:70–80:30), subclose, adnexed, white at the

margin. *Cortina* not seen, probably white. *Flesh* faded in the pileus but possibly concolorous with the surface tissues, pale violet (HSV250:30–40:90) in the stipe, lacking a distinctive odour and taste.



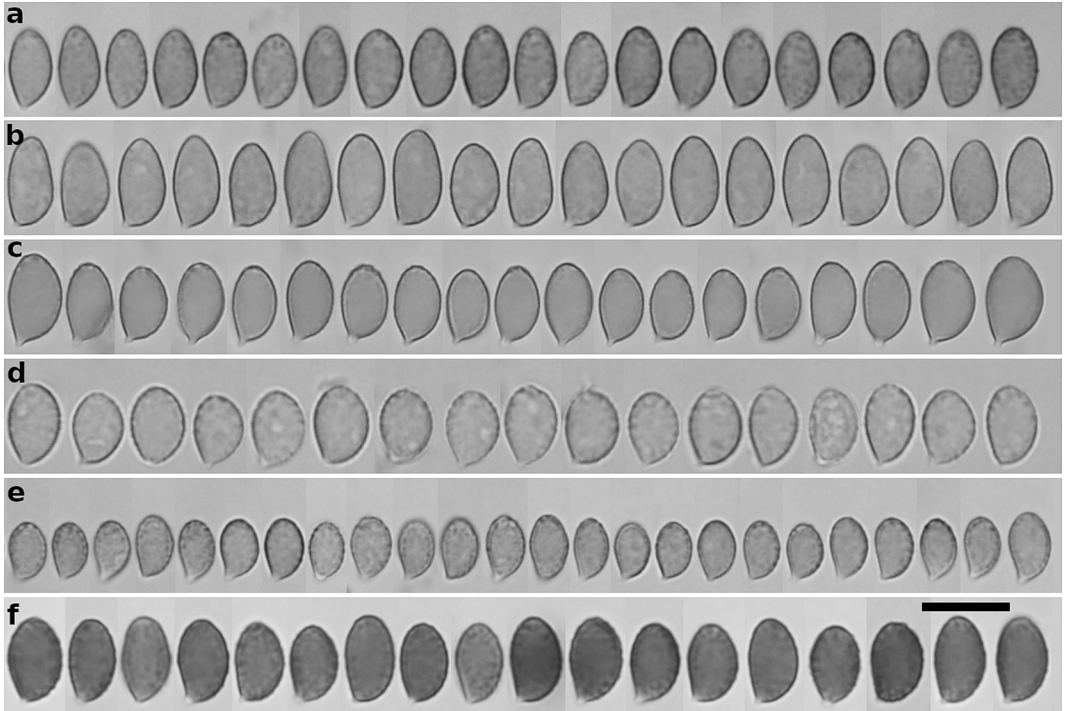
**FIGURE 2.** Basidiomata. a. *Cortinarius plumulosus*. b. Silky Webcap (*Cortinarius evernius*). c. *Cortinarius cicindela*. d. Conifer Webcap (*Cortinarius gentilis*). e. *Cortinarius caninoides*. f. *Cortinarius pseudobiformis*. Scale bar = 10 mm. Photos: D. Malloch.

*Basidiospores* bright orange brown (HSV25:70:80–90) in spore print, elliptical to obovate in profile, infrequently ovate, coarsely roughened, weakly dextrinoid,  $8.2\text{--}9.7 \times 4.8\text{--}5.8 \mu\text{m}$ ,  $Q = 1.53\text{--}1.93$  (mean [60]:  $9.1 \pm 0.4 \times 5.2 \pm 0.2 \mu\text{m}$ ,  $Q = 1.75 \pm 0.09$ ). *Cheilocystidia* forming a partly sterile margin, barely distinguishable from immature basidia, narrowly clavate to almost cylindrical, with a basal clamp connection. *Basidia* clavate, four-spored, with a basal clamp connection. *Lamellar trama* parallel, brown, with clamp connections at the septa, only rarely encrusted. *Pileipellis duplex*, a cutis of hyaline hyphae over a hypoderm of brown hyphae that are rather short and almost

brick-like. *Clamp connections* present on most septa.

*Specimens examined*—CANADA, New Brunswick: Charlotte Co., Little Lepreau,  $45.135^\circ\text{N}$ ,  $66.492^\circ\text{W}$ , 5 October 2020, D. Malloch 05-10-20/03 (NBM-F-009374), GenBank no. OP353626 (ITS); 24 September 2021, D. Malloch 24-09-21/01 (NBM-F-009378; not sequenced or included in the description above although similar macro- and micro-morphologically).

Closely related to *Cortinarius evernius* (Liimatainen *et al.* 2020) but with narrower basidiospores. Both of the New Brunswick collections had rather robust basidiomata with turbinate pilei and relatively thick stipes, in contrast to the more slender



**FIGURE 3.** Basidiospores. a. *Cortinarius plumulosus*. b. Silky Webcap (*Cortinarius evernius*). c. *Cortinarius cicindela*. d. Conifer Webcap (*Cortinarius gentilis*). e. *Cortinarius caninoides*. f. *Cortinarius pseudobiformis*. Scale bar = 10  $\mu$ m. Photos: D. Malloch.

basidiomata of *C. evernius*. *Cortinarius cagei* Melot is similar but differs in its association with hardwood trees, such as species of beech (*Fagus* L.), linden (*Tilia* L.), and hazel (*Corylus* L.; Brandrud *et al.* 1998). In common with most other members of the section *Bicolores*, all of these species have hygrophamous pilei, brown lamellae, and firm tapered stipes with blue flesh. Landry *et al.* (2021) reported a collection as *C. cf. cagei* that is very similar to ours and might be conspecific. Aside from that possibility, *C. plumulosus* seems to be unreported in North America.

Collections of this species have not been reported frequently in the literature. The type specimen was collected in the Vosges Mountains of France in a forest of European Silver Fir (*Abies alba* Miller). Our collection was in a dense patch of moss (*Rhytidiadelphus* (Limpr.) Warnst. sp.) in an area of a lawn shaded by two large Balsam Fir (*Abies balsamea* (L.) Miller) trees.

***Cortinarius evernius* (Fr.) Fr.** (Silky Webcap; Figures 2b, 3b)

*Pileus* conic-turbinate at first, expanding to more broadly so at maturity, with a low but prominent broad umbo, dry, fibrillose at first with the universal veil, shiny, medium grey brown (HSV35:30:50–60), hygrophamous, 18–23 mm in diameter. *Stipe* equal to

very narrowly clavate, often tapered at the base, very finely streaked or banded with universal veil material, pale yellow (HSV55:05:100) in the upper  $\frac{2}{3}$ , white to very pale violet (HSV250:03:100) below, dry, 55–93  $\times$  5–8 mm. *Lamellae* chocolate brown (HSV35:80:40–50), white toward the edge but not really marginate, subclose, adnexed. *Veil* difficult to interpret. The universal veil on the pileus margin appears to be pale yellow and contrasts with the violet cortina. However, the bands on the stipe are yellow while the veil near the stipe base appears to be violet. *Flesh* in the pileus is a dilute brown below the pileipellis but is otherwise nearly white; in the stipe it is mostly white but has definite but very pale shades of violet near the middle, with a nondescript mushroom odour, slightly sweet but otherwise without a distinctive taste.

*Basidiospores* not forming a spore print, ovate to elliptical in profile, rarely obovate, with walls moderately roughened, 9.0–10.8  $\times$  5.0–5.8  $\mu$ m, Q = 1.63–1.95 (mean [38]: 9.9  $\pm$  0.5  $\times$  5.5  $\pm$  0.2  $\mu$ m, Q = 1.81  $\pm$  0.09). *Basidia* four-spored, clamped at the basal septum. *Cheilocystidia* forming a sterile margin, clavate, clamped at the basal septum. *Lamellar trama* parallel, light brown, obscurely encrusted with fine granules. *Pileipellis* duplex, with a compact hyaline cutis

23–39 µm thick composed of narrow hyphae 1.4–2.5 µm in diameter, with a well-developed orange-brown hypoderm of broad encrusted hyphae.

*Specimen examined*—CANADA, New Brunswick, Charlotte Co., New River Beach Provincial Park, 45.125°N, 66.525°W, 23 September 2018, *D. Malloch 23-09-18/03* (NBM-F-009368), GenBank no. OP352901 (ITS).

*Cortinarius tortuosus* (Fr.) Fr. is superficially similar in having a brown hygrophanous pileus and brown lamellae. Although the stipe apex may have some violaceous colours, the flesh of the stipe, as in *C. evernius*, is never strongly violaceous.

*Cortinarius evernius* is commonly reported to be associated with conifers. There are other collections of this species in the herbarium of the New Brunswick Museum, but these have not been confirmed genetically. Brandrud *et al.* (1990) stated that it is usually thought to associate with conifers in northern or mountain habitats, often with *Sphagnum* L., but that it has also been collected in subalpine birch forests. In Quebec, it has been found on wet soils in coniferous forests, often with *Sphagnum* (Landry et Labbé 2022). Our collection was gregarious to clustered in a carpet of Red-stemmed Feathermoss (*Pleurozium schreberi* (Brid.) Mitt.) and other mosses in a well-drained site, associated with Balsam Fir. No *Sphagnum* was present.

#### *Cortinarius* subgenus *Telamonia*, section *Brunnei*

*Cortinarius cicindela* Kytöv., Niskanen & Liimat.  
(Figures 2c, 3c)

*Pileus* not seen when young, broadly conical and then irregularly buckled in age, with a prominent umbo, finely striate at the margin, dry, glabrous, dark brown (HSV10:80:30–40), dark brown to black in exsiccates, hygrophanous, 21–33 mm in diameter. *Stipe* equal, light silvery grey (HSV20:00–10:100), soon darkening to brown (HSV20:70:40–50), dry, glabrous, 60–80 × 3–5 mm. *Lamellae* very pale orange brown (HSV15:50:60), adnexed, subclose, not marginate. *Flesh* concolorous with the surface tissues, lacking a distinctive odour and taste.

*Basidiospores* reddish brown in spore print, mostly elliptical in profile, varying obscurely between ovate and obovate, coarsely roughened (especially at the apex), darkening slightly in Melzer's Solution, 7.4–10.8 × 4.2–6.4 µm, Q = 1.47–1.88 (mean [42]: 8.5 ± 0.7 × 5.3 ± 0.4 µm, Q = 1.61 ± 0.08). *Pileipellis* duplex, with a thin and compact cutis of pale narrow encrusted hyphae and a thick dark brown hypoderm of short broad strongly encrusted hyphae. *Lamellar trama* parallel, with hyphae clamped and strongly encrusted externally.

*Specimen examined*—CANADA, New Brunswick,

Northumberland Co., Kennedy Lakes Protected Natural Area, 46.792164°N, 66.478584°W, 4 July 2019, *D. Malloch 04-07-19/08* (NBM-F-009031), GenBank no. OP352899 (ITS).

A typical member of section *Brunnei*, characterized by dark brown hygrophanous pilei, dark brown lamellae, and basidiomata that become blackened when dried. All are associated with coniferous trees. Niskanen *et al.* (2009) studied section *Brunnei* extensively and provided a key to the species. Identification in the group is difficult, requiring precise determination of basidiospore size and shape. *Cortinarius cicindela*, one of the smaller members of the section, is very similar to *Cortinarius carabus* Kytöv., Niskanen & Liimat. and can be distinguished from it mainly by its slightly longer and less markedly obovate basidiospores and by its habitat, *C. carabus* growing mainly in sandy forests of pine (*Pinus* L.) and *C. cicindela* growing in more mesic forests of spruce (*Picea* A. Dietrich) and fir (*Abies* Miller). However, Niskanen *et al.* (2009) reported one sequence matching that of *C. carabus* from roots of Western Hemlock (*Tsuga heterophylla* (Rafinesque) Sargent) in British Columbia, which suggests the species is not restricted to *Pinus* spp. Both species were reported from Quebec by Landry *et al.* (2021).

In their original description of *C. cicindela*, Niskanen *et al.* (2009) reported that, in northern Europe, it can occur in *Sphagnum* bogs and other wet places with spruce and pine species, but also in mesic or dry forests with these trees. It was reported by Landry et Labbé (2022) from Radisson, northern Quebec, in mesic to humid soil among *Sphagnum*. Our collection was gregarious on *Sphagnum* in a wet forest dominated by Red Spruce (*Picea rubens* Sargent), Balsam Fir, and Paper Birch (*Betula papyrifera* Marshall).

*Cortinarius gentilis* (Fr.) Fr. (Conifer Webcap;  
Figures 2d, 3d)

*Pileus* conic-convex at first, expanding to broadly convex, with a low umbo, moist, glabrous except for some marginal pubescence, light brown to brown (HSV05–20:70:50–70), with marginal pubescence pale yellow to light yellow (HSV40:20–30:100), 13–37 mm in diameter. *Stipe* equal, yellowish white to pale yellow (HSV40:05–10:100), reddish brown (HSV380:70:30–40) where bruised, glabrous to fibrillose with yellow veil material, 40–70 × 3–7 mm. *Lamellae* light brown (HSV15:50:60) at first, more yellow when viewed on edge, darkening at maturity, adnexed to sinuate. *Universal veil* yellowish white (HSV40:05:100). *Flesh* concolorous with the surface tissues, concolorous with the bruising colour in the interior of the stipe, with a raphanoid odour, fairly tasteless.

*Basidiospores* orange brown (HSV35:50–60:90) in spore print, elliptical to obovate in profile, infre-

quently ovate, roughened with small spine-like warts, unchanging in Melzer's solution, darkening in KOH,  $7.8\text{--}9.7 \times 5.6\text{--}6.6 \mu\text{m}$ ,  $Q = 1.34\text{--}1.60$  (mean [49]:  $8.7 \pm 0.4 \times 6.0 \pm 0.2 \mu\text{m}$ ,  $Q = 1.45 \pm 0.07$ ). *Basidia* clavate, four-spored, with a basal clamp connection. *Hymenial cystidia* lacking. *Pileipellis* duplex, composed of a compact cutis of pale encrusted hyphae, with a brown hypoderm of short and broad encrusted hyphae. *Lamellar trama* parallel, of narrow brown finely encrusted hyphae.

*Specimens examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.491°W, 24 September 2003, *D. Malloch 24-09-03/04* (NBM-F-00454), GenBank no. OP352903 (ITS); Little Lepreau, 45.135°N, 66.475°W, 24 September 2003, *D. Malloch 24-09-03/02* (NBM-F-000452; not sequenced but morphologically similar).

*Cortinarius gentilis* was traditionally placed in *Cortinarius* subgenus *Leproclybe* among other bright orange-brown species (e.g., Hansen and Knudsen 1992); however, ITS sequences show it to be a member of subgenus *Telamonia*, sect. *Brunnei* (Høiland and Holst-Jensen 2000). Although its association with coniferous trees and the overall stature of its basidiomata are consistent with the *Brunnei*, the colour of the basidiomata and the bright yellow veil remnants on the stipe are less so. There are several collections of *C. gentilis* in NBM, including others from New Brunswick and one (NBM-F-0311) from Newfoundland and Labrador. Two records, possibly representing separate species, have been reported for Quebec by Landry *et al.* (2021). Their collection YL3407, as photographed, is very similar in appearance to those made in New Brunswick.

This well-known species was stated by Niskanen *et al.* (2009) to occur in dry to mesic coniferous forests with pine and spruce in northern Europe. Landry *et al.* (2022) give the habitat as soil under conifers and cite two sequenced collections from Chibougamau and Jamesie, both northerly localities in Quebec. The collection presented here was gregarious in litter among sparse Red-stemmed Feathermoss, associated with Balsam Fir and Red Spruce.

***Cortinarius* subgenus *Telamonia*, section *Firmiores*  
*Cortinarius caninoides* Rob. Henry (Figures 2e, 3e)**

*Pileus* conical at first, expanding to broadly convex at maturity, with a low rounded umbo, dry to moist, glabrous, dull orange (HSV25:60:70–80) on the umbo, light brown (HSV15:30:50–60) elsewhere, hygrophanous, darkening in 3% KOH but without colour changes, 32–63 mm in diameter. *Stipe* clavate, with a bulbous base, dry, with a white sheath-like universal veil extending from the base to the annular zone, very pale brownish white above the annular

zone, 72–100 × 8–10 mm. *Lamellae* light orange brown (HSV30:30–40:80), close, adnate to adnexed, not marginate. *Universal veil* abundant, white. *Flesh* concolorous with the surface tissues in the pileus but fading to white as it dries, pale dull orange yellow (HSV30:10–20:80) in the stipe except for the violaceous apex, darkening in 3% KOH but without colour changes, with a nondescript odour and taste.

*Basidiospores* orange brown in spore print, obovate in profile, usually with a pronounced supra-hilar depression, coarsely roughened,  $6.1\text{--}7.5 \times 3.8\text{--}4.7 \mu\text{m}$ ,  $Q = 1.48\text{--}1.71$  (mean [53]:  $6.7 \pm 0.3 \times 4.2 \pm 0.2 \mu\text{m}$ ,  $Q = 1.58 \pm 0.05$ ). *Hymenial cystidia* lacking. *Basidia* four-spored, with a basal clamp connection. *Pileipellis* a series of three distinct layers: (1) a thin hyaline cutis of narrow hyphae that may be slightly gelatinous, (2) a thicker hyaline zone of shorter and broader cells, and (3) a compact layer of brown narrow hyphae with conspicuous pigment encrustations. *Pileus trama* parallel, of loosely arranged and nearly colourless hyphae.

*Specimen examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.491°W, 24 September 2020, *D. Malloch 24-09-20/02* (NBM-F-009370), GenBank no. OP352900 (ITS).

A medium-sized brown hygrophanous species characterized by its white sock-like peronate universal veil extending up almost to the apex of the stipe, light orange-brown lamellae and bulbous stipe. The blue colour of the flesh near the apex of the stipe is obscure and was only noticed in the photograph. The basidiomata in the photograph of *C. caninoides* in Landry *et al.* (2021), with their orange-brown basidiomata, seem dissimilar to ours.

*Cortinarius caninoides* and *C. circinans* were originally described validly in the same publication. Landry *et al.* (2021) pointed out that the types of these two names had ITS sequences similar enough that they could be considered conspecific, and, following Art. 11.5 of The International Code of Nomenclature for algae, fungi, and plants (Turland *et al.* 2018), they chose to recognize *C. caninoides* as their preferred name for this species, citing *C. circinans* as a synonym.

Robert Henry's original description (Kühner and Romagnesi 1953) lists the habitat as soil under pine and birch (*Betula* L.). Landry *et al.* (2021) reported three sequenced collections from Quebec and gave the habitat as being under conifers, possibly with Jack Pine (*Pinus banksiana* Lambert). Landry *et al.* (2022) reported what appear to be the same collections on soil under conifers and plantations of Jack Pine with poplars (*Populus* sp.). Our material was gregarious to clustered among Red-stemmed Feathermoss, associated with Heart-leaved Birch (*Betula cordifolia* Regel) and Balsam Fir.

***Cortinarius pseudobiformis* Bidaud & Carteret**

(Figures 2f, 3f)

*Pileus* convex when young and remaining so at maturity, with a low broad umbo, dry, silky-shiny, glabrous or with a very sparse covering of white universal veil material, dark reddish brown (HSV00:20:50), hygrophanous, with fading beginning in a ring surrounding the umbo, 38–40 mm in diameter, unchanging in KOH. *Stipe* tapering up gradually from an only very slightly enlarged base, thickly covered with the white silky universal veil, mostly white but with a very dilute violaceous colour at the apex, dry, 70 × 13 mm. *Lamellae* orange brown (HSV25:40:50–60), close, adnate to adnexed, finely eroded at the margin, not marginate. *Universal veil and cortina* white. *Flesh* concolorous with the surface tissues in the areas of the pileus surrounding the broad umbo but only in the uppermost 1 mm on the umbo, violaceous (HSV280:30–40:60–70) in the upper 20 mm of the stipe but with this colour soon fading to greyish when exposed to air, light brown (HSV25:40:60–70) in the stipe cortex, dull whitish in the umbo and lower part of the stipe, with a pronounced but nondescript mushroom odour and taste, unchanging in KOH.

*Basidiospores* weak reddish brown in spore print, elliptical to obovate in profile, rarely ovate, with a tapering apex, usually with a suprahilar flattening, coarsely roughened, strongly dextrinoid, 8.3–10.7 × 5.1–6.1 μm, Q = 1.42–1.82 (mean [53]: 9.5 ± 0.5 × 5.8 ± 0.2 μm, Q = 1.63 ± 0.09). *Basidia* clavate, four-spored, with a basal clamp connection, occasionally filled with a yellow-brown substance. *Cheilocystidia* not well defined, appearing as narrow clavate cells arising from the terminal ends of the lamellar trama. *Pileipellis* duplex, a cutis of narrow hyaline hyphae above a subpellis of short brown encrusted cells. *Clamp connections* present on most septa.

*Specimen examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.490°W, 17 June 2021, *D. Malloch 17-06-21/01* (NBM-F-009373), GenBank no. OP352906 (ITS).

*Cortinarius pseudobiformis* has a dark brown hygrophanous pileus, a nearly cylindrical stipe covered by a thick white universal veil, orange-brown lamellae, and violaceous flesh in the upper part of the stipe. Unlike other species in this report, it has markedly dextrinoid basidiospores. Landry *et al.* (2021) reported and illustrated this species from Quebec. The basidiomata in their photograph resemble our material except for the slightly bulbous base of the stipe. Although Landry *et al.* (2021) described the lamellae of their collection as brownish violet at first, we did not observe any violaceous colours in ours, perhaps because they were more mature.

This species is not commonly reported and habitat data are limited. Landry *et al.* (2022) report it on acid soil under fir trees among mosses near a bog. Landry *et al.* (2021) state it is found under Balsam Fir, poplar (“trembles”), and birch. Their illustrations show the habitat to be well drained and with Red-stemmed Feathermoss and *Dicranum* Hedw. Our collection was solitary in a well-drained area at the base of a mature Balsam Fir among numerous seedlings of that species, associated with Balsam Fir and a few individuals of Heart-leaved Birch. Its appearance in mid-June is much earlier than the Quebec collections.

***Cortinarius* subgenus *Telamonia*, section *Tortuosi******Cortinarius tortuosus* (Fr.) Fr.** (Figures 4a, 5a)

*Pileus* conic-turbinate at first, broadly convex at maturity, with a rounded to subacute umbo, dry, glabrous, chocolate brown (HSV25:80:30–40), strongly hygrophanous, 26–38 mm in diameter. *Stipe* equal or slightly swollen at the base, with a slightly flocculose annular zone in some but with this lacking in others, white with an appressed universal veil layer over a very pale straw-coloured ground colour, dry, 45–65 × 4–5 mm. *Lamellae* medium brown (HSV20:70:50–60), subclose, adnexed, not marginate. *Cortina* white, sparse, not visible on mature basidiomata. *Flesh* concolorous with the surface tissues in the pileus, pale yellow orange (HSV40:20:98) in the stipe, lacking a distinctive odour and taste.

*Basidiospores* orange brown in spore print, elliptical to ovate in profile, infrequently obovate, coarsely roughened, 8.0–11.5 × 5.0–6.1 μm, Q = 1.54–1.92 (mean [70]: 9.3 ± 0.5 × 5.4 ± 0.2 μm, Q = 1.71 ± 0.08). *Basidia* four-spored, clavate. *Hymenial cystidia* lacking. *Pileipellis* duplex, a cutis of narrow brown encrusted hyphae overlying a thicker layer of broad hyphae. *Clamp connections* produced at nearly all septa.

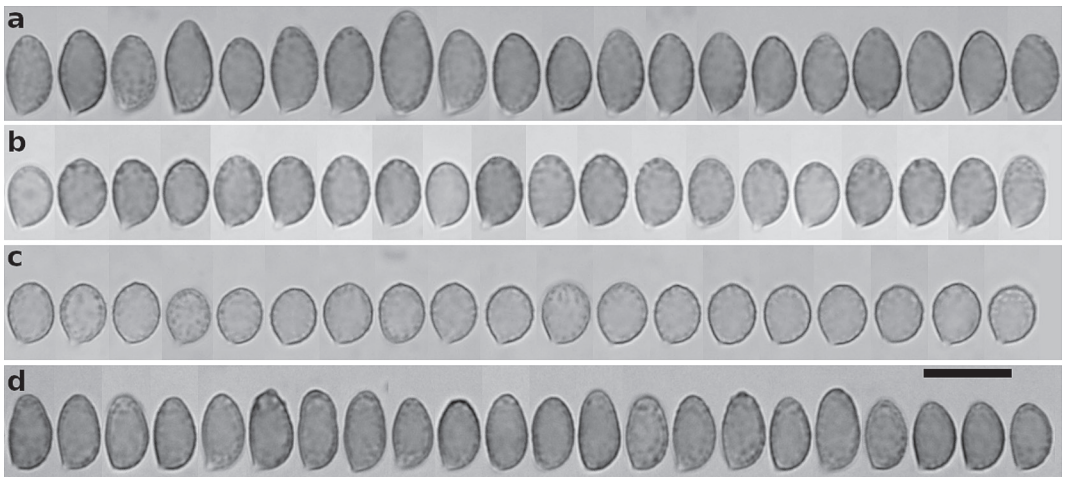
*Specimen examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.488°W, 27 September 2020, *D. Malloch 27-09-20/02* (NBM-F-009375), GenBank no. OP352907 (ITS).

Some earlier authors, e.g., Brandrud *et al.* (1998), included *C. tortuosus* in the section *Bicolores* along with the superficially similar *C. evernius*, but more recent molecular results (Liimatainen *et al.* 2022) suggest placement in a separate section. Although the stipe of *C. tortuosus* may be lightly violaceous at its apex (Brandrud *et al.* 1990), it is never as markedly violaceous throughout its length, inside and out, as that of fresh basidiomata of *C. evernius*.

The neotype was growing among *Sphagnum* in a spruce forest (probably Norway Spruce [*Picea abies* (L.) H. Karsten]) in Sweden. Liimatainen *et al.* (2017)



**FIGURE 4.** Basidiomata. a. *Cortinarius tortuosus*. b. *Cortinarius valgus*. c. *Cortinarius harvardensis*. d. *Cortinarius fulvescens*. Scale bar = 10 mm. Photos: D. Malloch.



**FIGURE 5.** Basidiospores. a. *Cortinarius tortuosus*. b. *Cortinarius valgus*. c. *Cortinarius harvardensis*. d. *Cortinarius fulvescens*. Scale bar = 10  $\mu$ m. Photos: D. Malloch.

stated that *C. tortuosus* has a very narrow ecological niche, growing in wet and acidic soils with conifers. Soop (2021) reported that, in Sweden, it is fairly common in moist spruce forests, often in *Sphagnum*. Landry et Labbé (2022) report it in Quebec on poorly drained soil in coniferous forests, usually in

*Sphagnum*. Our collection was not in *Sphagnum* but was clustered among Red-stemmed Feathermoss, associated with Heart-leaved Birch and Balsam Fir. There are other collections of this species in the herbarium of the NBM, but these have not been confirmed genetically.

***Cortinarius* subgenus *Telamonia*, section *Valgi******Cortinarius valgus* Fr. (Figures 4b, 5b)**

*Pileus* conic-convex at first, expanding to more broadly so at maturity, with a low rounded umbo, dry, glabrous except for the minutely white-fibrillose margin, dark orange brown (HSV25:50:50) when young and fully hydrated, strongly hygrophanous and soon fading and revealing some orange shades on the umbo, 21–43 mm in diameter. *Stipe* equal down to the distinctly bulbous base, slightly white fibrillose with veil material but otherwise glabrous, with a weakly defined annular zone when young, mostly pale straw coloured with some darker regions below, very obscurely violaceous at the apex, dry, 40–60 × 4–8 mm. *Lamellae* light brown (HSV30:30–40:70), subclose, adnexed, not marginate. *Cortina* not seen. The universal veil as seen on the stipe and pileus margin is sparse but appears to be white. *Flesh* pale greyish white, lacking a distinctive odour and taste.

*Basidiospores* orange brown in spore print, broadly elliptical to slightly ovate in profile, less frequently slightly obovate, coarsely roughened, slightly dextrinoid, 6.9–9.7 × 4.9–6.7 μm, Q = 1.30–1.65 (mean [40]: 7.9 ± 0.6 × 5.4 ± 0.4 μm, Q = 1.45 ± 0.06). *Hymenial cystidia* lacking. *Basidia* clavate, four-spored, with a basal clamp connection. *Pileipellis* a thin cutis of narrow brown encrusted hyphae, not clearly duplex and with hypoderm poorly defined. *Clamp connections* present throughout.

*Specimen examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.488°W, 27 September 2020, *D. Malloch 27-09-20/04* (NBM-F-009377), GenBank no. OP352908 (ITS).

This collection is difficult to characterize. Landry *et al.* (2021) reported *C. valgus* from Quebec and stated that their collection's ITS sequence was identical to that of the neotype, as is ours. They describe their basidiomata as having some slightly olivaceous colours, the pileus with an uneven margin, and the lamellae slightly violaceous when young.

We did not observe any violaceous colour in our collection. *Cortinarius rheubarbarinus* Rob. Henry, a later synonym with ITS sequence identical to that of *C. valgus* (Liimatainen *et al.* 2020), was illustrated by Brandrud *et al.* (1992, 1994). Although their collections resemble ours, they were described as growing in dry calcareous soil in association with beech, hornbeam (*Carpinus* L.), and oak (*Quercus* L.). It is possible that these collections have not been sequenced.

According to Soop (2021), *C. valgus* grows in both acidic and richer forests of spruce. Landry *et al.* (2022) report two collections from Quebec as growing on soil in young plantations of spruce and pine. The New Brunswick material was clustered in a relatively moist rocky site among *Sphagnum* sp. and

Red-stemmed Feathermoss, associated with Heart-leaved Birch and Balsam Fir.

***Cortinarius* subgenus *Camphorati*, section *Anomali******Cortinarius harvardensis* L. Nagy, Dima & Ammirati (Figures 4c, 5c)**

*Pileus* conical when young, expanding to more broadly so at maturity, with a low rounded umbo or without an umbo, dry to moist, glabrous, light orange brown (HSV30-40:30:70–100) and dull grey (HSV15:05:70) toward the margin when young, later maintaining the colour on the umbo but otherwise dull orange grey (HSV25:05:90; photos show violaceous colours in the cap not recorded in the description), possibly hygrophanous, 16–41 mm in diameter. *Stipe* equal down to the swollen base, without a distinct bulb, slightly white fibrillose with veil material but otherwise glabrous, with a moderately well-defined annular zone when young, mostly white, very obscurely violaceous at the apex, dry, 36–78 × 3–8 mm. *Lamellae* light brown (HSV30:30:60–80) to dull violaceous grey (HSV310:10–15:70), subclose to close, adnexed, not marginate. *Cortina* possibly white. *Flesh* dark bluish grey (HSV280:10:50) to dull reddish grey (HSV00:10:60) in the pileus, violaceous grey (HSV270:20–30:50) in the centre of the upper stipe, concolourous with the surface tissues in the cortex of the stipe, paler grey in the rest of the stipe context, concolourous with the surface tissue in the stipe cortex, lacking a distinctive odour and taste.

*Basidiospores* reddish brown in spore print, broadly elliptical to slightly obovate in profile, less frequently slightly ovate, finely echinulate-roughened, 6.6–9.9 × 5.3–6.6 μm, Q = 1.22–1.49 (mean [80, of two collections]: 7.5 ± 0.5 × 5.8 ± 0.2 μm, Q = 1.28 ± 0.05). *Basidia* clavate, four-spored, with a basal clamp connection. *Hymenial cystidia* lacking. *Lamellar trama* parallel, with a few adhering colourless crystals but not encrusted with pigment material. *Pileipellis* duplex, a cutis of hyphae one or two cells deep overlying a compact subpellis of short broad hyphae, with cuticular hyphae containing a yellowish cytoplasmic pigment. *Clamp connections* on nearly all hyphae.

*Specimens examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.490°W, 27 September 2020, *D. Malloch 27-09-20/02* (NBM-F-009369), GenBank no. OP352904 (ITS); Little Lepreau, 45.135°N, 66.487°W, 27 September 2020, *D. Malloch 27-09-20/05* (NBM-F-009376), GenBank no. OP352908 (ITS).

Reported from Massachusetts (holotype), Nova Scotia, and Quebec by Dima *et al.* (2021). It is characterized by its orange-brown to bluish-grey pileus, its white stipe with flesh in upper part blue, and lamellae

that are blue at first. The subglobose basidiospores are also characteristic.

The type was reported to be associated with pine and oak (Dima *et al.* 2021). Landry et Labbé (2022) list three Quebec specimens confirmed by sequences. No species of oak were recorded from any of the Quebec localities. All of the photos of Quebec material, except one made on a scanner, show well-drained habitats with Red-stemmed Feathermoss. Records from Nova Scotia include three collections made by Keith N. Egger, all found in association with Eastern Hemlock (*Tsuga canadensis* (L.) Carrière) and verified by ITS sequences (<https://mushroomobserver.org/470612>, <https://mushroomobserver.org/496070>, <https://mushroomobserver.org/496079>). An additional Nova Scotia record is from an environmental sequence obtained from roots of Red Spruce by Gavin Kernaghan (GenBank MK131480). One of the two New Brunswick collections was clustered among *Dicranum* sp. and Red-stemmed Feathermoss, associated with Heart-leaved Birch and Balsam Fir (NBM-F-009376). The other was among *Dicranum* spp. and Red-stemmed Feathermoss in wet forest, associated with Balsam Fir, Black Spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenburg), Tamarack (*Larix laricina* (Du Roi) K. Koch), and Heart-leaved Birch (NBM-F-009369).

***Cortinarius* section *Fulvescentes***—position in *Cortinarius* currently unresolved

***Cortinarius fulvescens* Fr.** (Figures 4d, 5d)

*Pileus* convex-hemispherical at first, expanding to more broadly so at maturity, with a low inconspicuous umbo, moist, glabrous to very finely appressed fibrillose, chestnut brown (HSV00:60–70:40) throughout at first, later becoming orange yellow (HSV45:50:100) beneath the reddish colour at the margin, not hygrophanous, 18–30 mm in diameter. *Stipe* equal down to the slightly enlarged base, dull greyish white but becoming light reddish brown (HSV15:30:70) where handled, dry, minutely fibrillose, 25–38 × 3–6 (9) mm. *Lamellae* light yellow brown (HSV35:30–40:80–90) at first, bright orange brown (HSV35:70:90) at maturity, subclose, adnexed, not marginate. *Cortina* white. *Flesh* concolorous with the surface tissue in the pileus, bright orange brown (HSV35:70:60–80) in the stipe, lacking a distinctive odour and taste.

*Basidiospores* bright rusty orange brown (HSV 35:80:80) in spore print, narrowly ovate to elliptical in profile, less frequently obovate, coarsely roughened, unchanging in Melzer's solution,  $7.4\text{--}9.7 \times 4.5\text{--}5.7 \mu\text{m}$ ,  $Q = 1.48\text{--}2.00$  (mean [56]:  $8.5 \pm 0.5 \times 4.9 \pm 0.2 \mu\text{m}$ ,  $Q = 1.73 \pm 0.10$ ). *Basidia* clavate, four-spored, with a basal clamp connection. *Hymenial*

*cystidia* lacking. *Pileipellis* duplex, a thin cutis of narrow finely encrusted hyphae over a subpellis of short-celled broad hyphae. *Clamp connections* present on most septa.

*Specimen examined*—CANADA, New Brunswick, Charlotte Co., Little Lepreau, 45.135°N, 66.490°W, 18 October 2020, D. Malloch 18-10-20/02 (NBM-F-009372), GenBank no. OP352902 (ITS).

The overall appearance of this collection is similar to that of *C. valgus*. It differs in the more orange-brown colour of the lamellae and in the orange-brown colour of the flesh of the stipe. Landry *et al.* (2021) note that the bands of reddish-brown veil material on the surface of the stipe are a diagnostic feature of the Quebec material. This may also be true of our collection, although much of the brown colour appears to be due to bruising.

The habitat range of *C. fulvescens* appears to be fairly broad. The neotype from Finland was collected in submesic forest dominated by Norway Spruce mixed with some birch and European Aspen (*Populus tremula* L.; Hyde *et al.* 2016). Soop (2021) reported it in Swedish spruce forests, often near *Sphagnum*. According to Hyde *et al.* (2016), it grows in mesic to dry coniferous forests with spruce and/or pine and hemlock (*Tsuga* (Endler) Carrière). Landry et Labbé (2022) report sequenced material from Quebec collected in sandy soil among mosses in coniferous forests and plantations with fir, pine, and spruce. The New Brunswick collection was gregarious in gravel at the edge of a driveway, associated with Heart-leaved Birch and Balsam Fir. The uncharacteristically short stipe in this collection was probably because of the rather thin disturbed soil.

## Discussion

Seven species, *C. caninoides*, *C. cincinnata*, *C. fulvescens*, *C. harvardensis*, *C. plumulosus*, *C. pseudo-biformis*, and *C. valgus*, are new distribution records for New Brunswick. The collection of *C. plumulosus* may also be a new record for North America. Although previous collections of *C. evernius*, *C. gentilis*, and *C. tortuosus* from New Brunswick have been accessioned in the herbarium of the NBM, their identification has not been confirmed genetically. Most datasets for species of *Cortinarius* generated using molecular techniques have been based on the ITS and LSU regions (Landry *et al.* 2021; Liimatainen *et al.* 2022). Our results are thus consistent with recent usage.

All of the collections presented here, except *C. cincinnata*, were made close to the shore of the Bay of Fundy in southeastern Charlotte County, New Brunswick. This area is in the Fundy Coast Ecoregion (Zelazny 2007). Clayden *et al.* (2011) characterized this region as having a “perhumid” climate, one

in which precipitation much exceeds evaporation and plant transpiration, resulting in year-round wetness. Fog occurs frequently during the summer. Mean summer temperatures are about 14.5°C and mean annual precipitation is 1000–1400 mm (McAlpine and Smith 2010). The vegetation is mainly boreal to hemiboreal, characterized by low-diversity stands of Red Spruce, Black Spruce, Balsam Fir, and Heart-leaved Birch. Much of the understorey is dominated by bryophytes, especially carpets of the mosses Red-stemmed Feathermoss, Broom Forkmoss (*Dicranum scoparium* Hedw.), Glittering Woodmoss (*Hylocomium splendens* (Hedw.) Schimp.), Knights Plume Moss (*Ptilium crista-castrensis* (Hedw.) De Not.), and *Sphagnum* spp., and the liverwort Greater Whipwort (*Bazzania trilobata* (L.) Gray).

*Cortinarius cicindela* was collected in the Butter-milk Ecodistrict of the Valley Lowlands Ecoregion, an area characterized by a greater representation of shade-tolerant hardwoods mixed with fir and spruce (Zelazny 2007). The annual precipitation is 1000–1300 mm (McAlpine and Smith 2010), but summers are warmer and less foggy and winters colder than in the Fundy Coast Ecoregion, so more of this may come from snow.

### Author Contributions

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

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## Note

### A substantial eastern disjunction of Douglas' Knotweed (*Polygonum douglasii* Greene, Polygonaceae) in New Brunswick, Canada

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#### Abstract

We report an isolated population of the native annual Douglas' Knotweed (*Polygonum douglasii* Greene) from a dry, south-facing outcrop of conglomerate and sandstone at Big Bluff, near Sussex Corner, New Brunswick, Canada, consisting of about 2500 plants in 2018 and 2022. This occurrence is disjunct by ~450 km from the eastern limit of the known range of Douglas' Knotweed in southwestern Maine, USA. The nearest known occurrence in Canada is in southern Quebec, ~660 km from Big Bluff. Several lines of evidence indicate that the population in New Brunswick is native. New state records for Wisconsin and Alaska found in online data sources are also verified.

Key words: Range disjunction; *Polygonum douglasii*; Douglas' Knotweed; New Brunswick; Wisconsin; Alaska

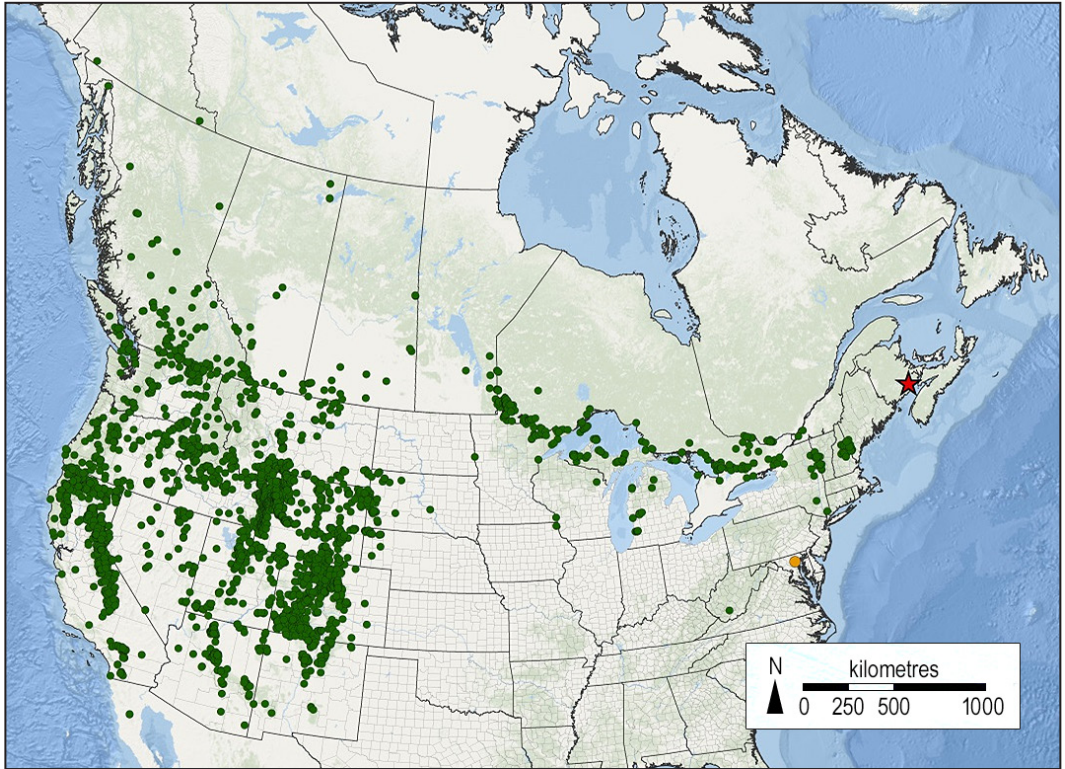
Douglas' Knotweed (*Polygonum douglasii* Greene, Polygonaceae) is an endemic North American species of dry, open, usually rocky habitats. It occurs in western montane regions from southern Yukon to northern Mexico and irregularly eastward through the southern boreal forest, the Great Lakes region, and into New England (Figure 1). Here we document a previously unreported occurrence at Big Bluff, Kings County, New Brunswick (Figures 2 and 3). This is the first report of the species in New Brunswick where it is disjunct beyond the eastern limit of its continuous range by ~450 km.

On 30 June 2018, we collected immature plants too young for definitive identification, but believed to be Douglas' Knotweed, at Big Bluff, and cultivated them off-site in garden soil. We photographed flowering cultivated plants on 8 August 2018 and collected vouchers from the wild population on 14 August 2018 (G. Bishop GB 18-632; NBM VP-043980 and UNB 69470, New Brunswick Museum and University of New Brunswick herbaria, respectively). Our determination of the specimens as Douglas' Knotweed relied primarily on the Flora of North America treatment (Costea *et al.* 2005).

Douglas' Knotweed is a slender, annual member of *Polygonum* section *Duravia* S. Watson (sometimes treated as the genus *Duravia* (S. Watson) Greene, as in Weakley and Southeastern Flora Team 2022). The section *Duravia* includes 18 species that occur west of the Mississippi River as well as Douglas' Knotweed and Slender or Pleat-leaved Knotweed (*Polygonum tenue* Michaux), found in eastern North America (Costea and Tardif 2005; Costea *et al.* 2005). Molecular research suggests that species formerly treated in the genus *Polygonella* Michaux also belong within *Polygonum* section *Duravia* (Schuster *et al.* 2011).

Douglas' Knotweed plants from Big Bluff have flat (unpleated) leaves with ocreae 2–6 mm long, pedicels >2 mm long and reflexed so that the flowers face downward, flowers partly open, and perianth >2 mm long. These characteristics separate them from Pleat-leaved Knotweed (pleated leaves, ocreae 6–15 mm long, pedicels to 1.5 mm long and erect, flowers closed, perianth 2.5–4.2 mm). Coastal Jointweed (*Polygonum articulatum* L.) is the only other member of section *Duravia* in the northeastern United States and adjacent Canada. It has spread to sandy roadsides in southwest New Brunswick from its native range

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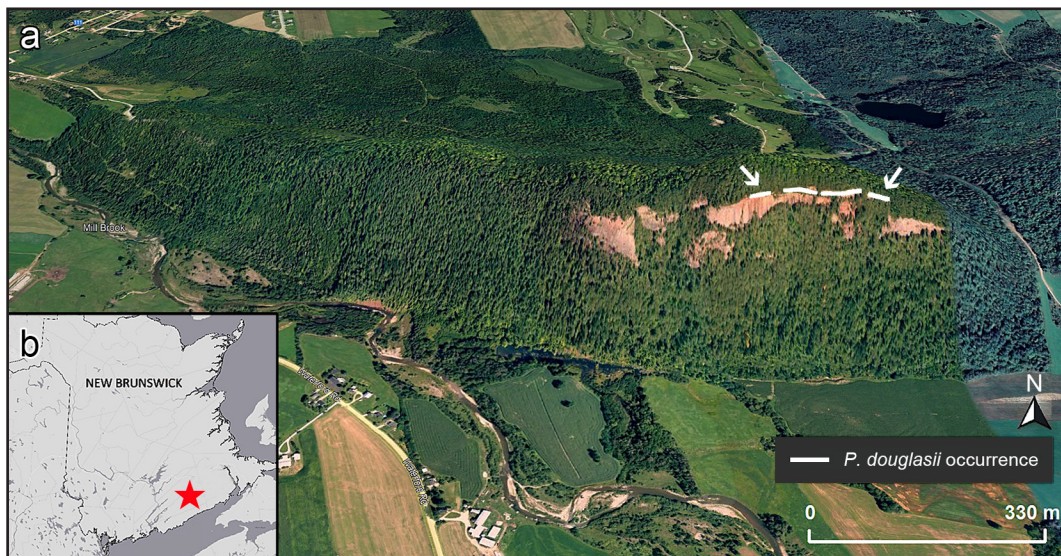
**FIGURE 1.** Distribution of Douglas' Knotweed (*Polygonum douglasii*) based on compiled digital records (data provided in Appendix S1). Sources were: Kartesz (2015), AC CDC (2022), GBIF (2022), New York Flora Atlas (2022), SEINet (2022), Centre de Données sur le Patrimoine Naturel du Québec (pers. comm. 5 October 2022), Saskatchewan Conservation Data Centre (pers. comm. 13 October 2022), Fraser Herbarium at University of Saskatchewan (pers. comm. 19 October 2022), specimen records of Daniel Brunton (pers. comm. 24 May 2023), and the personal observations of C.S.B. The star in New Brunswick is the occurrence at Big Bluff. The Maryland occurrence (orange dot) is introduced (C. Frye pers. comm. 13 October 2022); all other records are considered native (NatureServe 2023).

south and west of the province (Hinds 2000; Hill and Blaney 2010) but differs from Douglas' Knotweed in having minute and early-deciduous leaves, pedicels with a swollen joint, and strongly overlapping ocreae (versus persistent leaves, pedicels not swollen, ocreae not strongly overlapping; Costea and Tardif 2005; Costea *et al.* 2005). All other New Brunswick *Polygonum* species are classified in the cosmopolitan *Polygonum* section *Polygonum*, from which Douglas' Knotweed differs in having leaves that lack obvious secondary veins (versus leaves with distinct pinnate venation), nodding pedicellate flowers well-exserted from the ocreae (versus flowers enclosed within or only slightly exserted from the ocreae), four-angled stems (versus 8–16-ribbed stems), and pink to purple anthers (versus whitish yellow anthers).

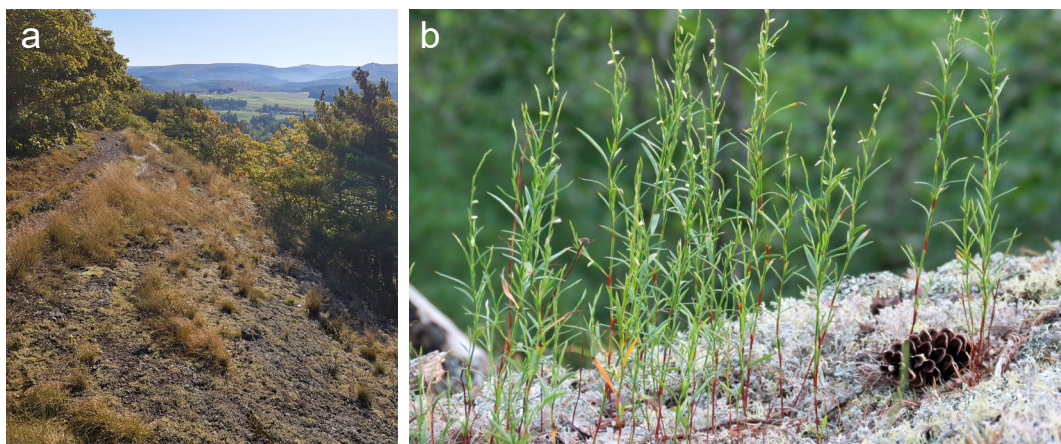
The Douglas' Knotweed population at Big Bluff occurs on thin soil in a narrow band (up to ~7 m wide) of open habitat along the crest of the exposed bluff and slightly down the slope, at an elevation of ~150

m above sea level. The occurrence extends ~255 m from east to west, centred at 45.6997°N, 65.4407°W (Figures 2 and 3). Plants occur fairly continuously with sporadic gaps of 10–50 m. The population consisted of ~2500 plants in 2018 and 2022. Many individuals exhibit thin, unbranched stalks ~20 cm tall, and the largest plants are 35–40 cm tall with multiple branches. Plants are most plentiful in narrow, linear troughs about 10–20 cm wide and 3–7 m long along the bluff. Plants are generally absent immediately adjacent to a footpath that runs along the top of the bluff, where a dense band of the introduced Canada Bluegrass (*Poa compressa* L.) predominates.

The substrate at the site consists of sandstone conglomerate, listed in Barr *et al.* (2005) as red to grey, granule to cobble polymictic conglomerate and lithic sandstone. At the Big Bluff site, plants occupy dry, rocky, sparsely vegetated openings below a moderately open and dry ridge-top forest dominated by Red Oak (*Quercus rubra* L.). Other locally frequent species



**FIGURE 2.** a. Location of Douglas' Knotweed (*Polygonum douglasii*) at Big Bluff, Sussex Corner, New Brunswick, Canada, 45.6998°N, 65.4409°W. The line indicates the extent of the *P. douglasii* occurrence on Big Bluff. Image source: Google Earth Pro 7.3.4.8642. Imagery date: 22 August 2008. Data provider: CNES/Airbus. Accessed 10 October 2022. b. Location of Douglas' Knotweed occurrence in New Brunswick. Base maps from ESRI ArcGIS.



**FIGURE 3.** a. Douglas' Knotweed (*Polygonum douglasii*) ridge crest habitat with heavily used walking trail running through it. b. Plants growing *in situ* at Big Bluff, 30 June 2018. Photo a: Stephen Clayden. Photo b: James Goltz.

associated with Douglas' Knotweed at the site include native vascular plants Poverty Oat-grass (*Danthonia spicata* (L.) Beauvois ex Roemer & Schultes), Rock Spikemoss (*Selaginella rupestris* (L.) Spring), Common Bearberry (*Arctostaphylos uva-ursi* (L.) Sprengel), Three-toothed Cinquefoil (*Sibbaldia tridentata* (Aiton) Paule & Soják), Cow-wheat (*Melampyrum lineare* Desrousseaux), White Goldenrod (*Solidago bicolor* L.), and Round-leaved Serviceberry (*Amelanchier sanguinea* (Pursh) de Candolle) along with non-native Common St. John's-wort (*Hypericum*

*perforatum* L.) and Canada Bluegrass. Bristly Haircap Moss (*Polytrichum piliferum* Hedwig), Fire Moss (*Ceratodon purpureus* (Hedwig) Bridel), Green Reindeer Lichen (*Cladonia mitis* Sandstede), Thorn Lichen (*Cladonia uncialis* (L.) Weber ex F.H. Wiggers), Easter Foam Lichen (*Stereocaulon paschale* (L.) Hoffmann), Peppered Rock-shield Lichen (*Xanthoparmelia conspersa* (Acharius) Hale), and Cumberland Rock-shield Lichen (*Xanthoparmelia cumberlandia* (Gyelnik) Hale) are also associated with Douglas' Knotweed at Big Bluff.

Douglas' Knotweed is rare along the eastern margin of its range, with NatureServe ranks of S3 (Vulnerable) in Quebec, S2 (Imperilled) in Vermont, New Hampshire, and Maine, S1S2 (Critically Imperilled to Imperilled) in New York, and SH (Possibly Extirpated) in West Virginia (NatureServe 2023), although Harmon *et al.* (2006) considered the West Virginia population of *P. douglasii* spp. *douglasii* to be adventive (North American native arriving in West Virginia without known intentional introduction). The known occurrences nearest to New Brunswick are in southwestern Maine, 450 km southwest of Big Bluff (Maine Natural Areas Program 2022). The nearest occurrences in Canada are in southern Quebec in the vicinity of Montréal, 660 km west of Big Bluff. A record from the Québec City area (*Néron 80-233*, QFA0488505 [Herbier Louis-Marie], <https://www.gbif.org/occurrence/1248740155>) was determined to be Marshpepper Smartweed (*Persicaria hydropiper* (L.) Delarbre; J. Labrecque pers. comm. 5 October 2022).

Several lines of evidence contribute to our conclusion that Douglas' Knotweed at Big Bluff is native. First, human-assisted transport over long distances from natural openings is not frequent based on the comments of experienced eastern North American field botanists (e.g., C.S.B. pers. obs. [Ontario]; pers. comm. 13 October 2022 from Don Cameron [Maine], Aaron Marcus [Vermont], Jacques Labrecque [Quebec], Michael Oldham [Ontario], and Anton Reznicek [Michigan]). Aside from the possibly adventive record in West Virginia, the only known instance of extra-limital occurrence is a single Maryland record. It was reported from an ore pile on the Baltimore waterfront (Reed 1964), and the species is not considered a persistent member of the Maryland flora (C. Frye pers. comm. 13 October 2022).

Second, the extensive dry, south-facing rock barren habitat at Big Bluff supports at least three other provincially rare native species of southern and western affinity, two of which are also at or near their extreme eastern range limit: Rock Spikemoss, S1 in New Brunswick, and Back's Sedge (*Carex backii* Boott), S1 in New Brunswick (AC CDC 2022). The third rare species is American False Pennyroyal (*Hedeoma pulegioides* (L.) Persoon), S3 in New Brunswick and in Nova Scotia.

Third, habitat at Big Bluff is typical of other natural occurrences of the species in eastern North America, e.g., "rocky slopes and dry soil" in northeast North America (Fernald 1950: 580); "rocky summits and rock outcrops in forest openings, woodlands, and graminoid dominated native meadows ... in cracks in non-shaded calcareous bedrock outcrops" in New York (New York Flora Association 2022); and "thin

soil of ledges, cliff bases, and rocky woodlands" in New England (Native Plant Trust 2022).

The absence of Douglas' Knotweed records at Big Bluff before 2018 despite at least nine visits by knowledgeable botanists (AC CDC 2022) is likely a result of the species being overlooked. Most visits were by botanists not familiar with the species and at least seven of the visits were before its mid-July flowering time or in late summer or autumn when plants may have dropped leaves and fruit.

Douglas' Knotweed is currently ranked S1 (Critically Imperilled) in New Brunswick by the Atlantic Canada Conservation Data Centre and New Brunswick Department of Natural Resources and Energy Development (AC CDC 2022). The species is intrinsically vulnerable in the province because of its limited range and small total population. Furthermore, it is significantly threatened by heavy use of the popular Sussex Bluffs Trail, which can damage or kill developing plants, promote plant community change toward dominance of exotic Canada Bluegrass, and permanently remove habitat via erosion of the thin layer of soil and vegetation over bedrock (Figure 3). A substantial portion of its open slope rim habitat, which is generally <7 m wide, is occupied by the trail, and trail impacts are likely increasing.

In researching this paper, we verified new state records of Douglas' Knotweed from Wisconsin (45.335262°N, 88.252213°W, 15 August 2022, observed by Schmitt [iNaturalist 2023a]; 45.32368°N, 88.34930°W, 19 June 2022, observed by Nate Martineau [iNaturalist 2023b]; identifications of both observations verified by C.S.B. and M. Costea) and Alaska (edge of highway ca. 18 miles [29 km] north of Haines, 4 August 1975, *J. Taylor 20084*, KANU-269308 [R.L. MacGregor Herbarium, Kansas University], <https://www.gbif.org/occurrence/177009443>; verified by C. Freeman, pers. comm. 28 October 2022). The absence of previous state records for Wisconsin was confirmed by M. Feist (pers. comm. 19 October 2022) and for Alaska by J. Fulkerson (pers. comm. 28 October 2022). The Wisconsin occurrences should be documented with voucher specimens.

Four states, for which the only records we are aware of are collections mediated by GBIF (2022) or in Costea *et al.* (2005), are excluded from the distribution of Douglas' Knotweed based on the following.

- Texas: 2 mi. [3 km] E of Glenrio, 17 August 1960, *S.F. Glassman 5436*, F-2265123 [Field Museum], <https://www.gbif.org/occurrence/1424771927>; misidentified, a *Polygonum* section *Polygonum* species.
- Oklahoma: NY [New York Botanical Garden], <https://www.gbif.org/occurrence/1929076579>. Databasing error. This sheet contains two col-

lections. NY 04266953 is *Polygonum douglasii* from “Banner County, Nebraska, 10 July 1891, *P.A. Rydberg 346*”. NY 03141693 from “Oklahoma, Indian Territory, chiefly on the False Washita [River], between Fort Cobb and Fort Arbuckle, 1868, *E. Palmer 288*”, includes immature plants identified as *P. tenue* by Palmer, and is annotated in pencil as “not *douglasii*” by a later botanist.

- Illinois: Beardstown, 17 August 1924, *H.C. Benke 3924*, F-V0388004F (<https://www.gbif.org/occurrence/1424771939>); identification not confirmable via image by taxon expert M. Costea (pers. comm. 19 October 2022), and the similar *Polygonum tenue* would be more likely in southern Illinois.
- Virginia: Reported from Virginia in Costea *et al.* (2005), but origin of report not known to Costea (pers. comm. 19 October 2022) nor to Virginia Natural Heritage Program (J. Townsend pers. comm. 13 October 2022), and also excluded by Weakley *et al.* (2022).

### Author Contributions

Conceptualization: G.B., C.S.B., S.R.C., and J.P.G.; Investigation: G.B., C.S.B., S.R.C., and J.P.G.; Writing – Original Draft: C.S.B., G.B., and S.R.C.; Writing – Review & Editing: C.S.B., G.B., and S.R.C.

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collection records. John Townsend (Virginia Natural Heritage Program) provided information on the Virginia report of *P. douglasii* in Flora of North America. Chris Frye (Maryland Natural Heritage Program) provided details of the ephemeral Maryland occurrence reported from Baltimore. Craig Freeman (Kansas Biological Survey) confirmed the identification of the Alaska specimen at University of Kansas. Justin Fulkerson (Alaska Natural Heritage Program) and Mary Ann Feist (Wisconsin Herbarium, University of Wisconsin at Madison) confirmed that Alaska and Wisconsin records represented first occurrences for their states. Charity Robicheau (Atlantic Canada Conservation Data Centre) produced the maps.

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#### SUPPLEMENTARY MATERIAL:

**APPENDIX S1.** Data used to generate distribution map of Douglas' Knotweed (*Polygonum douglasii*).

## The lichen genus *Rinodina* (Physciaceae) in New Brunswick, Canada

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### Abstract

Fifteen species of the crustose lichen genus *Rinodina* are confirmed in New Brunswick, Canada. We report four corticolous species, *Rinodina pachysperma*, *Rinodina populicola*, *Rinodina septentrionalis*, and *Rinodina tenuis*, and the saxicolous *Rinodina tephrae* in the province for the first time. A previous report of *Rinodina granuligera* is based on a specimen that we have re-identified as *Rinodina cinereovirens*. We note distinguishing characteristics, habitats, substrata, relative abundance, and biogeographic relationships of each species and provide an identification key and distribution maps. The most frequently occupied phorophytes (tree substrata) are Sugar Maple (*Acer saccharum*), Yellow Birch (*Betula alleghaniensis*), and Eastern White Cedar (*Thuja occidentalis*). Some species are closely associated with particular habitats, phorophytes, or both. For example, we found *R. pachysperma* only in floodplain forests dominated by Silver Maple (*Acer saccharinum*), and *R. tenuis* only on Eastern White Cedar in wet cedar-dominated stands. In contrast, we recorded *Rinodina freyi* on numerous phorophyte species in a relatively wide range of habitats. Other than Eastern White Cedar and Balsam Fir (*Abies balsamea*), conifers are rarely colonized by *Rinodina* species in New Brunswick. Most *Rinodina* species are probably not currently of conservation concern in the province. However, *R. cinereovirens* is known from only two collections, one dating from 1902. The other, from 2007, was on Black Ash (*Fraxinus nigra*) in a swamp forest next to an active peat-mining operation. The expected devastation of ash species by the invasive Emerald Ash-borer (*Agrilus planipennis*) is a further threat to this occurrence and to any lichens for which ash may be an important phorophyte.

Key words: Biogeography; disjunct distribution; Atlantic Canada; Wolastoq (Saint John River); protected natural areas; phorophyte; conservation; seasonality of spore production

### Introduction

The lichen-forming ascomycete genus *Rinodina* (Ach.) Gray includes species that share a crustose growth form, apothecia mostly with a thalline margin and unpigmented hypothecium, and brown, mostly 1-septate ascospores with unevenly thickened inner walls (Sheard 2010). Their green algal symbionts are species of *Trebouxia* Puym. (Helms *et al.* 2001; Sanders and Masumoto 2021). The name “Pepperspore Lichens” was introduced for the genus *Rinodina* by Brodo *et al.* (2001), but most of its species lack common names. Over the past few decades, molecular phylogenetic studies have shown that the combination of characters defining *Rinodina* is represented in several distinct lineages in the family Physciaceae (e.g., Helms *et al.* 2003; Nadyeina *et al.* 2010; Resl *et al.* 2016; Kondratyuk *et al.* 2021). Independent transitions between crustose and foliose or squamulose growth forms have occurred in some of

these lineages. Although the polyphyletic character of the genus is clear from these findings, some clades including species of *Rinodina sensu lato* (*s.l.*, in the broad sense) are not yet well resolved within the Physciaceae, and the placements of many species remain uninvestigated. For these reasons, the genus is still widely treated in its broad sense.

Collectively, *Rinodina* species are distributed from subtropical to Arctic/subantarctic and alpine environments, and they occur on many substrata, including rock, tree bark, wood, bryophytes, plant debris, and soil. Knowledge of their species-level diversity and distributions has advanced greatly in recent decades. A monograph of the genus in North America north of Mexico by Sheard (2010), based on more than 40 years of study, recorded 96 species. Publication of this work catalyzed other investigations, bringing the number of species currently known in North America to 113 (Sheard 2018; Lendemer *et al.* 2019; Morse

and Sheard 2020). Comparable progress in the study of *Rinodina* in eastern Asia has led to further changes in the taxonomy and known distributions of several North American species (Sheard *et al.* 2017).

The regional diversity of *Rinodina* in North America is greatest in the cordilleran and coastal systems of the west. For example, 51 species are known in California and at least 37 in British Columbia (Sheard 2010, 2018). About half as many species occur in areas of roughly comparable size in eastern North America (Sheard 2010). Intensive recent studies of *Rinodina* in the southern Appalachian Mountains have recorded 22 species (Lendemer *et al.* 2012, 2014, 2019; Sheard *et al.* 2012). Five of these, including two regional endemics, had not been described previously, highlighting the significance of the southern Appalachians as a hotspot of lichen diversity (Tripp and Lendemer 2019). In New England and eastern Canada, state and provincial records of *Rinodina* species confirmed by Sheard (2010) have been supplemented in some cases by recent or updated general lichen surveys. For example, Seaward *et al.* (2017) reported 10 species from the coastal region of eastern Maine, and Brodo *et al.* (2021a,b) 15 species from the Ottawa region of Ontario and Quebec.

In this paper, we aim to assess the diversity, distributions, habitats, and relative abundance of *Rinodina* species in the maritime eastern Canadian province of New Brunswick. Eleven species were reported for the province by Sheard (2010, 2018): *Rinodina ascociscana* (Tuck.) Tuck., *Rinodina cinereovirens* (Vain.) Vain., *Rinodina efflorescens* Malme, *Rinodina freyi* H. Magn., *Rinodina gennarii* Bagl., *Rinodina granuligera* H. Magn., *Rinodina moziana* (Nyl.) Zahlbr., *Rinodina polyspora* Th. Fr., *Rinodina subminuta* H. Magn., *Rinodina subpariata* (Nyl.) Zahlbr., and *Rinodina willeyi* Sheard & Giralt. Most of these records are based on only a few specimens. An in-depth study of the lichens of Fundy National Park in New Brunswick by Gowan and Brodo (1988) detailed the local habitats and substrata of five species. Over the past few decades, wide-ranging surveys of lichen diversity in the province have yielded many new *Rinodina* collections. From this material, we have been able to gain a better understanding of the status of the species reported by Sheard (2010, 2018) and to add five species that were not previously known to occur in the province.

## Study Area

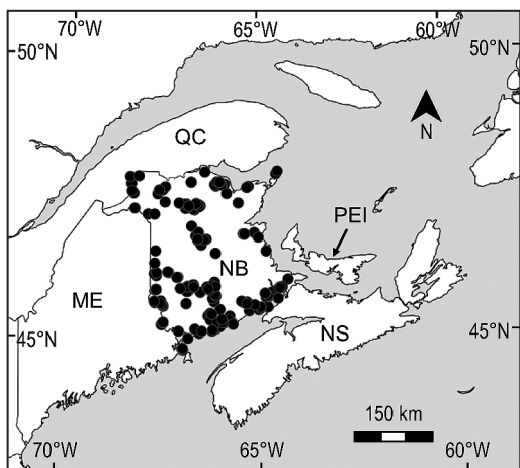
New Brunswick is about 73 000 km<sup>2</sup> spanning 3.5 degrees of latitude and 5 degrees of longitude: 44.5° to 48°N, 64° to 69°W. It includes part of the northern Appalachian Mountain system, with elevations ranging from sea level along its coasts to 820 m in the northern interior. The climate is intermediate between

continental and oceanic types, being dominated by airflows from the west but moderated by maritime influences (Hare and Thomas 1974). Conditions are most oceanic near the Bay of Fundy in the south, with January mean temperature −6° to −8°C, July/August mean 15° to 17°C, and precipitation 1300 to 1500 mm/yr. In the most continental areas, January and July means are −12° to −14°C and 16° to 19°C, respectively, and precipitation averages 1000 to 1200 mm/yr. Degree-days above 5°C vary from less than 1200 at elevations above 600 m in the highlands to more than 1900 in the middle Wolastoq (Saint John River) valley (Hassan *et al.* 2007; Clayden 2010; ECCC 2022).

The province falls largely within the Acadian Forest Region (Rowe 1972), which is the northeasternmost portion of the transition between temperate deciduous and boreal coniferous forests in North America. In the bioclimatic system of Tuhkanen (1984), New Brunswick is mainly in the hemiboreal zone, with some representation of the southern boreal zone in its northern highlands and of the north/cool temperate zone in the southern interior (Clayden 2010). Climatic and associated vegetation gradients in the province are not simply orientated along a south-north axis. Instead, topographic, coastal–inland, and latitudinal variation are reflected in a mosaic of ecoregions (Loucks 1962a; Clayden 2000, 2010; Zelazny 2007). The natural vegetation of the province has been much altered by settlement, agriculture, forestry, and invasive pathogens; however, about 85% of the land-area remained forested as of the early 2000s (Loo and Ives 2003). According to Global Forest Watch (2023), the net change in forest cover (gain versus loss) in New Brunswick between 2000 and 2020 was −6.8%, compared with a net change of −2.8% over the same period in Canada as a whole. As of 2022, 10% of New Brunswick has been allocated to biodiversity conservation in areas protected under provincial and federal legislation and by non-government organizations (NBDNRED 2022).

## Methods

This study is based largely on collections made by the three authors and deposited in the herbarium of the New Brunswick Museum (NBM). We also cite selected specimens collected over the past few decades by our colleagues Frances Anderson, William Buck, Richard Harris, James Lendemer, and Steven Selva, among others. We examined and identified or confirmed 324 specimens from throughout the province (Figure 1). More precisely, the sample consisted of 324 species-occurrence records, as it included *Rinodina* species occurring as associates of other lichens in multi-species collections (in single



**FIGURE 1.** Map of New Brunswick and neighbouring areas, showing distribution of all *Rinodina* collections included in our study. Abbreviations: Canada: NB, New Brunswick; NS, Nova Scotia; PEI, Prince Edward Island; QC, Quebec. United States: Maine, ME. Basemap from SimpleMappr (Shorthouse 2010).

herbarium packets). Herbarium acronyms follow Thiers (2022+). Except as noted, specimens are in the herbarium of the NBM.

Most collections were made during general surveys of lichen diversity. Field work covered numerous representative examples of the province's range of forest community types and other environments (e.g., rocky coastal and river shores) that are known or potential habitats for *Rinodina* species (Figure 2). Mature upland deciduous and mixed forests and forested wetlands dominated by Eastern White Cedar (*Thuja occidentalis* L.) were especially well represented, as our early surveys indicated that these are species-rich habitats for *Rinodina* in the province. Recently wind-thrown trees or broken branches found on the forest floor were inspected for canopy-dwelling species.

We recorded the identities of the lichen phorophytes (tree or shrub species) wherever feasible and tallied the distributions and frequencies of *Rinodina* species by phorophyte in the sample. At least one specimen of each species is cited for each of the 15 counties of the province from which we have seen material. Lichen nomenclature follows Esslinger (2021). The scientific and common names of trees and shrubs follow Brouillet *et al.* (2010+). In descriptions of forest communities, short forms of common names are used for some tree species: fir for Balsam Fir (*Abies balsamea* (L.) Miller), beech for American Beech (*Fagus grandifolia* Ehrhart), hop-hornbeam for Eastern Hop-hornbeam (*Ostrya virginiana* (Miller) K. Koch), cedar for Eastern White Cedar, and hemlock for Eastern Hemlock (*Tsuga canadensis* (L.)

Carrière). The full common names of these species are given where they refer to the phorophytes of *Rinodina* specimens and species.

Since 2009, S.R.C. and K.E.D. have made extensive collections in the larger protected natural areas (PNAs) of the province through the BiotaNB project led by the NBM (McAlpine 2022). All collection sites in provincial PNAs established as of 2022 are referred to by their current PNA names; however, some of these PNAs had not been established and named at the time the specimens were collected.

Methods for microscopic study of specimens followed Sheard (2010, 2018). Hand-cut sections of apothecia and thalli were mounted in water or Melzer's reagent and examined at 100× to 1000× magnification. Some sections were viewed in polarized light to assess the presence or absence of crystals of atranorin or sphaerophorin. To clear and highlight the internal structure of the spores of recently collected specimens, water mounts were gently heated over an alcohol lamp. Measurements of ascospores were made to the nearest 0.5 μm and are reported in the format: (minimum–) mean–SD – mean+SD (–maximum), followed by the number of measurements (*n*). The structure and developmental type(s) of ascospores occurring in each species are noted following standardized terminology (Sheard 2010). The characteristic medial swelling of spores of the *Dirinaria*-type was assessed by adding 10% potassium hydroxide (KOH) to the water mounts.

The occurrence of secondary chemical products in thalli was examined using standard reagents, following Brodo *et al.* (2001): sodium hypochlorite (C), 10% potassium hydroxide (K), and an alcoholic solution of para-phenylenediamine (P). Tests for the presence or absence of pannarin in the epihymenium of apothecia were made in microscopically examined thin sections. Selected specimens were analyzed with standardized thin-layer chromatography (TLC), using solvent system C and glass-backed plates (Culbertson 1972; Orange *et al.* 2001).

## Results

Fifteen species of *Rinodina* are confirmed to occur in New Brunswick. Five of these are reported here for the first time from the province: the corticolous species *Rinodina pachysperma* H. Magn., *Rinodina populicola* H. Magn., *Rinodina septentrionalis* Malme, and *Rinodina tenuis* Müll. Arg., and the saxicolous species *Rinodina tephrae* (Tuck.) Herre. We found 14 species in the field, but not *R. moziana*. The latter is known from New Brunswick based on a single specimen that was identified and reported by Sheard (2010). A previous report of *R. granuligera* from the province (Sheard 2010) is based on a specimen that we re-examined and identified as *R. cinereovirens* (see below).



**FIGURE 2.** Habitats of selected *Rinodina* species in New Brunswick, Canada. a. Forest dominated by Silver Maple (*Acer saccharinum*) on floodplain of middle Wolastoq (Saint John River) valley, with Black Willow (*Salix nigra*) in foreground. *Rinodina pachysperma* is frequent on tree trunks in this type of community. b. Eastern White Cedar (*Thuja occidentalis*) at base of forested slope next to a river. *Rinodina tenuis* is present on the curving dead branch in the foreground. c. Damp siliceous rocks, with *Rinodina tephraspis*, next to a waterfall, Lepreau River. d. Late-successional hardwood forest dominated by Sugar Maple (*Acer saccharum*), American Beech (*Fagus grandifolia*), and Yellow Birch (*Betula alleghaniensis*), with *Rinodina ascociscana*, *Rinodina subminuta*, *Rinodina subpariata*, and *Rinodina willeyi* on the tree trunks. Photos: S.R. Clayden.

Three of the 15 recorded *Rinodina* species are saxicolous on siliceous (non-calcareous) rock: *R. gennarii* (rarely lignicolous), *R. moziana*, and *R. tephraspis*. The 12 corticolous species were found on 29 phorophyte species. The representation of corticolous *Rinodina* species and their main phorophytes in the set of specimens is shown in Figure 3. No phorophyte species had more than six associated *Rinodina* species. The most frequently collected species was *R. subminuta*. Its most frequent phorophyte, and the most frequent phorophyte species overall, was Sugar Maple (*Acer saccharum* Marshall).

*Rinodina freyi* and *R. subpariata* were found on the greatest number of phorophyte species (16). However, *R. freyi* was collected less frequently overall than several other *Rinodina* species. In contrast, *R. tenuis* was found on only one phorophyte, Eastern White Cedar, but was represented by 18 specimens from 14 localities. Although the sample of specimens collected and

identified was loosely stratified by forest type and phorophyte species, it undoubtedly reflects collecting biases, e.g., an emphasis on mid- to late-successional stands. Also, parts of the province with fewer and/or smaller protected areas are under-represented. This is especially true of Carleton County and Victoria County in western New Brunswick, where most of the land is privately owned. Another gap centres on the lowlands of eastern New Brunswick, where extensive peatlands alternate with mostly early- to mid-successional coniferous and mixed forests (Clayden 2000; Crossland 2006). With these caveats, the distributions of specimens and species provide an approximation of the relative abundance and phorophyte associations of corticolous *Rinodina* species in New Brunswick. The distinguishing characteristics, distributions, habitats, and substrata of each species are described below.

	<i>ascobiscana</i>	<i>efflorescens</i>	<i>freiji</i>	<i>pechysperma</i>	<i>polyspora</i>	<i>populicola</i>	<i>subminuta</i>	<i>subparvata</i>	<i>tenuis</i>	<i>willeji</i>	<i>Rinodina</i> specimens	<i>Rinodina</i> species
<i>Abies balsamea</i>	■	■									10	3
<i>Acer pensylvanicum</i>	■	■									6	4
<i>Acer rubrum</i>	■	■					■	■			20	3
<i>Acer saccharinum</i>			■	■							9	2
<i>Acer saccharum</i>	■		■				■	■		■	94	6
<i>Acer spicatum</i>							■	■			5	2
<i>Alnus incana</i>		■	■								6	2
<i>Betula alleghaniensis</i>	■	■					■	■		■	27	6
<i>Betula papyrifera</i>		■						■			4	2
<i>Fagus grandifolia</i>	■	■		■			■	■			15	5
<i>Fraxinus americana</i>	■						■	■		■	9	4
<i>Fraxinus nigra</i>	■			■	■	■					22	6
<i>Fraxinus pennsylvanica</i>				■							4	2
<i>Populus balsamifera</i>		■	■				■	■			8	5
<i>Populus tremuloides</i>		■	■				■	■			8	5
<i>Quercus rubra</i>	■	■						■		■	6	5
<i>Sorbus americana</i>							■	■			4	4
<i>Thuja occidentalis</i>	■		■					■	■	■	30	5
<i>Ulmus americana</i>			■	■			■				10	3
<b><i>Rinodina</i> specimens</b>	40	29	28	14	13	4	89	51	18	30		
<b>Phorophyte species</b>	8	9	16	5	5	4	14	16	1	7		

**FIGURE 3.** Principal phorophytes of corticolous *Rinodina* species in New Brunswick. The overall dataset included 318 specimens representing 29 phorophyte and 13 *Rinodina* species. Ten phorophyte species from which only one or two *Rinodina* specimens were collected, and two *Rinodina* species (*R. cinereovirens*, *R. septentrionalis*) represented by only one or two specimens, are not shown (see text for details). Shading indicates the number of *Rinodina* specimens from each phorophyte, in four arbitrary classes: white (no shading) = 0 specimens; light-grey = 1 to 5 specimens; medium-grey = 6 to 20 specimens; black > 20 specimens.

**Key to *Rinodina* species known or expected to occur in New Brunswick**

Eighteen species are included in the key. Three of these, *Rinodina bischoffii* (Hepp) A. Massal., *Rinodina buckii* Sheard, and *Rinodina oxydata* (A. Massal.) A. Massal. [enclosed in square brackets] have not been found in New Brunswick but are known from neighbouring Maine and/or Quebec. The key is based on those of Sheard (2010, 2018; Sheard *et al.* 2017).

1. On rock ..... 2
1. On bark or wood, or on bryophytes over bark ..... 6
2. On coastal rocks (rarely on rusted metal or wood) subject to salt spray and/or enrichment by guano; spores somewhat swollen at the septum (swelling more pronounced in KOH; *Dirinaria*-type) ..... ***R. gennarii***
2. On rocks near freshwater or in forested or open upland settings; spores swollen or not at the septum ..... 3
3. On calcareous rock; spores with a broad dark-pigmented band around the septum, walls not thickened at the apices (*Bischoffii*-type) ..... [***R. bischoffii***]
3. On siliceous rock; spores with or without a thin dark-pigmented ring-structure (“torus”) where the septum meets the lateral wall, walls thickened at the apices ..... 4
4. Thallus K<sup>-</sup>, lacking atranorin (no crystals visible in the cortex of thallus and apothecium sections examined in polarized light), containing zeorin ..... ***R. tephraspis***
4. Thallus K<sup>+</sup> yellow, containing atranorin (crystals visible in the cortex of thallus and apothecium sections examined in polarized light), lacking zeorin ..... 5
5. Spores averaging 22.0–22.5 × 12.0–13.0 μm ..... ***R. moziana***
5. Spores averaging 18.5–19.5 × 10.5–11.5 μm ..... [***R. oxydata***]

6. Soredia present ..... 7
6. Soredia absent ..... 10
7. Thallus K+ yellow, P+ yellow, containing atranorin, lacking pannarin ..... *R. subpariata*
7. Thallus K-, lacking atranorin, P+ red-orange, containing pannarin ..... 8
8. Areoles convex, not uplifted at margins; soredia initially developing on the surface of the areoles, relatively coarse, 40–65 µm in diameter ..... [*R. buckii*]
8. Areoles ± plane, often slightly uplifted at margins; soredia developing at the margins or on the surface of the areoles, relatively fine, 15–30 µm in diameter ..... 9
9. Areoles grey-brown to dark grey-green; prothallus thin and dark brown; soredia pale greenish-yellow, in discrete soralia developing at margins or on surface of areoles, soralia KC+ yellow-orange (reaction sometimes weak); thallus (in New Brunswick populations) not overgrowing bryophytes ..... *R. efflorescens*
9. Areoles light to dark grey; prothallus not evident; soredia grey, developing at margins of areoles, KC-; thallus (in New Brunswick populations) sometimes becoming ± entirely sorediate and overgrowing *Frullania* and small pleurocarpous mosses ..... *R. willeyi*
10. Spores more than 8 in most asci ..... 11
10. Spores not more than 8 per ascus ..... 12
11. Spores 12–16 per ascus, averaging 15.0–16.0 µm long, with persistent apical and septal wall thickenings (*Physcia*-type), not constricted at the septum; apothecia mostly scattered, discs becoming convex, thalline margins thin and becoming excluded; thallus thin and inconspicuous ..... *R. polyspora*
11. Spores 16–32 per ascus, averaging 12.5–13.5 µm long, lacking wall thickenings at maturity (*Physconia*-type), often becoming slightly constricted at the septum; apothecia often becoming contiguous, discs remaining plane, margins distinct and not becoming excluded; thallus usually well developed, areolate ..... *R. populicola*
12. On wood (typically on rock) in coastal habitats subject to salt spray and/or enrichment by guano; spores somewhat swollen at the septum (swelling increasing in KOH) ..... *R. gennarii*
12. On bark or rarely wood, mainly of living trees, mostly in non-coastal habitats; spores not swollen at the septum ..... 13
13. Thallus P+ red-orange, containing pannarin ..... *R. tenuis*
13. Thallus P-, lacking pannarin ..... 14
14. Medulla of apothecium margins densely filled with fine crystals of sphaerophorin (visible in polarized light); lower part of apothecial cortex expanded, 20–60 µm deep ..... *R. cinereovirens*
14. Medulla of apothecium margins lacking sphaerophorin (no crystals evident in polarized light); lower part of apothecial cortex not or little expanded, <20 µm deep ..... 15
15. Spores averaging >25 µm long; thallus usually thick and continuous, surface often waxy; margins of apothecia often becoming radially grooved ..... *R. ascociscana*
15. Spores averaging <22 µm long; thallus inconspicuous or thin to moderately thick and areolate, surface matt; margins of apothecia smooth to rough, but not becoming radially grooved ..... 16
16. Spores with thick lateral and apical walls, lumina ± rounded (*Pachysporaria*-type) ..... *R. pachysperma*
16. Spores with apical walls thicker than lateral walls, lumina distinctly angular, at least in early stages of development (*Physcia*-type) ..... 17
17. Apothecia initially immersed and erupting from the thallus, remaining broadly attached; spores averaging > 18.5 µm long; thallus often within the substratum or very thin and ± continuous, mainly on lower part of tree trunks ..... *R. subminuta*
17. Apothecia not erupting from the thallus, broadly to narrowly attached; thallus superficial on substratum, usually consisting of discrete areoles, mainly on twigs and young branches; spores averaging <17 µm long ..... 18
18. Thallus typically on and around axils and leaf scars of twigs and young tree branches; areoles ± plane and contiguous, up to 0.7 mm wide; apothecia crowded ..... *R. freyi*
18. Thallus typically on ± smooth bark of twigs and young tree branches; areoles convex (especially when moist) and dispersed, <0.2 mm wide; apothecia dispersed ..... *R. septentrionalis*

## Annotated Checklist of *Rinodina* in New Brunswick

The list is sorted alphabetically by species, with the distribution map indicated. The lists of specimens are sorted alphabetically by **county** and by date (oldest to most recent). In cases where more than one specimen of a species was collected at, and cited from, a single locality, the abbreviation “*ibid.*” is used to minimize duplicated information on the locality, habitat, substrate, and date, as appropriate.

The Latin abbreviations *s.l.* and *sine numero* (*s.n.*, without number, when no collector number was given to the collection) also are used when relevant.

### *Rinodina ascociscana* (Tuck.) Tuck. (Figure 4a)

Reported for New Brunswick by Gowan and Brodo (1988) and Sheard (2010). Characterized by its somewhat glossy, grey-brown, thin to thick thallus consisting of plane, coalescing areoles; apothecia with radially striate margins; and large *Physcia*- to *Physconia*-type spores measuring  $(25.0\text{--}28.9\text{--}35.1\text{--}38.0) \times (13.0\text{--}13.6\text{--}16.2\text{--}17.5) \mu\text{m}$  ( $n = 37$ ) in New Brunswick specimens. North American thalli of *R. ascociscana* lack secondary metabolites detectable with TLC (Sheard 2010). They thus lack crystals in the medulla, unlike *R. cinereovirens*, which contains sphaerophorin and which also has a different type of apothecial margin, smaller spores, and a thinner thallus. Zeorin is present rarely in populations of *R. ascociscana* in northeastern Asia (Sheard *et al.* 2017). We analyzed 12 New Brunswick specimens with TLC but did not detect zeorin in any of them.

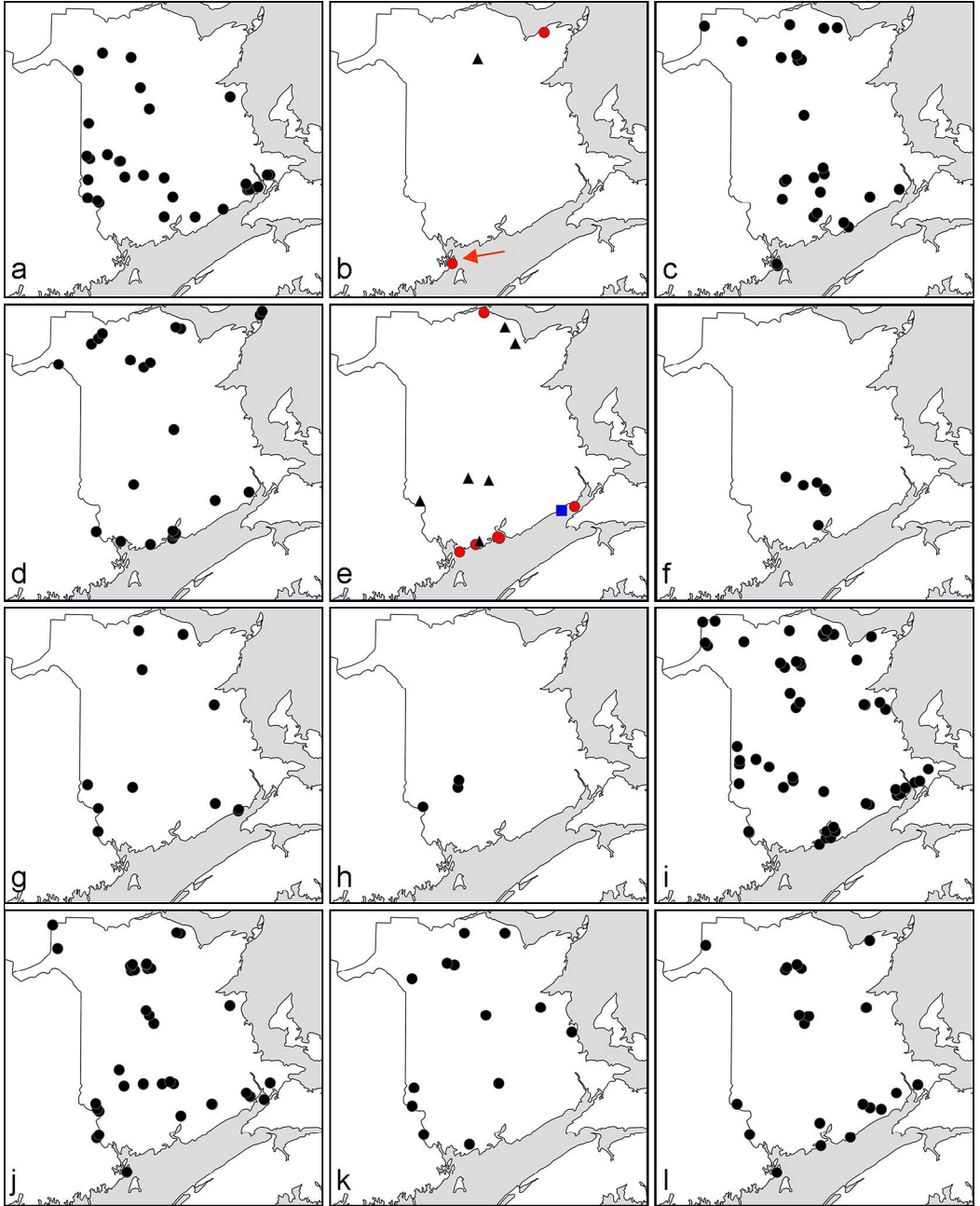
The spores of *R. ascociscana* are the largest of those in any *Rinodina* species in eastern North America. In most specimens from New Brunswick (collected during the spring to fall months), the apothecia contain mainly overmature and deformed spores. However, a specimen collected in late December (Clayden 27379) has abundant, intact, well-developed spores releasing readily from the asci in water mounts. Sheard (2010) also noted what appeared to be seasonal variation among specimens of *R. ascociscana* in the representation of spores in different stages of development.

In North America, this species has a well-defined Appalachian–Great Lakes–Maritimes distribution (Brodo *et al.* 2001; Sheard 2010), coinciding largely with that of temperate deciduous forests dominated by Sugar Maple. It was long thought to be endemic to this region, but recent studies have shown that it also occurs in climatically similar areas of northeastern Asia (Sheard *et al.* 2017). Its distribution and habitats are similar to those of *R. subminuta*, but somewhat less extensive. For example, it has not been found in the Ozark Highlands of the south-central USA,

where *R. subminuta* is present (Sheard 2010; Lendemer *et al.* 2014). In New Brunswick, it occurs mainly in closed forests of long historical continuity (e.g., Selva 1994), whereas *R. subminuta* can also occur on open-grown trees and at forest edges (Gowan and Brodo 1988; S.R.C. pers. obs.). It is less frequent in the province than *R. subminuta*, occurring mainly in mature hardwood and mixed forests in mesic sites, but also rarely on Eastern White Cedar in swamp forests, always in the understorey. *Rinodina ascociscana* occurs on Sugar Maple up to the elevational limit of this tree species in the northern interior (e.g., at 510 m on Gover Mountain, see below), but we did not find it in many hardwood stands in the northernmost areas of the province where *R. subminuta* is present (compare Figures 4a and 4i).

Among the specimens of *R. ascociscana* from New Brunswick examined for this study, 21 were on Sugar Maple, nine on American Beech, three on White Ash (*Fraxinus americana* L.), two on Black Ash (*Fraxinus nigra* Marshall), and one each on Yellow Birch (*Betula alleghaniensis* Britton), Eastern Hop-hornbeam, Red Oak (*Quercus rubra* L.), and Eastern White Cedar. The single occurrence on Red Oak is from a lakeshore forest where a species-rich epiphytic lichen community was present, apparently influenced by aerosol enrichment of the tree-bark resulting from wave splash on nearby shoreline rocks. The lack of records of *R. ascociscana* on Red Maple (*Acer rubrum* L.) matches the apparent absence or rarity of *R. subminuta* and *R. willeyi* on this maple species in New Brunswick. The substratum of a collection made by W.G. Farlow on Campobello Island in 1902 (not seen by us; examined and cited by Sheard [2010]) is unknown. Recent lichen surveys on the island have not detected *R. ascociscana*. (S.R.C. *et al.* unpubl. data).

*Selected specimens examined*—**Albert Co.:** Caledonia Gorge PNA, upland between Rhody Brook and Wells Brook, 45.7726°N, 64.8210°W, 323 m, old-growth hardwood forest dominated by Sugar Maple, Yellow Birch, and beech, on American Beech, 28 June 2011, S.R. Clayden 22071. **Carleton Co.:** Meduxnekeag River valley, terrace and E-facing slope between river and Plymouth Road, 46.18558°N, 67.68175°W, 140 m, mature hardwood forest dominated by Sugar Maple, on Sugar Maple, 7 May 2008, S.R. Clayden 18189. **Kings Co.:** Canadian Forces Base Gagetown, Nerepis Hills, ~3.8 km ESE of Welsford, 45.4413°N, 66.2978°W, 120 m, mature mixed forest of Red Spruce (*Picea rubens* Sargent), hemlock, Eastern White Pine (*Pinus strobus* L.), Yellow Birch, Heart-leaved Birch (*Betula cordifolia* Regel), and Red Maple, on SW-facing slope, on trunk of Yellow Birch, 7 September 2014, S.R. Clayden 24840. **Madawaska**



**FIGURE 4.** Known distributions of *Rinodina* species in New Brunswick, Canada. a. *Rinodina ascociscana*. b. *Rinodina cineovirens* (circles, with arrow indicating historical occurrence on Campobello Island), *Rinodina septentrionalis* (triangle). c. *Rinodina efflorescens*. d. *Rinodina freyi*. e. *Rinodina gennarii* (circles), *Rinodina moziana* (square), *Rinodina tephrae* (triangles). f. *Rinodina pachysperma*. g. *Rinodina polyspora*. h. *Rinodina populicola*. i. *Rinodina subminuta*. j. *Rinodina subpariata*. k. *Rinodina tenuis*. l. *Rinodina willeyi*. Basemaps from SimpleMappr (Shorthouse 2010).

**Co.:** “Black Brook District” of J.D. Irving Ltd, SW-facing hillside, ~5 km ENE of confluence of Harrison Brook with Grande Rivière, 47.24193°N,

67.86828°W, 266 m, mature hardwood forest dominated by Sugar Maple and beech, with scattered hop-hornbeam and Black Ash, on trunk of old Black Ash,

29 August 2008, *S.R. Clayden 19144*. **Northumberland Co.:** Gover Mountain PNA, plateau near mountain top, 47.036°N, 66.737°W, 510 m, mature deciduous forest dominated by Sugar Maple, with scattered Yellow Birch, Red Maple, and Red Spruce, on Sugar Maple, 20 October 1993, *S.R. Clayden 7914*; Kennedy Lakes PNA, along unnamed brook flowing S to SW off unnamed hill between Route 108 and Dunganon River, 46.7782°N, 66.5704°W, 380 m, mature forest of Yellow Birch, Sugar Maple, beech, and Red Spruce, on trunk of Sugar Maple, 2 July 2019, *S.R. Clayden 27863B*; Hells Gate Hardwoods PNA, ~6.5 km ENE of Saint Margarets, 46.9232°N, 65.1121°W, 40 m, mature hardwood forest dominated by Sugar Maple, Red Maple, and Yellow Birch, on trunk of White Ash, 14 September 2019, *S.R. Clayden 27996*; **Queens Co.:** Wolastoq (Saint John River) valley E and S of Route 102 near Queenstown, ~1.5 km SW of E end of Otnabog Lake, “Nickerson Woodlot”, 45.69034°N, 66.14550°W, 110 m, mature, mesic forest of Sugar Maple, beech, and Yellow Birch, with scattered ash (*Fraxinus* L.), hop-hornbeam, and Red Spruce, on Eastern Hop-hornbeam, 13 May 2008, *S.R. Clayden 18243*. **Restigouche Co.:** Mount Carleton Provincial Park, off the W side of the Mount Bailey trail, between 1 and 1.5 km from trailhead, 47.41°N, 66.91°W, hardwood stand dominated by Sugar Maple, with moderate amount of Yellow Birch, corticolous on Sugar Maple, 22 July 1989, *S.B. Selva 4059*. **Saint John Co.:** along woods road E of Little Salmon River, 6 km SE of Crawford Lake, 45.532°N, 65.256°W, small patch of selectively logged forest of Sugar Maple, beech, and Yellow Birch, on trunk of large *Nectria*-cankered American Beech, 2 September 1994, *S.R. Clayden 8907*. **Sunbury Co.:** Portobello Creek National Wildlife Area, French Island, NE shore, opposite Sand Point, 45.92417°N, 66.30011°W, 8 m, lakeshore with sandstone ledges and mixed conifer-hardwood forest including Red Oak, hemlock, White Spruce (*Picea glauca* (Moench) Voss), Silver Maple (*Acer saccharinum* L.), cedar, and Grey Birch (*Betula populifolia* Marshall), on trunk of large Red Oak, 9 August 2014, *S.R. Clayden 24562*. **Victoria Co.:** Highway 17, 3.2 km SW from Restigouche County line, on Sugar Maple, 24 May 1981, *W.S.G. Maass & B.L. Hoisington 81C-28a*. **Westmorland Co.:** Walker Road, ~6 km NW of Sackville, W side of Trans-Canada Hwy, 45.95°N, 64.42°W, mixed hardwoods, on American Beech, 18 June 1976, *S.R. Clayden 90*. **York Co.:** Spednic Lake PNA, between South Branch Mosquito Brook and McAllister Brook, 45.66670°N, 67.65411°W, 150 m, swampy forest of Red Maple, cedar, Speckled Alder (*Alnus incana* subsp. *rugosa* (Du Roi) R.T. Clausen), Black Spruce (*Picea mariana* (Miller) Britton, Sterns

& Poggenburgh), and scattered Black Ash, with herb-rich understorey, on trunk of Eastern White Cedar, 14 August 2017, *S.R. Clayden 26733*; Crabbe Mountain, NE-facing slope, 46.12403°N, 67.10011°W, 240 m, hardwood forest dominated by Sugar Maple, Yellow Birch, beech, and Striped Maple (*Acer pensylvanicum* L.), with scattered fir, on trunk of Sugar Maple, 28 December 2018, *S.R. Clayden 27379*.

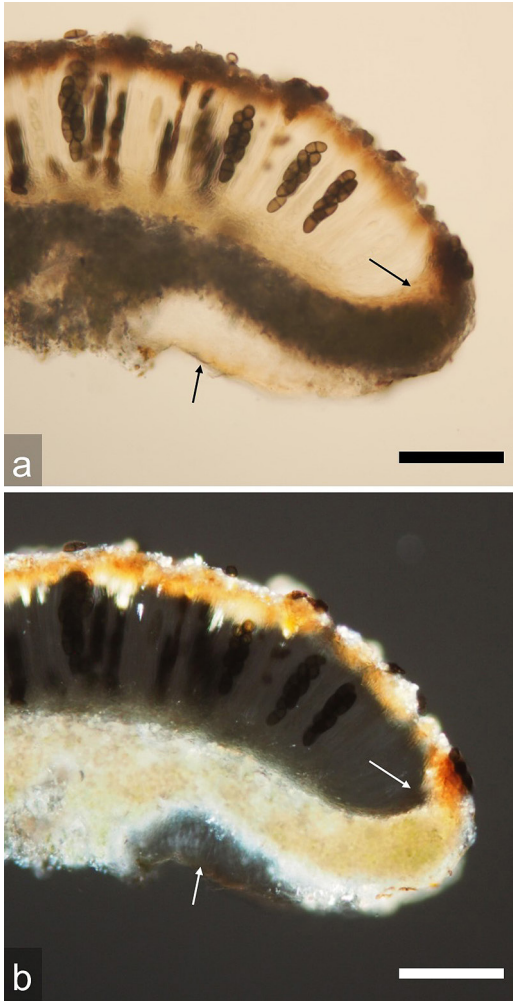
Also known from **Charlotte Co.:** Campobello Island, July 1902, *W.G. Farlow*, s.n. (Farlow Herbarium, Harvard University [FH 00478186]), cited by Sheard (2010); Grand Falls Flowage on St. Croix River, 45.2781°N, 67.4789°W, hardwood (maple [*Acer* L.], beech, birch [*Betula* L.]) forest, on maple, 30 April 2011, *J.C. Lendemer 27816* (William and Lynda Steere Herbarium, New York Botanical Garden [NY]).

***Rinodina cinereovirens*** (Vain.) Vain. (synonym [syn.] *R. turfacea* var. *cinereovirens* (Vain.) H. Mayrhofer [Sheard *et al.* 2017; Sheard 2018]; Figure 4b)

Reported for New Brunswick by Sheard *et al.* (2017) without details of the single occurrence known at the time, which are provided here. Characterized by its thin, greyish, distinctly areolate, corticolous or lignicolous thallus containing sphaerophorin; narrowly attached apothecia; apothecial margins with the cortex expanded in its lower part (Figure 5a) and I+ blue; and large *Physcia*-type ascospores with a well-developed torus.

A second, previously overlooked, historical occurrence of *R. cinereovirens* in New Brunswick came to light during the present study. This is based on a specimen in the Farlow Herbarium (FH) collected by W.G. Farlow on Campobello Island in the Bay of Fundy in 1902 (Figure 4b). It was reported by Sheard (2010) as *R. granuligera* H. Magn., but we have re-identified the specimen as *R. cinereovirens* (corroborated by J.W. Sheard, 19 May 2023). Its morphology and chemistry (confirmed with TLC) are fully consistent with this species. *Rinodina granuligera* differs from *R. cinereovirens* in having a more continuous thallus containing atranorin, not sphaerophorin, a P+ red-orange ephymenium containing pannarin, and smaller *Dirinaria*-type ascospores that swell at the septum in KOH (Sheard 2010, 2018). It is endemic to the Piedmont and Coastal Plain regions of the southeastern United States (Sheard 2010; Lendemer *et al.* 2014).

In the two New Brunswick specimens of *R. cinereovirens*, the spores are (20.5–)23.8–28.5(–30.5) × (10.0–)11.2–12.8(–13.5) μm, with a length/width ratio of (1.8–)2.0–2.4(–2.6) ( $n = 46$ ). Uncommonly for *R. cinereovirens*, some of the apothecia in both specimens have somewhat pruinose discs, the light-grey



**FIGURE 5.** *Rinodina cinereovirens*, section of apothecium (Clayden 1811). a. In brightfield illumination. b. In polarized light. Arrows indicate expanded lower cortex of thalline exciple and proper exciple next to hymenium, both lacking sphaerophorin crystals. Dense deposits of birefringent sphaerophorin crystals are present in the medulla, and sparse streaks in the epihymenium. In brightfield, the medulla appears dark, but its opaqueness is due to the abundance of sphaerophorin crystals, which are colourless. Scale bars: 100  $\mu$ m. Photos: S.R. Clayden.

pruina apparently consisting of crystals of sphaerophorin. Crystals are also present in scattered streaks extending into the upper part of the hymenium, distinct from the more diffuse red-brown epihymenial pigment (Figure 5b). The presence of sphaerophorin in the specimen from Campobello Island was confirmed by TLC.

*Rinodina cinereovirens* was treated by Mayrhofer and Moberg (2002) as a corticolous variety of

*Rinodina turfacea* (Wahlenb.) Körb., and by Sheard (2010) as part of a continuum of variation within that species. However, Sheard *et al.* (2017) found that the ascospores of Arctic terricolous and boreal corticolous/lignicolous populations of *R. turfacea* s.l. differ subtly in average size, shape, and number per ascus, supporting the reinstatement of *R. cinereovirens* at species rank. Although the asci of *R. cinereovirens* often contain only four spores (Sheard *et al.* 2017), only eight-spored asci were observed in the New Brunswick specimens.

This species is widely but sparsely distributed in boreal forests around the Northern Hemisphere (Mayrhofer and Moberg 2002; Sheard *et al.* 2017; Galanina *et al.* 2021a,b). In North America, it has been documented to date from fewer than 20 localities scattered from Alaska to Newfoundland (Sheard *et al.* 2017; Sheard 2018). The historical occurrence on Campobello Island reported here is the southernmost on record. Farlow did not note its precise location on the island, which lies between 44.83°N and 44.96°N, or details of the habitat or substratum of the specimen. Ecologically, Campobello Island is in New Brunswick's Fundy Coast Ecoregion (Zelazny 2007), which has a hemiboreal rainforest climate and vegetation (Clayden *et al.* 2011). The other New Brunswick occurrence of *R. cinereovirens* is near the province's northern (Baie des Chaleurs) coast, about 350 km northeast of Campobello Island. However, this area has a more continental climate than the Bay of Fundy coast, with warmer summers, colder and snowier winters, lower annual precipitation, and much less fog (Clayden 2000, 2010).

Our examination of the bark characteristics of Farlow's specimen from Campobello Island indicates that it probably came from a mountain-ash, most likely American Mountain-ash (*Sorbus americana* Marshall), which is a frequent component of coastal spruce (*Picea* A. Dietrich)–fir–birch forests on the island. The specimen consists of several fragments of dark thin outer bark (periderm) typical of a mature or possibly senescent individual of this tree species. Several other lichens are present on the same bark fragments: an unidentified, small, poorly developed species of *Caloplaca* s.l. (probably *Athallia pyracea* (Ach.) Arup, Frödén & Söchting), *Leptogium cyane-scens* (Rabenh.) Körb., *Parmelia* cf. *squarrosa* Hale (small immature lobes), *Rinodina subpariata* (Nyl.) Zahlbr., and possibly *Rinodina efflorescens* Malme (too fragmentary for chemical analysis).

Farlow made two visits to Campobello Island, in 1898 and 1902, during which he collected numerous specimens of several groups of cryptogams (Pfister 2016). Most notable among the lichens was the type material of the rare cyanolichen Boreal

Felt Lichen (*Erioderma pedicellatum* (Hue) P.M. Jørg.), and an accompanying fragment of Vole Ears (*Erioderma mollissimum* (G. Sampaio) Du Rietz; Jørgensen 1972). Conifer needles and bark present in the specimen envelopes indicate that the collections of these species were from Balsam Fir (Jørgensen 1972; Maass 1980). Neither *Erioderma* species has been found subsequently on the island, despite intensive searching (Maass 1980; Maass and Yetman 2002; COSEWIC 2009, 2014). Their presumed local extirpation was attributed by Maass (1980; Maass and Yetman 2002) to a combination of logging, human-caused forest fires, and acid precipitation. It is possible that *R. cinereovirens* has likewise disappeared from Campobello Island. However, there are several hundred hectares of relatively intact coastal forest protected within Roosevelt Campobello International Park and Herring Cove Provincial Park on the island. Further lichen surveys in these areas, including targeted searching of mountain-ash, should be carried out in order to assess the current local status of *R. cinereovirens*.

The occurrence of *R. cinereovirens* on Black Ash in northern New Brunswick was in an opening in a wet minerotrophic swamp forest dominated by cedar. The site is adjacent to a large (~300 ha) ombrotrophic bog where an extensive peat-harvesting operation began a few years before *R. cinereovirens* was found in the area. Drainage ditches from the bog are directed toward the swamp-forest community, and the current status of *R. cinereovirens* at the site is unknown. The diversity of lichens and lichenicolous fungi in this type of forest community in the province and region is generally high (Clayden 2010; S.R.C., K.E.D., and S.B. Selva unpubl. data). Ongoing studies demonstrate that it supports a number of rare and/or previously undescribed species occurring on various coniferous and hardwood trees, including Black Ash (e.g., Holien *et al.* 2015; Driscoll *et al.* 2016; Selva and Tuovila 2016; Haughian *et al.* 2018; Ertz *et al.* 2021).

Black Ash has a relatively high bark pH, reported by Nimis (1985) to be  $7.2 \pm 0.3$  in the southern boreal Clay Belt region of Ontario, where it is likewise a component of swamp forests dominated by cedar. Lichens growing next to *R. cinereovirens* on Black Ash at the New Brunswick locality included *Lecidea erythrophaea* Flörke ex Sommerf., *Parmelia sulcata* Ach., *Ramalina dilacerata* (Hoffm.) Hoffm., and *Ramalina roesleri* (Hochst. ex Schaer.) Hue. The presence of several cyanolichens and species such as *Bacidia polychroa* (Th. Fr.), *Gyalolechia xanthostigmoidea* (Räsänen) Sochting, Frödén & Arup, and *Heterodermia speciosa* (Wulfen) Trevis. on neighbouring trees is indicative of locally base-rich conditions. The complex of swamp forests and fens in this area is

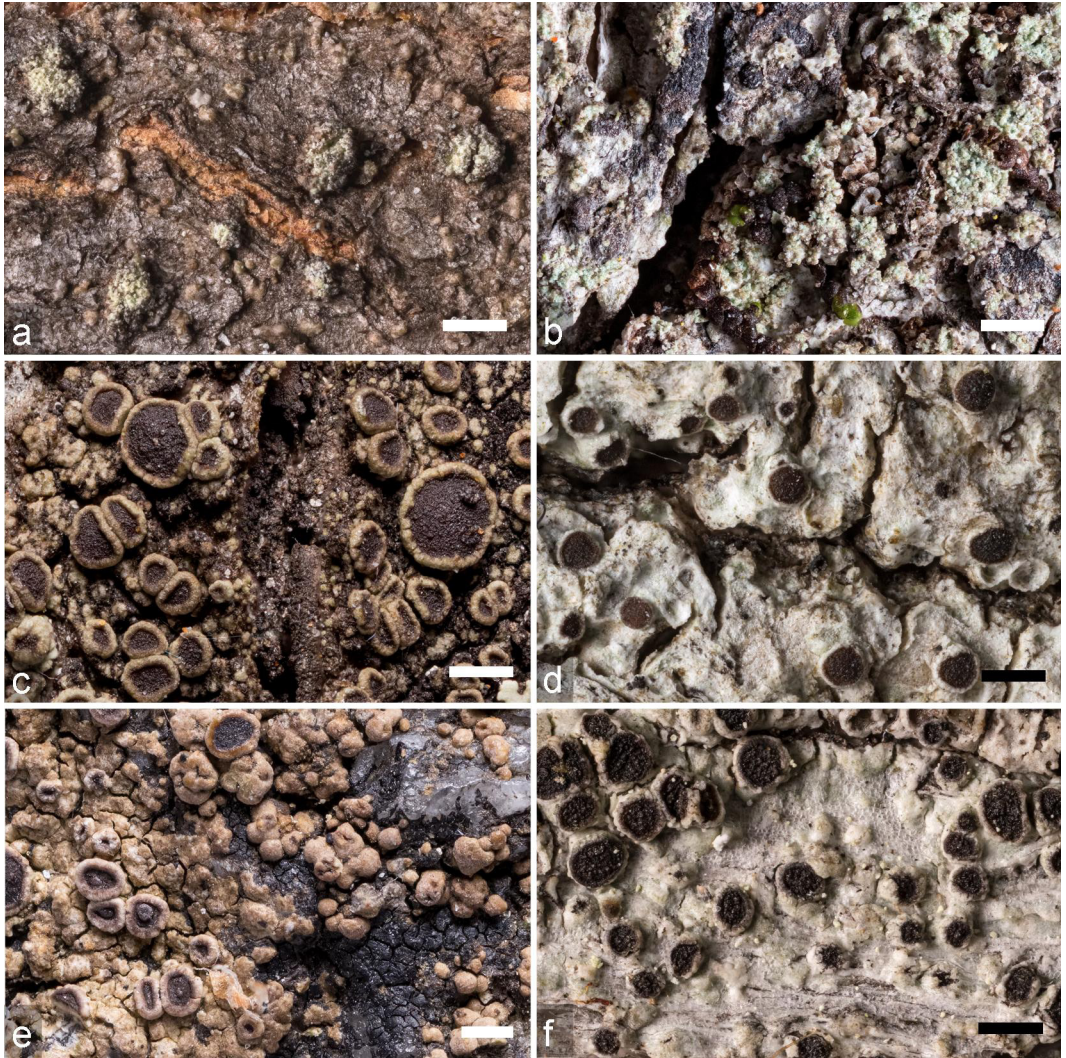
associated with subsurface deposits of early postglacial, calcareous, marine silt and clay (Michalica *et al.* 2000). Several provincially uncommon to rare calciphilous vascular plants are present in the area, including Small Round-leaved Orchid (*Galearis rotundifolia* (Banks ex Pursh) R.M. Bateman) and Sage Willow (*Salix candida* Flügge ex Willdenow; Blaney 2000).

The invasive non-native Emerald Ash Borer (*Agrilus planipennis* Fairmaire) now poses a threat to lichens and other biota, known and unknown, that occur on ash species in North America. Black Ash appears to be the most susceptible ash species (COSEWIC 2018). Emerald Ash Borer was first detected in New Brunswick and Atlantic Canada in the Edmundston area in 2018 and, soon after, further south in the province, eastward into Nova Scotia, and northeastward in the Gaspésie region of Quebec (CFIA 2022). In the Ottawa region, it has caused extensive mortality of Black Ash, and declines of several lichens locally restricted to this tree species are expected (Brodo *et al.* 2021a).

*Specimens examined*—**Charlotte Co.:** Campobello Island, July 1902, *W.G. Farlow, s.n.* (FH 00478 279). **Gloucester Co.:** North side of Lambert Barren, ~7.5 km SW of Pokeshaw, 47.7232°N, 65.3004°W, 55 m, swampy open woods dominated by cedar, Red Maple, fir, and Black Spruce, with scattered Black Ash, Yellow Birch, and Paper Birch (*Betula papyrifera* Marshall), on Black Ash, 7 October 2007, *S.R. Clayden 18111* (confirmed by J.W. Sheard).

#### *Rinodina efflorescens* Malme (Figure 4c)

Reported for New Brunswick by Sheard (2010), based on specimens collected by Emmanuel Sérusiaux in 1988 in Fundy National Park (Albert County) and Kouchibouguac National Park (Kent County). Characterized by its grey-brown areolate thallus containing pannarin (P+ red-orange, K-) and trace amounts of zeorin, with discrete, contrasting, often more or less punctiform, usually pale greenish-yellow soralia (Figure 6a) containing secalonic acid A (KC+ yellow-orange). *Rinodina willeyi*, like *R. efflorescens*, contains pannarin and zeorin, but its soredia are greyish and KC- and (in New Brunswick material) often spread diffusely, especially in thalli overgrowing bryophytes (Figure 6b). We have not found *R. efflorescens* growing on corticolous bryophytes, although it is reported to do so elsewhere (Tønsberg 1992; Mayrhofer and Moberg 2002). *Rinodina subpariata* has a light-grey thallus and contrasting, white soredia, both containing abundant atranorin (K+ yellow). These three species also differ in ascospore morphology and/or size; however, apothecia are lacking in most thalli. They are present in seven of the 30 New Brunswick specimens of *R. efflorescens*



**FIGURE 6.** Thalli of selected *Rinodina* species occurring in New Brunswick. a. *Rinodina efflorescens* (Clayden 28686), with yellowish soredia. b. *Rinodina willeyi* (Clayden 28931), soredia concolorous with thallus. c. *Rinodina populicola* (Clayden 28963), with large and small apothecia. d. *Rinodina subminuta* (Clayden 28773), note two eroded apothecia at the extreme right. e. *Rinodina tephropsis* (Clayden 26829), thallus continuous at left to dispersed-areolate at right. f. *Rinodina tenuis* (Clayden 28748), with apothecia erumpent when young. Scale bars: 0.5 mm. Photos: Roger Smith.

examined for our study and have *Physcia*-type ascospores measuring  $(12.5\text{--}14.6\text{--}18.9\text{--}21.5) \times (7.0\text{--}7.6\text{--}9.5\text{--}10.0) \mu\text{m}$  ( $n = 42$ ). One specimen (Clayden 26910) is unusual in having numerous apothecia and only sparsely developed soralia, but its ascospore characters and chemistry (confirmed with TLC) are consistent with those of *R. efflorescens*. In most specimens, the dark colour of the thallus is imparted largely by the very thin prothallus, described by Tønsberg (1992: 146) as a “brown stain” between the usually dispersed, somewhat lighter-coloured areoles

(Figure 6a).

*Rinodina efflorescens* is widely distributed in forested, north-temperate to hemiboreal, climatically humid areas of North America and Eurasia, with southward extensions in montane forests (Mayrhofer and Moberg 2002; Sheard 2010; Lendemer *et al.* 2014; Galanina *et al.* 2021a). Although it is frequent throughout New Brunswick, it has not yet been reported from the other provinces of Atlantic Canada, possibly because sorediate species are generally under-collected. In New Brunswick, it occurs in

a wide range of mesic to wet forest types; however, it is scarce or lacking in mature hardwood forests on relatively base-rich soils where *R. willeyi* is sometimes frequent. We have not found *R. efflorescens* on Sugar Maple, which is the most frequently recorded phorophyte of *R. willeyi* in the province. Conversely, *R. efflorescens* occurs commonly on several tree and shrub species with more acidic bark and on which *R. willeyi* is scarce or lacking. Among the specimens we examined, 10 were on Red Maple, six on Balsam Fir, four on Speckled Alder, two each on Yellow Birch and Paper Birch, and one each on Striped Maple, Mountain Maple (*Acer spicatum* Lamarck), American Beech, Red Oak, and American Mountain-ash.

*Selected specimens examined*—**Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, Liberty Point, trail to Lower Duck Pond, 44.832°N, 66.931°W, 40 m, coastal spruce–fir–birch woods with scattered American Mountain-ash, on mountain-ash, 24 September 2016, *K.E. Driscoll 1347*; *ibid.*, along Fox Hill Drive, ~2 km W of Liberty Point Drive, at base of Fox Hill, 44.85344°N, 66.95304°W, mature forest dominated by Yellow Birch, on stem of Mountain Maple, 25 September 2016, *S.R. Clayden 26298*. **Gloucester Co.:** Jacques River Gorge PNA, ~1.6 km E of Big Meadow, 47.7822°N, 65.8825°W, 175 m, forest of Red Maple, beech, fir, Paper Birch, and White Spruce, on smooth bark of American Beech, 8 August 2010, *S.R. Clayden 21033*. **Kings Co.:** Shippee Nature Reserve, near top of ridge between Cedar Camp and Chambers Settlement, 45.68733°N, 65.30949°W, 275 m, mainly deciduous forest with Red Oak, hop-hornbeam, Sugar Maple, beech, White Spruce, and Red Spruce, on trunk of Red Oak, 26 August 2017, *S.R. Clayden 26910*; Canadian Forces Base Gagetown, Nerepis Hills, near Askwith Brook, ~500 m ENE of end of Cochrane Lane, 45.4402°N, 66.3008°W, 70 m, moderately open young stand of Red Maple, poplar (*Populus* L.), and birch, on trunks of Red Maple, 7 May 2022, *S.R. Clayden 28686*. **Northumberland Co.:** Nepisiguit PNA, along unnamed brook SW of Popple Depot, 47.38678°N, 66.53639°W, 310 m, mixed forest of fir, Trembling Aspen (*Populus tremuloides* Michaux), Sugar Maple, and birch, on thin branches of Balsam Fir, 17 September 2015, *S.R. Clayden 25658*. **Queens Co.:** Grand Lake PNA, along forest road from Coy Road to East Branch Baltimore Stream, 45.97138°N, 66.11748°W, 50 m, young forest of fir, Paper Birch, and Red Maple, on smooth bark of Balsam Fir, 13 June 2013, *S.R. Clayden 23859*. **Restigouche Co.:** South side of lake at Summit Depot, 47.78125°N, 68.31897°W, 410 m, young forest dominated by fir and White Spruce, on trunk of Balsam Fir, 1 August 2012, *S.R. Clayden, 23537*.

**Sunbury Co.:** Portobello Creek National Wildlife Area, French Island, NE shore, opposite Sand Point, 45.92677°N, 66.30252°W, 10 m, moderately open young forest of Grey Birch, cedar, and Red Maple, with scattered older/larger trees, on large broken Red Maple, 19 August 2014, *K.E. Driscoll 1054*. **York Co.:** Upper part of Kellys Creek, on N side, between Trans-Canada Hwy and Mazerolle Settlement Road, 45.87756°N, 66.82538°W, 95 m, wet forest of Red Maple, fir, Trembling Aspen, and Speckled Alder, on Speckled Alder, 8 June 2008, *S.R. Clayden 18530*.

Also known from Albert County and Kent County, as noted above.

**Rinodina freyi** H. Magn. (syn. *R. glauca* Ropin [Sheard 2010]; Figure 4d)

Reported for New Brunswick by Gowan and Brodo (1988), as *R. magnussonii* Sheard *ined.*, and by Sheard (2010). Characterized by its non-erumpent, broadly to sometimes narrowly attached apothecia which are typically clustered on and around branch axils and leaf scars of twigs and thin branches; thin, green-grey to brownish, areolate to continuous/fisured thallus lacking secondary metabolites detectable by TLC; and eight-spored asci with *Physcia*-type spores measuring (12.5–)14.3–16.9(–19.0) × (6.0–)6.7–7.9(–8.5) μm ( $n = 86$ ) in New Brunswick specimens. The habits of the apothecia and thalli can sometimes resemble those of *R. pachysperma* and *R. populicola*, but these species are readily distinguished by other characters: *R. pachysperma* by its *Pachysporaria*-type spores, and *R. populicola* by its 16–32-spored asci. *Rinodina subminuta* has more dispersed, erumpent apothecia, larger spores, and contains zeorin; it also occurs mainly on tree boles and large branches. The species most similar to *R. freyi* is *R. septentrionalis*. Their differences are noted under *R. septentrionalis*, below.

*Rinodina freyi* is widely distributed in the southern boreal and hemiboreal zones of North America and Eurasia (Sheard 2010, 2018; Brodo 2016; Sheard *et al.* 2017). Its circumscription, nomenclature, and distribution were first clearly resolved by Sheard (2010). In New Brunswick, it occurs on trees and shrubs in a wide range of habitats. However, its small thalli are often inconspicuous and scattered, and it is probably underrepresented in collections. It has been found, for example, on twigs of conifers on coastal headlands subject to salt spray, on planted trees in urban areas, and in openings, edges, or in the canopy of early successional to mature forests of varied composition. Shared features of these disparate microhabitats appear to be nutrient enrichment by external inputs or by leakage from the substrata, and relatively high light levels. The phorophytes of specimens examined

for our study or reliably identified by other collectors included Balsam Fir, Norway Maple (*Acer platanoides* L.), Silver Maple, Sugar Maple, Speckled Alder, Yellow Birch, ash (species not determined), Tamarack (*Larix laricina* (Du Roi) K. Koch), apple (*Malus* Miller), Balsam Poplar (*Populus balsamifera* L.), Trembling Aspen, Pin Cherry (*Prunus pensylvanica* L.), Red Oak, elderberry (*Sambucus* L.), cedar, and White Elm (*Ulmus americana* L.).

*Selected specimens examined*—**Albert Co.:** Caledonia Gorge PNA, along road to Canada Creek, 45.77275°N, 64.78191°W, 333 m, edge of young mixed forest along road, on branches of Pin Cherry, 17 August 2012, *S.R. Clayden* 23652. **Gloucester Co.:** Miscou Island, along boardwalk-trail E of Route 113 at Lac Chenière, 47.96458°N, 64.53225°W, 7 m, open, wet coastal bog with scattered thickets of Tamarack, Black Spruce, and tall shrubs, on branch of Tamarack, 10 July 2015, *S.R. Clayden* 25330. **Kings Co.:** Poley Mountain, just E of ski hill, 45.67478°N, 65.38319°W, 205 m, mixed forest of maple, birch, spruce, fir, hemlock, hop-hornbeam, and poplar, on N-facing slope, on thin young branch of Balsam Fir, 24 February 2017, *S.R. Clayden* 26420. **Madawaska Co.:** Saint-Basile, along Wolastoq (Saint John River), 47.342°N, 68.218°W, 140 m, forest of Silver Maple on levee and floodplain of river, on Silver Maple, 24 June 2010, *S.R. Clayden* 20992. **Northumberland Co.:** close to Doaktown, on elderberry near old saw mill, 5 May 1978, *I. Walker*, s.n. **Restigouche Co.:** Mount Carleton Provincial Park, off W side of Mount Bailey trail, between 1 and 1.5 km from trailhead, 47.41°N, 66.91°W, hardwood stand dominated by Sugar Maple, with moderate amount of Yellow Birch, corticolous on branches of Yellow Birch, 22 July 1989, *S.B. Selva* 4064; Kedgwick River, at confluence with Restigouche River, 47.665°N, 67.491°W, on Trembling Aspen, 29 July 1989, *S.P. Gowan* 5663; MacFarlane Brook PNA, ~5 km NW of confluence with Restigouche River, 47.602°N, 67.626°W, 290 m, broad, shallow brook valley with mesic to wet forest dominated by cedar, with Black Spruce, fir, and scattered Paper Birch, with wet openings dominated by Speckled Alder, on Speckled Alder, 25 May 2007, *S.R. Clayden* 17247. **Saint John Co.:** City of Saint John, Manawagonish Road between Centennial Drive and Hillcrest Drive, 45.241°N, 66.117°W, on elm (*Ulmus* L.), 25 September 1975, *H.R. Hinds* 75-88, 75-97 (det. J.W. Sheard); City of Saint John, Riverview Memorial Park, 45.26817°N, 66.08233°W, 30 m, city park with mature planted trees, mostly Norway Maple, on bark of Norway Maple, 2 June 2004, *M. Mildenberger* 15; *ibid.* on branches from crown of large Red Oak, 3 August 2004, *S.R. Clayden* 12983. **Westmorland Co.:** Fairfield Hills, Walker Road, 6.5

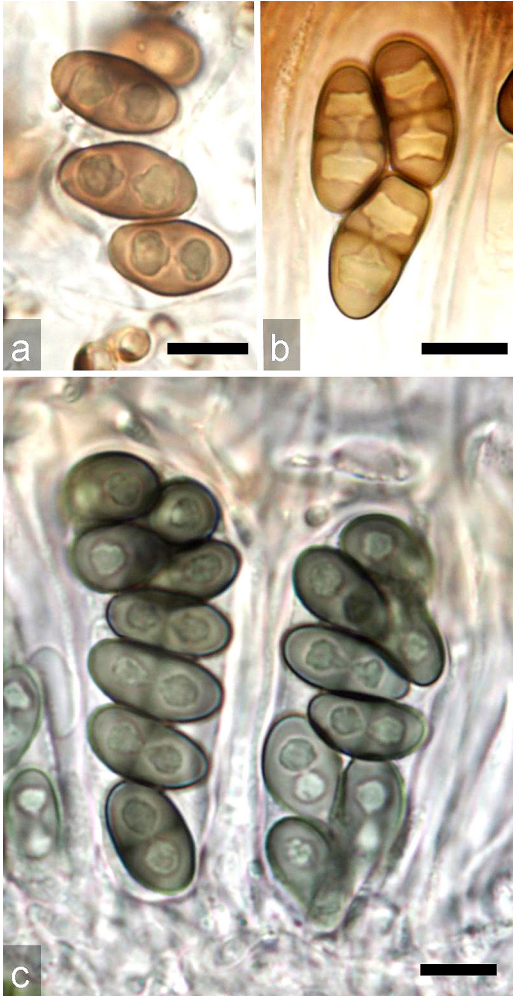
km NNW of Sackville, swampy mature Red Spruce–Red Maple forest, on canopy twigs of 110-year-old Red Maple, 28 June 1987, *H. Harries* 870628-01. **York Co.:** between Trans-Canada Hwy and upper part of Kellys Creek, SW of Mazerolle Settlement, 45.87232°N, 66.82954°W, 95 m, mesic to wet forest of cedar, fir, Red Spruce, Red Maple, and hemlock, on twigs of Eastern White Cedar, 28 April 2006, *S.R. Clayden* 14318.

Also known from **Charlotte Co.:** New River Beach Provincial Park, Barnaby Head Trail between Raspberry Cove and Chitticks Beach, 45.1306°N, 66.5253°W, wet coastal mixed conifer (fir, spruce) forest with scattered hardwoods (mountain-ash [*Sorbus* L.], alder [*Alnus* Miller], birch) and rock outcrops, on alder, 29 April 2011, *W.R. Buck* 57639 (NY); Grand Falls Flowage on St. Croix River, peninsula N of parking area at terminus of NB 725, 45.28°N, 67.48°W, roadside and mixed forest of poplar and fir, on upper branches of fallen poplar, 30 April 2011, *R.C. Harris* 56678 (NY); Caughey-Taylor Nature Preserve, E of NB 127, N and E of Sam Orr Pond, 45.1656°N, 67.0469°W, mixed conifer forest with rhyolite and basaltic outcrops, on apple, 2 May 2011, *R.C. Harris* 56765-A (NY).

#### *Rinodina gennarii* Bagl. (Figure 4e)

Reported for New Brunswick by Räsänen (1933: 15) as “*Rinodina demissa* (Flk.) Mass.” and by Sheard (2010). Both reports are based on a specimen collected by Tapio Reijonen in 1930 at Dalhousie, Restigouche Co., near the north coast of the province. Characterized by its saxicolous (rarely lignicolous) grey-brown areolate thallus; lack of secondary metabolites detectable with TLC; relatively small ascospores tending to become swollen at the septum (Figure 7a), especially in KOH-mounts (*Dirinaria*-type); and occurrence on or near maritime shores (Sheard 2010).

Although it is locally frequent on coastal rocks along the Bay of Fundy, the only previously documented occurrence in the province was the one at Dalhousie, where it was found “on a field stone” (Räsänen 1933: 15). *Rinodina gennarii* is widely distributed in temperate to low-boreal regions of the Northern and Southern Hemispheres (Trinkaus *et al.* 1999). In North America, it occurs exclusively in maritime habitats, mainly in the spray (supralittoral) zone and on surfaces enriched by guano (Sheard 2010, 2018). It is one of the most abundant crustose lichens on rock at a large nesting colony of cormorants and gulls on Manawagonish Island near Saint John, where it is associated with lichens such as *Amandinea punctata* (Hoffm.) Coppins & Scheid., *Lecidella scabra* (Taylor) Hertel & Leuckert, *Myriolectis* species, *Physcia adscendens* (Fr.) H. Olivier, and *Xanthoria parietina*



**FIGURE 7.** Ascospores of selected *Rinodina* species. a. *Rinodina gennarii* (*Dirinaria*-type, lacking a torus and with slight swelling at septum, in 10% KOH; Bremner AB30). b. *Rinodina subminuta* (*Phycia*-type, at intermediate stage of development, with strongly angular lumina, apically thickened walls and darkened torus; Clayden 24853). c. *Rinodina pachysperma* (*Pachysporaria*-type, with rounded lumina, laterally and apically thickened walls, and poorly defined torus; Clayden 28971). Scale bars: 10  $\mu$ m. Photos: S.R. Clayden.

(L.) Th. Fr. It also occurs on driftwood logs at this site. An incidental occurrence on rusted metal at another coastal site (see below) probably also reflects localized nutrient enrichment. On Sable Island, Nova Scotia, *R. gennarii* is “common on cement and concrete” (Richardson *et al.* 2009: 568).

*Specimens examined*—**Albert Co.:** W side of Cape Enrage, coastal sandstone cliff, on HCl+ rock, with *Athallia holocarpa* (Hoffm.) Arup, Frödén & Söchting, *Flavoplaca flavocitrina* Arup, Frödén &

Söchting, and *Myriolecis schofieldii* (Brodo) Šliwa, Zhao Xin & Lumbsch, 45.597°N, 64.781°W, 26 July 1992, S.R. Clayden 7254. **Charlotte Co.:** Pea Point Lighthouse, 1.7 km SW of Black’s Harbour, 45.0392°N, 66.8069°W, on rusted steel plate on the ground, with *A. holocarpa*, *Candelariella aurella* (Hoffm.) Zahlbr., and *X. parietina*, 21 May 2008, D. Malloch, s.n.; New River Beach Provincial Park, Carrying Cove, near start of Barnaby Head trail, rocky coastal shore, 45.1298°N, 66.5277°W, 20 August 2018, S.R. Clayden 27257. **Saint John Co.:** Manawagonish Island, on rock, 45.209°N, 66.108°W, 1 July 1987, S.R. Clayden 5772; *ibid.*, 45.2083°N, 66.1100°W, rocky beach, on driftwood, with *Lecanora xylophila* Hue, 16 October 2006, A.M. Bremner AB30; *ibid.*, 45.20717°N, 66.11021°W, low siltstone rock-outcrops among thickets of North American Red Raspberry (*Rubus idaeus* subsp. *strigosus* (Michaux) Focke) in area with many nesting gulls and cormorants, 13 May 2021, S.R. Clayden 28491, 28493; *ibid.*, 45.20969°N, 66.10654°W, low NW-facing siltstone bluffs at top of cobble beach, 3 to 5 m above mean high tide line, 13 May 2021, S.R. Clayden 28501; Saints Rest Marsh—F. Gordon Carvell Nature Preserve, at mouth of Manawagonish Creek, rocky coastal shore, on rock, 45.22309°N, 66.14230°W, 16 August 2013, S.R. Clayden 24130 p.p.

Also known from Restigouche Co., as noted above.

***Rinodina moziana*** (Nyl.) Zahlbr. (syn. *Mischoblastia moziana* (Nyl.) S.Y. Kondr., L. Lökös & J.-S. Hur [Kondratyuk *et al.* 2021]; *Rinodina destituta* Zahlbr. [Sheard *et al.* 2017]; Figure 4e)

Reported for New Brunswick by Sheard (2010) as *R. destituta*, based on a specimen collected by Sharon Gowan in Fundy National Park in 1980 (details below). Characterized by its areolate, grey, saxicolous thallus containing atranorin in the cortex (K+ yellow, crystals visible in polarized light), and lightly pigmented ascospores with strongly thickened apical walls and triangular to rounded lumina (*Mischoblastia*-type: Sheard [2010]). The New Brunswick specimen was originally reported as *Rinodina arenaria* (Hepp) Th. Fr. or *Rinodina iowensis* Zahlbr. (Gowan and Brodo 1988: 279, 305, 322). It was accurately described as having a K+ yellow thallus and spores 21–24  $\times$  10–14  $\mu$ m (Gowan and Brodo 1988); however, the taxonomy and nomenclature of these species were not well resolved at the time (Sheard 2010). *Rinodina arenaria* is a synonym of *Rinodina teph-raspis* (Tuck.) Herre, which is distinguished from *R. moziana* by its K– cortex (lacking atranorin), among other characters; *R. iowensis* is a synonym of *Rinodina cana* Zahlbr., which also lacks atranorin and is

not known to occur in eastern Canada or northern New England (Sheard 2010).

*Rinodina oxydata* (A. Massal.) A. Massal. resembles *R. moziana* in having *Mischoblastia*-type spores and a saxicolous thallus containing atranorin. However, its thallus is typically thinner and more fissured (“rimose”) than that of *R. moziana*, and its spores are smaller (Sheard 2010). Although it has not been found in New Brunswick, *R. oxydata* is to be expected in the province, as scattered occurrences are known in southern Ontario, Quebec, southeastern Newfoundland, and Maine (Sheard 2010; Lendemer et al. 2014; Seaward et al. 2017). In contrast, the record of *R. moziana* in Fundy National Park is isolated by more than 700 km from the closest known occurrences in Ontario (Sheard 2010; Brodo et al. 2021a) and southern New England (Sheard 2010; Lendemer et al. 2014). It has not been recorded elsewhere in Atlantic Canada, Quebec, or Maine. S.R.C. revisited the *R. moziana* locality in Fundy National Park in July 2022, but did not relocate the species during a ~2.5-hour search.

*Specimen examined and cited by J.W. Sheard* (Sheard 2010)—**Albert Co.:** Fundy National Park, Point Wolfe, below covered bridge, on south facing conglomerate cliffs above water, 19 June 1980, S.P. Gowan 2456 (Canadian Museum of Nature Lichen Herbarium [CANL]).

#### *Rinodina pachysperma* H. Magn. (Figure 4f)

New to New Brunswick. Endemic to eastern North America, this species is readily distinguishable from other corticolous *Rinodina* species in Atlantic Canada with K- and P- thalli by its *Pachysporaria*-type ascospores with rounded lumina and both lateral and apical internal wall-thickenings (Figure 7c). The spores in the New Brunswick specimens are slightly larger,  $(13.5\text{--}15.8\text{--}18.7\text{--}21.5) \times (6.5\text{--}7.8\text{--}9.7\text{--}11) \mu\text{m}$  ( $n = 75$ ), and more variable in shape (length/width ratio  $(1.6\text{--}1.7\text{--}2.3\text{--}2.6)$ ) than reported for this species by Sheard (2010, 2018). In *R. freyi* and *R. subminuta*, the spore lumina are angular (see Figure 7b) until overmature, and the apical walls are distinctly thicker than the lateral walls (*Physcia*-type). Thalli of *R. pachysperma* rarely form “consoredia” that break down into individual soredia  $10\text{--}20 \mu\text{m}$  in diameter (Sheard 2010, 2018); however, we have not found sorediate thalli of *R. pachysperma* in New Brunswick. *Rinodina papillata* H. Magn. has *Pachysporaria*-type spores similar to those of *R. pachysperma*, but it has a glossier thallus with marginal, bulbous to cylindrical, bud-like propagules (“blastidia”) measuring  $\sim 200\text{--}300 \times 150 \mu\text{m}$  (Sheard 2010, 2018). In Canada, *R. papillata* has been reported from a single locality in southern Ontario (Sheard 2010).

*Rinodina pachysperma* is locally abundant in bot-  
tomland hardwood forests dominated by Silver Maple on the floodplain of the Wolastoq (Saint John River) and its tributaries in south-central New Brunswick. The hydrology, climate, and biota of this area are exceptional in several respects. It includes the largest freshwater lake (Grand Lake) and wetland complex in Atlantic Canada; it has the warmest climate of any of New Brunswick’s ecoregions; and it forms the northeastern limit of the ranges of several species of temperate North American hardwood trees and other vascular plants (Clayden 2000; Zelazny 2007).

In some stands we examined, *R. pachysperma* forms extensive cover on the trunks and lower branches of Silver Maple down to or below the spring high-water line. It also occurs on Red Ash (*Fraxinus pennsylvanica* Marshall), Black Willow (*Salix nigra* Marshall), Basswood (*Tilia americana* L.), and White Elm in or at the edge of the floodplain forests (Figure 2a). It is sometimes accompanied by species of *Phaeophyscia* and *Physcia*. However, epiphytic lichen species richness and coverage on Silver Maple in the floodplain forests, at least in the shaded understorey of stands with a continuous canopy, is generally much lower than on Sugar Maple and associated hardwoods in mesic upland settings in the province (S.R.C. unpubl. data). We did not find any of the characteristic *Rinodina* species of upland hardwoods (*R. ascoiscana*, *R. subminuta*, *R. willeyi*) on Silver Maple in the floodplain forests (Figure 3).

The floodplain habitat of *R. pachysperma* in New Brunswick is similar to that of an occurrence in Ontario reported by Brinker (2020). Records of this species posted on the website of the Consortium of Lichen Herbaria (2023) indicate, likewise, that seasonally flooded forests are its most common habitat. This association may account for a concentration of records of *R. pachysperma* along the upper Mississippi River and its major tributaries in the central United States (Sheard 2010). It is apparently rare or at least generally overlooked in upland settings in the Appalachian Mountains (Lendemer et al. 2014). Records from coastal pine-oak forests on Long Island (Brodo 1968) were revised by Sheard (2010) to *Rinodina maculans* Müll. Arg. The latter species has a mainly coastal distribution and reaches its northeastern range limit in southern New England (Sheard 2010).

The occurrences of *R. pachysperma* in New Brunswick fill a large gap in the reported distribution of this species in the Northeast. Previously, the only record east and north of southern Quebec was an anomalous outlier in boreal western Newfoundland, documented by a specimen (and duplicates) collected by A.C. Waghorne at Deer Lake in 1897 (Sheard 2010). This collection (Waghorne 842) was first reported by Arnold

(1899) as *Rinodina sophodes* f. *albana* A. Massal. (= *Rinodina albana* (A. Massal.) A. Massal.), a species with larger spores and differently shaped spore-lumina that is not known to occur outside Europe (Nadyeina *et al.* 2010). Waghorne did not record details of the habitat or substratum of the specimen. However, the authenticity of his late 19th-century collections of many uncommon and rare lichens has been validated by recent rediscoveries of a number of these species in Newfoundland (J.W. McCarthy pers. comm. 10 August 2022). A possible phorophyte for his collection of *R. pachysperma* could have been Balsam Poplar. Isolated occurrences of several temperate mosses are known from this tree species in western Newfoundland (Belland 1981; Belland and Brassard 1981). Waghorne collected at least one such moss, *Pyloisia selwynii* Kindb., at Deer Lake (Belland and Brassard 1981).

**Selected specimens examined—Kings Co.:** unnamed wooded island near mouth of Nerepis River, 1 km NW of Woodmans Point, 45.37°N, 66.24°W, 5 m, Silver Maple riparian forest on alluvial island, on exfoliating bark of large Silver Maple overhanging river, 30 August 1988, *S.R. Clayden 6500*. **Queens Co.:** Grand Lake PNA, between Raft Channel and Jemseg River, 45.79493°N, 66.10117°W, 5 m, floodplain forest of Silver Maple and Red Ash on deep alluvial soil, abundant on smooth bark of young Red Ash, 16 August 2014, *S.R. Clayden 24720 & K.E. Driscoll*. **Sunbury Co.:** Portobello Creek National Wildlife Area, along Route 690, 1 km SW of Lakeville Corner, 45.8999°N, 66.2585°W, 5 m, floodplain forest of Silver Maple along lakeshore, on trunk of Silver Maple, 15 June 2013, *S.R. Clayden 24101* (det. J.W. Sheard). **York Co.:** Lower Lincoln, between mouth of Oromocto River and Wolastoq (Saint John River), Thatch Road, ~800 m SE of junction with Route 102, 45.86586°N, 66.50396°W, 5 m, floodplain forest of Red Ash, Silver Maple, Basswood, and Butternut (*Juglans cinerea* L.), on Basswood, 22 September 2019, *S.R. Clayden 28073*; Upper Shores Island, 45.96925°N, 66.81758°W, mature riparian forest of Red Ash, Basswood, Butternut, and Silver Maple, on trunk of young Red Ash, 7 April 2022, *S.R. Clayden 28649*.

***Rinodina polyspora*** Th. Fr. (Figure 4g)

Reported for New Brunswick by Gowan and Brodo (1988) and Sheard (2010). Characterized by its very thin thallus; scattered (not clustered) apothecia which are usually <0.5 mm in diameter and soon become convex, excluding the thalline margin; and 12–16-spored asci with *Physcia*- to *Physconia*-type ascospores (apical walls initially thick, but sometimes becoming thinner in mature stages). *Rinodina populicola* has a more conspicuous, distinctly areolate thallus, and larger, persistently marginate apothecia

mostly containing 16–32 *Physconia*-type spores per ascus. In both species, eight-spored asci are also uncommonly present together with asci with higher spore numbers (Sheard 2010; our study).

*Rinodina polyspora* is known from eastern and western North America (Sheard 2010) and eastern and western Eurasia (Mayrhofer and Moberg 2002; Sheard *et al.* 2017). In eastern North America, it is distributed in a fairly narrow latitudinal band from the western Great Lakes region to the Maritime provinces (Sheard 2010). Records from the northeastern United States, including Maine, Massachusetts, New Hampshire, New York, Pennsylvania, and Vermont, all appear to date from the 19th and early 20th centuries (Consortium of Lichen Herbaria 2023). Declines or extirpations of *R. polyspora* in Europe are also inferred to have occurred (Mayrhofer and Moberg 2002; Wirth *et al.* 2013; Nimis *et al.* 2018; Wirth 2021), but the factors underlying these changes are uncertain (Wirth 2021). Owing to the limited extent and depth of lichen surveys in New Brunswick and the other Maritime provinces before recent decades, it is not possible to assess whether *R. polyspora* has declined in abundance in this region.

Gowan and Brodo (1988) reported this species from old field and roadside habitats in Fundy National Park, where it was found on Trembling Aspen. Another roadside occurrence near Sussex, Kings Co. (not “Sussex Co.”) was reported by Sheard (2010). Our study documents eight further occurrences scattered throughout the province in forest habitats ranging from wet mixed-wood stands dominated by cedar to mesic upland hardwoods. Among the 13 specimens with phorophyte data, including those from Fundy National Park, seven were on Black Ash, three on Trembling Aspen, and one each on Sugar Maple, American Beech, and Balsam Poplar. The occurrences on ash were mostly on smooth bark of saplings in openings in cedar swamp forests.

**Specimens examined—Charlotte Co.:** St. Croix River, Clark Point PNA, ~0.5 to 1 km SE of point, 45.319°N, 67.442°W, 77 m, wet mixed forest dominated by cedar, Red Maple, and Black Ash, with scattered fir and Black Spruce, on young Black Ash, 27 May 2007, *S.R. Clayden 17502 p.p.* **Gloucester Co.:** Jacquet River Gorge PNA, between Antinouri Lake and Big Meadow, 47.771°N, 65.944°W, 215 m, young moderately open forest dominated by Sugar Maple, with scattered Paper Birch and White Spruce, on stems of young Black Ash, 15 August 2010, *S.R. Clayden 21181*. **Kings Co.:** Poley Mountain, ~11 km SE of Sussex, 45.67588°N, 65.37412°W, 265 m, forest of Sugar Maple, beech, White Ash, hop-hornbeam, Yellow Birch, and Paper Birch, on steep NE-facing slope, on smooth bark of American Beech,

branch from crown of recently fallen tree, 15 November 2013, *S.R. Clayden 24337*. **Northumberland Co.:** Goodfellow Brook PNA, between Lake Brook and Goodfellow Brook, ~16 km SSW of Miramichi, 46.896°N, 65.380°W, 35 m, wet mixed forest of Red Maple, Black Ash, cedar, spruce, fir, Speckled Alder, and Mountain Holly (*Ilex mucronata* (L.) M. Powell, V. Savolainen & S. Andrews), on Black Ash sapling, 23 May 2007, *S.R. Clayden 16930*; Nepisiguit PNA, at confluence of unnamed creek and Little South Branch Nepisiguit River, 47.3317°N, 66.6891°W, riparian forest with Balsam Poplar, spruce, Paper Birch, and fir, somewhat disturbed, on Balsam Poplar, 4 July 2015, *K.E. Driscoll 1218*. **Restigouche Co.:** Berry Brook PNA, headwaters area of Berry Brook, ~8 km S of Saint-Arthur, 47.81414°N, 66.75800°W, 310 m, mesic to wet forest of cedar, fir, and Black Spruce, with scattered Red Maple and Black Ash, on dead branch of Black Ash, 5 November 2006, *S.R. Clayden 16703 p.p.* **York Co.:** Eel River PNA, ~2 km SW of Browns Mountain, N side of large open peatland, 45.89629°N, 67.64210°W, 143 m, wet, moderately open forest of cedar and Tamarack, on Black Ash, 3 August 2006, *S.R. Clayden 15714 p.p.*; N side of Kellys Creek, ~1.7 km E of junction of Mazerolle Settlement Road and Mountain Road, 45.8723°N, 66.8414°W, 75 m, thicket of Speckled Alder, Black Ash, Red Maple, and Chokecherry (*Prunus virginiana* L.) near brook, on Black Ash, 7 June 2008, *S.R. Clayden 18479 p.p., 18481 p.p., 18490 p.p.*; Spednic Lake Provincial Park, Boulderwalk Trail, 45.60709°N, 67.44422°W, 145 m, mesic hardwood forest dominated by beech, Sugar Maple, and Yellow Birch, on trunk of large Sugar Maple, 16 June 2018, *S.R. Clayden 27081*.

Also known from Albert Co. (Gowan and Brodo 1988).

#### *Rinodina populicola* H. Magn. (Figure 4h)

New to New Brunswick. This species differs from *R. polyspora* not only in its greater spore number per ascus, smaller spore size, and lack of persistent apical spore-wall thickenings, but also in the external morphology of the thallus and apothecia (see above and Figure 6c). In one case (*Clayden 18490*), the two species were found growing together on a branch of Black Ash. The habit and colouration of the thalli of *R. populicola* can resemble those of some other *Rinodina* species, including *R. pachysperma* (Sheard 2010). Thus, field identification is not feasible.

*Rinodina populicola* is endemic to central and eastern North America (Sheard 2018). Much like *R. pachysperma*, it extends westward to the edge of the forest/prairie transition in the centre of the continent. East of the lower St. Lawrence River valley, it has

been documented previously only from a few scattered localities in Quebec and Maine (Sheard 2010). The collections reported here date from 2008 to 2022 and are from four localities in south-central and southwestern New Brunswick. Two were from canopy branches of poplars (Balsam Poplar, Trembling Aspen), and all were in relatively humid settings near waterbodies, a set of general habitat characteristics that might guide future searches for this lichen in the province and elsewhere in eastern Canada.

*Specimens examined*—**York Co.:** N side of Kellys Creek, ~1.7 km E of junction of Mazerolle Settlement Road and Mountain Road, 45.8723°N, 66.8414°W, 75 m, thicket of Speckled Alder, Black Ash, Red Maple, and Chokecherry near brook, on Black Ash, 7 June 2008, *S.R. Clayden 18490 p.p.* (with *R. polyspora*); Spednic Lake PNA, Lower Palfrey Neck, 45.62548°N, 67.45639°W, mixed forest of beech, Red Maple, hemlock, spruce, birch, and poplar, on branch of Trembling Aspen fallen from crown of tree, 24 June 2018, *S.R. Clayden 27239*; S side of Wolastoq (Saint John River) at Island View, 45.95904°N, 66.82554°W, 10 m, forest of Red Ash, Butternut, and Black Willow, on river bank, on trunk of Red Ash, 23 May 2022, *S.R. Clayden 28693* (with *R. pachysperma*); French Village, Mactaquac Biodiversity Facility [Fish Hatchery], 45.95738°N, 66.84356°W, 10 m, line of tall Balsam Poplar along road adjoining mowed fields, on branches of Balsam Poplar from tree canopy, found on the ground, 25 September 2022, *S.R. Clayden 28963*.

#### *Rinodina septentrionalis* Malmé (Figure 4b)

New to New Brunswick. This species is closely related to *R. freyi* (Nadyeina et al. 2010; Sheard 2010; Kondratyuk et al. 2021), differing in its more dispersed apothecia that are often more narrowly attached at maturity, and by its smaller, more convex, and likewise more dispersed areoles. There may also be a slight difference in mean ascospore size between the two species, at least in North American populations: “16.0–16.5 × ca. 8.0 μm” in *R. septentrionalis*, versus “15.0–15.5 × 7.5 μm” in *R. freyi* (Sheard 2018: 407). In the single specimen of *R. septentrionalis* reported here, the ascospores are (14.0–)15.1–17.9 (–20.0) × (7.0–)7.3–8.0(–8.5) μm ( $n = 44$ ). The mean size is 16.5 × 7.6 μm, versus 15.6 × 7.3 μm in New Brunswick collections of *R. freyi* (see above), consistent with the difference noted by Sheard (2018).

The two species also differ ecologically and in their geographical distributions. *Rinodina septentrionalis* occurs on relatively smooth portions of tree branches, whereas *R. freyi* is mostly confined to branch axils and leaf scars (Sheard 2010; Sheard et al. 2017). Sheard (2010) suggested that this difference

reflects more rapid drying of areas of smooth bark than of axil and leaf-scar micro-niches. At the single known locality in New Brunswick, *R. septentrionalis* was found on branches of Balsam Poplar together with *A. pyracea*, *Caloplaca cerina* (Hedw.) Th. Fr., *Hypogymnia incurvodes* Rass., *Melanohalea septentrionalis* (Lyngé) O. Blanco *et al.*, *Parmelia sulcata* Taylor, *Physcia aipolia* (Ehrh. ex Humb.) Fűrnr., *Scoliosporum chlorococcum* (Graewe ex Stenh.) Vězda, and the calicioid fungus *Phaeocalicium populneum* (Brond. ex Duby) A.F.W. Schmidt.

*Rinodina septentrionalis* has a more northerly distribution than *R. freyi*, occurring in the boreal to hemiarctic zones and their elevational counterparts in North America and Eurasia. In North America, it has been recorded widely in the western Cordillera, from Alaska to Colorado, and eastward to Hudson Bay, Lake Superior, and the Clay Belt region of western Quebec (Sheard 2010). The occurrence in northern New Brunswick reported here extends its known range eastward by about 900 km. The locality is in the bottom of a river valley in the Highlands ecoregion of the province, which has a strong representation of boreal plant communities and species (Loucks 1962a; Clayden 2000, 2010; Zelazny 2007). Although the local elevation of the valley floor is only ~250 m, species distributions in the area reflect the influence of night-time cold-air drainage off adjoining slopes during the growing season. The frost-free season is shortest in valley-floor, lower-slope, and hilltop positions, the latter locally above ~550 m. These situations are accordingly dominated by boreal conifers, whereas stands of temperate hardwoods are present on the warmer mid-slopes. Similar topo-climatic and associated vegetation gradients in northwestern New Brunswick were elucidated in a classic study by Loucks (1962b). It seems likely that *R. septentrionalis* is more frequent in valley-floor settings in northern New Brunswick than the single record reported here might suggest.

*Specimen examined*—**Northumberland Co.:** Nepisiguit PNA, Popple Depot, 47.39709°N, 66.51492°W, 250 m, edge of heathy forest of Black Spruce and Jack Pine (*Pinus banksiana* Lambert), with poplar, Paper Birch, and willow, adjoining a cleared and levelled (bulldozed) area, on branches of Balsam Poplar, 15 September 2015, S.R. Clayden 25620 (confirmed by J.W. Sheard).

*Rinodina subminuta* H. Magn. (syn. *R. annulata* H. Magn. [Sheard 2010]; *R. halei* H. Magn. [Sheard 2010]; Figure 4i)

Reported for New Brunswick by Gowan and Brodo (1988) and Sheard (2010). Characterized by its usually inconspicuous thallus, which is partly to

largely within the bark substratum, or else superficial, thin, and pale grey, green grey, or grey brown; apothecia initially immersed in the thallus or substratum, and remaining broadly attached, the discs often becoming eroded (Figure 6d); *Physcia*-type ascospores (Figure 7b) measuring (15–)17.4–20.9(–24) × (7.5–)8.7–10.5(–11.5) μm ( $n = 88$ ) in New Brunswick specimens; and chemistry (K–, P–, containing zeorin only).

Sheard (2010) noted that ascospores are scarce in the apothecia of many specimens of *R. subminuta*, possibly due to physical inhibition of ascus development by dense gelatinization of the hymenium. While we, too, observed this tendency, a specimen collected in late winter (8 March 2021, *Clayden 28457*) is an exception. This contains numerous well-developed mature asci and spores. The question thus arises whether spore development and discharge in this species are also distinctly seasonal, as they appear to be in *R. ascociscana*.

This is the most common *Rinodina* species in New Brunswick. It is widely distributed in eastern North America, its range coinciding largely but not entirely with that of Sugar Maple, the tree species on which it has been recorded most frequently (Sheard 2010; Brodo 2016). It is also common in mixed and broad-leaf deciduous forests in temperate northeastern Asia (Sheard *et al.* 2017; Galanina *et al.* 2021a). It is apparently less frequent in the southern Appalachians (Lendemmer *et al.* 2014) than in the broad zone of Sugar Maple-dominated forests extending from the Great Lakes region to the Maritime provinces (Gowan and Brodo 1988; Wong and Brodo 1992; Selva *et al.* 2004; Harris 2015).

Among 89 specimens of *R. subminuta* from New Brunswick that we examined for this study, 48 were on Sugar Maple, 10 on Black Ash, nine on Yellow Birch, five on White Elm, four on Balsam Poplar, two each on Mountain Maple, American Beech, White Ash, and Trembling Aspen, and one each on Striped Maple, Red Maple, Butternut, Smith's Willow (*Salix × smithiana* Willdenow), and American Mountain-ash. We did not find *R. subminuta* on Eastern White Cedar. Its apparent rarity on Red Maple and the lack of records from Silver Maple also stand out. Although most records are from forests, *R. subminuta* has also been found in New Brunswick on open-grown trees in fields and along roadsides in rural and suburban settings.

The type of *R. subminuta* is a 19th-century specimen collected by Edward Tuckerman in the White Mountains of New Hampshire, reportedly on *Acer "saccharinum"* (Magnusson 1947; Sheard 2010). However, the substratum noted on the label of the type specimen and isotypes (no. 88 in the exsiccata

Reliquiae Tuckermanianae) is “*Acer saccharinum* Wang.” The latter name was widely misapplied to Sugar Maple in the 19th and early 20th centuries before it emerged that Linnaeus had validly described Silver Maple as *A. saccharinum* L. in 1753 in his *Species Plantarum* (Shaw 1977). Thus, the type of *R. subminuta* almost certainly originated from Sugar Maple, not Silver Maple. These two maple species occur in distinct environments, as noted above under *R. pachysperma*: Sugar Maple on well drained, mostly upland sites, and Silver Maple largely in seasonally flooded bottomlands. The type specimen of *R. halei* (= *Rinodina subminuta* [Sheard 2010]) is likewise from Sugar Maple (Magnusson 1953), not Silver Maple (Sheard 2010). These associations are consistent with the frequency of *R. subminuta* on Sugar Maple in eastern North America and with its apparent absence on Silver Maple, at least in New Brunswick, but possibly more widely.

Most records of *R. subminuta* in New Brunswick are from the lower part of tree boles. We have not found it on canopy branches in forests, although it sometimes occurs on small, thin, shade-suppressed hardwoods in the understorey of mature stands. Hinds (1970) documented a similar vertical distribution of *R. subminuta* (as *R. annulata*) on Balsam Poplar in northern Michigan: it was present only near the tree bases, not on smooth bark higher on the trunks. Tall deciduous shrubs such as Hobblebush (*Viburnum lantanoides* Michaux) and Beaked Hazel (*Corylus cornuta* Marshall) are common in the understorey of upland hardwood forests in New Brunswick, but we have not found *R. subminuta* on these species.

There is a single unusual New Brunswick record of *R. subminuta* (Clayden 24853) from American Mountain-ash. The collection is from the trunk of a dead tree that remained in a recently clearcut boreal forest dominated by fir. Mountain-ash was not among the phorophytes of North American specimens of *R. subminuta* examined by Sheard (2010). However, it occurs on mountain-ash in Japan and Russia (Sheard et al. 2017; Galanina et al. 2021b). The occurrence in New Brunswick is from an elevation higher than that of the local topoclimatic limit of Sugar Maple. Mean temperatures at a climate station (Upsalquitch Lake) at a similar elevation (625 m) about 12 km northeast of this occurrence are 15.9°C in July and -13.1°C in January, with annual growing-degree-days (5°C threshold) averaging 1204 (ECCC 2022). These values place the locality well within the (oro-)boreal zone (Clayden 2010). Associated lichens on the tree with *R. subminuta* included, e.g., *Buellia disciformis* (Fr.) Mudd, *Caloplaca borealis* (Vain.) Poelt, *Lobaria pulmonaria* (L.) Hoffm., and *Nephroma resupinatum* (L.) Ach., an assemblage indicative of a relatively

high bark pH.

*Rinodina subminuta* has also been found on mountain-ash (Showy Mountain-ash [*Sorbus decora* (Sargent) C.K. Schneider]) in subalpine (upper oroboreal) fir–birch forest at ~900 m elevation on Mount Katahdin in neighbouring Maine, USA (Hinds et al. 2009). This occurrence and the record from montane northern New Brunswick indicate that the potential range of *R. subminuta* in northeastern North America is greater than that of its main phorophyte, Sugar Maple. However, it has not been recorded from the island of Newfoundland, or north of the Gulf of Saint Lawrence, where mountain-ash is a frequent component of fir-dominated forests. Sugar Maple is absent from Newfoundland, but outlying occurrences of a number of lichens characteristic of temperate deciduous forests are known on the island (Ahti 1983; McCarthy et al. 2015).

*Selected specimens examined*—**Albert Co.:** Lewis Mountain PNA, headwaters area of Turtle Creek, 45.8405°N, 64.8476°W, 345 m, old-growth hardwood forest dominated by Sugar Maple, beech, and Yellow Birch, on trunk of White Ash, 5 July 2011, S.R. Clayden 22308; Wilson Brook PNA, south side of Wilson Brook, ~1.3 km W of Albert Mines Road, 45.86034°N, 64.67532°W, 65 m, mixed forest of fir, birch, and maple near base of N-facing gypsum bluffs along brook, on stem of Mountain Maple, 21 September 2020, S.R. Clayden 28356. **Carleton Co.:** 250 to 400 m N of Southern Carleton Elementary School at Bedell, 46.14965°N, 67.62825°W, 160 m, mature forest of Sugar Maple with high canopy and rich understorey flora, on Sugar Maple, 7 May 2008, S.R. Clayden 18172. **Charlotte Co.:** Pomeroy Ridge, ~4.1 km NW of intersection of Route 735 and Route 732, 45.3087°N, 67.4362°W, 65 m, moderately open, wet forest of Red Maple, Black Ash, fir, Balsam Poplar, Speckled Alder, and Common Winterberry (*Ilex verticillata* (L.) A. Gray), on Black Ash, 5 June 2008, K. E. Driscoll 166. **Gloucester Co.:** Bass River PNA, south side of East Branch Bass River, just W of Route 8, 47.4502°N, 65.524°W, 145 m, mature forest of Sugar Maple, Yellow Birch, beech, Striped Maple, and Beaked Hazel, on Sugar Maple, 27 May 1999, S.R. Clayden 9889. **Kent Co.:** Kouchibouguac National Park, N side of Black River, 1.4 km W of Route 117, 46.8387°N, 65.0102°W, 10 m, terrace of river, with mixed forest of Red Maple, Sugar Maple, fir, Black Spruce, Trembling Aspen, Yellow Birch, and scattered large dead White Elm, on trunk of White Elm, 5 July 2001, S.R. Clayden 11059. **Kings Co.:** McDermott Hill, ~5 km SE of Waterford, 45.65636°N, 65.31539°W, 330 m, old-growth hardwood forest dominated by Sugar Maple, Yellow Birch, and beech, on Sugar Maple, 3 May 2005, S.R. Clayden

13365. **Madawaska Co.:** Jalbert Brook, between forest road and First Lake, 47.647°N, 68.300°W, 230 m, mature forest of fir, White Spruce, Black Ash, and Mountain Maple, with a few large snags and small living trees of White Elm, corticolous on White Elm, 23 June 2010, *S.R. Clayden 20979*. **Northumberland Co.:** South of Chatham, along Lake Brook, tributary of Black River, Black Ash swamp forest near edge of marsh, on Black Ash, 26 August 1979, *I. Walker, s.n. (H. Harries 79104)*; Mount Carleton Provincial Park, off south side of Big Brook Trail, ~6.3 km from Pine Point, 47.36°N, 66.84°W, mixed hardwood forest dominated by Sugar Maple and Yellow Birch, corticolous on Yellow Birch, 1 August 1989, *S.B. Selva 4155*; ~4.7 km NW of Popple Depot, height of land just outside NE corner of Nepisiguit PNA, 47.41912°N, 66.56480°W, 680 m, clear-cut forest of fir, Heart-leaved Birch, and American Mountain-ash, on a hilltop, corticolous on trunk of dead mountain-ash, 18 September 2014, *S.R. Clayden 24853*; Hells Gate Hardwoods PNA, ~6.5 km ENE of Saint Margarets, 46.9232°N, 65.1121°W, 40 m, mature hardwood forest dominated by Sugar Maple, Red Maple, and Yellow Birch, on trunk of Sugar Maple, 14 September 2019, *S.R. Clayden 27998A*. **Queens Co.:** Grand Lake PNA, just south of Route 105 at Trout Creek, 1 km SW of Jemseg, 45.82332°N, 66.12413°W, 5 m, floodplain forest of Silver Maple and Red Ash, on trunk of White Elm, 13 August 2014, *S.R. Clayden 24691*. **Restigouche Co.:** Jacquet River Gorge PNA, upland between Winston Gulch and Cook Gulch, near forest road, 47.74908°N, 66.11139°W, 285 m, mixed mature forest of Sugar Maple, Yellow Birch, and White Spruce, abundant on smooth bark of Yellow Birch, 24 June 2008, *S.R. Clayden 18719*; *ibid.*, W side of Jacquet River, at mouth of Big Hole Brook, 47.825°N, 66.077°W, 50 m, forest of Balsam Poplar, fir, and Black Ash on alluvial terrace next to river, on trunk of Balsam Poplar, 14 May 2010, *S.R. Clayden 21330*. **Saint John Co.:** City of Saint John, Seaside Park, 45.24746°N, 66.08243°W, 45 m, lawn with planted trees, on branch of Smith's Willow, 18 October 2020, *S.R. Clayden 28385*; City of Saint John, Red Head Road ¾ mile before Mispec Point Road, 45.250°N, 66.000°W, on roadside European Elms [probably Scotch Elm (*Ulmus glabra* Hudson): S.R.C. pers. obs.], 20 June 1975, *H.R. Hinds 75-98* (det. J.W. Sheard); **Westmorland Co.:** 3 to 4 km N of Cookville, on trunk of old elm trees in old field area, 16 August 1977, *H. Harries 77153*. **York Co.:** Between Williamstown and Lakeville, along NB Trail, 46.37033°N, 67.67613°W, 125 m, forest of Sugar Maple, Yellow Birch, beech, and fir, on Sugar Maple, 4 August 2006, *S.R. Clayden 15907*; Odell Park, 45.95428°N, 66.66842°W, 75 m, old mixed

forest dominated by Sugar Maple, beech, hemlock, and Yellow Birch, on thin branch of sapling of American Beech, 8 March 2021, *S.R. Clayden 28457*.

***Rinodina subpariata*** (Nyl.) Zahlbr. (syn. *Rinodina degeliana* Coppins [Resl *et al.* 2016; Sheard *et al.* 2017]; Figure 4j)

Reported for New Brunswick by Sheard (1995, 2010) and Resl *et al.* (2016, inadvertently spelled *R. "subpariata"*). Readily separable from the other two sorediate *Rinodina* species occurring in the province by its K+ yellow and P+ yellow thallus containing atranorin. *Rinodina efflorescens* and *R. willeyi* contain pannarin, not atranorin, and are K- and P+ red orange; *R. efflorescens* additionally contains secalonic acid A (soralia KC+ yellow orange). Both *R. subpariata* and *R. willeyi* have lighter-coloured thalli than *R. efflorescens*, in which the areoles usually have a brownish hue and are often distributed on a darker brown very thin prothallus. *Rinodina subpariata* and *R. willeyi* can usually be distinguished from one another in the field by the colour of their soredia: in *R. subpariata* they are persistently white, contrasting with the light-grey corticate portions of the areoles, whereas in *R. willeyi* both areoles and soredia are greyish. Well-developed thalli of *R. subpariata* with upturned areole-margins can sometimes superficially resemble the micro-squamulose lichen *Toensbergia leucococca* (R. Sant.) Bendiksby & Timdal. The light grey, marginally sorediate squamules of this species are K+ and P+ yellow, but also C+ pink. It contains alectorialic acid (not atranorin), and the thalli turn pinkish over time in herbarium specimens (Tønsberg 1992—as *Hypocnomyce leucococca* R. Sant.; S.R.C. pers. obs.). These two species also differ ecologically. In New Brunswick, *R. subpariata* occurs widely on a range of hardwood tree species, less frequently on Eastern White Cedar (Cupressaceae), and rarely on Balsam Fir and spruce (Pinaceae); *T. leucococca* is confined to pinaceous conifers and hardwoods with comparably acidic bark and is so far known only from the northern counties of the province (S.R.C. and K.E.D. unpubl. data).

Apothecia are sparsely present in 14 of the 51 New Brunswick specimens of *R. subpariata* that we examined. However, the ascospores are poorly developed or overmature in most of this material, a finding consistent with observations made by J.W. Sheard (Resl *et al.* 2016; Sheard *et al.* 2017). In *Clayden 28373A*, the spores are (17–)18.2–22.1(–23) × (9–)9.3–10.7(–11) µm, with a length/width ratio of (1.8–)1.9–2.2(–2.4) ( $n = 12$ ). The type specimen of *R. subpariata*, from Japan, is fertile (with apothecia), but lacks soredia (Resl *et al.* 2016; Sheard *et al.* 2017). Other such thalli are known from high elevations in Japan, but

Resl *et al.* (2016) showed that these are nested phylogenetically in a clade that also includes sorediate thalli. We have not found fertile non-sorediate thalli of *R. subpariata* in New Brunswick.

The North American and global distributions of *R. subpariata* (including *R. degeliana*) are broadly similar to those of *R. efflorescens* (Sheard 1995, 2010; Lendemer *et al.* 2014; Sheard *et al.* 2017; Galanina *et al.* 2021b). In eastern North America, it occurs extensively in the Appalachian–Great Lakes–Maritimes region and was recently reported from Newfoundland (Sheard 2018). A study of the molecular phylogenetic relationships of collections of *R. subpariata* from several parts of its range in the Northern Hemisphere showed that material from eastern North America (including Clayden 24048 from New Brunswick, cited below) groups most closely with collections from eastern Asia (Resl *et al.* 2016). Two other clades, one including material from western Europe and western North America, and the other western North American specimens only, are possibly species-level lineages, but on current evidence these are distinguishable only by molecular characters (Resl *et al.* 2016).

We have found *R. subpariata* throughout New Brunswick in mesic hardwood and mixed forests, as well as in wetter stands dominated by cedar. It occurs on a wide range of hardwood trees, on Eastern White Cedar, and rarely on Balsam Fir and spruce (“*Picea* sp.”, *S.B. Selva* 4089 *p.p.* [NBM]). Among the specimens we examined in which the phorophytes were determined to species, nine were on Yellow Birch, eight on Red Maple, seven on Sugar Maple, five on Eastern White Cedar, three each on Striped Maple and Mountain Maple, two each on Paper Birch, American Beech, White Ash, and Red Oak, and one each on Balsam Fir, Butternut, Large-toothed Aspen (*Populus grandidentata* Michaux), Trembling Aspen, and American Mountain-ash.

*Selected specimens examined*—**Albert Co.:** Caledonia Gorge PNA, Crooked Creek valley, ~500 m NW of mouth of Caledonia Brook, 45.7992°N, 64.7782°W, 185 m, mixed forest dominated by Red Spruce and Yellow Birch, on steep slope, with scattered large Large-toothed Aspen, on Large-toothed Aspen, 2 July 2011, *S.R. Clayden* 22219. **Charlotte Co.:** Grand Falls Flowage on St. Croix River, at end of Route 725 NW of Upper Little Ridge, 45.278°N, 67.479°W, 80 m, mixed and hardwood forest dominated by Red Spruce, hemlock, fir, Red Maple, beech, and Yellow Birch, on trunk of Red Maple, *S.R. Clayden* 21878; Campobello Island, Roosevelt Campobello International Park, along Fox Hill Drive, 44.8544°N, 66.9453°W, wet spruce–fir woods with scattered Red Maple and pockets of birch and

mountain-ash, on birch, 25 September 2016, *K.E. Driscoll* 1365. **Kings Co.:** Big Bluff, Rockville, SE of Sussex Corner, 45.70014°N, 65.44115°W, 170 m, forest of Sugar Maple, hop-hornbeam, and Red Oak, at top of bluffs, on trunk of Eastern Hop-hornbeam, 28 June 2018, *S.R. Clayden* 27243. **Madawaska Co.:** Gagné Brook, between forest road and Green River, 1.8 km south of First Lake, 47.608°N, 68.251°W, 225 m, forest of fir, White Spruce, Mountain Maple, and Speckled Alder, along brook, on Mountain Maple, 23 June 2010, *S.R. Clayden* 20914. **Northumberland Co.:** Nepisiguit PNA, upland between West Branch Portage Brook and headwaters of Pentland Brook, 47.4392°N, 66.6222°W, 470 m, mature forest of Sugar Maple and Yellow Birch, with scattered Heart-leaved Birch, fir, Red Spruce, and Red Maple, on smooth bark of Yellow Birch, 15 August 2016, *S.R. Clayden* 25930; Kennedy Lakes PNA, along road from Route 108 to Pratts Camp, ~2 km NW of Louis Lake, 46.86265°N, 66.62674°W, 505 m, forest of Sugar Maple, Yellow Birch, and beech, abundant on smooth bark of trunks of American Beech, 1 July 2019, *S.R. Clayden* 27851A; Hells Gate Hardwoods PNA, ~6.5 km ENE of Saint Margarets, 46.9232°N, 65.1121°W, 40 m, mature hardwood forest dominated by Sugar Maple, Red Maple, and Yellow Birch, over bark and lichens on trunk of Sugar Maple, 14 September 2019, *S.R. Clayden* 28018. **Restigouche Co.:** Mount Carleton Provincial Park, along the William’s Falls trail, 47.426°N, 66.883°W, mixed conifer forest, corticolous on Eastern White Cedar, 17 August 1989, *S.B. Selva* 4226 *p.p.* **Sunbury Co.:** Grand Lake PNA, along forest road from Coy Road to East Branch Baltimore Stream, 45.96092°N, 66.12723°W, young mixed forest of fir, Red Maple, and Paper Birch, with scattered White Ash and hemlock, on trunk of White Ash, *S.R. Clayden* 24048 (voucher for ITS sequence: Resl *et al.* 2016). **Westmorland Co.:** near site of Pink Rock wharf, coastal disturbance belt of forest, on trunk of scaly-barked old Red Maple, November 1979, *H. Harries* 79206 (det. *S.R. Clayden*); Mount View Road between Trans-Canada Hwy and brow of hill, second growth forest with Red Spruce–fir tendency, on Red Maple, 29 March 1980, *H. Harries* 80141 (det. *S.R. Clayden*). **York Co.:** N slope of Crabbe Mountain, 46.12365°N, 67.09935°W, 280 m, mixed forest of Sugar Maple, Red Spruce, fir, Yellow Birch, Heart-leaved Birch, and beech, on smooth bark of young Balsam Fir, 23 December 2016, *S.R. Clayden* 26401; Fredericton, Odell Park, ~450 m SSW of park lodge, 45.95354°N, 66.66621°W, 80 m, old mixed forest dominated by maple, beech, birch, and hemlock, on trunk of Butternut, 12 October 2018, *S.R. Clayden* 27365.

Also reported from Kouchibouguac National Park

in Kent Co. (Sheard 2010).

***Rinodina tenuis* Müll. Arg.** (syn. *Rinodina adirondackii* H. Magn. [Sheard *et al.* 2017]; Figure 4k)

New to New Brunswick and Atlantic Canada. Characterized by its light-grey, thin but continuous thallus containing pannarin (P+ red orange); apothecia initially immersed in the thallus and remaining broadly attached (Figure 6f); and large *Pachysporaria*-type ascospores measuring  $(24\text{--}26.3\text{--}31.0\text{--}33) \times (10.5\text{--}12.8\text{--}16.2\text{--}19.0) \mu\text{m}$  ( $n = 55$ ) in New Brunswick specimens. Magnusson (1947) described *R. adirondackii* based on a specimen collected on Eastern White Cedar in the Adirondack Mountains of northern New York state. Under this name, it was considered until recently to be endemic to the Appalachian–Great Lakes region (Sheard 2010; Lendemer *et al.* 2014).

Detailed studies of *Rinodina* in northeastern Asia led Sheard *et al.* (2017) to conclude that *R. adirondackii* is a synonym of *R. tenuis*, described from Japan by J. Müller Argoviensis in 1892. The two taxa are similar morphologically and both produce pannarin. However, specimens from Asia have longer spores: “(27.0–) 32.0–35.5(–39.0)  $\times$  (12.5–) 14.5–17.0(–18.5)  $\mu\text{m}$  ( $n = 63$ )” [mean  $33.8 \times 15.8 \mu\text{m}$ ] (Sheard *et al.* 2017: 659), versus “(21.5–)28.0–30.0(–36.5)  $\times$  (9.0–)14.0–16.0(–20.5)  $\mu\text{m}$ ” [mean  $29.0 \times 15.0 \mu\text{m}$ ;  $n$  unknown] in North American specimens reported as *R. adirondackii* (Sheard 2010: 35). Sheard *et al.* (2017) suggested that this size-difference might be related to a difference in spore number per ascus. In Asian specimens, the asci sometimes contain four rather than eight spores (Sheard *et al.* 2017), whereas only eight-spored asci have been noted in North American specimens (Sheard 2010; our study). Spore size in the sample from New Brunswick (mean  $28.7 \times 14.5 \mu\text{m}$ ;  $n = 55$ ) is consistent with other North American material, and smaller than in collections of *R. tenuis* from Japan and the Russian Far East. Molecular evidence is needed to better assess the relationship of these widely disjunct populations. *Rinodina tenuis* has also been reported recently from the Western Caucasus region of southern Russia (Urbanavichus *et al.* 2020), an area known for disjunct occurrences of otherwise eastern North American–eastern Asian lichens (Otte 2004).

In New Brunswick and elsewhere in the northern part of its range in North America, *R. tenuis* has a striking fidelity to Eastern White Cedar as a phorophyte. All known occurrences in the province (14 localities documented by 18 specimens) are on this tree species. We and others have also found *R. tenuis* in swamp forests dominated by cedar in adjacent northern Maine and Gaspésie, Quebec (Lendemer

*et al.* 2014; S.R.C., K.E.D., and S.B. Selva unpubl. data). It is typically present as scattered discrete thalli on tree trunks or on living or dead, corticate or decorticate, lower branches (Figure 2b). The occurrences in New Brunswick are in mature stands on wet sites at elevations ranging from 35 m to 275 m, especially on terraces near streams or rivers, but also on N- to NE-facing seepage slopes. Eastern White Cedar often hosts a species-rich assemblage of lichens in these settings, commonly including cyanolichens. Among the latter, *Fuscopannaria leucosticta* (Tuck.) P.M. Jørg., like *R. tenuis*, is strongly associated with cedar in New Brunswick (Haughian *et al.* 2018).

Records of *R. tenuis* posted on the website of the Consortium of Lichen Herbaria (2023) indicate that the known occurrences of *R. tenuis* in Quebec, Ontario, Maine, and the Great Lakes states are, likewise, mostly on Eastern White Cedar, with only a few on Balsam Fir, Tamarack, and hemlock. In the central and southern Appalachians, where Eastern White Cedar is very sporadically distributed or lacking, it occurs on hardwoods, especially oak (*Quercus* L.) species (Lendemer *et al.* 2014). The single collection reported from the Russian Caucasus by Urbanavichus *et al.* (2020) was on Oriental Beech (*Fagus orientalis* Lipsky).

The number and distribution of collections of *R. tenuis* reported here might suggest that it is a common species in New Brunswick. However, our findings reflect the emphasis we placed on locating and surveying old wet cedar forests. It appears that *R. tenuis* is infrequent throughout its range in North America (Sheard 2010; Lendemer *et al.* 2014) and that its extent of occurrence may have declined. The only record for Ontario is a specimen collected on Eastern White Cedar by R.F. Cain near Lake Temagami in 1945 (Sheard 2010; Consortium of Lichen Herbaria 2023). In Quebec, the only record outside Gaspésie is from Lac Clair near Quebec City, where it was collected on an unspecified substratum by W.G. Farlow in 1888 (Sheard 2010; Consortium of Lichen Herbaria 2023).

*Specimens examined* (all on Eastern White Cedar)—**Charlotte Co.:** Clark Point PNA, St. Croix River, ~0.5 to 1 km SE of Clark Point, NE of Clark Ridge, 45.32036°N, 67.43995°W, 70 m, wet mixed forest dominated by cedar, Red Maple, and Black Ash, with scattered fir and Black Spruce, 25 August 2006, S.R. Clayden 16155; Pennfield Parish, W and south of small lake at head of unnamed tributary of Love Lake Brook, 45.205°N, 66.635°W, 80 m, wet to mesic forest of cedar along brook, 16 April 2011, S.R. Clayden 21754. **Kent Co.:** Route 11, ~7 km south of Rexton, dense cedar forest along stream, 1 September 1979, H. Harries 79364 (det. S.R. Clayden).

**Madawaska Co.:** “Black Brook District” of J.D. Irving Ltd., Little Beaver Brook, ~4.8 km NNW of confluence with Beaver Brook, 47.2423°N, 67.7003°W, 265 m, wet to mesic forest of cedar, with scattered Black Spruce and fir, along terrace adjoining brook, 29 August 2008, *S.R. Clayden 19073, 19122*. **Northumberland Co.:** Goodfellow Brook PNA, ~2 km E of Weldfield-Collette Road, 13 km W of Saint Margarets, 46.8991°N, 65.3666°W, 35 m, mature wet forest of cedar, fir, spruce, and Red Maple, with scattered Eastern White Pine and hemlock, 16 September 2019, *S.R. Clayden 28062*; Kennedy Lakes PNA, S side of North Branch Renous River, 250 m NW of mouth of Quigley Brook, 46.80440°N, 66.35524°W, 205 m, forest of Yellow Birch, Red Maple, fir, and cedar on NE-facing slope and terrace next to river, 13 August 2022, *S.R. Clayden 28748*. **Queens Co.:** Grand Lake PNA, SE of forest road, 1.6 km E of point where Coy Road crosses Baltimore Stream, 45.9641°N, 66.1209°W, swampy open forest of Black Spruce, cedar, and Red Maple, 13 June 2013, *S.R. Clayden 23880*. **Restigouche Co.:** Mount Carleton Provincial Park, N side of Nepisiguit Lakes Road near its junction with Little Tobique Road, just E of Little Tobique River, 47.425°N, 66.933°W, cedar swamp with moderate amount of spruce, 23 August 1989, *S.B. Selva 4256, 4263A*; Little Tobique River, 1 to 1.5 km NE of mouth of Red Brook, 47.44485°N, 67.06620°W, 232 m, mesic to wet forest dominated by cedar and fir, on river terrace, 13 June 2006, *S.R. Clayden 15161A, 15162*; Berry Brook PNA, headwaters of Berry Brook, ~8 km S of Saint-Arthur, 47.8177°N, 66.7561°W, 275 m, mesic to wet forest of cedar, fir, and Black Spruce, with scattered Red Maple and Black Ash, 14 June 2006, *S.R. Clayden 15285*; Jacquet River Gorge PNA, ~300 m W of Doyles Meadow, 47.816°N, 66.007°W, 184 m, mature wet forest of cedar, with scattered Black Spruce, fir, Black Ash, Red Maple, and Speckled Alder, 12 August 2010, *S.R. Clayden 21110; ibid.*, S side of Antinouri Lake Brook, 47.8205°N, 66.0137°W, 180 m, old, mainly coniferous forest of cedar, fir, and Black Spruce, on N-facing slope toward brook, 16 August 2010, *S.R. Clayden 21283*. **York Co.:** Eel River PNA, ~1.5 km S of Browns Mountain, 7 km W of Hartin Settlement, 45.89725°N, 67.62759°W, 150 m, small patch of wet, mature, but disturbed cedar forest in a hollow traversed by a forest road, 13 May 2006, *S.R. Clayden 14480*; Spednic Lake PNA, ~1.5 km NE of McAllister Cove, 45.6679°N, 67.6548°W, wet mixed wood forest (cedar, fir, ash, maple), 14 August 2017, *S.R. Haughian 20170814.13; ibid.*, between South Branch Mosquito Brook and McAllister Brook, 45.6667°N, 67.6541°W, 150 m, swampy forest of Red Maple, cedar, Speckled Alder, Black

Spruce, and scattered Black Ash, 14 August 2017, *S.R. Clayden 26728*.

***Rinodina tephrae* (Tuck.) Herre** (Figure 4e)

New to New Brunswick. Characterized by its saxicolous, grey to brown, areolate thallus (Figure 6e); broadly to narrowly attached apothecia with a persistent thalline margin; *Teichophila*-type ascospores with lumina varying from angular to rounded during development; and chemistry (zeorin present, atranorin lacking). The spores in New Brunswick specimens are  $(16.0\text{--})18.2\text{--}23.5\text{--}26.0) \times (7.5\text{--})9.0\text{--}12.1\text{--}14.0) \mu\text{m}$  ( $n = 59$ ). *Rinodina tephrae* often contains 5-*O*-methylhiascic acid ( $\pm$  lecanoric acid) in addition to zeorin (Sheard 2010). However, four New Brunswick specimens (*Clayden 24666, 26829; two thalli, 28403*) that we examined with TLC contained only zeorin. A specimen of *R. tephrae* from Pennsylvania (*Lendemer 11843* [NBM]) containing both zeorin and 5-*O*-methylhiascic acid was used as a control.

The occurrences reported here, from scattered locations throughout New Brunswick, are apparently the first modern records of this species from Atlantic Canada. It was previously known in the region only from collections made by A.C. Waghorne in 1897 in the Bay of Islands area of western Newfoundland (Sheard 2010). A report (as *R. arenaria*) from Fundy National Park, New Brunswick (Gowan and Brodo 1988), is referable to *R. moztiana*, as noted above. *Rinodina tephrae* is a common species elsewhere in temperate eastern North America (Sheard 2010; Lendemer *et al.* 2014). It also occurs in Europe and neighbouring areas of Russia and the Caucasus region (Mayrhofer and Moberg 2002), and it was recently reported from Korea (Yakovchenko *et al.* 2018).

The substrata of the occurrences in New Brunswick include a range of hard, siliceous, sedimentary and metamorphic rocks. At five of the six sites, the rocks are subject to occasional immersion or splashing (Figure 2c). At the other site, in a mesic hardwood forest, *R. tephrae* was found on a rock face with a northeast aspect and that appeared to be affected by seepage. A specimen from flat sandstone ledges on a well-lit open lakeshore has a brown hue. Those from shaded sites are light greenish-grey. There is wide variation in the form and density of areoles in the thalli (Figure 6e), with contrasting individuals sometimes occurring side by side.

*Rinodina oxydata*, like *R. tephrae*, occurs on moist siliceous rocks, and the two species have generally similar distributions in the eastern North American portions of their ranges. However, *R. oxydata* has not yet been found in New Brunswick or the other Maritime provinces (see above under *R. moztiana*). In contrast to *R. tephrae*, both *R. moztiana* and *R.*

*oxydata* contain atranorin and lack zeorin.

*Specimens examined*—**Charlotte Co.:** NW-facing bank of Lepreau River at Lepreau Falls, 45.16936°N, 66.46262°W, 15 m, edge of forest of Red Spruce, fir, and cedar, at top of waterfall, on humid shaded rock, 4 August 2022, *S.R. Clayden 28723*. **Gloucester Co.:** Tetagouche Falls, N-facing riverbank below falls, 47.6182°N, 65.8244°W (UTM zone 20T, 287768 m E, 5277729 m N), on shale rock, 1 August 2015, *F. Anderson, s.n.* (det. *S.R. Clayden*). **Restigouche Co.:** Jacquet River Gorge PNA, south side of Antinouri Lake Brook, 47.820°N, 66.014°W, 160 m, brook bed and N-facing slope above brook with old, mainly coniferous forest of cedar, fir, and spruce, on shaded vertical HCl- rock, ~1 m above water level of brook, 16 August 2010, *S.R. Clayden 21251* (det. *J. W. Sheard*). **Sunbury Co.:** Portobello Creek National Wildlife Area, French Island, NE shore, opposite Sand Point, 45.92461°N, 66.30010°W, 5 m, lakeshore with sandstone ledges and mixed conifer-*hardwood forest*, abundant on sandstone, 12 August 2014, *S.R. Clayden 24666 & K.E. Driscoll*. **York Co.:** Spednic Lake PNA, along Bolton Brook between Big Deadwater and Silas Cove, 45.66120°N, 67.51585°W, 120 m, bouldery brook and adjoining forest dominated by Yellow Birch, frequent on granitic boulders in brook, just above zone with *Dermatocarpon luridum* (With.) J.R. Laundon and *Ionaspis lacustris* (With.) Lutzoni, 18 August 2017, *S.R. Clayden 26829*; Fredericton, Odell Park, 45.95381°N, 66.66634°W, 75 m, mature hardwood forest dominated by Sugar Maple, beech, and Yellow Birch, with 1–3 m high sandstone outcrops, on rock, 27 October 2020, *S.R. Clayden 28403*.

***Rinodina willeyi*** Sheard & Giralt (Figure 41)

Reported for New Brunswick by Sheard (1995, 2010) as *R. willeyii*, based on collections made by Emmanuël Sérusiaux in 1988 in or near Fundy National Park, in Albert and Saint John Counties. The spelling of the epithet was modified by Sheard *et al.* (2012) to *willeyi* from the originally published *willeyii*. This species resembles *R. buckii* and *R. efflorescens* in having a sorediate thallus containing pannarin and zeorin. The soralia of *R. efflorescens* contain secalonin acid A (KC+ yellow orange), which is lacking in *R. buckii* and *R. willeyi*. *Rinodina buckii* is not yet known from New Brunswick or elsewhere in Canada, but it has been reported from neighbouring southeastern Maine (Sheard *et al.* 2012; Seaward *et al.* 2017). It has coarser soredia and more convex areoles than *R. willeyi*—see the key to species, above, and the detailed comparison and illustrations of these species in Sheard *et al.* (2012). *Rinodina buckii* and *R. willeyi* also differ in ascospore morphology but are usually sterile. Of 30 specimens of *R. willeyi* that

we have examined from 19 localities in New Brunswick, seven have apothecia, with *Pachysporaria*-type spores measuring (17.5–)20.0–25.5(–28.0) × (9.0–)10.3–13.9(–17.0) μm (*n* = 37).

Our field and herbarium studies indicate that soredium development in *R. willeyi* is often more extensive than has been reported previously. Thalli with thin plane areoles forming soredia at their margins are found mainly on bark, but also on blackened senescent lobes of *Parmelia*. The thalli often spread from bark onto neighbouring bryophytes, especially the liverwort *Frullania eboracensis* Lehm. and small pleurocarpous mosses. They may then become largely sorediate, obscuring the originally corticate areoles (Figure 6b). In the field, such thalli often have a distinctive minutely grey-and-white speckled appearance.

When it was first described in 1995, *R. willeyi* was known globally from fewer than 10 localities in the southern Appalachians and northeastern coastal region of eastern North America, including the two in New Brunswick noted above (Sheard 1995). It is now known to occur more widely in the Appalachian and Great Lakes regions (Lendemer *et al.* 2014), northeastern Asia (Sheard *et al.* 2017), the Western Caucasus region of Russia (Urbanavichus *et al.* 2020), and Alaska (McCune *et al.* 2018). In New Brunswick, it is locally frequent throughout the province. However, it appears to be restricted to mature hardwood (Figure 2d) and mixed forests on relatively base-rich soils in mesic to wet sites. It occurs up to the elevational limit of hardwood forests dominated by Sugar Maple. Among the specimens we examined, 15 were on Sugar Maple, five each on Yellow Birch and Eastern White Cedar, two on Black Ash, and one each on White Ash, Eastern Hop-hornbeam, and Red Oak.

*Rinodina willeyi* is likewise an old-forest species in Nova Scotia, where it has been recorded on Red Maple, Sugar Maple, and Yellow Birch (McMullin *et al.* 2008, 2018).

Also known from **Colchester Co., Nova Scotia:** Economy River Wilderness Area, 45.522°N, 63.940°W, 230 m, N end and NE side of Simpson Lake, forest of Sugar Maple, Yellow Birch, and beech, on SW-facing slope above lake, on Sugar Maple, 17 May 2004, *S.R. Clayden 12624*). The only other published Canadian record of *R. willeyi* is a mapped occurrence in southern Ontario (Lendemer *et al.* 2014), based on collections made on Eastern White Cedar in an old-growth swamp forest (*J.C. Lendemer 28234, 28286 & R.E. Lee* [NY]; not seen by us).

*Selected specimens examined*—**Albert Co.:** Fundy National Park, East Branch Trail, 45.6369°N, 65.1176°W, 350 m, mature mixed forest dominated by Yellow Birch, Sugar Maple, and Red Spruce, corticolous and bryocolous on trunk of Sugar Maple, 15

October 2021, *S.R. Clayden 28621*. **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, along Fox Hill Drive, ~2 km W of Liberty Point Drive, at base of Fox Hill, 44.8534°N, 66.9530°W, mature forest dominated by Yellow Birch, on bark and senescent thalli of *Parmelia* on trunk of Yellow Birch, 25 September 2016, *S.R. Clayden 26297*. **Gloucester Co.:** N side of Lambert Barren, ~7.5 km SW of Pokeshaw, S side of Pokeshaw River, 47.7238°N, 65.2994°W, 55 m, wet to mesic forest of cedar, Black Spruce, and Red Maple, overgrowing *Frullania* and lichens on upper side of leaning Eastern White Cedar, 7 October 2007, *S.R. Clayden 18161*. **Kings Co.:** McDermott Hill, ~5 km SE of Waterford, 45.65636°N, 65.31539°W, 330 m, old-growth hardwood forest dominated by Sugar Maple, Yellow Birch, and beech, on Sugar Maple, 3 May 2005, *S.R. Clayden 13368*; Big Bluff, Rockville, SE of Sussex Corner, 45.7001°N, 65.4412°W, 170 m, forest of Sugar Maple, hop-hornbeam, and Red Oak, at top of bluffs, corticolous on trunk of Eastern Hop-hornbeam, 28 June 2018, *S.R. Clayden 27242*; *ibid.*, on trunk of Red Oak, *S.R. Clayden 27243 p.p.* (with *R. subpariata*). **Madawaska Co.:** Jalbert Brook, between forest road and First Lake, 47.647°N, 68.300°W, 230 m, mature forest of fir, White Spruce, Black Ash, and Mountain Maple, on rich alluvial soil near stream, bryocolous and corticolous on Black Ash, 23 June 2010, *S.R. Clayden 20969*. **Northumberland Co.:** Mount Carleton Provincial Park, off the S side of the Big Brook Trail, ~6.3 km from Pine Point, 47.36°N, 66.84°W, mixed hardwood forest dominated by Sugar Maple and Yellow Birch, corticolous on Yellow Birch, 1 August 1989, *S.B. Selva 4156B* (det. S.R. Clayden) Nepisiguit PNA, E-facing slope in headwaters area of Pentland Brook, 47.43056°N, 66.62753°W, 510 m, mature moderately open hardwood forest dominated by Sugar Maple and Yellow Birch, with scattered fir and spruce, on trunk of Sugar Maple, 15 August 2016, *S.R. Clayden 25971*. **Saint John Co.:** City of Saint John, Lorneville, W of King William Road, 45.1895°N, 66.1860°W, 60 m, moderately open stand of Yellow Birch and Heart-leaved Birch on S-facing slope, with scattered fir, on bark and overgrowing *Frullania* on trunk of Yellow Birch, 9 December 2020, *S.R. Clayden 28427*. **Westmorland Co.:** ~600 m N of intersection of Lower Walker Road and King Street, NW of Sackville, 45.9381°N, 64.4635°W, 155 m, mature hardwood forest dominated by Sugar Maple and Yellow Birch, on trunk of Sugar Maple, 7 November 2019, *S.R. Clayden 28144*. **York Co.:** Spednic Lake PNA, near South Branch Mosquito Brook, ~1.5 km W of Musquash Lake, 45.69094°N, 67.67171°W, 140 m, mesic to wet coniferous forest dominated by cedar and fir, with scattered hemlock,

on top of trunk of tipped-up Eastern White Cedar, 14 August 2017, *S.R. Clayden 26752*.

## Discussion

Comparisons of the diversity and relative abundance of *Rinodina* species in New Brunswick and other areas of northeastern North America are limited by the unevenness of survey efforts and reporting. For example, only six species have been reported for Nova Scotia (McMullin *et al.* 2008, 2018; Sheard 2010), a number that is bound to grow with further study. The presence of 15 species in New Brunswick is consistent with the species richness recorded in several states of the northeastern USA: 13 species in Maine (Sheard 2010; Sheard *et al.* 2012), 18 in Massachusetts (Sheard 2010, 2018), and 17 in New York (Sheard 2010). Fifteen *Rinodina* species are known in the 7850 km<sup>2</sup> Ottawa region of southern Ontario and Quebec, where the lichen biota has been intensively explored over many years (Brodo *et al.* 2021a,b). Only two of the species reported here for New Brunswick, *R. cinereovirens* and *R. septentrionalis*, have not been found in any of the northeastern states or in the Ottawa region. Both of these species have boreal distributions.

In a broader context, the set of *Rinodina* species occurring in New Brunswick illustrates long-known similarities between the temperate biotas of eastern North America and eastern Asia. The biogeographic relationships of these two regions have been examined most intensively in their vascular plant floras (Wen 1999), but patterns of disjunction are also present in other major taxonomic groups, including lichens (e.g., Lendemer *et al.* 2014; Sheard *et al.* 2017). Thirteen of the 15 species of *Rinodina* found in New Brunswick, including the widely disjunct *R. ascociscana*, *R. subminuta*, *R. tenuis*, and *R. willeyi*, also occur in northeastern Asia (Sheard *et al.* 2017). In contrast, New Brunswick shares only three *Rinodina* species with the British Isles (Cannon *et al.* 2022), eight with Fennoscandia (Mayrhofer and Moberg 2002), and eight with British Columbia and Alaska (Sheard 2010, 2018). No *Rinodina* species with distinctly oceanic distributions are known in eastern North America, although several (e.g., *Rinodina disjuncta* Sheard & Tønsberg, *Rinodina stictica* Sheard & Tønsberg) occur in the more highly oceanic climates of western North America and western Europe (Sheard 2000; Mayrhofer and Moberg 2002).

Abundant fossil and molecular evidence indicate that disjunct eastern North American–eastern Asian distributions in vascular plants have had multiple origins from the Paleocene to the Pleistocene (Wen *et al.* 2010). A scenario of southward displacement and disruption of formerly more continuous higher-latitude

ranges by long-term cooling, mountain building, and changes in precipitation regimes is broadly supported by this evidence. However, long-distance dispersal may also underlie some species-level disjunctions and contribute to ongoing gene flow among widely separated populations occupying climatically similar niches (e.g., Xiang *et al.* 2015).

Among lichens, only a few studies have so far brought molecular evidence to bear on the origin and timing of eastern North American–eastern Asian disjunctions (Spribille 2011; Hoffman 2022). Resl *et al.* (2016) found that ITS sequences of specimens of *R. subpariata* from these two regions are more similar to one another than to sequences from western North American and western European specimens. However, the apparent lack of geographic structure in the eastern North American–eastern Asian clade was inferred by Sheard *et al.* (2017) to be suggestive of active gene flow via long-distance dispersal. Sampling of a wider range of localities, individuals, and DNA loci are needed to test this hypothesis.

Among the disjunct Asian(–Caucasian)–American *Rinodina* species represented in New Brunswick, *R. tenuis* may be an especially interesting candidate for phylogeographic analysis. Its American and Asian populations appear to have somewhat differentiated ascospore sizes, and the strong association of northern North American occurrences with Eastern White Cedar invites closer study. As recently as two million years ago, the range of this fossil tree species (*Thuja occidentalis*, the same as the modern species) extended to northernmost Greenland (Bennike and Böcher 1990), where it formed part of an open boreal-forest-like community (Kjaer *et al.* 2022). Although this community lacks any modern analogue, it seems likely that suitable contemporary niches for *R. tenuis* on Eastern White Cedar existed far north of its present range. The genus *Thuja* itself is disjunct between eastern Asia and eastern and western North America, with no fossil or other record of it having occurred in Europe at any time from the Paleocene to the present (Cui *et al.* 2015; Li *et al.* 2022). The three species of *Thuja* occurring in eastern Asia have extremely restricted distributions (Li *et al.* 2022), and none has been reported as a phorophyte of any *Rinodina* species (Sheard *et al.* 2017). However, in contrast to the relatively narrow phorophyte specificity of *R. tenuis* in North America, in the Russian Far East and Japan it occurs on a wide range of trees, including species of *Abies*, *Alnus*, *Betula*, *Picea*, *Prunus* L., *Quercus*, *Salix*, *Sorbus*, and *Ulmus* (Sheard *et al.* 2017; Galanina and Ezhkin 2019; Galanina *et al.* 2021a; note the east Asian species in these genera are all different from those occurring in Canada).

Although our study was not designed to critically

assess the phorophyte specificity of *Rinodina* species in New Brunswick, the pooled collections data highlight a number of associations, besides that of *R. tenuis* with Eastern White Cedar (Figure 3). Our findings are largely in agreement with other reports on the phorophytes of these species in North America (e.g., Gowan and Brodo 1988; Wong and Brodo 1992; Sheard 2010; Lendemer *et al.* 2014; Harris 2015), but we provide new or more extensive region-specific data on species that were either unknown or poorly documented previously in New Brunswick and the Maritime provinces. For example, the three sorediate species, *R. efflorescens*, *R. subpariata*, and *R. willeyi*, appear to be distributed among broadly overlapping but differentiated sets of tree species, possibly reflecting in part a gradient of bark acidity. Conversely, the two most common maple species in the province, Red Maple and Sugar Maple, are shown to have more distinct complements of *Rinodina* species than documented in earlier studies. The association of *R. pachysperma* with Silver Maple and other hardwoods in floodplain forests, and its absence or rarity in mesic upland stands, appears to be a novel finding. On the other hand, the general rarity of *Rinodina* on pinaceous conifers and other strongly acidic, nutrient-poor substrata is characteristic of the genus as represented in New Brunswick. Its association with relatively base-rich habitats is not limited to the corticolous species. The three saxicolous *Rinodina* species known in the province occur on siliceous rocks, but their habitats are enriched to varying degrees by periodic immersion, wave splash, seepage, or guano deposition.

Despite these generalizations, we are aware of the limitations of our local observations. It is well known that the substratum specificity of corticolous lichens varies along climate and vegetation gradients (e.g., Hale 1955; Brodo 1973; Schmitt and Slack 1990; Ellis 2012). It was beyond the scope of our study to investigate the complex interacting factors contributing to variation in the diversity and abundance of *Rinodina* species on different phorophytes. Instead, we present basic descriptions of the ecological and geographical distributions of these and the saxicolous *Rinodina* species with the aim of encouraging further exploration and more specialized studies.

### Author Contributions

Conceptualization: S.R.C. and K.E.D.; Investigation: S.R.C., K.E.D., and H.H.; Writing – Original Draft: S.R.C.; Writing – Review & Editing: S.R.C. and K.E.D.; Funding Acquisition: S.R.C.

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## Recent records of myxomycetes from New Brunswick, Canada

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### Abstract

Studies of the diversity of myxomycetes or plasmodial slime moulds (Amoebozoa) in New Brunswick are lagging behind those of many other groups of terrestrial organisms. Here, we summarize the myxomycetes of the province as documented by recently collected specimens held by the New Brunswick Museum (NBM). Between 2007 and 2019, 264 specimens were collected, representing 80 species in 29 genera. Most of these records result from targeted searching during NBM-led biodiversity surveys (the BiotaNB project) in provincial protected natural areas between 2014 and 2019 and a mycological foray on Campobello Island in 2016. Previously, only seven species had been reported for the province. Consistent with their worldwide distributions and abundance, *Arcyria cinerea*, *Fuligo septica*, *Ceratiomyxa fruticulosa*, and *Lycogala epidendrum* were the most collected species, whereas the globally rare species *Paradiacheopsis microcarpa* has been collected in New Brunswick six times. Forty-two species were found only once, and five of these (*Comatricha mirabilis*, *Fuligo laevis*, *Hemitrichia chrysozpora*, *Lepidoderma neoperforatum*, *Listerella paradoxa*) are rare worldwide.

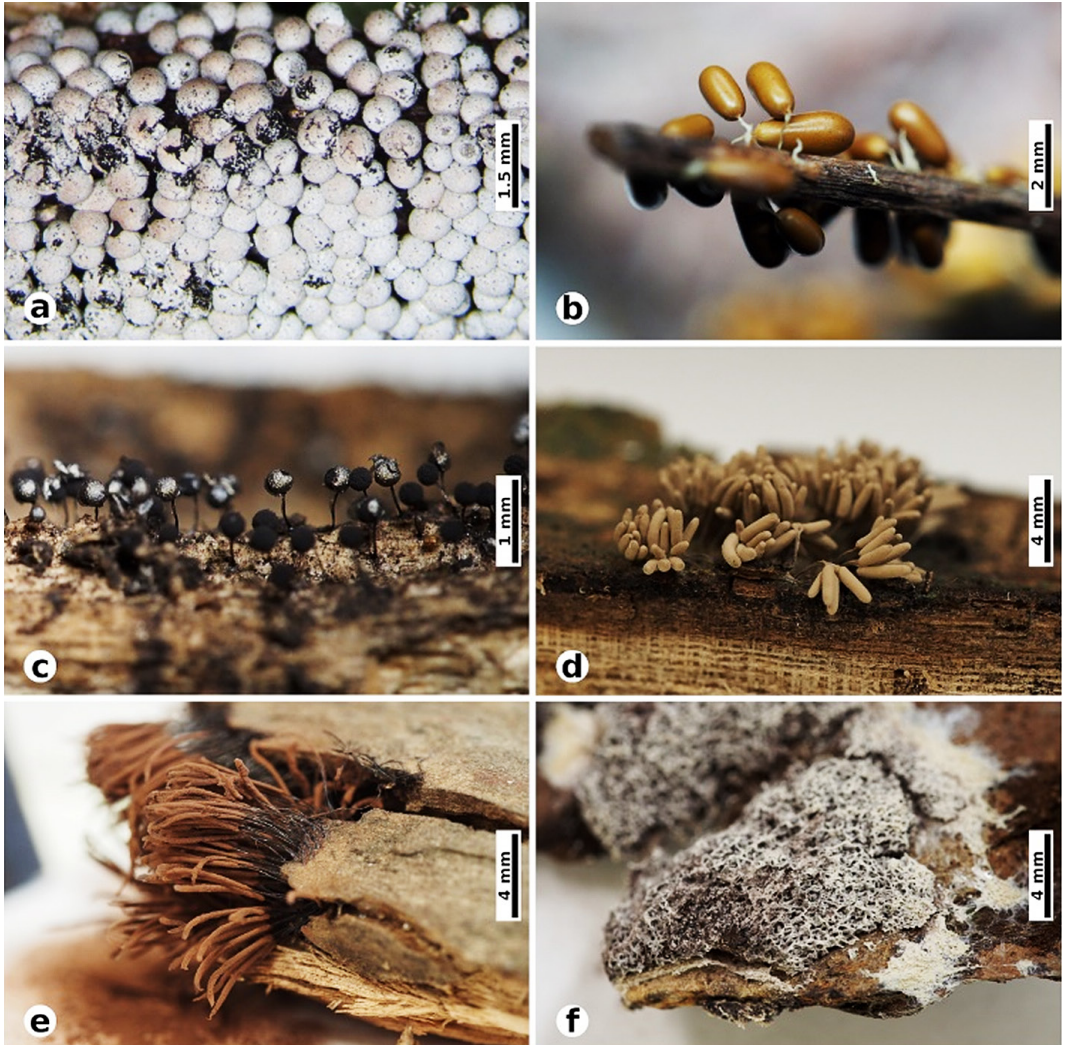
Key words: Slime moulds; Ceratiomyxomycetes; Amoebozoa; protected natural area; PNA; Atlantic Maritime Ecozone; herbarium; moist chamber; New Brunswick Museum; NBM; BiotaNB; Campobello mycological foray

### Introduction

Myxomycetes, or plasmodial slime moulds, are a group of eukaryotic microorganisms that occur in their trophic (feeding) stage in soil, decaying wood, leaf litter, or other organic material. They are often included in studies of fungi and in mycology textbooks; however, molecular evidence places them within a distinct evolutionary “supergroup”, the Amoebozoa (Adl *et al.* 2019). They consume mostly bacteria and contribute to the flow of nutrients from bacteria and other decomposers to the soil and, thus, to plants and higher trophic levels (Stephenson 2021). They have been recorded in every terrestrial habitat investigated to date (Stephenson and Rojas 2017); a few species have been found in aquatic habitats (Lindley *et al.* 2007), but their most important habitats are forests (Ing 1994). Although much remains to be learned about their role in soil ecology, they seem to be an essential biotic component of most soils (Stephenson 2021). Despite their importance and abundance in these substrates, myxomycetes are often overlooked because soil scientists tend to focus on fungi and bacteria (Stephenson 2021).

Most myxomycetes are cosmopolitan in distribution, absent only at very high latitudes and the highest elevations. However, some species appear to be restricted to temperate or tropical regions, and others have been collected only in deserts or other arid areas, or around melting snowbanks in alpine environments (Stephenson 2021; Schnittler *et al.* 2022). Many morphologically defined species may be “complexes of cryptic species showing more limited distribution patterns than the morphospecies as a whole” (Schnittler *et al.* 2022: 382).

These organisms are visually undetectable in the field during much of their life cycle. Although visible and identifiable by traditional methods during the fruiting stage (when spores are produced and dispersed), most species are very small, with a typical height <2 mm (Rollins and Stephenson 2011). However, larger species do exist, and one species (*Brefeldia maxima* (Fr.) Rostaf.) can reach 1 m<sup>2</sup> in size (Ing 1999). The fruiting stage exhibits a great variety of forms, sizes, and colours (Figure 1). The fruiting bodies can be found from early summer to late fall in temperate regions (Rollins and Stephenson 2011) and can



**FIGURE 1.** Slime moulds collected from New Brunswick. a. *Physarum diderma* – A.M. Bremner AB12.08.10-01 (NBM-MM-000001) – Jacquet River Protected Natural Area (PNA), 12 August 2010. b. *Leocarpus fragilis* V.F. Zoll 601 (NBM-MM-000132) – Nepisiguit PNA, 18 August 2016. c. *Collaria arcyronema* – V.F. Zoll 343 (NBM-MM-000062) – Grand Lake PNA, 10 August 2014. d. *Arcyria affinis* – V.F. Zoll 595 (NBM-MM-000146) – Nepisiguit PNA, 15 August 2016. e. *Stemonitis fusca* – A. Carter [B.W. Malloch B20130619-01] (NBM-MM-000153) – Grand Lake PNA, 19 June 2013. f. *Fuligo septica*: V.F. Zoll 336 (NBM-MM-000074) – Portobello Creek National Wildlife Area, 9 August 2014. Photos: A.M.B.

be cultured any time of year from organic matter in moist chambers (Stephenson and Stempen 1994).

With over 1000 described species (Lado and Hernández-Crespo 2021), the myxomycetes have traditionally been classified in six orders: Ceratiomyxales, Echinosteliales, Liceales, Trichiales, Stemonitales, and Physarales (Stephenson 2021). Modern molecular phylogenetic studies have upset traditional classifications and resulted in division into several classes, orders, and families (Fiore-Donno *et al.* 2013; Lado and Eliasson 2017; Leontyev *et al.* 2019).

Here, we follow the classification system for orders and families outlined by Leontyev *et al.* (2019). Species in the order Ceratiomyxales are not true myxomycetes, but are often treated along with them, and we have done so in our study. There are no widely used or accepted common names for myxomycetes.

Studies on the biodiversity of myxomycetes in Canada are rarely conducted, or at least rarely published. However, national and provincial lists of myxomycete species were recently compiled through the federal–provincial General Status of Species in

Canada program (CESCC 2022). Initiated in 1996, this program has reported at five-year intervals (2000, 2005, etc.) on the conservation status of species in numerous major groups of organisms. The report for 2020 (CESCC 2022) was the first to include myxomycetes. It lists 290 species for Canada and 51 for New Brunswick based on a variety of sources, including peer-reviewed literature, herbarium specimens, and community knowledge. However, it does not include specimen citations or other references to the specific sources of information supporting the species records. For most of the myxomycetes, there was insufficient information available to assess their conservation status (CESCC 2022). As far as we know, Alberta is the only province for which a relatively up-to-date peer-reviewed species checklist has been published (Richardson and Currah 1990).

Little has been published on the myxomycetes of New Brunswick. The earliest reference to any species occurring in New Brunswick was by James Fowler, who included *Lycogala epidendrum* (L.) Fr. in a short list of fungi appended to his catalogue of the provincial flora (Fowler 1879). No voucher specimen is known to exist, although collections of fungi made by Fowler are present in several herbaria (MyCoPortal 2022). Another early New Brunswick botanist, George Upham Hay, published more extensive lists of the fungi of the province, based on specimens he sent for identification to several leading American mycologists. Two of Hay's lists included a few myxomycetes. These were *Hemitrichia clavata* (Pers.) Rostaf. (as *Hemiarcyria clavata* (Pers.) Rostaf.) in Hay (1903) and *Fuligo muscorum* Alb. & Schwein. (as *Fuligo ochracea* (Peck) Peck), *Fuligo septica* (L.) F.H. Wigg., and *L. epidendrum* in Hay (1908). Of these species, we are aware of voucher material only of *L. epidendrum*, identified by C.G. Lloyd and housed at the U.S. National Fungus Collection (BPI; MyCoPortal 2022). Three additional species, *Mucilago crustacea* P. Micheli ex F.H. Wigg. (as *Mucilago spongiosa* (Leyss.) Morgan), *Physarum cinereum* (Batsch) Pers., and *Siphotychium casparyi* Rostaf. (as *Tubifera casparyi* (Rostaf.) T. Macbr.), were reported by Wehmeyer (1950).

In this paper, we present the findings of incidental and targeted collecting and study of myxomycetes in New Brunswick since 2007 by research associates and staff of the New Brunswick Museum (NBM). All collections resulting from this work have been deposited in the NBM herbarium. We are aware of other, earlier (pre-1980), unpublished collections, but a critical review of this material, which is scattered among herbaria outside New Brunswick, was outside the scope of our study. Information on these collections can be obtained via online data portals, especially MyCoPortal (<https://www.mycportal.org>) and the Global Biodiversity Information Facility (<https://www.gbif.org>).

They include important material well worthy of further study and publication. Examples are specimens from Campobello Island collected in 1898 and 1902 by the Harvard mycologist and all-round cryptogamist William Gilson Farrow (see Pfister 2016); specimens from the Campbellton area, collected in 1912 by plant pathologist John William Eastham, who at the time was employed at the Department of Agriculture in Ottawa (Cody *et al.* 1986) and who authored a checklist of the myxomycetes of the Ottawa region (Eastham 1912); and specimens from Kouchibouguac National Park, collected during a mycological survey of the park in 1977 and 1978 by staff of the Biosystematics Research Institute of Agriculture Canada (Cody *et al.* 1986).

### Study Area

The eastern Canadian province of New Brunswick has an area of about 73 000 km<sup>2</sup> and is situated at 44.5–48°N and 64–69°W. It adjoins the Bay of Fundy on its south coast and the Gulf of St. Lawrence on its east and north coasts. Its elevation reaches 820 m in the northern interior. Mean annual temperatures range from 6.8°C in the middle Saint John River valley in the south-central interior to 2.2°C or less at elevations above 600 m in the north (Environment Canada 2017). Precipitation varies from about 1000 mm/year in eastern and northern coastal locations to upwards of 1400 mm/year near the Bay of Fundy, with snowfall accounting for 13% to more than 30% of annual totals.

Along the major south–north gradient of vegetation in eastern North America, the province is situated in the transition zone between temperate deciduous and boreal evergreen forests. The eastern part of this zone in Canada is recognized as the Acadian Forest Region (Rowe 1972) or Atlantic Maritime Ecozone (McAlpine and Smith 2010). Red Spruce (*Picea rubens* Sargent) is its most characteristic tree species. Provincially, seven ecoregions (Highlands, Northern Uplands, Central Uplands, Valley Lowlands, Eastern Lowlands, Grand Lake, and Fundy Coast) are recognized, each with distinctive climatic features and landforms reflected in a recurring pattern of dominant vegetation (Zelazny 2007). In upland settings, the forest cover ranges from north-temperate hardwoods dominated by Sugar Maple (*Acer saccharum* Marshall) to mainly coniferous, montane (oro-)boreal stands of Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh) and Balsam Fir (*Abies balsamea* (L.) Miller). Floodplain forests in the middle Saint John River valley are dominated by Silver Maple (*Acer saccharinum* L.), one of several temperate hardwood species that reach their northeastern range limits in New Brunswick (Clayden 2000).

Although forests still cover about 85% of the province, settlement, forestry, agriculture, and introduced pathogens have brought about major shifts in the relative abundance and size–age distributions of native tree species over the past few centuries (Mosserer *et al.* 2003; Loo *et al.* 2010). Declines of late successional species, such as Eastern Hemlock (*Tsuga canadensis* (L.) Carrière) and American Beech (*Fagus grandifolia* Ehrhart), contrast with increases in the abundance of more disturbance-tolerant species, such as Trembling Aspen (*Populus tremuloides* Michaux), Red Maple (*Acer rubrum* L.), Grey Birch (*Betula populifolia* Marshall), White Spruce (*Picea glauca* (Moench) Voss), and Balsam Fir.

The collections we report here originate mostly from provincial protected natural areas (PNAs), with smaller numbers from two provincial parks (PPs), Portobello Creek National Wildlife Area, Fundy National Park, and Roosevelt Campobello International Park (Table 1, Figure 2). The PNAs encompass relatively intact portions of the New Brunswick landscape that are representative of its seven major ecoregions. Other localities where a single or a few collections were made are not listed in Table 1, but are mapped in Figure 2, with details provided under the specimen citations.

## Methods

### *Collection, culture, identification, and curation of specimens*

In 2009, an ongoing survey of the biodiversity of New Brunswick's larger PNAs, the BiotaNb program,

was initiated by the NBM (McAlpine 2022). This program has focussed mainly on the 10 largest PNAs, which range from 2823 to 26022 ha in area and were established in 2003 under the provincial *Protected Natural Areas Act*. The project has attracted researchers with a wide range of taxonomic expertise. Only sporadic collections of myxomycetes were made during the first several years. More intensive, targeted collecting began in 2014 when V.F.Z., who has studied myxomycetes in the neighbouring state of Maine, USA (Zoll and Stephenson 2013, 2015), joined the BiotaNb project. In 2016, V.F.Z. also took part in a mycological foray on Campobello Island and has encouraged other BiotaNb participants to search for myxomycetes, resulting in additional collections that are reported here.

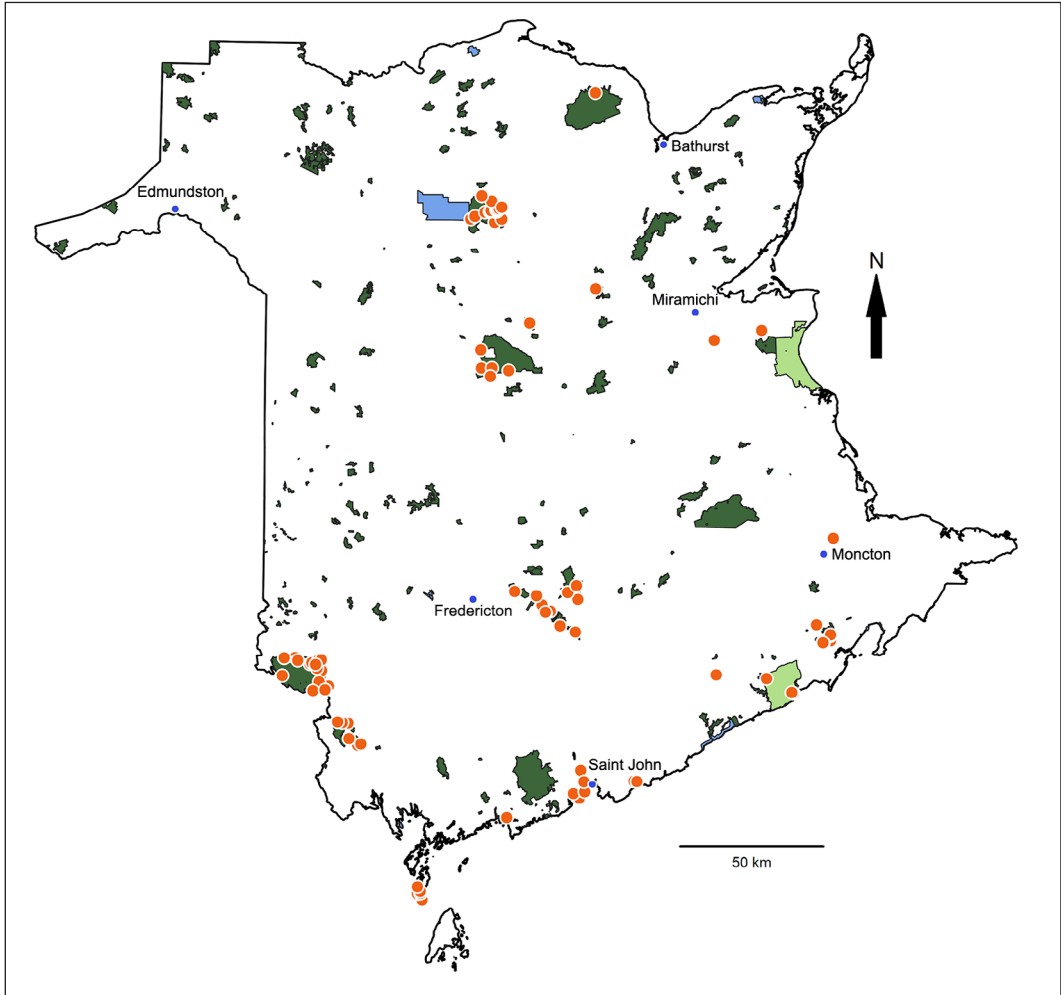
Most specimens were found fruiting in the field by various collectors examining downed branches, decaying logs, stumps, moss mats, bark on living trees, and various other substrates, sometimes with a hand lens (10–20× magnification). Samples of organic material including ground litter, leaves, decaying wood, bark, twigs, moss, and dung were collected from the field and placed in moist chambers (lidded plastic containers with moistened paper towel on the floor of the container) using the technique described by and illustrated in Stephenson and Stempen (1994). These chambers allow time for single-celled amoeboids and plasmodia to mature and fruit if present in the substrate. The moist chambers were maintained at room temperature and examined periodically up to three months after collecting the substrate or until the

**TABLE 1.** Targetted collecting areas for myxomycetes, by date, location, ecoregion, and number of specimens.

Date	Location*	Ecoregion	No. collections	Collectors
August 2014	Grand Lake PNA, Portobello Creek National Wildlife Area	Grand Lake	37	V.F.Z., S.R.C., K.E.D., K.J. Vanderwolf, A. Carter, and G. Bishop
June/July/September 2015	Nepisiguit PNA	Highlands	27	V.F.Z., A.M.B., S.R.C., K.E.D., D.W.M., B.W.M., D.F. McAlpine, and G. Bishop
May/August 2016	Nepisiguit PNA	Highlands	38	V.F.Z., A.M.B., D.W.M., and B.W.M.
September 2016	Campobello Island: Roosevelt-Campobello International Park, Herring Cove PP	Fundy Coast	15	V.F.Z., A.M.B., J.B. Tanney, D. Porter, and M. Mulvey
August 2017	Spednic Lake PNA, Andersonville PNA, Canoose Flowage PNA, Spednic Lake PP	Valley Lowlands	29	V.F.Z., A.M.B., D.W.M., B.W.M., A. Carter, S.R. Haughian, S.A. Sullivan, E. Hines, and J. Hines,
June/July 2018	Spednic Lake PNA, Canoose Flowage PNA, Spednic Lake PP	Valley Lowlands	67	V.F.Z., A.M.B., and D.W.M.
June/July 2019	Kennedy Lakes PNA, Upper Dugarvon PNA	Central Uplands	12	A.M.B., D.W.M., A. Carter, D.F. McAlpine, and J.R. Blacquiere

\*PNA = protected natural area, PP = provincial park.

Note: Except for the material originating from a four-day mycological foray (Campobello Island in 2016), all collections listed in this table were made during two-week-long NBM BiotaNb surveys of PNAs and other nearby protected areas.



**FIGURE 2.** Location of New Brunswick myxomycete collections deposited at the New Brunswick Museum, Saint John, New Brunswick, from 2007 to 2019. Collection locations = solid orange circles; protected natural areas = dark green; national parks = light green; provincial parks = blue.

substrate became covered with fungi.

Specimens from field collections and those harvested from the moist chamber cultures were glued with some of the substrate to archival mat boards cut to fit appropriate-sized pasteboard boxes. The specimens were air-dried at room temperature then placed through a freeze-thaw cycle ( $-20^{\circ}\text{C}$  for one week, room temperature for one week, then  $-20^{\circ}\text{C}$  for one week) to kill any pests. All specimens were deposited in the herbarium of the New Brunswick Museum (NBM). The collector (field) number and catalogue number are listed for each collection. Collector numbers are in square brackets when the number was assigned by someone other than the collector. The Latin abbreviation *s.n.*, without number (*sine*

*numero*), is used when no collector number was given to the collection.

Collections were identified or verified by V.F.Z. except for a collection of *Listerella paradoxa* E. Jahn identified by K.E.D. in 2015 and 13 collections identified by others before 2014. A solution of 3% potassium hydroxide was used for microscopic examination and measurements of collections are as described in Stephenson and Stempen (1994). Most identifications were made using Martin and Alexopoulos (1969), Stephenson and Stempen (1994), Lado and Pando (1997), Ing (1999), and Poulain *et al.* (2011).

#### Nomenclature

The nomenclature of the myxomycetes, including standardized abbreviations of author names,

essentially follows Lado (2005–2022). The scientific and common names of trees and other vascular plants follow Brouillet *et al.* (2010+). In the annotated list of myxomycete species, we have largely retained the verbatim descriptions of habitats and substrates recorded by the collectors. These descriptions often note either the common or the scientific names of trees and shrubs; we use both names on first mention in the manuscript then switch to common names. Besides those mentioned in the description of the study area, other tree and shrub species recorded were Striped Maple (*Acer pensylvanicum* L.), Mountain Maple (*Acer spicatum* Lamarck), Yellow Birch (*Betula alleghaniensis* Britton), Heart-leaved Birch (*Betula cordifolia* Regel), Red Ash (*Fraxinus pennsylvanica* Marshall), Canada Fly-honeysuckle (*Lonicera canadensis* Bartram & W. Bartram ex Marshall), Eastern Hop-hornbeam (*Ostrya virginiana* (Miller) K. Koch), Jack Pine (*Pinus banksiana* Lambert), Eastern White Pine (*Pinus strobus* L.), Red Oak (*Quercus rubra* L.), American Mountain-ash (*Sorbus americana* Marshall), Eastern White Cedar (*Thuja occidentalis* L.), and White Elm (*Ulmus americana* L.). Short forms of common names include fir for Balsam Fir, beech for American Beech, hemlock for Eastern Hemlock, white pine for Eastern White Pine, and cedar for Eastern White Cedar. Trees and shrubs that were sometimes recorded to genus only include maple (*Acer* L.), alder (*Alnus* Miller), birch (*Betula* L.), ash (*Fraxinus* L.), spruce (*Picea* A. Dietrich), poplar (*Populus* L.), mountain ash (*Sorbus* L.), and viburnum (*Viburnum* L.). The names “white birch” or “paper birch” as originally recorded could refer to either *Betula cordifolia* Regel or *Betula papyrifera* L. We report these instances as white birch, but their specific identity remains uncertain.

#### Data collation and presentation

Figure 2 was prepared using geographic information system software QGIS v. 3.22.7 (available from <https://www.qgis.org/en/site/>). Shape files for PNAs and PPs were downloaded from the GeoNB website (<http://www.snb.ca/geonb1/e/DC/catalogue-E.asp>) in February 2021. Shape files for Canadian national parks were downloaded from the Natural Resources Canada website (<https://www.nrcan.gc.ca/home>) in February 2021.

Sources consulted for information on the geographic ranges of species included Martin and Alexopoulos (1969), Ing (1999), Stephenson (2021), Global Biodiversity Information Facility (GBIF 2022), and “Global Mapper” function of Discover Life (2022). Species are listed as “cosmopolitan” unless they appeared to have substantial gaps in their ranges that are unlikely to be attributable merely to limited exploration and collecting. The preferred substrates

of species were determined from Martin and Alexopoulos (1969), Stephenson and Stempen (1994), Stephenson (2021), and personal observations by V.F.Z.

The number of specimens presented in the results, including Figure 2, represents a complete tally of relevant collections studied and deposited at the NBM up to 2019. However, detailed citations are provided only for specimens that are either identified to species or distinct from other species presented in the checklist. In two cases, the qualifier “cf.” (short for the Latin *confer/conferatur*, meaning compare; difficult to identify to species) is inserted before species names in the checklist.

## Results

The targeted search effort resulted in 225 collections from seven PNAs, two PPs, one national wildlife area, and one internationally managed park (Table 1). An additional 39 specimens were collected outside the main effort. Eighty species in 29 genera were recorded, belonging to eight orders and 12 families (Table 2).

The majority of the myxomycetes recorded are represented by specimens that fruited in the field under natural conditions, but some were collected from moist chamber cultures. Species known only from fruiting bodies appearing in moist chamber culture are indicated in the notes after each species.

The species of greatest abundance was *Arcyria cinerea* (Bull.) Pers., which was represented by 24 collections, followed by *L. epidendrum* (19), *Fuligo septica* (L.) F.H. Wigg. (15), and *Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr. (14). There were 42 species represented by only one collection. Five of these are apparently rare worldwide. These are *Comatricha mirabilis* R.K. Benj. & Poitras (Martin and Alexopoulos 1969), *Fuligo laevis* Pers. (Discover Life 2022), *Hemitrichia chrysozona* (Lister) Lister (Martin and Alexopoulos 1969), *Lepidoderma neoperforatum* A. Kuhnt (GBIF 2022), and *Listerella paradoxa* (Discover Life 2022). Another globally rare species, *Paradiacheopsis microcarpa* D.W. Mitch., has been collected in New Brunswick six times.

## Annotated Checklist of Species

The list is sorted alphabetically by genus, species, county, date (ascending), and NBM catalogue number (ascending). In cases where more than one specimen of a species was collected at, and cited from, a single locality, the abbreviation “*ibid.*” is used to minimize duplicated information on the locality, habitat, substrate, and date, as appropriate.

*Arcyria affinis* Rostaf. (Figure 1d). **Northumberland Co.:** Nepisiguit PNA, near forest road, ~2.75 km SW of Popple Depot, 47.38395°N, 66.54089°W, on

**TABLE 2.** Orders, families, and genera recorded in this study. The order Ceratiomyxales belongs in the class Ceratiomyxomycetes; all other orders are in the class Myxomycetes.

Order	Family	Genus
Ceratiomyxales	Ceratiomyxaceae	<i>Ceratiomyxa</i>
Clastodermatales	Clastodermataceae	<i>Clastoderma</i>
Cribrariales	Cribrariaceae	<i>Cribraria</i>
Liceales	Liceaceae	<i>Licea</i> <i>Listerella</i>
Physarales	Didymiaceae	<i>Diderma</i>
		<i>Didymium</i>
		<i>Lepidoderma</i>
	Lamprodermataceae	<i>Collaria</i>
Physaraceae	<i>Badhamia</i>	
	<i>Craterium</i>	
	<i>Fuligo</i>	
	<i>Leocarpus</i>	
	<i>Physarum</i>	
Reticulariales	Reticulariaceae	<i>Lycogala</i>
		<i>Reticularia</i>
		<i>Tubifera</i>
Stemonitidales	Amaurochaetaceae	<i>Comatricha</i>
		<i>Enerthenema</i>
		<i>Paradiacheopsis</i>
		<i>Stemonitopsis</i>
		<i>Stemonitis</i>
Trichiales	Dianemataceae	<i>Calomyxa</i>
		<i>Dictydiaethalium</i>
		<i>Trichia</i>
	Trichiaceae	<i>Arcyria</i>
		<i>Hemitrichia</i>
		<i>Metatrichia</i>
		<i>Perichaena</i>
		<i>Trichia</i>

underside of decaying white birch branch on ground, mixed forest with white birch, fir, Red Maple, 14 August 2016, *V.F. Zoll 590* (NBM-MM-000106); N part of Nepisiguit PNA, ~1.2 km S of Lower West Branch Portage Brook, 47.43942°N, 66.62305°W, on decaying wood, with hardwoods, birch, conifers, 15 August 2016, *V.F. Zoll 595* (NBM-MM-000146). Cosmopolitan. This species may be difficult to differentiate from *Arcyria incarnata* or other reddish species of *Arcyria*, but the specimens do have the deeper calyculus of *A. affinis*.

*Arcyria cinerea* (Bull.) Pers. **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, Fox Hill Drive, ~0.4 km SW of intersection of Fox Hill Drive and Glensevern Road, 44.85511°N, 66.93706°W, on decaying Balsam Fir log on ground, forest of fir and birch, 25 September 2016, *V.F. Zoll 632* (NBM-MM-000015); NW part of Canoose Flowage PNA, ~2.25 km SE of S end

of Mud Lake, 45.48967°N, 67.37869°W, on decaying branch on ground, old growth forest of maple, birch, Yellow Birch, beech, fir, and spruce, 15 August 2017, *V.F. Zoll 656* (NBM-MM-000032); 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.42639°N, 67.31766°W, on leaf litter, mixed forest with Red Maple, fir, cedar, birch, 14 June 2018, *V.F. Zoll 699* (NBM-MM-000160), *V.F. Zoll 701* (NBM-MM-000161), *V.F. Zoll 707* (NBM-MM-000162), *V.F. Zoll 731* (NBM-MM-000163), *V.F. Zoll 733* (NBM-MM-000164). **Northumberland Co.:** Nepisiguit PNA, W of forest road, ~7 km SSW of Popple Depot, 47.34154°N, 66.55291°W, on decaying branch on ground, Jack Pine, birch, fir, 14 August 2016, *V.F. Zoll 589* (NBM-MM-000087). **Saint John Co.:** Black River, N of Old Black River Road, 45.26989°N, 65.81964°W, on decomposed log, possibly Red Maple, 9 July 2018, *E. Hines EF.7.9.18.7s* (NBM-MM-000209). **Sunbury Co.:** Portobello Creek

National Wildlife Area, NE side of French Island at The Narrows between Portobello Creek and French Lake, 45.92429°N, 66.30027°W, Red Oak–hemlock forest, decaying log, in knothole with moss, 9 August 2014, *V.F. Zoll 322* (NBM-MM-000071); Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on decaying log, 11 August 2014, *V.F. Zoll 340* (NBM-MM-000067). **York Co.:** Spednic Lake PNA, ~1.8 km NNE of N end of East Brook Lake, 45.70610°N, 67.51768°W, on Moose (*Alces americanus*) dung, mixed forest including maple, birch, poplar, alders, 12 August 2017, *V.F. Zoll 664* (NBM-MM-000044); *ibid.*, on spruce bark, living tree, *V.F. Zoll 676* (NBM-MM-000045); Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, on decaying wood, mixed forest with birch, Red Maple, hemlock, fir, Striped Maple, 15 June 2018, *V.F. Zoll 697* (NBM-MM-000178); *ibid.*, on leaf litter, *V.F. Zoll 710* (NBM-MM-000179), *V.F. Zoll 748* (NBM-MM-000185); *ibid.*, on hemlock stump, *V.F. Zoll 715* (NBM-MM-000180), *V.F. Zoll 717* (NBM-MM-000181), *V.F. Zoll 718* (NBM-MM-000182), *V.F. Zoll 724* (NBM-MM-000183), *V.F. Zoll 727* (NBM-MM-000184); Spednic Lake PP, 45.60619°N, 67.44583°W, on spruce bark, living tree, mixed forest with beech, hemlock, Striped Maple, Red Maple, white birch, Yellow Birch, 16 June 2018, *V.F. Zoll 744* (NBM-MM-000199); *ibid.*, on Red Maple, living tree, *V.F. Zoll 745* (NBM-MM-000200); Spednic Lake PNA, near N end of Bolton Lake, 45.71394°N, 67.59278°W, on bark of dead branch of Red Oak, in mixed forest with poplar, spruce, Yellow Birch, and white birch, 21 June 2018, *V.F. Zoll 696* (NBM-MM-000246). Cosmopolitan, among the most common species globally. This species is particularly common in moist chamber cultures. The cylindrical white or ashy-grey sporangia are easily identifiable and are found on many substrates, including decaying wood, leaf litter, bark, and dung.

*Arcyria denudata* (L.) Wettst. **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on decaying branch, ground litter, 10 August 2014, *V.F. Zoll 327* (NBM-MM-000056). Only one collection of this species has been made in New Brunswick, unlike in the eastern USA (Stephenson *et al.* 2020), where this species is one of the most collected. A few collections have been made in other Canadian provinces.

*Arcyria ferruginea* Saut. **Charlotte Co.:** Campobello Island, northwestern part of Herring Cove PP, ~0.7 km NNE of intersection of Route 774 and Glensevern Road, 44.87969°N, 66.95319°W, on decaying wood on ground, forest of fir, spruce, and

birch, 22 September 2016, *V.F. Zoll 626* (NBM-MM-000020). Cosmopolitan. In addition to this record, there is only one other record reported for New Brunswick from Campbellton, 30 September 1912, collected by John W. Eastham, deposited in the University of British Columbia Herbarium (Mycportal 2022), despite this species being common throughout the Northern Hemisphere.

*Arcyria incarnata* (Pers. ex J.F. Gmel.) Pers. **Charlotte Co.:** NW part of Canoose Flowage PNA, ~2.3 km SE of S end of Mud Lake, 45.48904°N, 67.37852°W, on decaying wood under leaves, old growth forest, maple, birch, Yellow Birch, beech, fir, spruce, 11 August 2017, *V.F. Zoll 649* (NBM-MM-000029). **Northumberland Co.:** Nepisiguit PNA, NW of forest road at brook by culvert, ~2.3 km SW of Popple Depot, 47.38665°N, 66.53618°W, on bark, decaying branch, 4 July 2015, *B.W. Malloch s.n.* (NBM-MM-000116); N part of Nepisiguit PNA, ~1.2 km S of Lower West Branch Portage Brook, 47.43942°N, 66.62305°W, on decaying wood on ground, forest with hardwoods, birch, and conifers, 15 August 2016, *V.F. Zoll 597* (NBM-MM-000148); Nepisiguit PNA, N of Nepisiguit River, S of Melansons Gulch, near base of Mount Walker, ~11.9 km SW of Popple Depot, 47.36382°N, 66.66053°W, on bark, decaying branch, forest with fir and spruce, 19 August 2016, *V.F. Zoll 621* (NBM-MM-000102); Nepisiguit PNA, N of forest road, S of Nepisiguit River, ~2.7 km SW of Popple Depot, 47.38734°N, 66.5346°W, on decaying Balsam Fir log, partly decorticated, with some moss, in mixed forest with Red Maple, white pine, fir, cedar, birch, 21 August 2016, *V.F. Zoll 615* (NBM-MM-000127). **Queens Co.:** Grand Lake PNA, just S of Route 105 at Trout Creek, ~1.1 km SW of Jemseg, 45.82335°N, 66.12427°W, on decaying branch, on ground, flood plain with Silver Maple, Red Ash, elm, 13 August 2014, *V.F. Zoll 349* (NBM-MM-000054). **York Co.:** Spednic Lake PNA, S end of Upper Palfrey Neck, 45.63416°N, 67.47789°W, on decaying beech log, forest of maple, spruce, beech, and Yellow Birch, 12 August 2017, *V.F. Zoll 651* (NBM-MM-000039); Spednic Lake PNA, ~0.15 km NE of Diggity Stream, 45.62049°N, 67.42865°W, on decaying wood, forest including Red Maple and Striped Maple, 18 August 2017, *V.F. Zoll 671* (NBM-MM-000038). Cosmopolitan on decaying wood. It differs from *A. denudata* in having a capillitium that is easily detached from the calyculus on maturity.

*Arcyria pomiformis* (Leers) Rostaf. **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, N of Fox Hill Drive, near base of Fox Hill, 44.85354°N, 66.95303°W, on underside of decaying log on ground, forest of fir, and birch, 25 September 2016, *V.F. Zoll 636* (NBM-MM-000013).

**Northumberland Co.:** Nepisiguit PNA, N of forest road, ~1.4 km SW of Popple Depot, 47.39109°N, 66.52703°W, on decaying Balsam Fir log, mixed forest with fir, 15 August 2016, *V.F. Zoll 605* (NBM-MM-000131). Cosmopolitan on decaying wood and tree bark. This species can be confused with *A. cinerea* if the sporotheca appears more cylindrical than globose or ovate.

*Badhamia lilacina* (Fr.) Rostaf. **Sunbury Co.:** Grand Lake PNA, Fernmount, ~0.79 km S of intersection of Fernmount Road and Grub Road, 45.95860°N, 66.32943°W, on ground litter including *Sphagnum*, 8 August 2014, *G. Bishop [V.F. Zoll 326]* (NBM-MM-000079). Recorded only from the Northern Hemisphere (Europe, eastern Canada, and northeastern USA). This species is usually found on *Sphagnum* in boggy areas (Schnittler *et al.* 2022).

*Calomyxa metallica* (Berk.) Nieuwl. **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, on hemlock stump, mixed forest of birch, Red Maple, hemlock, fir, and Striped Maple, 15 June 2018, *V.F. Zoll 716* (NBM-MM-000186). Cosmopolitan. This species is typically found fruiting on tree bark. The single collection was from a moist chamber culture.

*Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr. **Albert Co.:** Caledonia Gorge PNA, 6.5 km NNW of Riverside Albert, Caledonia Brook, 45.80098°N, 64.77283°W, on root of living Balsam Fir among moss, 29 June 2011, *E.K. Duke EKD2011-17* (NBM-MM-000229). **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, Liberty Point, ~0.35 km S of the S end of Glensevern Road, 44.83167°N, 66.92900°W, on decaying wood, forest of fir, birch, and mountain ash, 23 September 2016, *D. Porter [V.F. Zoll 628]* (NBM-MM-000011). **Northumberland Co.:** Nepisiguit PNA, Popple Depot, E of Nepisiguit River, W of forest road, 47.39880°N, 66.51164°W, on decaying wood, with Trembling Aspen, fir, 30 June 2015, *V.F. Zoll 382* (NBM-MM-000142); Nepisiguit PNA, N of Nepisiguit River and S of forest road, ~4.9 km SW of Popple Depot, 47.38529°N, 66.57273°W, on decaying wood, mixed forest on S side of road with maple, birch, spruce, fir, poplar, Bracken Fern (*Pteridium aquilinum* (L.) Kuhn), 2 July 2015, *V.F. Zoll 388* (NBM-MM-000112); *ibid.*, on decaying bryophyte-covered log, *V.F. Zoll 390* (NBM-MM-000114); Nepisiguit PNA, W of forest road, ~7 km SSW of Popple Depot, 47.34154°N, 66.55291°W, on decaying branch on ground, Jack Pine, birch, fir, 14 August 2016, *V.F. Zoll 587* (NBM-MM-000086); SW part of Kennedy Lakes PNA, 46.7717°N, 66.57573°W, on rotting white birch branch on ground, young mixed forest of white birch, Yellow Birch, fir, spruce, maple,

poplar, and cedar, 2 July 2019, *A.M. Bremner et al. AB2019.07.02-09* (NBM-MM-000225). **Saint John Co.:** City of Saint John, Irving Nature Park, Sheldon Point trail, 45.23153°N, 66.07914°W, on rotting wood, open coastal mixed forest walking trail with many large trees, mostly fir and Yellow Birch, some mountain-ash, white birch, alder, and spruce, 7 August 2018, *E. Hines s.n.* (NBM-MM-000212). **Sunbury Co.:** Grand Lake PNA, Kenny Brook Area, 45.97447°N, 66.44526°W, on decorticated conifer, conifer forest, flat, dry, 16 June 2013, *J.B. Tanney [B.W. Malloch B20130616-02]* (NBM-MM-000158); Portobello Creek National Wildlife Area, NE side of French Island at The Narrows between Portobello Creek and French Lake, 45.92429°N, 66.30027°W, on decaying wood, 9 August 2014, *V.F. Zoll 324* (NBM-MM-000073); Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on dead branch, Red Maple, Silver Maple swamp, 10 August 2014, *V.F. Zoll 344* (NBM-MM-000063). **York Co.:** Spednic Lake PNA, ~1.6 km NW of N end of Bolton Lake, 45.72428°N, 67.60622°W, on decaying branch on ground, mixed forest, 10 August 2017, *V.F. Zoll 673* (NBM-MM-000052); Spednic Lake PP, ~3.6 km W of S end of First Lake, 45.60645°N, 67.44680°W, on decaying log, in mixed forest including birch, conifers, hemlock, and maples, 16 June 2018, *A.M. Bremner [V.F. Zoll 684]* (NBM-MM-000235); Spednic Lake PNA, between forest road and N end of Palfrey Lake, 45.6857°N, 67.4902°W, on decaying branch on ground, in mixed forest with poplar, spruce, Yellow Birch, and white birch, 20 June 2018, *V.F. Zoll 689* (NBM-MM-000240). Cosmopolitan; one of the most common species worldwide. The coraloid form and the poroid form are considered the same species and both were found. As noted previously, the Ceratiomyxales are not true myxomycetes; they bear spores on the outside of their fruiting bodies, rather than inside. The two other species in this genus occur only in the tropics.

*Clastoderma debaryanum* A. Blytt. **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, Liberty Point, ~0.5 km SSW of the S end of Glensevern Road, 44.83112°N, 66.93136°W, on decorticated log on ground, forest of fir, birch, and mountain ash, 23 September 2016, *V.F. Zoll 637* (NBM-MM-000008); *ibid.*, on decaying log on ground, 23 September 2016, *V.F. Zoll 638* (NBM-MM-000009). Cosmopolitan. Most commonly found on tree bark in moist chamber cultures, because of its small size.

*Collaria arcyryonema* (Rostaf.) Nann.-Bremek. ex Lado (Figure 1c). **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of

intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, with *Physarum viride* on dead branch of Red Maple, Silver Maple swamp, 10 August 2014, *V.F. Zoll 328* (NBM-MM-000057); *ibid.*, on dead branch of Red Maple, *V.F. Zoll 329* (NBM-MM-000058), *V.F. Zoll 330* (NBM-MM-000059), *V.F. Zoll 343* (NBM-MM-000062); *ibid.*, with *C. fruticulosa* on dead branch, Red Maple, *V.F. Zoll 344* (NBM-MM-000063); *ibid.*, on dead branch of Red Maple, 11 August 2014, *V.F. Zoll 320* (NBM-MM-000064). Cosmopolitan. Easily recognized by its silvery or iridescent bronze peridium.

*Comatricha mirabilis* R.K. Benj. & Poitras. **Northumberland Co.:** SW part of Kennedy Lakes PNA, 4.3 km NW of Upper Peaked Mountain Lake, 46.77170°N, 66.57573°W, with *L. neoperforatum* on Mountain Maple twigs, young mixed forest of white birch, Yellow Birch, spruce, fir, maple, poplar, and cedar (saplings), 2 July 2019, *A. Carter [A.M. Bremner AB2019.07.02-10]* (NBM-MM-000216). Widespread but apparently rare; recorded from Europe, North America (Canada, USA, and Mexico) and South America.

*Comatricha nigra* (Pers. ex J.F. Gmel.) J. Schröt. **Northumberland Co.:** Kennedy Lakes PNA, 5.8 km SW of peak of Fowler Mountain, near South Branch Renous River, 46.7923°N, 66.4772°W, on underside of well-rotted piece of moss-covered wood/bark standing upright (perhaps an old tree trunk), in open mature coniferous forest of fir, spruce, white pine, 4 July 2019, *A.M. Bremner AB2019.07.04-03* (NBM-MM-000217). Cosmopolitan; frequently collected. Reported here on decaying wood, this species is also often found on tree bark in moist chamber cultures.

*Comatricha pulchella* (C. Bab.) Rostaf. **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on wood, decaying log, 11 August 2014, *V.F. Zoll 325* (NBM-MM-000065). Cosmopolitan.

*Craterium minutum* (Leers) Fr. **York Co.:** Spednic Lake PNA, ~0.37 km NW of N end of Bolton Lake, 45.71639°N, 67.59516°W, on decaying birch, mixed forest including birch, fir, Red Maple, Striped Maple, 17 August 2017, *V.F. Zoll 666* (NBM-MM-000048). Cosmopolitan. The fruiting bodies look like tiny goblets with lids.

*Cribraria argillacea* (Pers. ex J.F. Gmel.) Pers. **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~2.8 km SW of Popple Depot, 47.38266°N, 66.54118°W, on decaying wood, fir, hardwood forest including maple, and Yellow Birch, 28 June 2015, *V.F. Zoll 380* (NBM-MM-000091); Nepisiguit PNA, N of forest road, S of Nepisiguit River, ~2.7 km SW of Popple Depot, 47.38734°N, 66.53460°W,

on decaying Balsam Fir log, partly decorticated, with some moss, in mixed forest with Red Maple, white pine, fir, cedar, birch, 20 August 2016, *V.F. Zoll 609* (NBM-MM-000123). Cosmopolitan. Normally found on decaying conifer wood, this species is a shiny silvery-grey colour when immature, but later turns clay coloured.

*Cribraria cancellata* (Batsch) Nann.-Bremek. **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on decaying wood, 10 August 2014, *V.F. Zoll 332* (NBM-MM-000061); Grand Lake PNA, between Ripples and Clarks Corner, off Coy Road, ~4.7 km SE of Ripples, 45.97014°N, 66.16402°W, on decaying wood, 12 August 2014, *V.F. Zoll 334* (NBM-MM-000082). **York Co.:** Spednic Lake PNA, N of Georgia Pacific Road, near SW edge of Big La Coote Stream, 45.69927°N, 67.49879°W, on wood which was partly submerged, forest of poplar, birch, and maple, 13 August 2017, *A. Carter [V.F. Zoll 652]* (NBM-MM-000041). **Northumberland Co.:** Nepisiguit PNA, Popple Depot, W of Nepisiguit River, 47.39718°N, 66.51435°W, on decaying spruce log, E side of dirt road in coniferous forest, 26 June 2015, *V.F. Zoll 384* (NBM-MM-000140), *V.F. Zoll 392* (NBM-MM-000141). Cosmopolitan; frequently collected. This species is easily recognized, with its delicate longitudinal ribs and nodding sporotheca on dark-coloured stalks.

*Cribraria confusa* Nann.-Bremek. & Y. Yamam. **York Co.:** Spednic Lake PP, 45.60645°N, 67.44680°W, on maple bark, living tree, 16 June 2018, *V.F. Zoll 694* (NBM-MM-000245). Cosmopolitan. This collection was from a moist chamber culture.

*Cribraria intricata* Schrad. **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, with *Physarum album* on decaying branch, greyish-brown peeling bark, 11 August 2014, *V.F. Zoll 335* (associated record of NBM-MM-000066); Grand Lake PNA, between Ripples and Clarks Corner, off Coy Road, ~4.7 km SE of Ripples, 45.97014°N, 66.16402°W, on decaying branch on ground, forest with Red Maple, fir, and birch, 12 August 2014, *V.F. Zoll 319* (NBM-MM-000080). Cosmopolitan. This species is found on decaying wood.

*Cribraria microcarpa* (Schrad.) Pers. **Charlotte Co.:** SW part of Andersonville PNA, N of Northwest Branch Digdeguash River, ~0.56 km SSW of intersection of Route 3 and Route 755, 45.40698°N, 67.25471°W, on decaying branch on ground, mixed forest, 16 August 2017, *V.F. Zoll 662* (NBM-

MM-000025). **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~1.4 km SW of Popple Depot, 47.39109°N, 66.52703°W, on decaying Balsam Fir log, mixed forest with fir, 18 August 2016, *V.F. Zoll 617* (NBM-MM-000136); *ibid.*, on decaying Balsam Fir log, mixed forest with Red Maple, white pine, fir, cedar, birch, 18 August 2016, *V.F. Zoll 679* (NBM-MM-000137). **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, with *C. arcyronema* on Red Maple, lignin, dead branch, 10 August 2014, *V.F. Zoll 330* (NBM-MM-000059). **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72277°N, 67.66444°W, with *A. cinerea* on hemlock stump, mixed forest of birch, Red Maple, hemlock, fir, and Striped Maple, 15 June 2018, *V.F. Zoll 727* (NBM-MM-000184). Cosmopolitan. Found on decaying wood and on ground litter in moist chamber cultures, this species is fairly easy to recognize with its tiny, nodding fruiting bodies on long, delicate stalks.

*Dictydiaethalium plumbeum* (Schumach.) Rostaf. **Northumberland Co.:** Nepisiguit PNA, N of Nepisiguit River, ~0.15 km ENE of mouth of Little South Branch Nepisiguit River, 47.35328°N, 66.68336°W, on moss, 27 June 2015, *V.F. Zoll 378* (NBM-MM-000089). **York Co.:** Spednic Lake PNA, Todds Island, ~1.2 km SSE of N end of island, 45.6025°N, 67.5102°W, on decaying hemlock, 22 June 2018, *D.W. Malloch [V.F. Zoll 692]* (NBM-MM-000243). Cosmopolitan. This species forms a pseudoaethalium, which consists of closely compacted cylindrical sporangia, each with a little cap. The pseudoaethalium may reach 10 cm or more in width.

*Diderma cinereum* Morgan. **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~1.5 km SW of Popple Depot, 47.39254°N, 66.52930°W, on leaf litter, mixed forest of White Spruce, Jack Pine, Red Maple, and Trembling Aspen, 18 August 2016, *B.W. Malloch [V.F. Zoll 607]* (NBM-MM-000138). Probably cosmopolitan; not particularly common. Although *Diderma* species typically have a peridium with two layers, this species has only one.

*Diderma niveum* (Rostaf.) T. Macbr. **York Co.:** Spednic Lake PNA, Bolton Lake, 45.71394°N, 67.59278°W, on bark of oak dead branch, mixed forest with poplar, spruce, Yellow Birch, white birch, 21 June 2018, *V.F. Zoll 737* (NBM-MM-000206). Cosmopolitan. This specimen from a moist chamber culture fits descriptions of *D. niveum*, which is, however, a nivicolous species (i.e., normally detected at the edge of melting snowbanks). This and two other species detected in the present study (*Lepidoderma carestianum* (Rabenh.) Rostaf. and *L. neoperforatum*) are reported to be truly nivicolous rather than merely

requiring cool conditions (Schnittler *et al.* 2022). It is, therefore, notable that the substrate on which the fruiting bodies of *D. niveum* eventually appeared in culture and the fruiting bodies of the two species of *Lepidoderma* were collected in late June/early July with no sign of recent snowmelt nearby.

*Diderma testaceum* (Schrad.) Pers. **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, on leaf litter, mixed forest with birch, Red Maple, hemlock, fir, Striped Maple, 15 June 2018, *V.F. Zoll 711* (NBM-MM-000189), *V.F. Zoll 713* (NBM-MM-000190), *V.F. Zoll 738* (NBM-MM-000191). Probably cosmopolitan; found in Europe and in North and Central America. These collections were from moist chamber cultures of leaf litter, although this species can also be found fruiting in the field.

*Diderma* sp. **Queens Co.:** Grand Lake PNA, ~0.2 km NE of intersection of Route 690 and Pondstream Road, 45.94438°N, 66.11012°W, on decaying branch on ground, 13 August 2014, *K.E. Driscoll [V.F. Zoll 347]* (NBM-MM-000077). The yellow plasmodium developed into grey sporangia heaped in separate mounds, each on a shiny yellowish hypothallus, containing dark brown, minutely warted spores. Appearing to have a single peridium, yellowish granular lime, and no columella, this specimen could not be identified to a species, but was distinct from the other three species of *Diderma* found in our study.

*Didymium iridis* (Ditmar) Fr. **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~1.4 km SW of Popple Depot, 47.39109°N, 66.52703°W, on decaying Balsam Fir log, mixed forest with fir, 18 August 2016, *V.F. Zoll 602* (NBM-MM-000133). **Westmorland Co.:** Irishtown Nature Park, on E shore of the reservoir, 46.15774°N, 64.74706°W, on moss, 7 August 2007, *B.A. Bagnell & G. Bishop s.n.* (NBM-MM-000150). Cosmopolitan. Like most species of *Didymium*, the fruiting body is covered with white starlike lime crystals.

*Didymium melanospermum* (Pers.) T. Macbr. **Charlotte Co.:** NW part of Canoose Flowage PNA, ~2.3 km SE of S end of Mud Lake, 45.48904°N, 67.37852°W, on decaying hardwood, old growth forest of maple, birch, Yellow Birch, beech, fir, and spruce, 11 August 2017, *B.W. Malloch [V.F. Zoll 648]* (NBM-MM-000028). **Northumberland Co.:** Hells Gate Hardwoods PNA, 46.9332°, 65.1094°W, on thallus of *Peltigera* (*Peltigera apthosa* (L.) Willd. or *Peltigera leucophlebia* (Nyl.) Gyeln.) lichen, bryophytes, and bark, on forest floor, mature mixed forest of Red Spruce, Yellow Birch, Red Maple, and hemlock, 13 August 2019, *S.R. Clayden 27966* (NBM-MM-000267); Nepisiguit PNA, N of Nepisiguit River, S of Melansons Gulch, near base of Mount

Walker, ~11.9 km SW of Popple Depot, 47.36382°N, 66.66053°W, on twig embedded in moss, with fir and spruce, 19 August 2016, *V.F. Zoll 606* (NBM-MM-000100); *ibid.*, on moss, *V.F. Zoll 608* (NBM-MM-000101); Upper Dungarvon PNA, 5.3 km SW of Grassy Lake, E side of Dungarvon River, 46.8019°N, 66.6241°W, on decaying plant debris on ground, young coniferous forest of fir and spruce, some deciduous trees present (birch, maple, beech), under tree trunk, 5 July 2019, *A.M. Bremner AB2019.07.05-02* (NBM-MM-000215); South Branch Big Sevoгле River PNA, 47.09452°N, 66.00510°W, growing on *Bazzania* (liverwort), brook ravine with waterfalls, shale rock bluffs and mature coniferous forest of spruce and white pine with some maple and Yellow Birch, 15 September 2019, *A.M. Bremner et al. AB2019.09.15-05* (NBM-MM-000218); Goodfellow Brook PNA, 46.89888°N, 65.36604°W, on bark, at base of cedar, sheltered shaded log, mature wet forest of cedar, fir, spruce, and Red Maple, 16 September 2019, *J. Gagnon [V.F. Zoll 754]* (NBM-MM-000228). **York Co.:** Spednic Lake PNA, ~0.37 km NW of N end of Bolton Lake, 45.71639°N, 67.59516°W, on decaying birch, mixed forest including birch, fir, Red Maple, Striped Maple, 17 August 2017, *V.F. Zoll 667* (NBM-MM-000049). Cosmopolitan; very common. One of the more common species collected in New Brunswick.

*Didymium minus* (Lister) Morgan. **Northumberland Co.:** Nepisiguit PNA, N of forest road, S of Nepisiguit River, ~2.7 km SW of Popple Depot, 47.38734°N, 66.54360°W, on decaying Balsam Fir log, partly decorticated, with some moss, in mixed forest with Red Maple, white pine, fir, cedar, birch, 20 August 2016, *V.F. Zoll 610* (NBM-MM-000124); *ibid.*, on ground litter, *V.F. Zoll 612* (NBM-MM-000126). **York Co.:** Spednic Lake PNA, ~0.37 km NW of N end of Bolton Lake, 45.71639°N, 67.59516°W, on decaying branch on ground, mixed forest including birch, fir, Red Maple, Striped Maple, 17 August 2017, *V.F. Zoll 668* (NBM-MM-000050); Canoose Flowage PNA, ~1.34 km WSW of mouth of Canoose Stream, 45.4851°N, 67.3540°W, on fallen birch branch, 18 August 2017, *B.W. Malloch [V.F. Zoll 674]* (NBM-MM-000027). Cosmopolitan. Somewhat similar to *D. melanospermum*, but with smaller fruiting bodies and smaller spores.

*Didymium nigripes* (Link) Fr. **Charlotte Co.:** NW part of Canoose Flowage PNA, ~2.3 km SE of S end of Mud Lake, 45.48904°N, 67.37852°W, on decaying Balsam Fir on ground, old growth forest of maple, birch, Yellow Birch, beech, fir, and spruce, 11 August 2017, *V.F. Zoll 655* (NBM-MM-000031). Cosmopolitan. Very similar to *D. iridis*, but with a darker stalk.

*Didymium cf. proximum* Berk. & M.A. Curtis.

**Northumberland Co.:** Nepisiguit PNA, N of Nepisiguit River, S of Melansons Gulch, near base of Mount Walker, ~11.9 km SW of Popple Depot, 47.36342°N, 66.66077°W, on moss, grass, and spruce cone, 16 September 2015, *A.M. Bremner AB2015.09.16-07* (NBM-MM-000098). *Didymium proximum* is essentially cosmopolitan, but mostly found in eastern Canada and the USA, and in Europe. It is less common and perhaps not as widespread as *D. iridis* and *D. nigripes*. This species is very similar to *D. iridis* but can be distinguished by the colour of the plasmodium: yellow in *D. proximum* and cream or brown in *D. iridis*. The cited specimen is provisionally named because the plasmodium was not seen, but the yellow peridium and the slightly larger spores fit with *D. proximum*.

*Enerthenema papillatum* (Pers.) Rostaf. **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, Liberty Point, ~0.35 km S of the S end of Glensevern Road, 44.83167°N, 66.92900°W, on decorticated log on ground, forest of fir, birch, and mountain ash, 23 September 2016, *V.F. Zoll 627* (NBM-MM-000010); Campobello Island, Roosevelt Campobello International Park, N of Fox Hill Drive, near base of Fox Hill, 44.85354°N, 66.95303°W, on decaying Balsam Fir, forest of fir, and birch, 25 September 2016, *A.M. Bremner [V.F. Zoll 635]* (NBM-MM-000014). **Sunbury Co.:** Near western point of Fulton Island between Main Thoroughfare and Blind Thoroughfare, 45.90122°N, 66.25619°W, on oak bark, 13 August 2014, *S.R. Clayden 24696 [V.F. Zoll 338]* (NBM-MM-000070). **York Co.:** NE end of Spednic Lake PNA, off Route 630, W of Sixth Lake, 45.717°N, 67.468°W, on decaying wood, among viburnum and cedar, 12 August 2017, *A. Carter [V.F. Zoll 654]* (NBM-MM-000051). Cosmopolitan; apparently common in the Northern Hemisphere. Distinguished by its unusual “may-pole” arrangement of the capillitium.

*Fuligo laevis* Pers. **Saint John Co.:** Manawagonish Island Nature Preserve, ~0.23 km SW of N end of Manawagonish Island, 45.20897°N, 66.10733°W, on side of pole covered in lichens, supporting birds nest platform, 17 May 2016, *A.M. Bremner AB2016.05.17-02* (NBM-MM-000022). Probably cosmopolitan; known from Europe, North America, Asia, and Australia. This species is globally rare, and we are aware of only three other collections from Canada and the USA (GBIF 2022; MyCoPortal 2022), all at least 90 years old and recorded as *Fuligo septica* var. *laevis* (Pers.) Fr.

*Fuligo leviderma* H. Neubert, Novotny & K. Baumann. **Charlotte Co.:** NW part of Canoose Flowage PNA, ~2.3 km SE of S end of Mud Lake, 45.48904°N, 67.37852°W, on dead maple, old growth forest of

maple, birch, Yellow Birch, beech, fir, and spruce, 11 August 2017, *E. Hines* [V.F. Zoll 653] (NBM-MM-000030). Widespread in the Northern Hemisphere; most commonly reported in Europe.

*Fuligo septica* (L.) F.H. Wigg. (Figure 1f). **Albert Co.:** Caledonia Gorge PNA, W of Canada Creek, 45.77404°N, 64.78297°W, on rotten log (conifer?) lying on the ground, 29 June 2011, *D.W. Malloch s.n.* (NBM-MM-000005). **Charlotte Co.:** Campobello Island, Herring Cove PP, trail to Dicks Pond, E of Adams Estate, 44.87957°N, 66.95304°W, infected with (and filed under) *Nectriopsis violacea* (J.C. Schmidt ex Fr.) Maire, an ascomycete fungus specific to *F. septica* (Rossman *et al.* 1999), among mosses and debris on forest floor, old humid forest dominated by Red Spruce, with Balsam Fir, Yellow Birch, Heart-leaved Birch, and American Mountain-ash, 23 September 2016, *S.R. Clayden s.n.* (NBM-FF-008382); Campobello Island, Roosevelt Campobello International Park, Fox Hill Drive, ~0.4 km SW of intersection of Fox Hill Drive and Glensevern Road, 44.85511°N, 66.93706°W, on moss on tree base, forest of fir and birch, 24 September 2016, *M. Mulvey* [V.F. Zoll 630] (NBM-MM-000016); *ibid.*, on decaying wood on ground, *A.M. Bremner* [V.F. Zoll 631] (NBM-MM-000017); NW part of Canoose Flowage PNA, ~2.25 km SE of S end of Mud Lake, 45.48967°N, 67.37869°W, on moss over decaying conifer, old growth forest of maple, birch, Yellow Birch, beech, fir, and spruce, 15 August 2017, *V.F. Zoll 657* (NBM-MM-000033). **Northumberland Co.:** NE corner of Nepisiguit PNA, headwaters of Pentland Brook, 47.41973°N, 66.56937°W, on moss and ground litter, in forest dominated by Balsam Fir, Heart-leaved Birch, White Spruce, Black Spruce, American Mountain-ash, and Mountain Maple, on W-facing slope, 7 July 2015, *S.R. Clayden et al.* 25253 (NBM-MM-000144); Nepisiguit PNA, N of forest road, near brook running N toward Nepisiguit River, ~2.25 km SW of Popple Depot, 47.38704°N, 66.53635°W, on bryophytes on base of dead Balsam Fir, near a beaver pond in mature hardwood forest, 16 August 2016, *V.F. Zoll 600* (NBM-MM-000118); *ibid.*, on decaying wood (bark) ground litter, *A.M. Bremner* [V.F. Zoll 616] (NBM-MM-000121); Upper Dungarvon PNA, 5.3 km SW of Grassy Lake, E side of Dungarvon River, 46.8019°N, 66.6241°W, on moss-covered rotting tree trunk, in young coniferous forest of fir and spruce, some deciduous trees present (birch, maple, beech), 5 July 2019, *A.M. Bremner* AB2019.07.05-01 (NBM-MM-000214). **Saint John Co.:** City of Saint John, 277 Douglas Avenue, New Brunswick Museum, hillside above Marble Cove, 45.26875°N, 66.08289°W, on dried whale bone (kept outside during preparation as a zoology specimen), in

open gravel, paved area near mixed forest, NW side of building, 9 July 2008, *D.F. McAlpine & A.M. Bremner s.n.* (NBM-MM-000262); Saint John, Tucker Park, between Tucker Beach Road and Kennebecasis Drive, 45.3106°N, 66.0993°W, on forest floor, mixed forest of spruce, fir, and birch, 27 July 2017, *A.M. Bremner* [V.F. Zoll 645] (NBM-MM-000023). **Sunbury Co.:** Portobello Creek National Wildlife Area, NE side of French Island at The Narrows between Portobello Creek and French Lake, 45.92429°N, 66.30027°W, on ground litter, 9 August 2014, *V.F. Zoll 323* (NBM-MM-000072), *V.F. Zoll 336* (NBM-MM-000074); *ibid.*, on decaying log, *V.F. Zoll 339* (NBM-MM-000075). **York Co.:** Spednic Lake PNA, near SW edge of Todds Island, ~0.68 km SSE from N end of island, 45.59782°N, 67.50765°W, on decaying wood, 17 August 2017, *S.A. Sullivan* [V.F. Zoll 669] (NBM-MM-000037). Cosmopolitan; among the most common myxomycetes globally. This species has relatively large fruiting bodies, from 2 to ~20 cm wide. It is found on decaying wood, ground litter, living plants, and soil. All three specimens collected on Campobello Island during the Campobello Mycological Foray in 2016 are covered with a thick purple and white mycelium and purple perithecia belonging to *N. violacea*.

*Hemitrichia calyculata* (Speg.) M.L. Farr. **Albert Co.:** Fundy National Park, Maple Grove Trail, along both sides of forest road, 45.59008°N, 64.98361°W, on rotting wood, hardwood forest dominated by Sugar Maple, Yellow Birch, and beech, with scattered Red Spruce and Balsam Fir, 24 September 2013, *M. Burzynski s.n.* (NBM-MM-000264). **Charlotte Co.:** Canoose Flowage PNA, ~1.2 km SE of mouth of Canoose Stream, 45.48374°N, 67.32349°W, on decaying wood, toward bog, 14 August 2017, *D.W. Malloch*, [V.F. Zoll 672] (NBM-MM-000026). **Queens Co.:** Grand Lake PNA, just S of Route 105 at Trout Creek, ~1.1 km SW of Jemseg, 45.82335°N, 66.12427°W, on decaying wood on ground, floodplain with Silver Maple, elm, and Red Ash, 13 August 2014, *V.F. Zoll 348* (NBM-MM-000053); *ibid.*, on decaying log on ground, *V.F. Zoll 350* (NBM-MM-000055). **Sunbury Co.:** Near western point of Fulton Island between Main Thoroughfare and Blind Thoroughfare, 45.90122°N, 66.25619°W, on decaying wood, 13 August 2014, *V.F. Zoll 345* (NBM-MM-000069). **York Co.:** Spednic Lake PNA, ~0.37 km NW of N end of Bolton Lake, 45.71639°N, 67.59516°W, on decaying birch, mixed forest including birch, fir, Red Maple, Striped Maple, 17 August 2017, *V.F. Zoll 665* (NBM-MM-000047). Cosmopolitan; common. This species is found fruiting on decaying wood. Similar in appearance to *H. clavata* except for a longer, slender stalk, it resembles a cone of cotton candy.

*Hemitrichia chrysozona* (Lister) Lister. **Kings Co.:** Glebe Mine, 2.4 km SE of Parlee Brook (12.4 km SE of Sussex), 45.65995°N, 65.38129°W, on rotting old mining timber lying on floor of mine, 23 March 2011, *A.M. Bremner et al. AB2011.03.23-01* (NBM-MM-000002). Known from Europe, North America, and Africa; rare. There are apparently only four earlier records from North America, all collected in the USA in the 1950s.

*Hemitrichia clavata* (Pers.) Rostaf. **Northumberland Co.:** Nepisiguit PNA, Popple Depot, E of Nepisiguit River, W of forest road, 47.39880°N, 66.51164°W, on decaying wood, with Trembling Aspen, Balsam Fir, 30 June 2015, *V.F. Zoll 383* (NBM-MM-000143). Cosmopolitan; common. Similar in appearance to *H. calyculata* except for its shorter, stouter stalk and deeper calyculus.

*Hemitrichia leiocarpa* (Cooke) Lister. **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~2.8 km SW of Popple Depot, 47.38266°N, 66.54118°W, on decaying wood, hardwood forest, including maple and Yellow Birch, 28 June 2015, *D.W. Malloch [V.F. Zoll 379]* (NBM-MM-000097). Cosmopolitan; relatively uncommon. Previous records from Canada (Ontario) are from the 1930s and the most recent record from the eastern USA (West Virginia) is from 1982. Consequently, little is known about the species' status in eastern North America.

*Hemitrichia serpulula* (Scop.) Rostaf. ex Lister. **Northumberland Co.:** Nepisiguit PNA, near forest road, ~2.75 km SW of Popple Depot, 47.38395°N, 66.54089°W, on decaying birch on ground, birch, maple, fir, 14 August 2016, *V.F. Zoll 593* (NBM-MM-000109). Cosmopolitan. This species is easily recognized by its yellow to brownish, pretzel-like plasmodiocarp.

*Leocarpus fragilis* (Dicks.) Rostaf. (Figure 1b). **Albert Co.:** Fundy National Park, Dickson Falls Trail, 45.58690°N, 64.97468°W, on rotting wood on forest floor, in rocky, humid, brook ravine with rapids and falls, and mixed forest dominated by Red Spruce, Yellow Birch, Heart-leaved Birch, and Red Maple, 23 September 2013, *W.R. Buck s.n.* (NBM-MM-000233). **Charlotte Co.:** Lepreau Parish, 1.5 km NW of Little Lepreau, 45.13741°N, 66.48784°W, on bark of hardwood log cut for firewood and piled, origin of log unknown, probably southern New Brunswick, 30 September 2018, *D.W. Malloch s.n.* (NBM-MM-000211). **Northumberland Co.:** Nepisiguit PNA, near forest road, ~2.75 km SW of Popple Depot, 47.38395°N, 66.54089°W, on decaying birch bark on ground, birch, maple, fir, 14 August 2016, *V.F. Zoll 591* (NBM-MM-000107); Nepisiguit PNA, N of forest road, ~1.4 km SW of Popple Depot, 47.39109°N, 66.52703°W, on leaf litter, mixed forest with fir, 18

August 2016, *V.F. Zoll 601* (NBM-MM-000132). Cosmopolitan; apparently common globally. This species can resemble a cluster of insect eggs.

*Lepidoderma carestianum* (Rabenh.) Rostaf. **Albert Co.:** Caledonia Gorge PNA, W side of Rhody Brook, 45.77350°N, 64.81337°W, Canada Fly-honey-suckle, on living stem, 28 June 2011, *D.W. Malloch s.n.* (NBM-MM-000004). Probably cosmopolitan; widespread in the Northern Hemisphere, recorded for the Southern Hemisphere only from Australia and New Zealand. This species is normally found at higher elevations, usually at the edge of melting snowbanks. See notes under *D. niveum*.

*Lepidoderma neoperforatum* A. Kuhnt. **Northumberland Co.:** SW part of Kennedy Lakes PNA, 4.3 km NW of Upper Peaked Mountain Lake, 46.77170°N, 66.57573°W, on Mountain Maple twigs, young mixed forest of white birch, Yellow Birch, spruce, fir, maple, poplar, and cedar (saplings), 2 July 2019, *A. Carter [AB2019.07.02-10]* (NBM-MM-000216). So far known mostly from Europe (Norway, Germany, France, Austria) and the USA (Kuhnt 2017; GBIF 2022). The only North American record is a paratype collected in New Hampshire in 1909. The specimen from New Brunswick is significant considering the lack of modern records outside Europe; however, the species was only recently recognized as distinct and described by Kuhnt (2017), partly from older collections filed under other names. It is too soon to say whether the species is rare in North America or merely overlooked. Similar to *Lepidoderma perforatum* Mar. Mey. & Poulain, except for smaller perforations in the peridium. Although normally *L. neoperforatum* is a snowbank species, this collection was not made in such a habitat. See notes under *D. niveum*.

*Licea minima* Fr. **Northumberland Co.:** Nepisiguit PNA, W of forest road, ~7 km SSW of Popple Depot, 47.34154°N, 66.55291°W, on Jack Pine bark, forest with fir, birch, Jack Pine, 14 August 2016, *V.F. Zoll 682* (NBM-MM-000088). Cosmopolitan; frequently collected in the Northern Hemisphere. The single collection of this species was from a moist chamber culture, as is the case with most collections of *L. minima*. Because of their small size, the fruiting bodies are not usually noticed unless brought in with a collection of larger myxomycetes.

*Licea operculata* (Wingate) G.W. Martin. **Charlotte Co.:** 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.42639°N, 67.31766°W, on moss on base of maple, mixed forest of Red Maple, fir, cedar, birch, 14 June 2018, *V.F. Zoll 702* (NBM-MM-000165). **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~2.8 km SW of Popple Depot, 47.38266°N, 66.54118°W, on bark of Yellow Birch, hardwood forest, including maple,

and Yellow Birch, 28 June 2015, *V.F. Zoll 681* (NBM-MM-000096). **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, on bryophyte-covered Balsam Fir log on ground, mixed forest with birch, Red Maple, hemlock, fir, Striped Maple, 15 June 2018, *V.F. Zoll 728* (NBM-MM-000192); Spednic Lake PP, 45.60619°N, 67.44583°W, on hemlock bark, living tree, mixed forest with beech, hemlock, Striped Maple, Red Maple, white birch, Yellow Birch, 16 June 2018, *V.F. Zoll 740* (NBM-MM-000201). Cosmopolitan. All four of these collections were from moist chamber cultures, where it usually appears on bark.

*Licea pygmaea* (Meyl.) Ing. **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, with *A. cinerea* on hemlock stump, mixed forest of birch, Red Maple, hemlock, fir, Striped Maple, 15 June 2018, *V.F. Zoll 715* (NBM-MM-000180), *V.F. Zoll 724* (NBM-MM-000183), *V.F. Zoll 727* (NBM-MM-000184); *ibid.*, on hemlock stump, *V.F. Zoll 723* (NBM-MM-000193, NBM-MM-000194); *ibid.*, on bryophyte-covered Balsam Fir log on ground, *V.F. Zoll 742* (NBM-MM-000195). Cosmopolitan; infrequently collected in North America. All these collections were from moist chamber cultures. Because of their small size, the fruiting bodies are seldom noticed in the field unless brought in with a collection of larger myxomycetes.

*Licea variabilis* Schrad. **York Co.:** Spednic Lake PNA, ~1.8 km NNE of N end of East Brook Lake, 45.70610°N, 67.51768°W, on decaying wood, 12 August 2017, *A. Carter [V.F. Zoll 650]* (NBM-MM-000043). Widespread in the Northern Hemisphere, and recorded from South America. This species is found on decaying wood.

*Listerella paradoxa* E. Jahn. **Northumberland Co.:** Nepisiguit PNA, Popple Depot 47.39766°N, 66.51409°W, on Green Reindeer Lichen (*Cladonia mitis* Sandstede), abandoned road and adjoining well-lit Jack Pine–Black Spruce forest, ground with heavy lichen cover and lots of exposed mineral soil and stones, 30 June 2015, *K. E. Driscoll 1163* (NBM-MM-000258). Widespread but apparently rare, collected in Europe, New Zealand, and from scattered locations in North America, including the USA states of California, Michigan, and West Virginia as well as Ontario, Canada (Eliasson and Gilert 1982; Stephenson *et al.* 2009; MyCoPortal 2022). It occurs on lichens in the genus *Cladonia* and other substrates.

*Lycogala epidendrum* (L.) Fr. **Albert Co.:** Caledonia Gorge PNA, N of Canada Creek, 45.77877°N, 64.77415°W, on surface of living moss, 2 July 2011, *K.J. Vanderwolf s.n.* (NBM-MM-000006); Caledonia Gorge PNA, 6 km WNW of Riverside Albert, E side of Rhody Brook, 45.77081°N, 64.81094°W, on

mossy decaying logs next to brook, mainly beech and Yellow Birch, hardwood dominant, some Red Spruce, about 1 m from brook, 2 July 2011, *E.K. Duke EKD2011-55* (NBM-MM-000231); Fundy National Park, Dickson Falls Trail, 45.58690°N, 64.97468°W, on rotten wood, rocky, humid, brook ravine with rapids and falls, and mixed forest dominated by Red Spruce, Yellow Birch, Heart-leaved Birch, and Red Maple, 23 September 2013, *W.R. Buck s.n.* (NBM-MM-000259); Fundy National Park, Maple Grove Trail, along both sides of forest road, 45.59008°N, 64.98361°W, on wet wood of maple, hardwood forest dominated by Sugar Maple, Yellow Birch, and beech, with scattered Red Spruce and Balsam Fir, 24 September 2013, *G.J. Samuels s.n.* (NBM-MM-000265); Fundy National Park, East Branch Trail, 45.64317°N, 65.11551°W, on rotting wood, moderately open, mixed, mature forest of Yellow Birch and Red Spruce, with Heart-leaved Birch, maple, beech, and fir, 25 September 2013, *M. Burzynski s.n.* (NBM-MM-000263); *ibid.*, on bark of dead birch tree, *A.M. Bremner AB2013.09.25-09* (NBM-MM-000266). **Charlotte Co.:** Campobello Island, Herring Cove PP, E of Glensevern Road, ~0.1 km NNW of the westernmost end of Lake Glensevern, 44.86286°N, 66.93859°W, on decaying wood, birch forest, 24 September 2016, *V.F. Zoll 629* (NBM-MM-000018). **Northumberland Co.:** Nepisiguit PNA, Popple Depot, W of Nepisiguit River, 47.39718°N, 66.51435°W, on decaying spruce, with Black Spruce, Jack Pine, 26 June 2015, *V.F. Zoll 377* (NBM-MM-000139); Nepisiguit PNA, near forest road, ~3.4 km SW of Popple Depot, 47.38107°N, 66.54884°W, on decaying wood and moss, N-facing slope Nepisiguit River valley, mature hardwood forest dominated by Sugar Maple, Yellow Birch, and Striped Maple, 28 June 2015, *S.R. Clayden 25034B [V.F. Zoll 381]* (NBM-MM-000104); Nepisiguit PNA, N of forest road, ~1.4 km SW of Popple Depot, 47.39109°N, 66.52703°W, on decaying Balsam Fir log, mixed forest with fir, 18 August 2016, *V.F. Zoll 604* (NBM-MM-000135); NW part of Kennedy Lakes PNA, 3.5 km NW of Louis Lake, next to brook that runs N between Halfmoon Lake and North Branch Renous River, 46.8696°N, 66.6275°W, on rotting spruce trunk on ground, coniferous dominant forest of fir, spruce, birch, and ash, 30 June 2019, *A.M. Bremner et al. AB2019.06.30-02* (NBM-MM-000222); Kennedy Lakes PNA, S of Highway 108, 46.77093°N, 66.57540°W, on decaying wood, 2 July 2019, *J.R. Blacquiere & S. Mathé [V.F. Zoll 753]* (NBM-MM-000226). **Sunbury Co.:** Grand Lake PNA, 1.5 km NE of McGowans Corner, 45.89594°N, 66.28232°W, on rotted wood, in maple stand, 16 June 2013, *L.K. McAlpine [B.W. Malloch B20130616-02]* (NBM-MM-000152); Grand Lake

PNA, 1.5 km NE of McGowans Corner, 45.89404°N, 66.28051°W, on decorticated wood, seasonal floodplain area, stand of ash, elm, maple, and alder, 22 June 2013, *E.K. Duke ED20130622-05* (NBM-MM-000155); Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on decaying wood on ground, 10 August 2014, *V.F. Zoll 331* (NBM-MM-000060). **York Co.:** Spednic Lake PNA, W of Dead Brook, ~1 km NW of intersection of Georgia Pacific Road and Route 630, 45.67765°N, 67.46612°W, on decaying wood in deep depression with wet leaf litter, mixed forest, 15 August 2017, *E. Hines [V.F. Zoll 659]* (NBM-MM-000040); Spednic Lake PNA ~0.65 km NW of N end of Pirate Lake, 45.72276°N, 67.66444°W, on decaying log, in mixed forest including birch, conifers, hemlock, and maples, 15 June 2018, *V.F. Zoll 683* (NBM-MM-000234); Spednic Lake PNA, S end of Upper Palfrey Neck, 45.63540°N, 67.47835°W, on dead wood on ground, in hardwood forest of beech and maple, 17 June 2018, *A.M. Bremner [V.F. Zoll 685]* (NBM-MM-000236); Spednic Lake PNA, N of Georgia Pacific Road, off gravel road near Big La Coote Stream bridge, 45.69959°N, 67.49805°W, on large decorticated log, in open clearing, 18 June 2018, *V.F. Zoll 688* (NBM-MM-000239). Cosmopolitan; very common. This species is often first noticed in the early stages of fruiting by its bright candy pink colour, which later changes to yellowish brown or almost black.

*Lycolgala exiguum* Morgan. **Albert Co.:** Caledonia Gorge PNA, 6.4 km WNW of Riverside Albert, E side of Rhody Brook, 45.77222°N, 64.81361°W, on decaying log, mossy, Yellow Birch, Sugar Maple, hardwood dominant, 2 July 2011, *E.K. Duke EKD2011-68* (NBM-MM-000232). Cosmopolitan; uncommon. This species differs from *L. epidendrum* by being generally smaller, with smaller spores and a different pattern of surface scales.

*Metatrichia floriformis* (Schwein.) Nann.-Bremek. **Sunbury Co.:** Grand Lake PNA, 1.5 km NE of McGowans Corner, 45.89397°N, 66.28050°W, decorticated maple, seasonal floodplain area, stand of ash, elm, maple, and alder, 22 June 2013, *E.K. Duke ED20130622-06* (NBM-MM-000156). Cosmopolitan; frequently collected in both the Northern and Southern Hemispheres.

*Metatrichia vesparia* (Batsch) Nann.-Bremek. ex G.W. Martin & Alexop. **Sunbury Co.:** Grand Lake PNA, Fernmount, ~0.79 km S of intersection of Fernmount Road and Grub Road, 45.95860°N, 66.32943°W, core of decaying birch inside bark, 8 August 2014, *V.F. Zoll 321* (NBM-MM-000078). **York Co.:** Spednic Lake PNA, ~1.36 km NW of N end of East Brook Lake, 45.70118°N, 67.52793°W,

underside of log, non-forested stream edge, 15 August 2017, *E. Hines [V.F. Zoll 661]* (NBM-MM-000042). Cosmopolitan; relatively common globally and across the USA and Canada. The name *vesparia* alludes to the resemblance of this species to paper wasp nests.

*Paradiacheopsis microcarpa* (Meyl.) D.W. Mitch. ex Ing. **Charlotte Co.:** 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.48766°N, 67.37828°W, on hemlock bark, mixed forest with maple, birch, Yellow Birch, beech, fir, spruce, 23 June 2018, *V.F. Zoll 747* (NBM-MM-000208). **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~2.8 km SW of Popple Depot, 47.38266°N, 66.54118°W, on maple bark, hardwood forest, including maple, Yellow Birch, 28 June 2015, *V.F. Zoll 677* (NBM-MM-000093), *V.F. Zoll 678* (NBM-MM-000094); *ibid.*, moss on maple bark, *V.F. Zoll 680* (NBM-MM-000095); N part of Nepisiguit PNA, ~1.2 km S of Lower West Branch Portage Brook, 47.43942°N, 66.62305°W, on maple bark, living tree, forest with hardwoods, birch, and conifer, 15 August 2016, *V.F. Zoll 618* (NBM-MM-000149). **York Co.:** Spednic Lake PP, 45.60619°N, 67.44583°W, on hemlock bark, living tree, mixed forest with beech, hemlock, Striped Maple, Red Maple, white birch, Yellow Birch, 16 June 2018, *V.F. Zoll 741* (NBM-MM-000202). Scattered records across the Northern Hemisphere; apparently rare. In North America known from a single specimen collected in 1940 in Kansas, USA. All the collections of *P. microcarpa* originated from moist chamber cultures, as is usual with *Paradiacheopsis* species because of their small size. In these cultures, they often develop on bark of living trees.

*Paradiacheopsis rigida* (Brändza) Nann.-Bremek. **York Co.:** Spednic Lake PNA, E side of gravel road E of stream bridge, 45.69959°N, 67.49805°W, on decaying birch branch on ground, mixed forest of conifers, poplar, and white birch, 19 June 2018, *V.F. Zoll 690* (NBM-MM-000241). Scattered records across the Northern Hemisphere; uncommon, in North America known only from one record each in Mexico and Ontario, Canada (Discover Life 2022; GBIF 2022; MyCoPortal 2022). This species normally appears in moist chamber cultures on bark of living trees.

*Perichaena chrysoesperma* (Curr.) Lister. **Charlotte Co.:** NW part of Canoose Flowage PNA, ~2.25 km SE of S end of Mud Lake, 45.48967°N, 67.37869°W, on Red Maple bark, old growth forest, maple, birch, Yellow Birch, beech, fir, spruce, 15 August 2017, *B.W. Malloch [V.F. Zoll 660]* (NBM-MM-000035). **York Co.:** Spednic Lake PP, 45.60619°N, 67.44583°W, on Red Maple, living tree, mixed forest with beech, hemlock, Striped Maple, Red Maple, white birch, Yellow Birch, 16 June 2018, *V.F. Zoll 743* (NBM-MM-000203). Cosmopolitan;

common. This species is found on decaying wood and bark and on many substrates in moist chamber cultures, including old hay bales.

*Perichaena corticalis* (Batsch) Rostaf. **Northumberland Co.:** Nepisiguit PNA, near forest road, ~2.75 km SW of Popple Depot, 47.38395°N, 66.54089°W, on bark of Red Maple, forest with birch, maple, fir, 14 August 2016, *V.F. Zoll 619* (NBM-MM-000110). Cosmopolitan. This collection was made from a moist chamber culture. It has only sparse sporangia, although these are normally found crowded in nature.

*Physarum album* (Bull.) Chevall. **Albert Co.:** Caledonia Gorge PNA, 6 km NW of Riverside-Albert, Rhody Brook, 45.77396°N, 64.81462°W, on bark of dead maple branch lying on the ground, mostly hardwood stand of Sugar Maple, beech, Red Spruce, white birch, and Striped Maple, 28 June 2011, *A.M. Bremner AB2011.06.28-08* (NBM-MM-000151). **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on decaying branch, greyish-brown peeling bark, 11 August 2014, *V.F. Zoll 335* (NBM-MM-000066). Cosmopolitan. This species is similar in appearance to *Physarum viride* except the lime in the fruiting body is white rather than yellow.

*Physarum bivalve* Pers. **Charlotte Co.:** 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.42639°N, 67.31766°W, on leaf litter, mixed forest with Red Maple, fir, cedar, birch, 14 June 2018, *V.F. Zoll 703* (NBM-MM-000166), *V.F. Zoll 732* (NBM-MM-000167). Cosmopolitan. These two collections are from moist chamber cultures, on leaf litter. Named *bivalve* because of the species' laterally compressed shape resembling little clams.

*Physarum contextum* (Pers.) Pers. **Northumberland Co.:** Nepisiguit PNA, near forest road, ~2.75 km SW of Popple Depot, 47.38395°N, 66.54089°W, on decaying birch branch on ground, birch, maple, fir, 14 August 2016, *V.F. Zoll 592* (NBM-MM-000108). Cosmopolitan, but poorly known in the Southern Hemisphere; in North America, it has been frequently collected across Canada and the USA. This species is usually found on ground litter.

*Physarum diderma* Rostaf. (Figure 1a). **Charlotte Co.:** 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.42639°N, 67.31766°W, on leaf litter, mixed forest with Red Maple, fir, cedar, birch, 14 June 2018, *V.F. Zoll 704* (NBM-MM-000168). **Restigouche Co.:** on PNA border line, ~0.5 km from Belledune Pond, Jacquet River Gorge PNA, 47.82011°N, 65.99975°W, on stem of fern, 12 August 2010, *A.M. Bremner AB12.08.10-01* (NBM-MM-000001). Widely distributed across the Northern Hemisphere; not especially common.

*Physarum flavicomum* Berk. **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, on bryophyte-covered fir log on ground, mixed forest with birch, Red Maple, hemlock, fir, Striped Maple, 15 June 2018, *V.F. Zoll 735* (NBM-MM-000196). Cosmopolitan. The single collection of this species was made from a moist chamber culture.

*Physarum galbeum* Wingate. **Northumberland Co.:** Nepisiguit PNA, N of forest road, near brook running N toward Nepisiguit River, ~2.25 km SW of Popple Depot, 47.38704°N, 66.53635°W, on decaying poplar branch, brook off Nepisiguit River, 16 August 2016, *D.W. Malloch [V.F. Zoll 598]* (NBM-MM-000119). Mostly found in the Western Hemisphere (the Americas and Hawaii), especially the USA, with just a few collections made in Europe.

*Physarum luteolum* Peck. **Northumberland Co.:** Nepisiguit PNA, N of forest road, S of Nepisiguit River, ~2.7 km SW of Popple Depot, 47.38734°N, 66.54360°W, on ground litter, mixed forest with Red Maple, white pine, fir, cedar, birch, 21 August 2016, *A.M. Bremner [V.F. Zoll 614]* (NBM-MM-000122). Probably cosmopolitan; most frequently found in Canada and the USA.

*Physarum psittacinum* Ditmar. **Charlotte Co.:** Baillie Settlement PNA, ~1 km NW of intersection of Mann Road and Route 3, 45.40220°N, 67.27095°W, on decaying branch resting on moss, mixed forest including fir, Red Maple, cedar, 16 August 2017, *V.F. Zoll 663* (NBM-MM-000024). **Northumberland Co.:** N part of Nepisiguit PNA, ~1.2 km S of Lower West Branch Portage Brook, 47.43942°N, 66.62305°W, on decaying deciduous log on ground, with hardwoods, birch, conifers, 15 August 2016, *V.F. Zoll 594* (NBM-MM-000145). Probably cosmopolitan but not recorded from Australia or New Zealand; in North America, most records are from the eastern half of Canada and the USA. Short bright orange stalks make this species easy to spot.

*Physarum virescens* Ditmar. **Charlotte Co.:** Campobello Island, Roosevelt Campobello International Park, Liberty Point, ~0.35 km S of the S end of Glensevern Road, 44.8317°N, 66.9290°W, on ground litter, forest of fir, birch, and mountain ash, 23 September 2016, *A.M. Bremner [V.F. Zoll 634]* (NBM-MM-000012). **Queens Co.:** Grand Lake PNA, ~0.58 km NE of Printz Cove, 45.99528°N, 66.11713°W, on pine needles, 11 August 2014, *K.J. Vanderwolf [V.F. Zoll 337]* (NBM-MM-000084). **Saint John Co.:** Black River, N of Old Black River Road, 45.26818°N, 65.80529°W, on leaf litter, 14 August 2018, *E. Hines s.n.* (NBM-MM-000210). **Sunbury Co.:** Grand Lake PNA, between Ripples and Clarks Corner, off Coy Road, ~4.7 km SE of Ripples, 45.97014°N, 66.16402°W, on dead maple leaf, fir/birch/Red Maple

forest, 12 August 2014, *A. Carter* [*V.F. Zoll 346*] (NBM-MM-000083). Cosmopolitan. This species has bright yellow or greenish-yellow heaped sporangia.

*Physarum viride* (Bull.) Pers. **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~1.4 km SW of Popple Depot, 47.39109°N, 66.52703°W, on decaying twig on ground, with deadfall fir covered with moss, 18 August 2016, *V.F. Zoll 603* (NBM-MM-000134); Nepisiguit PNA, N of forest road, S of Nepisiguit River, ~2.7 km SW of Popple Depot, 47.38734°N, 66.53460°W, on decaying fir log, partly decorticated, with some moss, in mixed forest with Red Maple, white pine, fir, cedar, birch, 20 August 2016, *V.F. Zoll 611* (NBM-MM-000125); Kennedy Lakes PNA, 5.8 km SW of peak of Fowler Mountain, near South Branch Renous River, 46.7923°N, 66.4772°W, on moss-covered rotting tree trunk, in young coniferous forest of fir and spruce, some deciduous trees present (birch, maple, beech), 4 July 2019, *D.W. Malloch* [*V.F. Zoll 760*] (NBM-MM-000227). **Queens Co.:** Grand Lake PNA, 1.25 km N of Coytown, 45.8463°N, 66.2050°W, rotten wood (probably *Alnus*), mixed forest, maple, alder, elm dominant; flat and damp, 19 June 2013, *A.M. Bremner* [*B.W. Malloch B20130619-02*] (NBM-MM-000154). **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on dead branch of Red Maple, 10 August 2014, *V.F. Zoll 328* (NBM-MM-000057); *ibid.*, with *C. arcyrionema* on Red Maple, wood, dead branch, *V.F. Zoll 330* (NBM-MM-000059); Grand Lake PNA, between Ripples and Clarks Corner, off Coy Road, ~4.7 km SE of Ripples, 45.97014°N, 66.16402°W, on decaying wood, 12 August 2014, *V.F. Zoll 333* (NBM-MM-000081). Cosmopolitan. This species has nodding yellow sporothecae similar to those of *P. album*, except for the colour of the lime.

*Reticularia splendens* Morgan. **Albert Co.:** Fundy National Park, Dickson Falls Trail, 45.58690°N, 64.97468°W, on rotting wood on forest floor, rocky, humid, brook ravine with rapids and falls, and mixed forest dominated by Red Spruce, Yellow Birch, Heart-leaved Birch, and Red Maple, 23 September 2013, *W.R. Buck s.n.* (NBM-MM-000260); Fundy National Park, Maple Grove Trail, along both sides of forest road, 45.59008°N, 64.98361°W, on wet wood of maple, hardwood forest dominated by Sugar Maple, Yellow Birch, and beech, with scattered Red Spruce, and Balsam Fir, 24 September 2013, *G.J. Samuels s.n.* (NBM-MM-000261). This species is widespread in the Northern Hemisphere.

*Stemonitis axifera* (Bull.) T. Macbr. **Charlotte Co.:** NW part of Canoose Flowage PNA, ~2.25 km SE of S end of Mud Lake, 45.48967°N, 67.37869°W,

on decaying stump of Yellow Birch, old growth forest of maple, birch, Yellow Birch, beech, fir, and spruce, 15 August 2017, *V.F. Zoll 658* (NBM-MM-000034). **Northumberland Co.:** Nepisiguit PNA, near forest road, Pentland Brook, ~7.4 km WSW of Popple Depot, 47.37904°N, 66.60507°W, on rotted log in full shade, road adjoining flood plain, mixed wood forest of spruce, fir, and poplar, 3 July 2015, *G. Bishop et al. s.n.* (NBM-MM-000103); Nepisiguit PNA, Nepisiguit River, ~5.4 km E of Popple Depot, 47.3815°N, 66.5794°W, on rotting wood, 5 July 2015, *D.F. McAlpine & S.R. Clayden s.n.* (NBM-MM-000105). Cosmopolitan; very common. This species is found on decaying wood.

*Stemonitis fusca* Roth (Figure 1e). **Queens Co.:** Grand Lake PNA, 1.25 km N of Coytown, 45.8464°N, 66.2050°W, rotten maple, mixed forest, maple, alder, elm dominant; flat and damp, 19 June 2013, *A. Carter* [*B.W. Malloch B20130619-01*] (NBM-MM-000153). **York Co.:** Spednic Lake PNA, near SW edge of Todds Island, ~0.75 km SSE from N end of island, 45.59748°N, 67.50655°W, on large fallen ash log, 17 August 2017, *S.R. Haughian* [*V.F. Zoll 670*] (NBM-MM-000036); Spednic Lake PNA, ~1 km E of Palfrey Stream and 1.2 km W of Route 630, 45.71584°N, 67.48369°W, on rotting birch log, mixed hardwood forest, 19 August 2017, *J. Hines* [*V.F. Zoll 675*] (NBM-MM-000046). **Sunbury Co.:** Portobello Creek National Wildlife Area, 1.5 km NE of McGowans Corner, 45.89725°N, 66.28226°W, decorticated wood, Silver Maple stand, 23 June 2013, *G.S. Sreedharan* [*B.W. Malloch B20130623-01*] (NBM-MM-000157). Cosmopolitan; very common. This species is found on decaying wood.

*Stemonitis pallida* Wingate. **Albert Co.:** Caledonia Gorge PNA, Crooked Creek at washed-out bridge, 45.79711°N, 64.77371°W, on fallen branch, white birch, 2 July 2011, *K.J. Vanderwolf s.n.* (NBM-MM-000007). Probably cosmopolitan; uncommon. This species is associated with decaying wood.

*Stemonitopsis aequalis* (Peck) Y. Yamam. **Charlotte Co.:** Campobello Island, northwestern part of Herring Cove PP, ~0.7 km NNE of intersection of Route 774 and Glensevern Road, 44.87969°N, 66.95319°W, on decaying Balsam Fir log, forest of fir, spruce, and birch, 22 September 2016, *V.F. Zoll 625* (NBM-MM-000019). Cosmopolitan; infrequently collected. This species is found on decaying wood.

*Stemonitopsis* cf. *hyperoptera* (Meyl.) Nann.-Bremek. **Northumberland Co.:** Nepisiguit PNA, N of Nepisiguit River and S of forest road, ~4.9 km SW of Popple Depot, 47.38529°N, 66.57273°W, on decaying bryophyte-covered log, mixed forest with maple, birch, spruce, fir, poplar, Bracken Fern, 2 July 2015, *V.F. Zoll 389* (NBM-MM-000113). This

specimen is provisionally identified because its spores do not appear to be reticulate, but it appears to otherwise fit the description of this species. *Stemonitopsis hyperoptera* is found on decaying wood, mostly in the Northern Hemisphere.

*Stemonitopsis typhina* (F.H. Wigg.) Nann.-Bremek. **Northumberland Co.:** 250 m E of Lower North Branch Little SW Miramichi River PNA border, 46.96844°N, 66.36342°W, on decaying wood, mixed hardwood forest of beech, birch, and spruce, 6 July 2019, *D.F. McAlpine [V.F. Zoll 758]* (NBM-MM-000220). Cosmopolitan. The silvery peridium which persists on the sporangium makes this species easy to identify. It is found on decaying wood.

*Trichia affinis* de Bary. **Charlotte Co.:** Canoose Flowage PNA, ~2.4 km SE of S end of Mud Lake, 45.48766°N, 67.37828°W, on underside of decaying branch on ground, mixed forest with Yellow Birch, maple, 23 June 2018, *V.F. Zoll 693* (NBM-MM-000244). Widely distributed in temperate and boreal areas, this species is associated with decaying wood and moss.

*Trichia botrytis* (J.F. Gmel.) Pers. **Charlotte Co.:** 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.42639°N, 67.31766°W, on leaf litter, mixed forest with Red Maple, fir, cedar, birch, 14 June 2018, *V.F. Zoll 706* (NBM-MM-000169). Cosmopolitan. The single collection of this species was from a moist chamber culture.

*Trichia contorta* (Ditmar) Rostaf. **Northumberland Co.:** N part of Nepisiguit PNA, ~1.2 km S of Lower West Branch Portage Brook, 47.43942°N, 66.62305°W, on moss over decaying log on ground, hardwoods, birch, conifers, 15 August 2016, *V.F. Zoll 596* (NBM-MM-000147). **York Co.:** Spednic Lake PNA, N of forest road, near Big La Coote stream bridge, 45.69959°N, 67.49805°W, on inner side of fallen trunk of Balsam Fir, in wet area near water, in mixed forest with birch, poplar, and conifers, 19 June 2018, *V.F. Zoll 686* (NBM-MM-000237); Spednic Lake PNA, W of Palfrey Stream, ~0.1 km NE from the confluence of Big La Coote Stream and Palfrey Stream, 45.701°N, 67.499°W, on bark on underside of fallen trunk of Balsam Fir, on old logging trail, in mixed forest of white birch, Yellow Birch, and Grey Birch, white pine, Balsam Fir, spruce, and poplar(?), 19 June 2018, *A.M. Bremner [V.F. Zoll 687]* (NBM-MM-000238); Spednic Lake PNA, Bolton Lake, 45.71394°N, 67.59278°W, on bark of dead branch of Red Oak, mixed forest with poplar, spruce, Yellow Birch, white birch, 21 June 2018, *V.F. Zoll 746* (NBM-MM-000207). Cosmopolitan. Associated with decaying wood and bark.

*Trichia decipiens* (Pers.) T. Macbr. **Northumberland Co.:** Nepisiguit PNA, N of forest road, S

of Nepisiguit River, ~2.7 km SW of Popple Depot, 47.38734°N, 66.53460°W, on decaying Balsam Fir log, under bark, mixed forest with Red Maple, white pine, fir, cedar, birch, 21 August 2016, *V.F. Zoll 622* (NBM-MM-000128), *V.F. Zoll 623* (NBM-MM-000129). **York Co.:** Spednic Lake PNA, between McAllister Cove and McAllister Brook, ~0.4 km W of N end of McAllister Cove, 45.65683°N, 67.67315°W, under bark on decaying poplar branch on ground, in mixed forest with poplar, spruce, Yellow Birch, white birch, and fir, 22 June 2018, *V.F. Zoll 691* (NBM-MM-000242). Cosmopolitan. This species is associated with decaying wood.

*Trichia erecta* Rex. **Charlotte Co.:** 350 m NW of Canoose Flowage PNA border, 3.6 km NW of Lynnfield, 45.42639°N, 67.31766°W, on leaf litter, mixed forest with Red Maple, fir, cedar, birch, 14 June 2018, *V.F. Zoll 700* (NBM-MM-000170), *V.F. Zoll 705* (NBM-MM-000171), *V.F. Zoll 719* (NBM-MM-000172), *V.F. Zoll 721* (NBM-MM-000173), *V.F. Zoll 729* (NBM-MM-000174), *V.F. Zoll 730* (NBM-MM-000175), *V.F. Zoll 739* (NBM-MM-000176). **York Co.:** Spednic Lake PNA, trail to Pirate Lake, 45.72276°N, 67.66444°W, on moss-covered wood, mixed forest with birch, Red Maple, hemlock, fir, Striped Maple, 15 June 2018, *V.F. Zoll 726* (NBM-MM-000198). Cosmopolitan. Although this species is usually associated with decaying wood of conifers, all of the New Brunswick collections were from moist chamber cultures of leaf litter, except for one culture of moss-covered wood.

*Trichia favoginea* (Batsch) Pers. **Northumberland Co.:** Nepisiguit PNA, N of Nepisiguit River and S of forest road, ~4.9 km SW of Popple Depot, 47.38529°N, 66.57273°W, on decaying birch log, mixed forest on S of road, with maple, birch, spruce, fir, poplar, Bracken Fern, 2 July 2015, *V.F. Zoll 387* (NBM-MM-000111); Nepisiguit PNA, NW of forest road at brook by culvert, ~2.2 km SW of Popple Depot, 47.38753°N, 66.53629°W, under spruce and Balsam Fir, in conifer-dominated patch of forest, 25 May 2016, *A.M. Bremner AB2016.05.25-06* (NBM-MM-000130). **Sunbury Co.:** Grand Lake PNA, near western edge of Loders Creek, ~1.45 km NE of intersection of Route 105 and Route 690, 45.89592°N, 66.28224°W, on alder bark, 12 August 2014, *A. Carter [V.F. Zoll 341]* (NBM-MM-000068). Cosmopolitan, but in the tropics only found at higher elevations (Ing 1999). This species is associated with decaying wood and bark and with ground litter in moist chamber cultures.

*Trichia scabra* Rostaf. **Northumberland Co.:** Nepisiguit PNA, N of forest road, near brook running N toward Nepisiguit River, ~2.25 km SW of Popple Depot, 47.38704°N, 66.53635°W, on decaying

deciduous branch on ground, near beaver pond, in mature hardwood forest, 16 August 2016, *V.F. Zoll 599* (NBM-MM-000117). Cosmopolitan. This species is found on decaying wood.

*Trichia varia* (Pers. ex J.F. Gmel.) Pers. **Northumberland Co.:** Nepisiguit PNA, N of forest road, ~2.8 km SW of Popple Depot, 47.38266°N, 66.54118°W, on decaying moss-covered log, hardwood forest, including maple, Yellow Birch, 28 June 2015, *V.F. Zoll 393* (NBM-MM-000092). Cosmopolitan. This species is normally found on decaying wood. The single collection reported here was from a moist chamber culture.

*Tubifera ferruginosa* (Batsch) J.F. Gmel. **Albert Co.:** Lewis Mountain PNA, 2 km SE of Rosevale, near West Branch Turtle Creek, 45.83888°N, 64.84603°W, on rotting wood, in hardwood dominant forest of Sugar Maple and Eastern Hop-hornbeam, 1 July 2011, *E. Duke EKD2011-48* (NBM-MM-000230). **Charlotte Co.:** Campobello Island, northwestern part of Herring Cove PP, ~0.7 km NNE of intersection of Route 774 and Glensevern Road, 44.87969°N, 66.95319°W, forest with fir, spruce, birch, 22 September 2016, *J.B. Tanney [V.F. Zoll 633]* (NBM-MM-000021). **Northumberland Co.:** Nepisiguit PNA, N of Nepisiguit River, S of Melansons Gulch, near base of Mount Walker, ~11.9 km SW of Popple Depot, 47.36345°N, 66.66066°W, on decaying conifer log covered with bryophytes with Black Spruce, fir, few birch, 1 July 2015, *V.F. Zoll 385* (NBM-MM-000099); Nepisiguit PNA, N of Nepisiguit River and S of forest road, ~4.9 km SW of Popple Depot, 47.38529°N, 66.57273°W, on decaying bryophyte-covered log, mixed forest on S side of road with maple, birch, spruce, fir, poplar, Bracken Fern, 2 July 2015, *V.F. Zoll 391* (NBM-MM-000115); Nepisiguit PNA, N of forest road, near brook running N toward Nepisiguit River, ~2.25 km SW of Popple Depot, 47.38704°N, 66.53635°W, collected on moss, hardwood dominant forest of Sugar Maple, poplar, Yellow Birch, white birch, Striped Maple, and Mountain Maple with some fir and spruce, 16 August 2016, *A.M. Bremner [V.F. Zoll 613]* (NBM-MM-000120); E side of Upper Dunganon PNA, 5.3 km SW of Grassy Lake, E side of Dunganon River, 46.8018°N, 66.6245°W, on moss-covered rotting tree trunk, in young coniferous forest of fir and spruce, some deciduous trees present (birch, maple, beech), 5 July 2019, *A.M. Bremner AB2019.07.05-08* (NBM-MM-000213). **Saint John Co.:** City of Saint John, Saints Rest Marsh-F. Gordon Carvell Nature Preserve, 45.22515°N, 66.13831°W, hollow of tree snag, in forest at edge of salt marsh, not very mature forest of fir, spruce, white birch, and beech, 16 August 2013, *A.M. Bremner AB16.08.13-01* (NBM-MM-000159). **Sunbury Co.:** Portobello Creek National Wildlife Area,

NE side of French Island at The Narrows between Portobello Creek and French Lake, 45.92429°N, 66.30027°W, on decaying log, 9 August 2014, *V.F. Zoll 342* (NBM-MM-000076). Cosmopolitan as traditionally circumscribed. Found on decaying wood and leaf litter, this is a relatively large myxomycete (up to 15 cm wide). According to Leontyev *et al.* (2015), what was considered one species may be a complex of morphologically similar species. One specimen (NBM-MM-000021) is placed here with some hesitation. It fits *T. ferruginosa* in most respects; however, the shape of its pseudoaethalium resembles that of *Tubifera dimorphotheca* Nann.-Bremek. & Loer.

## Discussion

The findings of this study can be usefully compared with those of Stephenson *et al.* (2020), who analyzed the diversity and relative abundance of myxomycetes in the eastern USA. Their study was based on 58 594 digitized occurrence records of 460 species from 32 states, and they assigned species to four abundance categories: very abundant (>3% of all records), less abundant (>1.5% to <3% of all records), occasional (>0.5% to <1.5% of all records), and rare (<0.5% of all records). All 11 species categorized by Stephenson *et al.* (2020) as very abundant (*A. cinerea*, *A. denudata*, *L. epidendrum*) or “less abundant” (*F. septica*, *H. calyculata*, *H. clavata*, *M. vesparia*, *P. viride*, *S. fusca*, *S. axifera*, and *T. favoginea*) were also found in our surveys in New Brunswick. However, several of these species were represented in New Brunswick by only one or a few records, including *A. denudata* by one collection, *M. vesparia* by two, and *T. favoginea* by three. Thirty-nine additional species were found by Stephenson *et al.* (2020) to be occasional in the eastern USA, and the remainder were rare. Of the 39 occasional species, 22 were found in New Brunswick.

Of the seven species of slime mould reported for New Brunswick by Wehmeyer (1950), two (*M. crustacea* and *P. cinereum*) are common globally (Martin and Alexopoulos 1969) but were not found in our current study. *Siphoptychium casparyi*, a widely distributed but uncommon species (Martin and Alexopoulos 1969) reported by Wehmeyer (1950), and *F. muscorum* reported by Hay (1903), as *F. ochracea*, also were not detected in the current study.

In the neighbouring state of Maine, USA, 166 species have been recorded (Zoll and Stephenson 2015). The highest numbers of collections are from three counties in the southeast and centre of the state, reflecting a concentration of centres for research and teaching in biology and natural history (University of Maine, Eagle Hill Institute, and Acadia National Park). Similar to New Brunswick, Maine is more than 80% forested and is largely situated in the transition

zone between eastern Canadian boreal forests and the mixed hardwood forests of the eastern USA. There are no comparable, recently published checklists of myxomycetes for any province in eastern Canada, although many collection records have been posted on online databases. The website of MycoQuébec lists 184 slime moulds that are known in Quebec (Landry and Labbé 2022) but does not include specimen citations. Gourley (1983) included 57 species of slime moulds in a checklist of the fungi of Nova Scotia. However, most of these species and the specimens on which the records are based were already reported for Nova Scotia by Wehmeyer (1950). Twenty of the myxomycete species on the Nova Scotia list (Gourley 1983) have not been detected in New Brunswick.

These comparisons indicate that much more research and larger sample sizes are needed before firm conclusions can be drawn about the diversity, relative abundance, and distributions of slime mould species in New Brunswick. Our study has focussed on their diversity in relatively intact mature forest communities in protected areas. We are unable to assess whether younger and/or managed forests in the province have lower species richness or different assemblages of species. However, the association of many myxomycetes with substrates that are especially well represented in older forests (e.g., rotting logs and other dead wood, deep litter layers, and bryophyte mats) makes it very likely that the PNAs and other such protected areas are important for conserving myxomycete diversity in New Brunswick.

This is the first formal publication on the myxomycetes of New Brunswick in more than 70 years, adding 77 species to the seven that were previously reported. Future fieldwork is planned to cover additional PNAs in New Brunswick (McAlpine 2022). Together with studies of historical collections, those surveys will undoubtedly add to the number of species known to occur in the province.

### Author Contributions

Conceptualization: V.F.Z., A.M.B., and S.R.C.; Investigation: V.F.Z., A.M.B., S.R.C., K.E.D., B.W.M., and D.W.M.; Data Curation: A.M.B., K.E.D., and V.F.Z.; Writing – Original Draft: V.F.Z., A.M.B., S.R.C., and K.E.D.; Writing – Review & Editing: V.F.Z., A.M.B., S.R.C., K.E.D., A.J., B.W.M., and D.W.M.

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## Litter-dwelling terrestrial molluscs of Nepisiguit Protected Natural Area and Mount Carleton Provincial Park, north-central New Brunswick

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### Abstract

No comprehensive study of the terrestrial gastropod fauna of northern New Brunswick has previously been undertaken. Most terrestrial gastropod molluscs are tiny and generally live unnoticed under debris, in leaf litter, and among other dead and living vegetation. Sifting and sorting collected samples of leaf litter are effective in sampling snails. In June–July 2015 and August 2016, 43 samples of forest leaf litter were collected in Nepisiguit Protected Natural Area and Mount Carleton Provincial Park. These samples yielded 22 species of terrestrial gastropods. Seven species are reported from New Brunswick for the first time.

Key words: Mollusca; Gastropoda; Maritime provinces; biodiversity; BiotaNB

### Résumé

Aucune étude approfondie de la faune de gastéropodes terrestres du nord du Nouveau-Brunswick n'a été entreprise auparavant. La plupart des mollusques gastéropodes terrestres sont minuscules et vivent généralement inaperçus sous les débris, dans la litière de feuilles et d'autres végétaux morts et vivants. Le tamisage et le tri des échantillons prélevés de litière de feuilles sont efficaces pour échantillonner les escargots. En juin–juillet 2015 et en août 2016, 43 échantillons de litière de feuilles forestières ont été prélevés dans l'zone naturelle protégée Nepisiguit et le parc provincial Mont-Carleton. Ces échantillons ont donné 22 espèces de gastéropodes terrestres. Sept espèces sont rapportées au Nouveau-Brunswick pour la première fois.

Mots clés : Mollusca; Gastropoda; escargots; litière de feuilles; mollusques terrestres; provinces maritimes; biodiversité; BiotaNB

### Introduction

Among the few publications on the terrestrial gastropods of New Brunswick, several stand out for their attempt to enumerate the fauna either locally or for the province. Bailey (1903) produced the first list of terrestrial molluscs of the province and included 25 species, all snails. Several decades later, La Rocque (1961) published an updated list, which included 26 species, both snails and slugs. Dimelow (1962, 1963) reported 10 and five species, respectively, in two separate studies of the terrestrial molluscs in southeastern New Brunswick. However, the most intensive, published study of terrestrial gastropod fauna anywhere in the province was by Clarke *et al.* (1968) who reported 24 species from Fundy National Park in southern, coastal New Brunswick. All these studies, except for some individual records cited by Bailey (1903), are from southern areas of the province. There has never been a comprehensive study of the terrestrial gastropod fauna of northern New Brunswick.

I report the results of surveys undertaken as part of the New Brunswick Museum's (NBM) BiotaNB program (McAlpine 2017, 2022) aimed at assessing the biodiversity of minute litter-dwelling terrestrial gastropods of Nepisiguit Protected Natural Area (PNA) and Mount Carleton Provincial Park (PP).

### Methods

#### *Study area*

The study was conducted in 2015 and 2016 as part of NBM's biological inventory project, BiotaNB, in the Nepisiguit PNA and the adjacent Mount Carleton PP in Northumberland and Restigouche counties, north-central New Brunswick (Figure 1). Nepisiguit is a Class II PNA and Mount Carleton PP encompasses its namesake mountain, at 820 m, the highest point of land in the Maritime provinces (Zelanzny 2007).

The study area is in the Atlantic Highlands ecoregion (CCEA 2014) and the Highlands ecoregion (Zelanzny 2007). Because of its elevation, the climate in

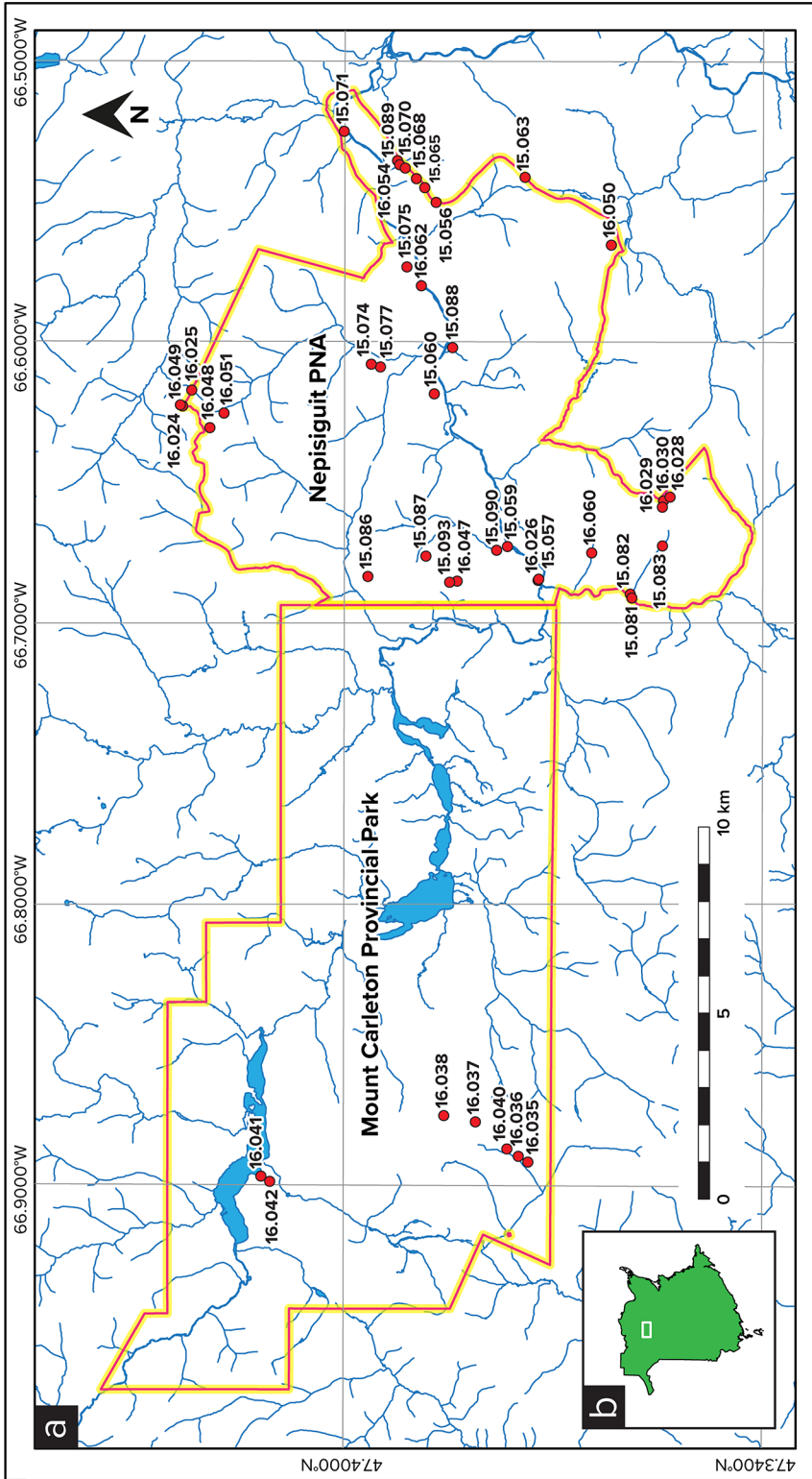


FIGURE 1. a. The 43 sites of leaf-litter collection of molluscs in Nepsiguit Protected Natural Area (PNA) and Mount Carleton Provincial Park, New Brunswick, Canada, in June–July 2015 and August 2016. b. Location of the study site.

the Highlands ecoregion is cooler and wetter than that of adjacent coastal areas. In the Köppen-Geiger system of climate classification, most of New Brunswick, including the study area, has a Dfb climate: humid continental climate, without dry season and warm summer (Kottek *et al.* 2006). The Highlands ecoregion has strong boreal affinities, with a climate that favours forests dominated by Balsam Fir (*Abies balsamea* (L.) Miller), White Birch (*Betula papyrifera* Marshall), Black Spruce (*Picea mariana* (Miller) Britton, Sterns & Poggenburgh), and White Spruce (*Picea glauca* (Moench) Voss; Zelanzy 2007).

#### Survey sites and specimen collections

In June 2015 and August 2016, leaf litter was collected at 36 sites in Nepisiguit PNA and seven sites in Mount Carleton PP (Figure 1, Table 1). Most geographic coordinates and elevations were obtained from a hand-held Garmin eTrex Vista HC (Olathe, Kansas, USA) global positioning system receiver, or similar, using the WGS84 geodetic datum. Coordinate degrees were rounded to four decimal places (~3 m accuracy) and elevations were rounded to 10 m to avoid false precision. Some elevations, and the approximate coordinates of one site (see note for Table 1) were subsequently derived using Google Earth Pro version 7.3.4.8642 (64 bit) for Microsoft Windows.

Because most gastropod biodiversity is composed of minute individuals that generally live somewhat cryptically under debris, in leaf litter, and among other dead and living vegetation, litter sampling is an effective means of collecting them. Thus, I gathered samples of leaf litter, augmented by visual searching and collecting snails by hand. Forest-floor litter samples were gathered by hand, with the most effort made in areas with deeper litter retaining some moisture. Litter samples were ~1–2 L, but some were larger; there was no standardization. They were dried, either at ambient room temperature or, usually, by placing in a food dehydrator. Once dried, the litter was passed sequentially through soil sieves of smaller mesh sizes, while checking for larger snails at each stage of processing. The final, finest material was then sorted by hand under a stereomicroscope. This technique has been used with success in New Brunswick and elsewhere for collecting samples of leaf-litter dwelling microsnails (Forsyth and Lepitzki 2015; Forsyth and Nicolai 2019; Forsyth *et al.* 2022). Only snails were collected by this sampling method, as slugs were not frequently found in the samples and were not identifiable in dried samples.

#### Identification and vouchers

Species were identified using Pilsbry (1940, 1946, 1948) supplemented by Nekola and Coles (2010, for *Columella* Westerlund, 1878), Nekola *et al.* (2018,

for *Vertigo* O.F. Müller, 1773), Forsyth and Oldham (2014, for *Strobilops* Pilsbry, 1893), and Horsáková *et al.* (2020, for *Euconulus* Reinhardt, 1883). Family-level taxa follow Bouchet *et al.* (2017), with modifications that transferred some genera from Oxychilidae to Gastrodontidae (Neiber *et al.* 2020). Common names follow Turgeon *et al.* (1998), except where not in that publication.

All specimens collected were deposited in the mollusc collection of the NBM (see Table S1 for voucher accession numbers), Saint John, New Brunswick.

## Results and Discussion

Twenty-two species of terrestrial gastropods were found in leaf-litter samples collected at sites in Nepisiguit PNA and Mount Carleton PP (Table 2, Table S1). Several species are especially noteworthy.

Ice Thorn (*Carychium exile* H.C. Lea, 1842) is reported from New Brunswick for the first time; specimens were collected at two sites (16.048, 16.054; Figure 1 and Table 1) in Nepisiguit PNA. Several other species have been collected in New Brunswick before and since my study but are unpublished (R.G.F. unpubl. data). These include Simple Column (*Columella simplex* (A. Gould, 1840)), Temperate Coil (*Helicodiscus shimiki* Hubricht, 1962), Eastern Flat-coil (*Planogyra asteriscus* (E.S. Morse, 1857)), Fine-ribbed Striate (*Striatura milium* (E.S. Morse, 1859)), Callused Vertigo (*Vertigo arthuri* E. von Martens, 1882), and Delicate Vertigo (*Vertigo bollesiana* (E.S. Morse, 1865)). Temperate Coil and Callused Vertigo were probably misidentified in the literature (e.g., La Rocque 1961 summarizes all the published works on New Brunswick terrestrial molluscs up to that time) as Compound Coil (*Helicodiscus parallelus* (Say, 1817)) and Variable Vertigo (*Vertigo gouldii* A. Binney, 1843)), respectively.

I found only a single specimen of Maze Pinecone (*Strobilops labyrinthicus* (Say, 1817); site 15.075; Figure 1 and Table 1). This species is usually rather common in most leaf-litter samples in other BiotaNB sampling in other PNAs (R.G.F. unpubl. data). However, it is also of interest to note that Clarke *et al.* (1968) did not find Maze Pinecone at any of their sites in Fundy National Park, in the southern part of the province.

Glossy Pillar (*Cochlicopa lubrica* (O.F. Müller, 1774)) is often associated with anthropogenic, disturbed habitats, although it also occurs in natural environments without disturbance (Forsyth 2004; R.G.F. pers. obs. from across Canada). *Cochlicopa* cf. *lubrica* was found in several very rich sites (15.065, 15.082, 16.024, 16.025, 16.048, 16.049; Figure 1 and Table 1) in three separate areas of Nepisiguit PNA. This name is applied to these specimens with uncertainty because specimens resemble Appalachian

TABLE 1. Location and description of mollusc collection sites ( $n = 43$ ) in Nepisiguit Protected Natural Area (PNA) and Mount Carleton Provincial Park (PP), New Brunswick, Canada.

Site	Collection date	Locality	Lat., °N	Long., °W	Elev., m	Collector(s)	Site notes	Method*
15.056	26-Jun-2015	Nepisiguit PNA; SW of Popple Depot; near main road	47.3783	66.5498	430	R.G.F.	Hardwood stand; birch ( <i>Betula</i> L. sp.) dominating; on gentle slope	L, H
15.057	27-Jun-2015	Nepisiguit PNA; N side, Nepisiguit River; SSE of Mount Wightman; end of Old River Road at bridge out	47.3534	66.6838	240	R.G.F.	Spruce ( <i>Picea</i> A. Dietrich sp.) woods with a few young birch	L, H
15.059	27-Jun-2015	Nepisiguit PNA; N side, Nepisiguit River; E of Melansons Gulch; along Old River Road	47.3610	66.6723	290	R.G.F.	Mixed woods, riparian zone; needle litter	L
15.060	27-Jun-2015	Nepisiguit PNA; N side, Nepisiguit River; W of Pentland Brook; along Old River Road	47.3787	66.6180	330	R.G.F.	Mixed woods	L
15.063	28-Jun-2015	Nepisiguit PNA; Corkers Gulch drainage; near main road	47.3568	66.5409	570	R.G.F.	Mixed woods, dominated by maples ( <i>Acer</i> L. sp.) and birch	L
15.065	28-Jun-2015	Nepisiguit PNA; near Popple Depot; near main road	47.3811	66.5446	380	R.G.F.	Hardwood stand with deep litter and logs; ~10 m from forest road	H, L
15.068	28-Jun-2015	Nepisiguit PNA; WSW of Popple Depot; near main road	47.3831	66.5414	350	Alex Roberts; Stephen Mott	Tolerant hardwoods	L
15.070	29-Jun-2015	Nepisiguit PNA; WSW of Popple Depot; near main road	47.3858	66.5376	310	R.G.F.	Tolerant hardwood stand, maple dominant	L
15.071	29-Jun-2015	Nepisiguit PNA; N side, Nepisiguit River, NW of Popple Depot	47.4006	66.5246	260	R.G.F.	—	L
15.074	30-Jun-2015	Nepisiguit PNA; W of Pentland Brook	47.3940	66.6074	390	R.G.F.	Spruce with White Pine ( <i>Pinus albicaulis</i> Engelm.) Forest, scattered Moosewood ( <i>Acer pensylvanicum</i> L.), little understorey, no forbs; well-drained slope between two 200-year-old pines	L
15.075	2-Jul-2015	Nepisiguit PNA; N side, Nepisiguit River; S of Mount LaTour; near Old River Road	47.3854	66.5728	300	R.G.F.	—	H, L
15.077	3-Jul-2015	Nepisiguit PNA; W of Pentland Brook	47.3918	66.6084	360	R.G.F.	—	L
15.081	4-Jul-2015	Nepisiguit PNA; along South Branch Nepisiguit River; SW of cabin along road	47.3309	66.6905	320	R.G.F.	Upland riparian zone; mixed woods, under Yellow Birch ( <i>Betula alleghaniensis</i> Britton)	L
15.082	4-Jul-2015	Nepisiguit PNA; along South Branch Nepisiguit River; at cabin	47.3312	66.6891	330	R.G.F.	Riparian zone; mixed woods, disturbed area at edge of camp lawn; under shrubby alders, young firs	L

TABLE 1. *Continued.*

Site	Collection date	Locality	Lat., °N	Long., °W	Elev., m	Collector(s)	Site notes	Method*
15.083	4-Jul-2015	Nepisiguit PNA; W slope of Mount Chandler; along road at stream crossing; stream	47.3235	66.6719	450	R.G.F.	Riparian zone; mixed woods with birch dominant	H, L
15.086	5-Jul-2015	Nepisiguit PNA; vicinity of Seventy Five Mile Creek	47.3947	66.6830	390	R.G.F.	Predominantly deciduous, regenerating woods; on slope; young maples, birch	L
15.087	5-Jul-2015	Nepisiguit PNA; headwaters of Melansons Gulch	47.3807	66.6757	380	R.G.F.	Regenerating forest	L
15.088	1-Jul-2015	Nepisiguit PNA; N side of Mount Marie	47.3743	66.6015	290†	Chelsey Chafe	Cedar ( <i>Thuja</i> L. sp.) stand on slope	L
15.089	7-Jul-2015	Nepisiguit PNA; WSW of Popple Depot; near main road	47.3864	66.5366	310	R.G.F.	Tolerant hardwood stand; deep litter; maple, birch	L
15.090	7-Jul-2015	Nepisiguit PNA; Melansons Gulch; road up E side of gulch	47.3636	66.6736	300†	R.G.F.	Spruce woods	L
15.093	7-Jul-2015	Nepisiguit PNA; N of Mount Wightman; along road to E boundary of Mount Carleton Park	47.3749	66.6850	390	R.G.F.; Richard Blacquiere	Deciduous woods; birch, poplar	L
16.024	10-Aug-2016	Nepisiguit PNA; near branch of Lower West Brook; near N border of NPA	47.4401	66.6220	560†	Ben Philipps, Stephen Clayden	Deciduous woods	L
16.025	10-Aug-2016	Nepisiguit PNA; near N border of PNA	47.4374	66.6167	420	Ben Philipps, Stephen Clayden	Deciduous woods; seep area at head of dry brook; Yellow Birch, Sugar Maple ( <i>Acer saccharum</i> Marshall), Mountain Maple ( <i>Acer spicatum</i> Lamarck)	L
16.026	11-Aug-2016	Nepisiguit PNA; N side, Nepisiguit River; SSE of Mount Wightman; near end, Old River Road at bridge out	47.3556	66.6843	310	Mary Sollows	Predominantly spruce and fir; among bryophytes	L
16.028	12-Aug-2016	Nepisiguit PNA; near road down to Blue Cabin	47.3217	66.6546	590†	R.G.F.	Deciduous woods; predominantly birch	L
16.029	12-Aug-2016	Nepisiguit PNA; near road down to Blue Cabin	47.3235	66.6581	540†	R.G.F.	Mixed woods	L
16.030	12-Aug-2016	Nepisiguit PNA; near road down to Blue Cabin	47.3233	66.6559	580	R.G.F.	Mixed woods	L
16.031	12-Aug-2016	Nepisiguit PNA; road down to Blue Cabin	47.3233	66.6559	600	R.G.F.	Deciduous forest; predominantly birch	L
16.035	13-Aug-2016	Mount Carleton PP; along trail to Mount Carleton	47.3555	66.8912	480	R.G.F.	Mixed woods	L

TABLE 1. Continued.

Site	Collection date	Locality	Lat., °N	Long., °W	Elev., m	Collector(s)	Site notes	Method*
16.036	13-Aug-2016	Mount Carleton PP; along trail to Mount Carleton	47.3578	66.8892	510	R.G.F.	Mixed woods	L
16.037	13-Aug-2016	Mount Carleton PP; along Mount Carleton Trail, at junction with Big Brook Trail	47.3682	66.8770	610	R.G.F.	Mixed woods	L
16.038	13-Aug-2016	Mount Carleton PP; Mount Carleton Trail, below Mount Carleton, at junction with Head Mountain Trail	47.3759	66.8748	740	R.G.F.	Mixed woods	L
16.040	13-Aug-2016	Mount Carleton PP; along Mount Carleton Trail, ca. 3 km from top (at 3 km sign)	47.3606	66.8865	540	R.G.F.	Mixed woods	L
16.041	13-Aug-2016	Mount Carleton PP; S side of Big Nictau Lake; road along lake	47.4200	66.8966	260	R.G.F.	Mixed woods	L
16.042	13-Aug-2016	Mount Carleton PP; S side, Big Nictau Lake; along road	47.4179	66.8985	270	Don McAlpine	Mixed woods; hardwoods dominant; Paper Birch, Red Maple ( <i>Acer rubrum</i> L.)	L
16.047	17-Aug-2016	Nepisiguit PNA; N of Mount Wightman	47.3600†	66.6800†	450†	Richard Blaquiere	Mixed woods; birch, spruce dominant	L
16.048	15-Aug-2016	Nepisiguit PNA; along small headwater tributary of Pentland Brook	47.4330	66.6301	520	R.G.F.	Along creek, rich hummus; very large Yellow Birch; Ostrich Fern ( <i>Matteuccia struthiopteris</i> (L.) Todaro)	L
16.049	15-Aug-2016	Nepisiguit PNA; tributary of W branch, Portage Creek; at N border of PNA	47.4396	66.6224	460	R.G.F.	Sugar Maple-dominated mixed woods	H, L
16.050	15-Aug-2016	Nepisiguit PNA; near main road	47.3360	66.5650	500†	Richard Blaquiere	—	L
16.051	15-Aug-2016	Nepisiguit PNA; tributary of Portage Brook	47.4296	66.6249	490	R.G.F.	Sugar Maple, Yellow Birch, Ostrich Fern, shrubs	H, L
16.054	20-Aug-2016	Nepisiguit PNA	47.3871	66.5365	260	R.G.F.; Val Calvin	—	H, L
16.060	20-Aug-2016	Nepisiguit PNA; Mount Walker	47.3406	66.6745	500	Richard Blaquiere	—	L
16.062	20-Aug-2016	Nepisiguit PNA; along Nepisiguit River	47.3819	66.5795	260†	Charles Graves	—	L

\*L = litter sample; H = visual search, hand collected.

†Subsequently derived from Google Earth. Geographic coordinates approximate.

**TABLE 2.** Species collected in leaf-litter samples in Nepisiguit Protected Natural Area (PNA) and Mount Carleton Provincial Park (PP), New Brunswick, in 2015 and 2016. See Table 1 for descriptions of sites and Table S1 for a list of voucher specimens, New Brunswick Museum accession numbers, and other data. Additional species observed in the study area but not found in litter samples were Upland Pillsnail (*Euchemotrema fraternum* (Say, 1824)) and Hairy Helicellid (*Trochulus hispidus* (Linnaeus, 1758)).

Species	Family	Nepisiguit PNA sites	Mount Carleton PP sites
<i>Anguispira alternata</i> (Say, 1817), Flamed Tigersnail	Discidae	16.051	
<i>Carychium exile</i> H.C. Lea, 1842, Ice Thorn	Ellobiidae	16.048, 16.054	
<i>Cochlicopa</i> cf. <i>lubrica</i> (O.F. Müller, 1774), Glossy Pillar	Cochlicopidae	15.065, 15.082, 16.024, 16.025, 16.048, 16.049	
<i>Columella simplex</i> (A. Gould, 1840), Simple Column	Truncatellinidae	15.070, 15.075, 15.089, 15.093, 16.024, 16.028, 16.051	
<i>Discus whitneyi</i> (Newcomb, 1864), Forest Disc	Discidae	15.057, 15.059, 15.060, 15.063, 15.065, 15.070, 15.071, 15.075, 15.086, 15.088, 15.089, 15.090, 15.093, 16.024, 16.028, 16.030, 16.048, 16.049, 16.051, 16.054	16.035, 16.036, 16.040, 16.042
<i>Euconulus fulvus egenus</i> (Say, 1825), Brown Hive	Euconulidae	15.063, 15.068, 15.070, 15.075, 15.077, 15.081, 15.082, 15.083, 15.087, 15.088, 15.089, 15.090, 15.093, 16.024, 16.028, 16.029, 16.030, 16.048, 16.049, 16.051, 16.060	16.035, 16.040, 16.041
<i>Helicodiscus shimiki</i> Hubricht, 1962, Temperate Coil	Helicodiscidae	15.056, 15.063, 15.070, 15.075, 15.077, 15.083, 15.086, 15.087, 15.088, 15.089, 15.090, 15.093, 16.028, 16.030, 16.049	16.042
<i>Novisuccinea ovalis</i> (Say, 1817), Ovate Ambersnail	Succineidae	15.063, 16.028	16.035
<i>Perpolita binneyana</i> (E.S. Morse, 1864), Blue Glass	Gastrodontidae	15.060, 15.063, 15.065, 15.068, 15.070, 15.071, 15.074, 15.075, 15.077, 15.083, 15.086, 15.087, 15.088, 15.089, 15.090, 15.093, 16.024, 16.025, 16.028, 16.029, 16.030, 16.047, 16.048, 16.049, 16.051, 16.054	16.040, 16.041, 16.042
<i>Planogyra asteriscus</i> (E.S. Morse, 1857), Eastern Flat-whorl	Valloniidae	15.060, 15.068, 15.071, 15.086, 15.089, 16.025, 16.028, 16.048, 16.054	16.040
<i>Punctum minutissimum</i> (I. Lea, 1841), Minute Spot	Punctidae	15.060, 15.070, 15.075, 15.083, 15.086, 15.088, 15.089, 15.090, 15.093, 16.028, 16.047, 16.048, 16.049, 16.051, 16.054, 16.062	16.035, 16.040, 16.041, 16.042
<i>Striatura exigua</i> (W. Stimpson, 1851), Ribbed Striate	Gastrodontidae	15.056, 15.057, 15.060, 15.063, 15.065, 15.068, 15.070, 15.071, 15.074, 15.075, 15.077, 15.081, 15.083, 15.086, 15.087, 15.088, 15.089, 15.090, 15.093, 16.024, 16.025, 16.028, 16.029, 16.030, 16.047, 16.048, 16.049, 16.051, 16.054, 16.062	16.035, 16.037, 16.040, 16.041, 16.042
<i>Striatura ferrea</i> E.S. Morse, 1864, Black Striate	Gastrodontidae	15.063, 15.086, 15.090, 16.028, 16.029, 16.031, 16.048, 16.049, 16.050, 16.060	16.037, 16.038, 16.040, 16.041
<i>Striatura milium</i> (E.S. Morse, 1859), Fine-ribbed Striate	Gastrodontidae	15.056, 15.065, 15.068, 15.071, 15.074, 15.077, 15.088, 15.089, 16.062	16.041
<i>Strobilops labyrinthicus</i> (Say, 1817), Maze Pinecone	Strobilopsidae	15.075	
<i>Vertigo arthuri</i> E. von Martens, 1882, Callused Vertigo	Vertiginidae	16.051	16.040
<i>Vertigo bollesiana</i> (E.S. Morse, 1865), Delicate Vertigo	Vertiginidae	15.068, 15.089	
<i>Vertigo cristata</i> Sterki in Pilsbry, 1919, Cristate Vertigo	Vertiginidae	15.057, 15.071, 15.074, 15.081, 15.083, 15.086, 15.088, 15.093, 16.030, 16.060	16.040

TABLE 2. Continued.

Species	Family	Nepisiguit PNA sites	Mount Carleton PP sites
<i>Vertigo gouldii</i> (A. Binney, 1843), Variable Vertigo	Vertiginidae	16.049, 16.061	
<i>Vitrina angelicae</i> H. Beck, 1837, Eastern Glass-snail	Vitrinidae	16.048	16.035
<i>Zonitoides arboreus</i> (Say, 1817), Quick Gloss	Gastrodontidae	15.068, 15.070, 15.075, 15.083, 15.086, 16.025, 16.026, 16.029, 16.031, 16.049, 16.051, 16.060	16.035, 16.036, 16.041, 16.042
<i>Zoogenetes harpa</i> (Say 1824), Boreal Top	Valloniidae	15.063, 15.068, 15.075, 15.081, 15.087, 15.088, 16.047, 16.048, 16.049, 16.051, 16.060, 16.062	

Pillar (*Cochlicopa morseana* (W. Doherty, 1878)), which is characterized by a thinner, more transparent “pale greenish corneus” shell (Pilsbry 1948: 1050) and lives in moist, upland woods in deep leaf litter (Hubricht 1985). However, partial cytochrome c oxidase subunit I DNA barcoding did not distinguish specimens from New Brunswick from others collected in urban areas of Ottawa and elsewhere (D. McAlpine pers. comm. 2016). Different genes or methods might differentiate this New Brunswick population, which otherwise appears so different—and in much different habitats—from the common, almost “weedy” *C. lubrica*.

Thirty-four shelled terrestrial gastropod mollusc species, excluding slugs, have been reported from New Brunswick by others (La Rocque 1961 [which summarizes earlier literature]; Dimelow 1962, 1963; Clarke *et al.* 1968; McAlpine *et al.* 2009; Forsyth 2015; Forsyth *et al.* 2016). If non-native species are removed, 29 species remain, but several of these are likely misidentifications and include some larger-bodied species which were not the focus of my study. I found 28 species. Clarke *et al.* (1968) reported 24 species from 79 sites, which is the only comparable published study for New Brunswick; collections from other BiotaNB years are still to be analyzed (R.G.F. unpubl. data). I found seven species not previously reported from the province.

Two larger species of terrestrial snails were collected in the study area but not found in leaf-litter samples. Larger snails are apparently rare and were absent from the leaf-litter samples, except for juveniles of Flamed Tigersnail (*Anguispira alternata* (Say, 1816)). Upland Pillsnail (*Euchemotrema fraternum* (Say, 1824)) was found in visual searches in the field. Hairy Helicellid (*Trochulus hispidus* (Linnaeus, 1758)) was collected around the Popple Depot buildings, but these and no other introduced species of snails were in litter samples.

Although most microsnail species are generalists (Speiser 2001) and broadly distributed (e.g., Pilsbry 1940, 1946, 1948; Hubricht 1985), my study should provide useful data on which to compare the

north-central New Brunswick terrestrial snail fauna with that in other parts of the province and, perhaps, determine any regional distribution patterns. These data are important to better understand the mollusc fauna of New Brunswick to assure sufficient conservation actions are taken.

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### Supplementary Material:

**Table S1.** Collections and observations of litter-dwelling terrestrial molluscs of Nepisiguit Protected Natural Area and Mount Carleton Provincial Park, north-central New Brunswick.

## Deutonymphs of *Neottialges caparti* Fain (Astigmata: Hypoderatidae) from North American Northern Gannet (*Morus bassanus*)

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### Abstract

Deutonymphs of the mite family Hypoderatidae are subdermal parasites of vertebrates, primarily birds. Here we report the presence of deutonymphs of *Neottialges caparti* Fain (no common name) in the subcutis of Northern Gannet (*Morus bassanus* (L.)) from Atlantic Canadian waters. We observed mites in 39% of 90 birds whose skin samples were examined microscopically. Our observations represent both the first record of *N. caparti* in Northern Gannet from the western North Atlantic and the second report of *N. caparti* since its initial description in 1967 from two Northern Gannets in Belgium.

Key words: Arachnida; Acariformes; Aves; deutonymphs; Hypoderatidae; *Neottialges caparti*; mites; new distribution record; Northern Gannet; subcutaneous parasites

### Résumé

Les deutonymphes de la famille d'acariens Hypoderatidae sont des parasites sous-cutanés des vertébrés, surtout des oiseaux. Nous décrivons ici la présence de deutonymphes de *Neottialges caparti* Fain (pas de nom commun) dans le tissu sous-cutané de Fous de Bassan (*Morus bassanus* (L.)) des eaux canadiennes de l'Atlantique. Nous avons observé des acariens dans 39 % de 90 oiseaux dont des échantillons de peau furent examinés microscopiquement. Nos observations représentent la première mention de *N. caparti* chez les Fous de Bassan de l'Atlantique nord-ouest et la seconde mention de *N. caparti* depuis sa description originale en 1967 chez deux Fous de Bassan de la Belgique.

Mots-clés : Arachnida; Acariiformes; Aves; deutonymphes; Fou de Bassan; Hypoderatidae; *Neottialges caparti*; nouvelle mention de distribution; parasites sous-cutanés

### Introduction

Metazoan parasites are ubiquitous in free-living wildlife and, as a group, can occupy essentially all possible niches on and in a host organism. The cost to a host may vary from negligible to lethal depending on several factors, including life stage of the parasite, host species, integrity of the host's immune system at the time of exposure, and number of individual parasites to which the host is exposed at a given time (Wobeser 2008). Metazoan parasites that are small, infect hosts that are difficult to access, inhabit well-concealed niches within their host, and cause few to no apparent detrimental effects to the host can easily go unnoticed and may thus remain poorly documented.

Northern Gannet (Sulidae: *Morus bassanus* (L.)) is a piscivorous bird that feeds by plunge-diving. It is broadly distributed along the eastern and western shores of the North Atlantic Ocean (Mowbray 2020; BirdLife International 2023). It is typically a coastal species that rarely comes over land except to breed. Its North American population is estimated at approximately 230 000 adults breeding in six colonies, all located in the Gulf of St. Lawrence and along the southeastern coast of insular Newfoundland, Canada (Chardine *et al.* 2013). The adults are monogamous and philopatric, the breeding pair reusing the same nest in successive years (Mowbray 2020). Arriving at the colonies in March–April, the adults start adding material to the nest, collecting it from the nesting

island, adjacent islands, or the sea. A single egg is laid, and incubation and care of the young are shared by both parents. The nests are evenly spaced and nearly touching, with their centres 60–80 cm apart. The young fledge in mid-September or later at ~90 days of age and the population migrates to waters along the southeastern United States and the Gulf of Mexico to overwinter (Chapdelaine 1996; Mowbray 2020).

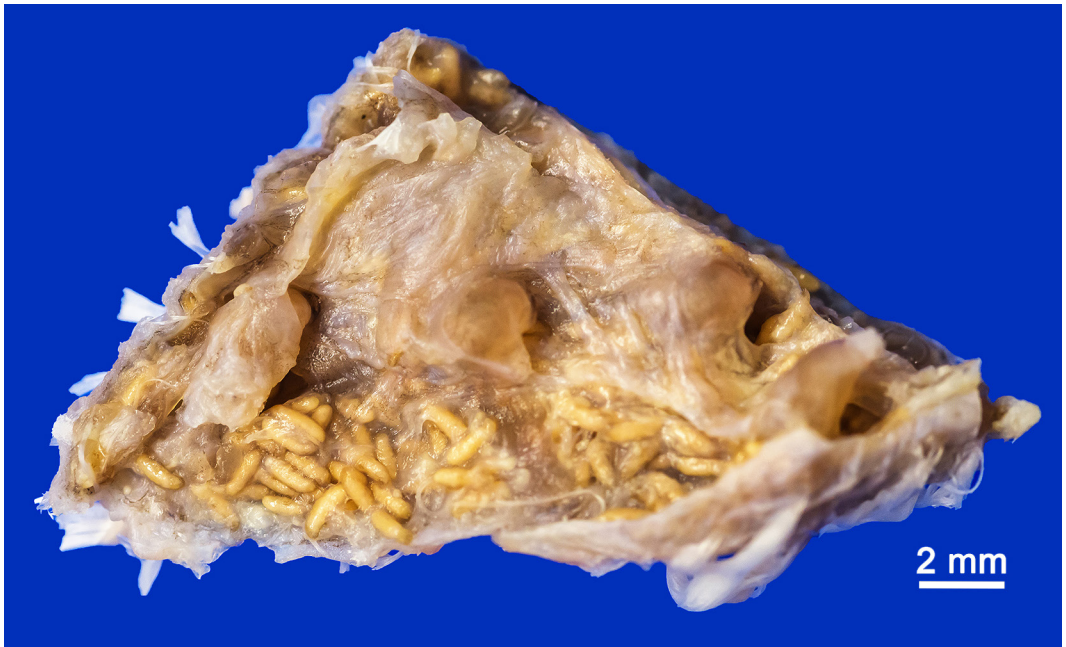
Here we report the occurrence of typically inconspicuous subcutaneous mites in a large number of Northern Gannets examined over 28 years.

### Methods

As part of a health surveillance program in free-living wildlife (Leighton *et al.* 1997), fresh or frozen carcasses of Northern Gannets that had been found seriously injured, sick, or dead along the shores of the three Canadian Maritime provinces (New Brunswick, Nova Scotia, and Prince Edward Island) were submitted for post-mortem examination to the Atlantic regional centre of the Canadian Wildlife Health Cooperative, based at the Atlantic Veterinary College, University of Prince Edward Island. Between 1990 and 2017, 313 carcasses were necropsied by P.-Y.D. Depending on the state of preservation of the carcasses, samples from observed lesions and standard samples from a variety of organs and tissues,

including one ~2.5-cm-long section of skin from the mid-ventral region of the abdomen, were collected. These samples were fixed in 10% neutral-buffered formalin, dehydrated in graded alcohol and xylene, and embedded in paraffin; 5- $\mu$ m-thick sections were cut from the paraffin blocks and stained with hematoxylin and eosin for light microscopic examination. The relative age of the birds (hatch-year [HY], immature [1–4 years], adult [ $\geq$ 5 years]) was determined based on plumage (Harrison 1983; Sibley 2000), presence or absence of a bursa of Fabricius, and degree of development of reproductive organs. The nutritional condition was subjectively assessed as poor, moderate, or good based on body weight, relative size of pectoralis muscles, and relative amount of subcutaneous, epicardial, and coelomic fat (Daoust *et al.* 2021).

Microscopic examination of the skin of some birds revealed small, often oblong structures morphologically compatible with mites. We retrieved intact specimens from the formalin-fixed, ventral skin section of three adult birds with particularly large numbers of them and confirmed that they were mites (Figure 1). A subset of the specimens was prepared by H.P. for slide-mounting. They were first transferred to tap water for several days to leach out the formalin. They were then placed in 80% lactic acid for 24–48 h to clear. Cleared specimens were punctured



**FIGURE 1.** Numerous deutonymphs of the hypoderatid mite, *Neottialges caparti* Fain, can be seen in the subcutis of a skin sample taken from the mid-ventral region of the abdomen of an adult Northern Gannet (*Morus bassanus*). Most of these nymphs are covered by a thin film of subcutaneous tissue, but are easily visible because of the absence of subcutaneous fat in this emaciated bird. Photo: Jordi Segers.

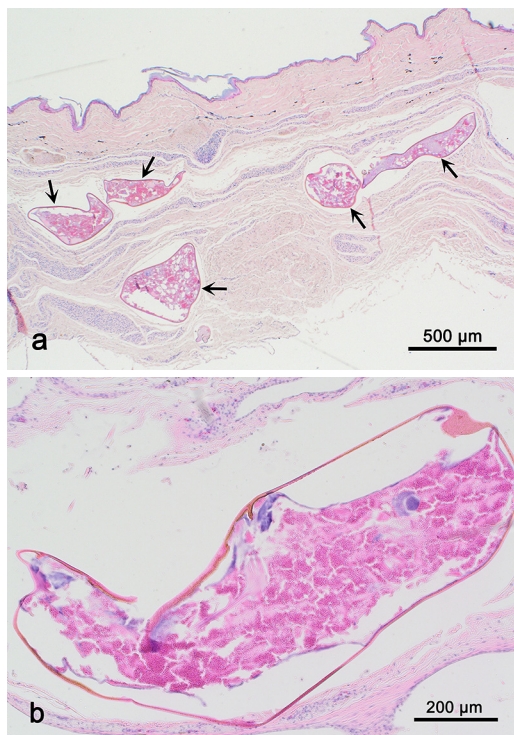
with a minuten pin, and body contents were gently expressed by squeezing with fine forceps. The mites were mounted on glass slides in commercially prepared polyvinyl alcohol mounting medium (BioQuip Products, Rancho Dominguez, California, USA) and covered with 15-mm round cover slips. Slides were then cured for four days on slide warmers set at 40°C. Mounted mites were examined using a Leica DMLB compound microscope with differential interference contrast (DIC) lighting and photographed using a Leica MC170 HD digital camera and LAS EZ software (Leica Microsystems Canada Inc., Richmond Hill, Ontario, Canada). Photographs were edited using Photoshop v. 23.1.1 (Adobe Inc., San Jose, California, USA).

## Results

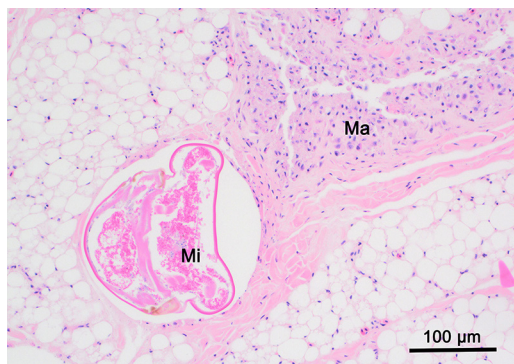
### *Necropsies*

A section from the ventral region of the skin was examined microscopically in 87 of 313 Northern Gannets (69 adult, five immature, 13 HY). In 31 of these birds, a few to several structures in the subcutis were identified as mites, based mainly on their size and thick body wall (Figure 2). No internal morphology as described by Gardiner and Poynton (1999) for arthropods in tissue sections could be identified. For one additional bird, although no structures compatible with mites were seen in the section from the ventral region of the skin, a structure identified as a mite was seen in the subcutis of a section of leg muscle that had been sampled to examine microscopic details of a traumatic lesion. In three other birds for which a section from the ventral region of the skin was not available, mites were seen in the subcutis of a section of skin taken in proximity to traumatic injuries, from a leg (proximal region) in one instance, and from a wing (distal region) in two instances. In total, we observed mites in 35 of 90 birds whose skin samples were examined microscopically (31 adult, two immature, two HY), indicating a prevalence of 39%.

Although 26 of these 35 birds were considered in poor nutritional condition, in none of them was this thought to be related to the presence of the mites. Based on microscopic examination of the ventral region of the skin, these mites were considered numerous in only five birds, including one in good nutritional condition. In 19 of the 26 birds in poor nutritional condition, an obvious cause, including chronic trauma, was identified. In all cases, inflammation associated with these parasites, which might have represented a drain on the birds' energy reserves, was either absent or minimal, consisting only of small aggregates of macrophages and, in a single case in an adult in good nutritional condition, small granulomas associated with remnants of mites (Figure 3).



**FIGURE 2.** a. Several subcutaneous mites (arrows) in a section from the ventral region of the skin of an adult Northern Gannet (*Morus bassanus*). b. Section of a subcutaneous mite at higher magnification, showing the sclerotized cuticle. Hematoxylin and eosin stain. Photos: Pierre-Yves Daoust.



**FIGURE 3.** Subcutaneous mite (Mi) in a section from the ventral region of the skin of an adult Northern Gannet (*Morus bassanus*). A large aggregate of macrophages (Ma) adjacent to this mite is presumed to represent an inflammatory reaction to its presence. Hematoxylin and eosin stain. Photo: Pierre-Yves Daoust.

Intact mite specimens retrieved from the formalin-fixed subcutis of three adult birds were examined with a stereomicroscope. They had a cylindrical shape

with two pairs of short legs anteriorly and two other pairs in the mid region of the body and had a uniform length of ~1.5 mm (Figure 4). Based on descriptions of small arthropods in a similar location in other species (e.g., Hendrix *et al.* 1987; Pence 2008), we identified them as deutonymphal hypoderatid mites (Acariformes: Astigmata: Hypoderatidae).

#### Slide-mounted mites

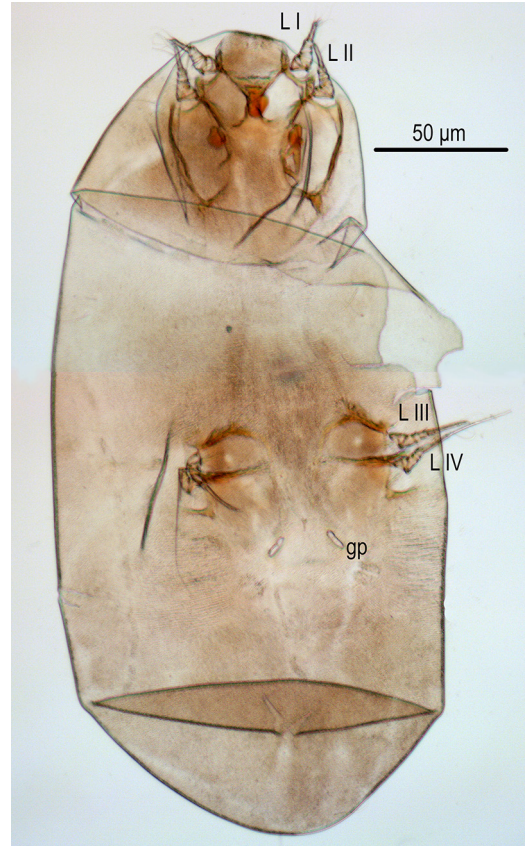
Only five slide-mounted specimens (one to three from each of three birds) had sufficiently complete appendages and setation to be confidently identified using the key and species descriptions in Fain's (1967) key to members of the family Hypoderatidae. All five mites proved to be *Neottialges (Pelecanectes) caparti* Fain (no common name). Diagnostic features included posteriorly diverging pairs of genital papillae with the posterior papilla larger than the anterior, genital sclerite incomplete and present only anteriorly, tarsus of Leg III with a short hooked tarsal claw, and tarsus of Leg IV with two large spine-like setae at the base of the segment and one small spine-like seta subterminally (Figures 5–7; note that in hypoderatid deutonymphs, tarsus IV terminates in a long whiplike macroseta rather than a tarsal claw). Representative specimens of *N. caparti* were deposited in the New Brunswick Museum, Saint John, NB, Canada (accession nos. NBM-GI-011575, NBM-GI-011576, and NBM-GI-011577) and in the E.H. Strickland Entomological Museum, University of Alberta, Edmonton, Alberta, Canada (accession nos. UASM 80600, 80601, 80602, 80603, and 80604).

#### Discussion

Approximately 80 species of Hypoderatidae have so far been described, mostly based on the host-associated deutonymphal stage (Mironov and Ramilo 2019). The presence of deutonymphal hypoderatid mites beneath the dermis of birds was reported for

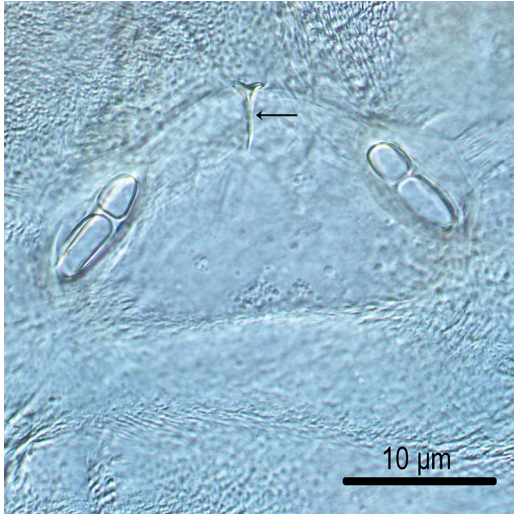


**FIGURE 4.** Deutonymphs of hypoderatid mites identified as *Neottialges caparti* from an adult Northern Gannet (*Morus bassanus*). Epimerites of the coxal fields are apparent as dark brown lines ventrally. Photo: Shelley Ebbett.



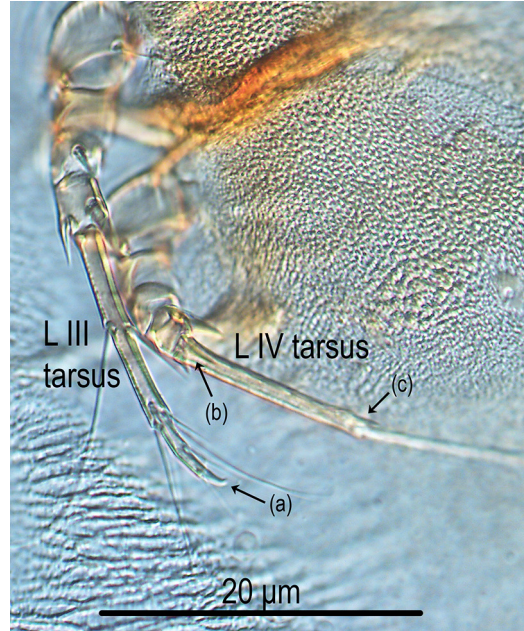
**FIGURE 5.** Ventral view of cleared, slide-mounted *Neottialges caparti* deutonymph. Labels indicate legs (L I to L IV) and location of genital papillae (gp). Photo: Heather Proctor.

the first time by Montagu (1811), who observed them in Northern Gannet from the eastern North Atlantic, although he misidentified them as insects (Fain 1967). Fain (1967) described *Neottialges (Pelecanectes) bassani* (Montagu) and *N. caparti* co-occurring in two specimens of Northern Gannet from Belgium, whereas Pence *et al.* (1997) later provided a record for *N. bassani* in a single Northern Gannet from Florida, USA. To our knowledge, this is both the first report of *N. caparti* in Northern Gannet from the western North Atlantic and the second report of *N. caparti* since its initial description by Fain (1967) in Belgium. *Neottialges bassani* is separated from *N. caparti* in Fain's (1967) key based on the length of one pair of dorsal setae (*d* 4), which were often missing or broken in our specimens. Given the small number of mites that were morphologically complete enough for us to identify to species (*n* = 5), we cannot rule out that *N. bassani* as well as *N. caparti* are parasites of Northern Gannet in the western North Atlantic.



**FIGURE 6.** Juvenile genitalic area of a *Neottialges caparti* deutonymph showing three features important for diagnosing this species: posterior genital papilla larger than anterior papilla, left and right pairs of genital papillae diverging from each other posteriorly, genital sclerite (arrow) present only in the anterior part of the genitalic field rather than extending posteriorly between the papillae. Photo: Heather Proctor.

Being very small, of a pale colour, and buried in the host's fat, deutonymphs of hypoderatid mites can easily be missed macroscopically. Yet, they have been reported (Fain 1967; Pence 2008; Mironov and O'Connor 2013; Mironov and Ramilo 2019) in avian hosts of most major orders, including Apodiformes (hummingbirds and swifts), Accipitriformes (hawks and eagles), Ciconiiformes (storks), Columbiformes (pigeons), Coraciiformes (rollers), Cuculiformes (cuckoos), Falconiformes (falcons), Gruiformes (cranes), Passeriformes (perching birds), Pelecaniformes (pelicans and relatives), Piciformes (woodpeckers), Psittaciformes (parrots), Strigiformes (owls), and Suliformes (gannets and relatives). Hypoderatid deutonymphs are most commonly observed in the host's subcutis and less often in various other locations in the body, such as around the esophagus and in air sacs and lungs (Fain and Laurence 1974). Northern Gannets, like some other species in the orders Suliformes and Pelecaniformes, have a very elaborate system of subcutaneous air diverticula, most extensive along the ventral region of the chest and abdomen, which communicate bilaterally with the respiratory air sacs in the axillary region (Daoust *et al.* 2008). It was not possible to determine in the present series of cases whether any of the deutonymphs had reached these air diverticula or whether they were all confined to the subcutis. Access to these diverticula could further facilitate the migration of these mites throughout the body.



**FIGURE 7.** Tarsi of legs (L III and L IV) of a *Neottialges caparti* deutonymph. Arrows indicate features important in diagnosing this species: (a) short, curved tarsal claw on L III, (b) restriction of thick spine-like setae to the base of L IV tarsus with (c) one smaller spine-like seta subterminally. Photo: Heather Proctor.

Our calculated prevalence of 39% is most likely an underestimate because it was based largely on the examination of a single histological section of skin, although the location where most of these sections were taken, in the ventral region of the body midway between the axillary and groin areas, is reported to be a common site for these mites (Fain 1967; Pence 2008). By comparison, Hendrix *et al.* (1987) observed deutonymphal hypoderatids in 21 of 24 (87.5%) adult Cattle Egret (*Bubulcus ibis ibis* (L.)) in Alabama, USA.

To our knowledge, this report is the first to provide information about the demographic distribution of hypoderatid deutonymphs in Northern Gannet. We identified these parasites in roughly the same proportion of adult and immature birds, but in a lower proportion in HY birds. The viability of the deutonymphs at the time of their hosts' death could not be assessed histologically on the basis of the integrity of their internal structure, possibly partly because of autolysis, but also because their internal morphology is normally greatly reduced (Alberti *et al.* 2016). However, the rarity of inflammation and its mild nature when present suggested that these mites were still alive when their hosts died, as dead parasites and their degradation products normally elicit a more intense

inflammatory reaction, as we observed in a single instance.

According to Mironov and Ramilo (2019), the full life-cycle of hypoderatid mites has been described for only four species, and most species are known only from deutonymphs. It is generally understood that, except for the deutonymphs, the various stages of hypoderatid mites live in their hosts' nesting material. The microscopic larvae hatching from the eggs penetrate the intact skin of the birds, presumably of both nestlings and their parents, where they transform into deutonymphs. Following gradual maturation in their host's subcutis, the deutonymphs become activated at nesting time, metamorphose to adults, and exit through their adult host's skin (Pence 2008). The presence of these mites in a least a few HY and immature birds in the present study suggests a long life span within their hosts, because, after fledging, Northern Gannet do not come to land until they reach sexual maturity at 5 years of age. These deutonymphs would need to remain sensitive for that length of time to physiological signals of their host indicative of the nesting season, possibly hormonal as in the classic case of the rabbit flea (*Spilopsyllus cuniculi* (Dale); Rothschild and Ford 1964). The precise nature of these signals is as yet unknown.

### Author Contributions

Conceptualization: P.-Y.D.; Data Curation: N.C. and P.-Y.D.; Funding Acquisition: H.C.P. and P.-Y.D.; Investigation: P.-Y.D.; Methodology: H.C.P. and P.-Y.D.; Writing – Original Draft: H.C.P. and P.-Y.D.; Writing – Review & Editing: H.C.P., N.D., and P.-Y.D.

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## Size records and demographics of an Eastern Painted Turtle (*Chrysemys picta picta*) urban population near the northern limit of the species' range in eastern Canada

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### Abstract

Understanding variation in demographics and life history across species ranges and differing landcover types is valuable for conservation planning. We examined the population demographics of a small urban population of Eastern Painted Turtle (*Chrysemys picta picta*) in New Brunswick, Canada, near the northern limit of the species' range. We captured turtles using hoop traps and by hand during four sampling periods. We estimated that our population included 17 females, nine males, and 29 juveniles in late summer 2015 using Jolly-Seber population size estimates. We captured several very large females at our study site; 5/17 females (29%) were larger than previous size records for the subspecies. Growth rates for juveniles were greater than most populations of Eastern Painted Turtles reported elsewhere. Growth rates at our site were significantly greater for smaller (younger) turtles and for females compared to males. Overwinter survivorship estimates were 100% from late summer 2014 to spring 2015. Active season (2015) survivorship was 100% for females, 89% for males, and 93% for juveniles. We speculate that the large body sizes found at our study site were achieved through high survivorship and larger growth rates compared to other areas reported previously. Our data supports previous findings that body size of Painted Turtles increases with latitude, and additionally, growth may have been enhanced by increased nutrient levels common in human-modified landscapes.

Key words: Age structure; growth; Jolly-Seber; mark-recapture; maximum size; New Brunswick; sex ratio; size structure; survivorship; urban

### Résumé

La compréhension des variations démographiques et biologiques entre les types d'habitats et géographiquement est précieuse pour la planification de la conservation. Nous avons examiné les données démographiques d'une petite population urbaine de Tortues Peintes de l'Est (*Chrysemys picta picta*) au Nouveau-Brunswick, Canada, près de la limite nord de l'aire de répartition de l'espèce. Nous avons capturé des tortues à l'aide des cerceau piège et à la main pendant quatre périodes d'échantillonnage. Nous avons estimé que notre population comprenait 17 femelles, neuf mâles et 29 juvéniles à la fin de l'été 2015 en utilisant les estimations de la taille de la population de Jolly-Seber. Nous avons capturé plusieurs très grosses femelles sur notre site d'étude; cinq des 17 femelles (29%) étaient plus grandes que les records de taille précédents pour la sous-espèce. Les taux de croissance des juvéniles étaient supérieurs à ceux de la plupart des populations de Tortues Peintes de l'Est signalées ailleurs. Les taux de croissance sur notre site étaient significativement plus élevés pour les tortues plus petites (plus jeunes) et pour les femelles par rapport aux mâles. Les estimations de la survie hivernale étaient de 100% de la fin de l'été 2014 au printemps 2015 (hiver). La survie pendant la saison active (2015) était de 100% pour les femelles, de 89% pour les mâles et de 93% pour les juvéniles. Nous supposons que les grandes tailles corporelles trouvées sur notre site d'étude ont été obtenues grâce à une survie élevée et à des taux de croissance plus importants par rapport à d'autres zones signalées précédemment. Nos données corroborent les conclusions précédentes selon lesquelles la taille corporelle des tortues peintes augmente avec la latitude et, en outre, la croissance peut avoir été améliorée par l'augmentation des niveaux de nutriments courants dans les paysages modifiés par l'homme.

Mots clés : Croissance; Jolly-Seber; marquage-recapture; Nouveau-Brunswick; rapports de masculinité; structure par âge; structure de taille; survie; taille maximum; urbaine

## Introduction

Turtles are the most threatened taxa among the major groups of vertebrates (Lovich *et al.* 2018). Historically, turtles had much larger population sizes, thus their declines are suspected to have significant impacts on ecosystem processes (Lovich *et al.* 2018). All turtle species native to Canada are now considered to be at-risk in at least parts of their range (COSEWIC 2022). Even the widely distributed and abundant Painted Turtle (*Chrysemys picta*) has experienced declines significant enough to warrant the status of Special Concern in Eastern Canada and Threatened for the Pacific Coast population (COSEWIC 2016, 2022). Turtles are impacted by a multitude of threats (including, but not limited to: habitat loss, road mortality, subsidized predators, invasive species, climate change, fisheries by-catch, pollution, disease, and collection) and their ability to withstand these impacts are limited due to their life history characteristics of late age of maturity and high adult survivorship coupled with low juvenile recruitment (Burger and Garber 1995; COSEWIC 2018). Understanding variation in demographics and life history characteristics among landcover types and geographically will be valuable for recovery planning.

Painted Turtle is one of the most abundant and widely distributed turtle species, making it a valuable subject to compare geographical variation of intra-specific ecological parameters (Zweifel 1989). Three subspecies exist (Crother 2017): Western Painted Turtle (*Chrysemys picta bellii*), Midland Painted Turtle (*Chrysemys picta marginata*), and Eastern Painted Turtle (*Chrysemys picta picta*). The subspecies differ in colour, morphology, and size (Conant and Collins 1991; Ernst *et al.* 1994). Western Painted Turtles tend to grow larger than the other subspecies (Ernst *et al.* 1994). Larger body size may have reproductive advantages because larger females tend to produce larger clutches of eggs (Tinkle *et al.* 1981; Iverson and Smith 1993; Rowe 1994). Size also varies geographically within the subspecies and among differing landcover compositions. Body size is positively correlated with latitude and elevation (Iverson and Smith 1993) and relatively larger body sizes have been observed for Painted Turtles in nutrient rich habitats, such as wastewater lagoons and golf course ponds (Ernst and McDonald 1989; Lindeman 1996; Failey *et al.* 2007).

We examined population size, structure, survivorship, age/size distribution, sex ratios, and growth for a small, urban population of Eastern Painted Turtle in New Brunswick. Our results are particularly valuable because they are the first demographic analysis for a Canadian population of Eastern Painted Turtle. Also of interest, our study population is a small population located in an urban park. Small populations

are of special interest with respect to minimum population size and long-term population viability (Soule 1987). Urbanization is rapidly altering habitats worldwide; thus, information from urban populations will be particularly valuable for conservation efforts.

## Methods

### Study area

Our study occurred in a network of lakes in Rockwood Park (45.2941°N, 66.0591°W) located in Saint John, New Brunswick, Canada. Rockwood Park is one of the oldest and largest city parks in Canada, established in 1896, and covers ~695 ha within park boundaries. There are 10 large lakes (1.4–10.3 ha) and several ponds (up to 0.8 ha) in Rockwood Park. Each of the lakes is connected by water bodies outside of the park; Crescent Lake drains to Alder Brook, while the other nine lakes drain to streams that feed into Marsh Creek. Lily Lake and Fisher Lakes are located within the park's designated recreation zone and are heavily used by the public for events and low impact recreation (e.g., hiking, cycling, swimming, angling, non-motorized boating, horseback riding, and dog exercise). Crescent Lake is located adjacent to the Rockwood Park golf course and was used for an aquatic driving range from 1973 to 2013; the aquatic driving range was closed from 2014 to 2017 but reopened in 2018. The other seven lakes are located within the park's designated wilderness area. The wilderness area has comparatively less human impact; however, it is used for low impact recreation.

### Turtle community

We surveyed for turtles at all 10 lakes, plus four smaller waterbodies in Rockwood Park (39.4 ha open water surface area) and at four waterbodies outside of the park in Saint John (37.9 ha open water surface area) from 2014 to 2016. Three species of turtles were found in Rockwood Park: Eastern Painted Turtle, Snapping Turtle (*Chelydra serpentina*), and the non-native Red-eared Slider (*Trachemys scripta elegans*). An Eastern Painted Turtle population resides at Crescent Lake in Rockwood Park with some use of a small pond in the golf course during the summer. Snapping Turtles are widely distributed in Rockwood Park; members of the public have submitted nine confirmed observations (photo evidence or expert identification) and 14 unconfirmed observations (observations reported without photo evidence) from a wide range of locations within the park or along its perimeter as well as seven locations (two confirmed, five unconfirmed) outside of the park in the city of Saint John. However, our trapping efforts from 18 sites only produced three individuals with 2669 trap days, which suggests that Snapping Turtles are at very low abundance (C.L.B. and S.A.S. unpubl. data). Red-eared Sliders are re-

leased pet turtles that occurred at Lily Lake and the Fisher Lakes area (Browne and Sullivan 2023). We caught and removed six individuals from Rockwood Park from 2014 to 2016 and implemented a public education program to discourage the release of pets in the park. Only one additional Red-eared Slider was sighted (and removed in 2022) since the six individuals were removed during 2014–2016.

#### Field methods

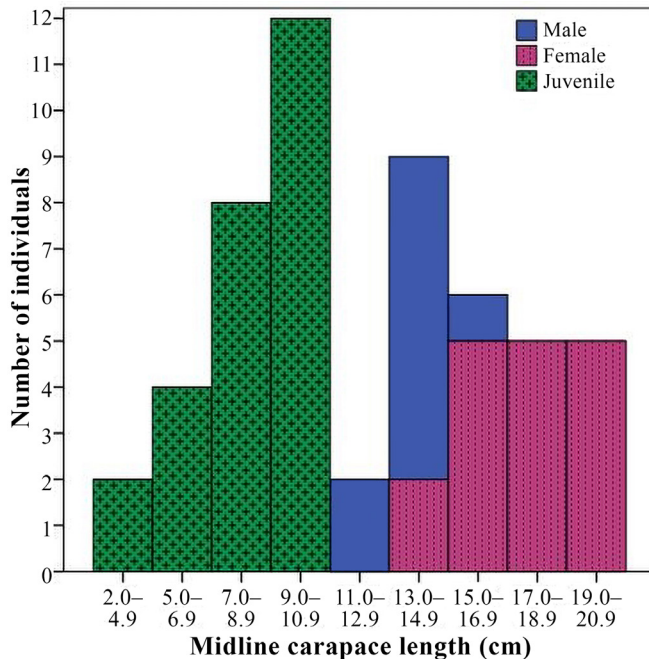
We used six baited hoop traps to catch turtles at Crescent Lake (7.4 ha open water surface area). Hoop traps were 84 cm long, had three oval hoops 45–48 cm in diameter, 2.5 cm mesh, and were baited with chopped native fish donated by local anglers (Browne and Sullivan 2023). We deployed traps during four sampling periods: (1) 24 August–12 September 2014 (sample one = Late Summer 2014), (2) 12 May–17 June 2015 (sample two = Spring 2015), (3) 24 August–27 September 2015 (sample three = Late Summer 2015), and (4) 17 May–15 June 2016 (sample four = Spring 2016) and checked traps daily. We also captured individuals by hand or dip-net when possible during the sampling periods. Painted Turtles from the Crescent Lake population were also captured at the golf course pond and Harrigan Lake during exploratory sampling in August 2016.

We sexed, measured, marked, and photographed each turtle captured. Individuals were identified

as male if they exhibited the presence of secondary sex characteristics (elongate foreclaws, enlarged tail base, and more posterior positioning of the vent; Cagle 1954; Christiansen and Moll 1973). We designated individuals not exhibiting male secondary sex characteristics as juveniles if straight midline carapace length (MCL; as per Method D in Iverson and Lewis 2018) was <13 cm and as females if MCL was  $\geq 13$  cm based on a natural break observed in the size structure of our population (Figure 1). We recorded MCL, straight maximum carapace length (Method B, Iverson and Lewis 2018), straight maximum carapace width, and straight midline plastron length (Method H, Iverson and Lewis 2018) with Vernier calipers (Grand Rapids Industrial Products, Wayland, Michigan, USA) to the nearest mm. We weighed turtles to the nearest 5 g using a spring scale (Pesola, Schindellegi, Switzerland) from 3 June 2016 on. We marked turtles using Cagle's (1939) method to provide a unique notch code for each turtle marked. We recorded any abnormalities present and the number of growth lines present if clearly visible. Females were recorded as gravid if eggs could be felt by palpating the cavity in front of the hind legs.

#### Data analysis

We used the Jolly-Seber method (Jolly 1965; Krebs 1999) in the program Ecological Methodology Version 5.2 (Exeter Software 1999) to calculate estimates



**FIGURE 1.** Size distribution of straight midline carapace length (cm) measurements from Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick in 2014–2016 ( $n = 53$ ).

for population size and survival probability. The assumptions of the Jolly-Seber method are: (1) every individual has the same probability of being caught in the  $t$ -th sample, regardless whether it is marked or unmarked; (2) every marked individual has the same probability of surviving from the  $t$ -th to the  $(t + 1)$ -th sample; (3) individuals do not lose their marks, and marks are not overlooked at capture; and (4) sampling time is negligible in relation to intervals between samples (Jolly 1965; Krebs 1999). We believe that our sampling methods met the assumptions, except for assumption #1. Catchability differed among males, females, and juveniles (Table 1), thus we calculated Jolly-Seber estimates for males, females, and juveniles separately to resolve this violation. Previous studies have also found that hoop traps overrepresent males and underrepresent juveniles (Ream and Ream 1966; Vogt 1979), while captures by hand or dipnet tend to produce less biased results (Ream and Ream 1966; Bider and Hoek 1971). Both of our capture methods were biased towards capturing adults over juveniles and males over females (Table 1), with the bias being more significant for hoop traps ( $\chi^2 = 42.71, P < 0.001$ ) than dipnet and hand captures ( $\chi^2 = 10.89, P < 0.005$ ).

A minimum of three samples are required to obtain population estimates. We used data collected from four sample periods that allowed us to calculate survivorship estimates for both the active season and overwintering period. Two males that were missing from Crescent Lake during the spring 2016 sample, but found nearby in late summer 2016 were added to the spring 2016 sample to prevent underestimating survivorship and population size. Input data are provided in Table S1. With these four sample periods, we obtained estimates of population size at sample two (Spring 2015) and sample three (Late Summer 2015), the probability of survival from sample one to sample two (overwintering period 2014–2015) and from sample two to sample three (active season 2015), and the proportion of the population marked in samples two, three, and four (Spring 2016).

We examined the sex and age ratio of the population by comparing the number of males to females,

and adults to juveniles, respectively. Because the capture ratios are biased, we used the Jolly-Seber population size estimates to calculate these ratios. We used the most recent MCL measurement taken from each individual to examine size structure of the population.

We calculated growth overwinter and during the summer by measuring the difference in MCL between trapping sessions. We calculated annual growth rates by measuring the difference in MCL between the Late Summer 2014 to Late Summer 2015 sessions or Spring 2015 to Spring 2016 sessions. We used a generalized linear model (GLM) with normal distribution and identity link function to determine whether the independent variables sex, initial MCL size, or sampling period influenced the amount of growth for three dependent variables: annual growth, overwinter growth, or summer growth. We also used GLM to examine the relationship with sampling session (Spring 2016 or Late Summer 2016), age/sex, and MCL on weight. We considered  $\alpha < 0.05$  to indicate statistical significance. We used IBM SPSS Statistics Version 24 for statistical tests (IBM Corp. 2016).

## Results

### Captures

We captured a total of 53 individual Painted Turtles in Rockwood Park by the end of our fourth sampling period: 10 males, 17 females, and 26 juveniles. Jolly-Seber estimates indicated that we marked all of the adults in this population and ~86% of the juveniles (Table S2). In the third and fourth sampling periods, all the adult turtles caught were recaptures; the only new captures were six juveniles in fall 2015 and three juveniles in spring 2016.

We caught nearly every marked individual in Spring 2016 (final) sample: seven males, 17 females, and 21 juveniles. Two of the missing males were confirmed to be alive later in the summer of 2016, found at the golf course pond and Harrigan Lake located 230 m and 580 m straight-line distance from Crescent Lake, respectively. The third missing male was caught in sample one and two, but not three or four; the fate of this individual is unknown. Five marked

**TABLE 1.** Bias among male, female, and juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick from 2014 to 2016 using hoop-traps and other methods was examined by comparing the percent of the population (calculated using Jolly-Seber population size estimates; see Table 2) to the percentage of turtles caught in traps ( $n = 192$ ) or by dipnet/hand ( $n = 154$ ).

	% of Population ( $N$ )	Trapped			Dipnet and hand captures		
		$n$	%	%/% $N$	$n$	%	%/% $N$
Male	16	59	31	1.94	38	25	1.56
Female	31	93	48	1.55	58	38	1.23
Juvenile	53	40	21	0.40	58	38	0.72

juveniles were not captured in 2016. We know one individual died and assume a second individual to have also died; they were observed with throat/mouth infections in late summer 2015, and one individual was sent to the Atlantic Wildlife Institute, where it died soon after arriving (see Browne *et al.* 2020 for more details). The individual that was not removed from the site had more severe symptoms, thus we assume that it is also died. The remaining three juveniles were last captured in late summer 2015 ( $n = 1$ ) and spring 2015 ( $n = 2$ ).

#### Population size estimates

The Jolly-Seber population size estimate for the Painted Turtle population calculated for sample two (Spring 2015) was 50 turtles (43–72 individuals, 95% CI), which included 10 males, 17 females, and 23 juveniles (Table 2). The population size estimate for sample three (Late Summer 2015) was 55 turtles (48–74 individuals, 95% CI), which included nine males, 17 females, and 29 juveniles. Crescent Lake is 7.4 ha, so the known density is 3.5 adult turtles/ha. Using the total population size estimate of 48–74 individuals, the density of this population is estimated to be 6.5–10 turtles/ha.

#### Survivorship

The Jolly-Seber survival probability estimates from Late Summer 2014 to Spring 2015 were all 1.000, which indicates that virtually all individuals survived the 2014–2015 winter (Table 3). Active season survival estimates (Spring 2015 to Late Summer 2015) were 1.000 for females, 0.890 for males, and 0.931 for juveniles (Table 3).

#### Population structure

The sex ratio of this population is female biased (M:F 1:1.9) and although more adult turtles were captured than juveniles, Jolly-Seber estimates indicate that the adult to juvenile ratio is 1:1.1. The size distribution of MCL ranged from 2.5 to 20.7 cm (Figure 1). Average MCL was  $17.5 \pm (\text{SE}) 0.5$  cm for females (range 14.3–20.7 cm,  $n = 17$ ),  $13.7 \pm 0.3$  cm for males (range 12.3–15.3 cm,  $n = 10$ ), and  $8.1 \pm 0.4$  cm for juveniles (range 2.5–10.3 cm,  $n = 26$ ).

#### Growth

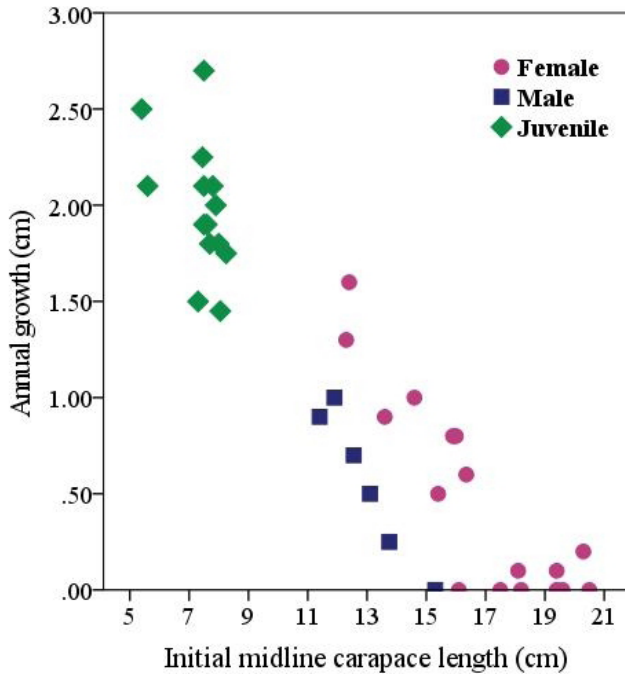
MCL growth occurred primarily during the summer period (Table S3). MCL growth did not differ significantly between years; sex/age and initial MCL were significant factors for MCL growth (Table S4). MCL growth was significantly greater for smaller turtles (Table S4). Juveniles experienced the greatest amount of MCL growth, followed by males then females (Table S3). However, annual MCL growth was greater for females compared to males of similar size (Figure 2, Table S4). Mass was significantly related with turtle MCL and sex/age, but not sampling session (Table S5, Figure S1). Juveniles had a lower mass to MCL ratio than adults ( $P < 0.001$ ), the difference was not significant between females and males ( $P = 0.088$ ). Juveniles began to reach adult size at ~3.5–4 years old (Table 4, Figure S2). The smallest male with secondary sexual characteristics was 11.4 cm in MCL. We only detected eggs in five individuals because our sampling did not directly overlap with the nesting period, but of these, the smallest gravid female observed was 15.9 cm.

**TABLE 2.** Jolly-Seber population size estimates for Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick for sampling period two (Spring 2015) and three (Fall 2015).

Group	Sample 2 (Spring 2015)			Sample 3 (Late Summer 2015)		
	Estimate	SE	95% CI	Estimate	SE	95% CI
Males	10.1	0.4	9.5–11.8	9.0	3.0	9.0–9.0
Females	17.0	0.5	16.4–18.5	17.0	4.1	17.0–17.0
Juveniles	22.6	5.3	16.6–41.6	28.8	8.2	21.5–48.2
Sum	49.7		42.5–71.9	54.8		47.5–74.2

**TABLE 3.** Jolly-Seber probability of survival for Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick from sample one (Late Summer 2014) to sample two (Spring 2015) and sample two (Spring 2015) to sample three (Late Summer 2015).

Group	Late Summer 2014 to Spring 2015			Spring 2015 to Late Summer 2015		
	Estimate	SE	95% CI	Estimate	SE	95% CI
Males	1.000	0.023	0.639–1.000	0.890	0.104	0.664–1.000
Females	1.000	0.000	0.686–1.000	1.000	0.000	0.951–1.000
Juveniles	1.000	0.073	0.672–1.000	0.931	0.133	0.694–1.000
Mean	1.000	0.032	0.666–1.000	0.940	0.079	0.770–1.000



**FIGURE 2.** Annual straight midline carapace length growth was greater for smaller/younger Eastern Painted Turtle (*Chrysemys picta picta*) and for females compared to males of similar size in Rockwood Park, New Brunswick.

**TABLE 4.** Straight midline carapace length (Method D in Iverson and Lewis 2018) and straight midline plastron length (Method H in Iverson and Lewis 2018) of each age class of juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick, from 2014 to 2016. Age was estimated by counting growth rings. Recaptures were included but each individual was not included more than once per sampling session. We assigned hatchlings observed in the Spring with no growth accumulated to age class 0 for a starting point. Estimated ages of 0, 1, 2, 3, and 4 years are measurements taken from the Spring sampling sessions; estimated ages of 0.5, 1.5, 2.5, and 3.5 years are measurements taken from the Late Summer sampling sessions.

Age	n	Carapace (cm)			Plastron (cm)		
		Mean	SE	Range	Mean	SE	Range
0.0	1	2.5		2.5–2.5	2.4		2.4–2.4
0.5	2	6.5	1.03	5.5–7.5	6.0	1.05	4.9–7.0
1.0	6	5.3	0.25	4.4–6.1	4.7	0.17	4.1–5.3
1.5	12	7.5	0.15	6.4–8.1	6.9	0.13	6.1–7.5
2.0	15	7.7	0.10	6.8–8.3	7.0	0.09	6.4–7.7
2.5	8	9.8	0.36	9.1–12.3	9.3	0.38	8.5–11.9
3.0	13	9.7	0.13	8.8–10.3	9.1	0.12	8.3–9.6
3.5	1	12.2		12.2–12.2	11.7		11.7–11.7
4.0	3	13.4	0.32	12.9–14	12.9	0.36	12.2–13.4

#### *Movement and dispersal*

We caught 12 individuals at the golf course pond, located 230 m straight-line distance from Crescent Lake, from 4 to 10 August 2016, and one individual at Harrigan Lake, located 580 m from Crescent Lake, on 3 August 2016. Each of these turtles were originally caught and marked at Crescent Lake. The Painted

Turtles appear to use the golf course pond for summer habitat but return to Crescent Lake for overwintering. The Painted Turtle that moved from Crescent Lake to Harrigan Lake was not captured at Crescent Lake in subsequent samples and was one of the few individuals not accounted for in the Spring 2016 sampling period, thus may be a dispersal event.

## Discussion

The Rockwood Park Painted Turtle population is small with only 17 adult females and nine adult males. This small, urban population may seem inconsequential, but our study revealed unique features that offer special conservation significance. Five females, representing 29% of the adult female population, were larger than the maximum size previously recorded for this subspecies: 18.98 cm, an individual from Gagetown, New Brunswick (Ultsch *et al.* 2000). Our largest individual was 20.7 cm. The mean size of adult females at our site was larger than that from other areas for Eastern Painted Turtle (Conant and Collins 1991; Rhodin and Mittelhauser 1994; Ultsch *et al.* 2000). Thus, our data support previous findings that body size of Painted Turtles increases with increasing latitude (Iverson and Smith 1993; Rhodin and Mittelhauser 1994; Ashton and Feldman 2003). The several new size records from Rockwood Park could be because the subspecies is poorly sampled near its northern range limit where individuals are expected to be larger. Sample sizes for New Brunswick studies (14 adult females in Ultsch *et al.* 2000; 17 adult females in our study) have been small in comparison to other areas (e.g., 122 adult females in Maine and 247 in Massachusetts; Rhodin and Mittelhauser 1994). This northern area of the subspecies' distribution has much potential for discovering new information about geographical variation within this subspecies.

Iverson and Smith (1993) list several explanations for why body size and latitude are correlated for Painted Turtles, including (1) larger body size is advantageous in cooler climates because rates of heat loss are theoretically lower (Lindsey 1966); (2) large body size facilitates survival through the winter (Murphy 1985); (3) small body size is an adaptive response to increased competition with other large emydid turtles in the southern part of its range (Moll 1973); (4) larger females dig deeper nests (Morjan 2003), which might decrease overwinter mortality of hatchlings from freezing temperatures (St. Clair and Gregory 1990); and (5) larger body size allows greater single clutch reproductive output (Iverson and Smith 1993).

Painted Turtles often have indeterminate growth (Congdon *et al.* 2013), thus large body sizes could be achieved through faster growth rates, delayed age of maturity, and/or higher survivorship rates. Juvenile turtles at our study site during our study period grew more rapidly than those at a long-term study site for Eastern Painted Turtles in Long Island, New York (Zweifel 1989). Age-size comparisons shifted across studies: one year old turtles at our site were smaller on average than at Zweifel's (1989) site

(mean MPL = 4.7 versus 5.04 cm), were similar sizes by two years (7.0 versus 7.02 cm), and larger by three years (9.1 versus 8.32 cm) and four years (12.9 versus 9.12 cm). Juveniles from our site and Zweifel's (1989) also grew more rapidly than those from a site in Michigan (Frazer *et al.* 1993). Adult turtles at our site also grew during our study period, but growth rates were greater for smaller (presumably younger) turtles and for females compared to males. Having 5/17 females larger than the previous size record seems extraordinary, so we suspect that additional factors could be playing a role at our site. Rapid growth rates could result from enhanced thermal environments (Gibbons *et al.* 1981; Thornhill 1982; Frazer *et al.* 1993), nutrient rich environments resulting in availability of preferred food items (Lindeman 1996; Failey *et al.* 2007), and delayed maturity to direct energy to growth rather than reproduction (Iverson and Smith 1993). Increased nutrient levels in human-modified landscapes, such as wastewater lagoons and golf course ponds, may provide turtles with more abundant food sources (Budischak *et al.* 2006; Failey *et al.* 2007; Roe *et al.* 2011). This could potentially explain the rapid growth rates at our site because our study lake was located adjacent to a golf course and at least 12 adults from our population moved seasonally to use a small pond located within the golf course during the summer. Water chemistry samples collected at our study lake on 19 August 2008 indicated that orthophosphate levels were 0.03409 mg/L (Table S6), which is considered to be meso-eutrophic (CCME 2004). Elevated nutrient levels and food opportunities could explain why turtles made seasonal movements to the golf course ponds. Alternatively, it could also be related to thermoregulation opportunities. The golf course ponds likely reach higher temperatures in the summer because they are small, shallow, and in full sun, which would increase metabolic rates and the ability to digest food more rapidly for the turtles.

The population at Rockwood Park appears to have high survivorship. Survivorship was estimated to be 1.000 overwinter for 2014–2015, and summer survivorship in 2015 was estimated to be 1.000 for females, 0.890 for males, and 0.931 for juveniles (Table 3). Additionally, we assume that the presence of several very large females in our population indicates that survivorship rates have been high in previous years as well. Our sample most likely captured the entire adult population, but the population was not large enough to effectively compare survivorship to other populations, because the loss of just one adult male made the survivorship rate 0.890 compared to 1.000 if this male had been recaptured. However, our survivorship rates are comparable to

other populations. Annual survivorship rates in Long Island averaged 0.810 for males (range 0.330–1.000) and 0.923 for females (range 0.714–1.000) from 1963 to 1979 (Zweifel 1989). In Algonquin Park, Ontario, annual survivorship for adult Midland Painted Turtles was  $0.975 \pm (\text{SE}) 0.015$  for males and  $0.985 \pm 0.010$  for females from 1990 to 2002 (Samson 2003). Juvenile survivorship increased with age and averaged  $0.711 \pm (\text{SD}) 0.134$  to  $0.747 \pm 0.074$  for one to three year-olds, and from  $0.939 \pm 0.031$  to  $0.967 \pm 0.028$  for four to seven year-olds in Algonquin Park (Samson 2003).

Numerous studies of Painted Turtles exist, but relatively few can provide reliable estimates of sex ratios because few have absolute estimates of abundance and trapping methods are biased (Ream and Ream 1966; Vogt 1979). The sex ratio of our population was female biased (males/females = 0.53), but within the range of normal fluctuations for a small population of Painted Turtles. The sex ratio of a small population (15–37 adults) in Long Island averaged 0.98 (male/female) over 18 years but fluctuated from 0.36 to 1.91 (Zweifel 1989).

Juveniles are well represented in our population, which demonstrates nesting and hatching success. Our adult:juvenile ratio was 0.9:1, which is lower than the average from Zweifel (1989) long-term study in Long Island (2.16:1), and lower than most Painted Turtle populations studied elsewhere (range 0.67:1 to 5.0:1, reviewed in Zweifel 1989). Lindeman (1996) reported a high proportion of juveniles for Western Painted Turtles at a wastewater lagoon site in Idaho (0.75:1 adult:juvenile). Lindeman (1996) speculated that the high proportion of juveniles at their site could be because their site (1) was recently colonized (18 years) and possibly still growing; (2) had low nest predation rates (zero of 13 nests depredated); and/or (3) had relatively large clutch sizes, high growth rates, and early maturity due to nutrient enrichment and food availability. A high proportion of juveniles may indicate a growing population (de Lathouder *et al.* 2009), but this may not be the case at our site considering the small population size, low density, and presence of several very large (presumably old) individuals. Our population has a slightly unusual pattern of size structure suggesting that young adults are somewhat underrepresented. We do not have the data to assess this further, but it could be possible that young naïve adults exploring their environment move to population sinks, such as lakes that are more frequented by the public or travel onto roads. Younger turtles have a disadvantage because they do not possess knowledge of the locations and relative quality of ponds withing the immediate landscape (Zweifel 1989; Bowne *et al.* 2006).

Population density was 6.5–10 turtles/ha at our site, which is lower than 10 wetlands examined in the USA (25–838 turtles/ha; Ernst *et al.* 1994). The low density may be a result of living close to the northern limit of its range or because urban populations face many challenges (Conner *et al.* 2005; Budischak *et al.* 2006; Peterman and Ryan 2009). Research investigating small populations have significant value because as species declines continue, small populations will become more common. Changes in environmental conditions, such as low water levels, may become more frequent as a result of rapid climate change and can place turtles at increased risk of stochastic events (e.g., mass mortality predation events) that can have long lasting detrimental impacts on species with slow life histories (Keevil *et al.* 2018; Gasbarrini *et al.* 2021). The persistence of these fragments will be important for conserving genetic diversity. Despite increased risk of extirpation, small populations do occur and persist; Zweifel's (1989) long-term study population of Eastern Painted Turtles in Long Island ranged in population size from 21–57 turtles and only 9–14 adult females over the 18-year study. Shoemaker *et al.* (2013) estimated that Bog Turtle (*Glyptemys muhlenbergii*) populations containing a minimum of 15 adult females would have >90% probability of persisting for >100 years. However, that estimate of persistence may be a gross overestimate because demographic and environmental stochasticity, loss of genetic variability, and catastrophes were not taken into account in these models (Reed and McCoy 2014). Despite the small population size and absence of nearby rescue populations, the Rockwood Park population appears to have high survivorship rates (at least for some adults) and demonstrated nesting/hatching success, and provides unique conservation value being an urban population at the northern limit of its range and home to the five largest Eastern Painted Turtles recorded to date.

### Author Contributions

Conceptualization: C.L.B.; Investigation: C.L.B. and S.A.S.; Data Curation: C.L.B. and S.A.S.; Project Administration: C.L.B.; Writing – Original Draft: C.L.B.; Writing – Review & Editing: C.L.B. and S.A.S.; Visualization: C.L.B.; Funding Acquisition: C.L.B.

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### Supplementary Materials:

**TABLE S1.** Input values used to calculate population size estimates for male, female, and juvenile Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick, from 2014–2016.

**TABLE S2.** Jolly-Seber estimates for the proportion of the Eastern Painted Turtle (*Chrysemys picta picta*) population in Rockwood Park, New Brunswick marked in sample two (Spring 2015), sample three (Late Summer 2015), and sample four (Spring 2016).

**TABLE S3.** Straight midline carapace length growth (cm) for Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick over (1) an annual period from Late Summer 2014 to Late Summer 2015 or Spring 2015 to Spring 2016; (2) overwinter period from Late Summer 2014 to Spring 2015 or Late Summer 2015 to Spring 2016; and (3) summer period from Spring 2015 to Late Summer 2015 or Spring 2016 to Late Summer 2016.

**TABLE S4.** Statistical significance ( $P$ ) for annual, overwinter, and summer growth of Eastern Painted Turtle (*Chrysemys picta picta*) in Rockwood Park, New Brunswick from a multivariate Generalized Linear Model with normal distribution and identity link function for the dependent variables.

**TABLE S5.** Statistical significance ( $P$ ) of sampling session, sex/age, and straight midline carapace length (MCL) of Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick from a multivariate Generalized Linear Model with normal distribution and identity link function for the dependent variable weight.

**TABLE S6.** Surface water chemistry of Crescent Lake, 19 August 2008 (unpubl. data from Atlantic Coastal Action Plan Saint John).

**FIGURE S1.** Weight and straight midline carapace length of adult male and female and juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick.

**FIGURE S2.** Straight midline carapace length for each age class of juvenile Eastern Painted Turtle (*Chrysemys picta picta*) captured in Rockwood Park, New Brunswick.

## Exotic Red-eared Slider (*Trachemys scripta elegans*) observations and removal from New Brunswick, Canada

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### Abstract

Observations of exotic Red-eared Slider (*Trachemys scripta elegans*) turtles are rare in New Brunswick (NB), Canada, but we found multiple individuals residing in the recreational area of Rockwood Park, Saint John. We present evidence that suggests that Red-eared Sliders are able to overwinter in at least one water body in Rockwood Park. Seven Red-eared Sliders were removed from water bodies in NB from 2014 to 2016 and one in 2022. Currently, there are no known locations with Red-eared Sliders persisting in NB.

Key words: Invasive species; New Brunswick; overwintering; Painted Turtle; Snapping Turtle; Wood Turtle; Red-eared Slider; threats; *Trachemys scripta*; urban

### Résumé

Les observations de Tortues à Oreilles Rouges (*Trachemys scripta elegans*) exotiques sont rares au Nouveau-Brunswick (NB), Canada, mais nous avons trouvé plusieurs individus résidant dans la zone récréative de Rockwood Park, Saint John. Nous présentons des preuves qui suggèrent que les Tortues à Oreilles Rouges sont capables d'hiverner dans au moins un plan d'eau du parc Rockwood. Sept Tortues à Oreilles Rouges ont été retirées de plans d'eau au NB de 2014 à 2016 et une en 2022. À l'heure actuelle, il n'y a aucun endroit connu où des Tortues à Oreilles Rouges persistent au NB.

Mots clés : Les espèces envahissantes; Nouveau-Brunswick; hiverner; Tortue Peinte; Tortue Serpentine; Tortue des Bois; Tortue à Oreilles Rouges; des menaces; *Trachemys scripta*; urbain

### Introduction

Red-eared Slider (*Trachemys scripta elegans*) is native to south-central United States and northeastern Mexico, but introduced populations (originating from the release of unwanted pets) are now established in more than 70 countries as well as multiple states in the United States where they historically did not occur (Turtle Taxonomy Working Group 2021). The Invasive Species Specialist Group of the International Union for the Conservation of Nature's Species Survival Commission has ranked Red-eared Slider one of the top 100 worst invasive alien species worldwide (Invasive Species Specialist Group 2023). Red-eared Sliders are a threat to the ecosystem because, as with any non-native or captive animal, they could be carriers of disease or parasites (Brenes *et al.* 2014; Invasive Species Specialist Group 2019). In addition, they could compete with native turtles for food or basking sites (Invasive Species Specialist Group 2019).

In Canada, Red-eared Sliders have been confirmed to overwinter and breed successfully in southwestern

Ontario, and records exist for 130 spatially distinct sites in Ontario (Gillingwater 2013; Seburn 2015; Dupuis-Desormeaux *et al.* 2022b). Kikillus (2010) calculated that Red-eared Sliders need 502 degree-days above 20.2°C for their eggs to incubate successfully. Thus, modelling suggests that Canada is too cool for successful incubation because the warmest areas are below this value (e.g., 459.9 degree-days above 18°C in Windsor, Ontario; ECCC 2022); however, degree-days vary at microsites across the landscape and can allow survival and successful reproduction in cooler regions (Kikillus 2010). In Maritime Canada, numerous slider observations exist in Halifax-Dartmouth, Nova Scotia, with at least one record for every large pond, lake, and stream in the area (J. Gilhen unpubl. data). However, such observations are rare in New Brunswick (NB; D. McAlpine unpubl. data). As of 3 February 2023, iNaturalist included only two Red-eared Slider observations in NB (Wilson 2020; Rogers 2021), while 56 occurred in Nova Scotia. Our goals were to document the presence of

feral Red-eared Sliders in NB, examine evidence for overwintering, and implement a removal program.

## Methods

### Study area

Rockwood Park in Saint John, NB (45.2941°N, 66.0591°W) is one of the oldest (established in 1896) and largest (~695 ha) city parks in Canada. It includes 10 large lakes (1.4–10.3 ha) and several ponds (up to 0.8 ha). Two of the lakes, Lily Lake and Fisher Lakes (a single lake composed of multiple water bodies connected by narrow channels), are located within the park's designated recreation zone. Both the lakes and their surrounding riparian areas receive heavy public use (e.g., hiking, cycling, swimming, angling, non-motorized boating, horseback riding, and dog exercise). Native turtle species found in Rockwood Park include Eastern Painted Turtle (*Chrysemys picta picta*) and Snapping Turtle (*Chelydra serpentina*). Wood Turtle (*Glyptemys insculpta*) is occasionally observed, but these individuals are suspected to have been translocated by people.

### Survey methods

In June 2014, we initiated a citizen science project, asking the public to submit records of turtles observed in NB. Records were listed as confirmed if they were accompanied by a clear photograph or submitted by a qualified herpetologist or naturalist; all others were listed as unconfirmed. Red-eared Sliders were identified to subspecies by their shell and head shape, colours, and striping patterns, which included the diagnostic red head stripes in the individuals that we captured. We engaged the public by posting signs in Rockwood Park, a data request on the Rockwood Park website, and using social media posts (Facebook). We visited sites in Rockwood Park and elsewhere in the Saint John area where citizens observed turtles to try to confirm species and whether individuals were still present.

We used baited hoop traps to sample for turtles at 14 sites in Rockwood Park and four sites in the Saint John area. Hoop traps were 84 cm long, had three oval hoops 45–48 cm in diameter, 2.5 cm mesh, and were baited with chopped fish. The hoop traps were deployed for a total of 2669 trap-days during the active season (May–September) in 2014–2016. Our hoop trap sampling covered all waterbodies in Rockwood Park, except for Lily Lake. Lily Lake is frequently visited by park staff and visitors; thus, we are fairly confident that any turtles present would be detected. Only Red-eared Sliders were observed in the Lily Lake area, so we only deployed a basking trap at this site and reserved our hoop traps for sites where multiple turtle species might be found.

### Additional data sources

The New Brunswick Museum and the Province of New Brunswick both compile turtle observations recorded in NB. Staff members from the Department of Energy and Resource Development (conservation officers and rangers) record turtle observations opportunistically while working in the field. Both organizations also compile observations voluntarily submitted by citizens.

### Red-eared Slider removal

At locations where Red-eared Sliders were confirmed present, we used baited hoop traps, a basking trap, and hand captures to capture sliders. Six baited hoop traps were deployed at the First Arch section of Fisher Lakes on 16–18 July, 20–25 July, and 5–8 August 2014. Basking traps are an effective method for catching turtle species that are prolific baskers (Browne and Hecnar 2005). We deployed a basking trap at the First Arch section of Fisher Lakes from 24 June to 21 July 2016 and at Lily Lake from 21 July to 9 September 2016. The basking trap was 61 × 122 cm in size and followed the design described in Browne and Hecnar (2005). We checked all traps daily. Adult sliders were sexed by the presence or absence of secondary sex characteristics (elongate foreclaws, enlarged tail base, and more posterior positioning of the vent in males; Ernst *et al.* 1994). Healthy Red-eared Sliders that we captured were rehomed with responsible pet owners.

To prevent the release of additional pet turtles, we developed a program to teach the public about the threat of exotic species and why pet turtles should not be released into the wild. We engaged the public using four tactics: an educational display featuring two of the wild-caught Red-eared Sliders at the Rockwood Park Interpretation Centre, talks and guided hikes by park interpretive staff, a volunteer program for park visitors to check the basking trap while canoeing/kayaking, and social media posts (Facebook) and online classified advertising (Kijiji).

## Results

### Observations

As of 7 March 2022, we collected 275 observations of turtles in NB from citizens. Of these, 72 observations were from Rockwood Park (our target area). These included 30 unconfirmed Red-eared Slider observations, all from within Rockwood Park from the 1990s to 2016. Red-eared Sliders were observed at Lily Lake and Fisher Lakes (including the First Arch, A-frame, A-frame picnic site pond, and main sections of Fisher Lakes), and possibly Long Lake in Rockwood Park. Three turtle shells, identified as adult sliders by a knowledgeable amateur herpetologist, were

observed at Little Harrigan Lake. Park staff found and submitted a dead Red-eared Slider from the main section of Fisher Lakes on 21 May 2015.

The New Brunswick Museum and provincial databases each contained one slider observation. One carcass was collected from York County, NB, on 30 May 2010 (D. McAlpine unpubl. data). One slider was observed walking along a driveway in a residential area in Fredericton, NB, in October 2015 (M. Toner unpubl. data).

### Captures

Between 2014 and 2016, we caught and removed seven Red-eared Sliders. Four were removed from the First Arch section of Fisher Lakes: two females were caught in hoop traps on 17 and 22 July 2014, one female was caught by hand on 6 May 2015, and one female was caught by basking trap on 2 July 2016. No individuals have been observed in First Arch since this date. We estimate that approximately five to nine individuals were present at First Arch when we began our study. Five Red-eared Sliders were caught by anglers in First Arch and released with swallowed hooks in 2014, some or all may have been killed by the hooks because we were not able to catch five individuals from First Arch following this event (C.L.B. and S.A.S. unpubl. data). On 12 March 2019, the two females caught in First Arch in 2014 were screened by radiograph for hooks, but none were found.

We removed two sliders from Lily Lake: a female captured by hand on 2 August 2015 and a male captured by basking trap on 2 August 2016. No turtles were observed in Lily Lake from this date until June 2022 when an additional female Red-eared Slider was observed, captured, and rehomed to the Rockwood Park Interpretation Centre indoor turtle display.

Outside our study area, one male was captured opportunistically by hand at a wetland just outside Saint John (45.3700°N, 65.9611°W) on 21 August

2015. Three Red-eared Sliders (species confirmed by photograph) have been observed in recent years; one on the Miramichi River (46.9548°N, 65.5836°W) on 20 August 2019 (A. Chester pers. comm. 20 August 2019), one in Rothesay (45.3805°N, 65.9264°W) on 28 July 2020 (Wilson 2020), and one in Dieppe (46.0664°N, 64.7036°W) on 6 August 2021 (Rogers 2021). Red-eared Sliders have not been resighted in these areas since the original sightings.

### Evidence of overwintering

Red-eared Sliders were observed in sequential years at only two locations in NB: Lily Lake (Table 1) and the First Arch section of Fisher Lakes (Table 2) in Rockwood Park. Staff at Maritime Daytripping observed Red-eared Sliders in Lily Lake in 2014 and 2015 and we removed individuals in 2015 and 2016 (Table 1). Red-eared Sliders were observed in First Arch each year from 2012 to 2016 (Table 2). Early and late year observations were recorded at First Arch (Table 2) and the slider observation on 5 May 2015 is noteworthy because the winter ice and snow did not clear from this area until late April in 2015. Two sliders were observed on 6 May 2015, and we were able to catch one. The captured turtle was shedding her scutes, and the older scutes had mineral staining (Figure 1), suggesting that she had spent significant time in bottom sediments.

### Discussion

Slider observations are less frequent in NB than in many other regions where they have been introduced (e.g., Florida, USA, Emer 2004; Ontario, Seburn 2015; California, USA, Lambert *et al.* 2019). This could be because the human population size (and presumably also the number of unwanted pet turtles) is relatively low in NB (Table 3). But a better explanation may be because the climate is colder than in other Canadian locations where overwintering has been documented (Table 3). It is unknown whether sliders

**TABLE 1.** Red-eared Slider (*Trachemys scripta elegans*) observations and three captures from Lily Lake in Rockwood Park, Saint John, New Brunswick.

Date	No.	Comments	Confirmed	Removed
2014	4	Sticking their heads out of the water in Lily Lake.	No	No
2014	1	Found by road at Lily Lake; moved to First Arch Lake.	No	Yes
Summer 2014	1	Swimming in Lily Lake.	No	No
July or Aug. 2014	1	On rock in Lily Lake.	No	No
20 Aug. 2014	1	Basking on a branch in Lily Lake.	No	No
30 July 2015	1	Swimming in Lily Lake.	Yes	No
2 Aug. 2015	1	Female caught by park staff by hand on grass next to Lily Lake.	Yes	Yes
15 Sept. 2015	1	Filmed by tourist; looks like a slider but video is not clear enough to confirm.	No	No
2 Aug. 2016	1	Male caught in basking trap in Lily Lake.	Yes	Yes
June 2022	1	Female caught by hand.	Yes	Yes

**TABLE 2.** Red-eared Slider (*Trachemys scripta elegans*) observations and four captures from First Arch Lake in Rockwood Park, Saint John, New Brunswick.

Date	No.	Comments	Confirmed	Removed
~1998	3	Small (~8 cm diameter) green turtles.	No	No
~2008	>1	On the rocks in First Arch.	No	No
2012	1		No	No
2012 or 2013	1		No	No
2012 or 2013	1		No	No
July 2013	3	On rocks on a hot sunny day.	No	No
4 Oct. 2013	3	Photo of two on the rock; appear to be sliders but cannot confirm.	No	No
Early spring 2014	1	Basking on largest rock in First Arch.	No	No
2014	5	Caught in one evening accidentally while fishing using worms for bait on small barbless J-hooks. Each turtle swallowed the hook, lines were cut and turtles released. All were slightly different sizes (~15–23 cm). Photographs confirm species.	Yes	No
2014	1	Found by road at Lily Lake; moved to First Arch Lake.	No	No
17 June 2014	2	One large turtle and one smaller turtle basking on rocks around noon.	No	No
29 June 2014	1	Small turtle basking around noon.	No	No
4 July 2014	2	Basking at 1530.	No	No
14 July 2014	3	Basking; photo appears to show sliders but cannot confirm.	No	No
17 July 2014	1	Female caught in hoop trap.	Yes	Yes
18 July 2014	2	Basking; photo of one looks like slider but cannot confirm.	No	No
22 July 2014	1	Female caught in hoop trap.	Yes	Yes
21 Aug. 2014	1	Basking; looked like slider but too distant to confirm.	No	No
27 Aug. 2014	1	Red-eared Slider swimming in the water.	Yes	No
5 May 2015	1	Basking on rocks; looked like slider but too distant to confirm.	No	No
6 May 2015	1	Female caught by hand at edge of water.	Yes	Yes
7 May 2015	1	Basking on rock; red stripes on sides of head.	Yes	No
2015	>1	Small turtles in water.	No	No
15 May 2015	2	Basking on rocks.	Yes	No
2016	1	Small turtle.	No	No
2016	1	Turtle head in the water.	No	No
2 July 2016	1	Female caught in basking trap.	Yes	Yes

can overwinter in most of NB; two slider carcasses found in May (York County in 2010 and the main section of Fisher Lakes in 2015) may have been the result of overwinter mortality. However, Red-eared Sliders have been recorded to successfully overwinter as far north as Nitaure, Latvia, at more than 57°N (Nekrasova *et al.* 2022), much farther north than NB's most northern points (<49°N). Failed overwintering attempts have been documented for both native and exotic adult turtles in Ontario and could be the result of water-level fluctuations, poor overwintering site selection, or seeking mid-winter basking opportunities (Dupuis-Desormeaux *et al.* 2022a).

Evidence of successful overwintering in NB does not exist except for our data from the First Arch in Rockwood Park. Although it is possible that the sliders residing in First Arch were the result of multiple releases each year and not a small number of

individuals that survived and overwintered, the latter situation is far more likely. Evidence to support this includes: observations of multiple individuals in sequential years; an individual captured on 6 May 2015, shortly after ice-out, with mineral staining from the bottom sediments; multiple individuals present at this site, but observations rare from other water bodies; and no reestablishment of sliders following our removal program.

The prolific basking habits of Red-eared Sliders generated numerous turtle observations submitted by citizens and originally gave an impression of abundance. However, the Red-eared Slider population at Rockwood Park in the Lily and Fisher Lakes area was probably only 11 or 12 individuals in total over the span of our study (six removed alive, five caught by anglers and released with ingested hooks on one night at First Arch, and one dead slider from the main



**FIGURE 1.** Mineral staining on three plastral scutes (one gular and two anal scutes) from a Red-eared Slider (*Trachemys scripta elegans*) that was caught at First Arch in Fisher Lakes on 6 May 2015. Photo: Andrew Sullivan.

section of Fisher Lakes). We eradicated the exotic Red-eared Slider population in Rockwood Park with relatively little effort using baited hoop traps, hand captures, and a basking trap combined with a public education program.

### Author Contributions

Conceptualization: C.L.B.; Investigation: C.L.B. and S.A.S.; Data Curation: C.L.B. and S.A.S.; Project Administration: C.L.B.; Writing – Original Draft: C.L.B.; Writing – Review & Editing: C.L.B. and S.A.S.; Visualization: C.L.B.; Funding Acquisition: C.L.B.

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**TABLE 3.** Provincial population size and climate comparisons from three representative sites in New Brunswick (NB), Nova Scotia (NS), and Ontario (ON).

Province	Human population size*	Location	Average daily temperature, °C (SD)†		Average annual degree-days‡	
			January	July	Above 10°C	Above 18°C
NB	$0.8 \times 10^6$	Saint John	-7.9 (2.3)	17.1 (0.7)	708.3	36.4
NS	$1.0 \times 10^6$	Halifax	-4.1 (1.9)	18.8 (1.0)	921.9	114.3
ON	$15.1 \times 10^6$	London	-5.6 (2.8)	20.8 (1.3)	1256.3	255.5

\*Statistics Canada 2022.

†From 1981 to 2010 (ECCC 2022).

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## Note

### First records of Seaside Dragonlet (*Erythrodiplax berenice*) in New Brunswick, Canada: range expansion possibly mediated by climate warming

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#### Abstract

The first occurrences of Seaside Dragonlet (*Erythrodiplax berenice* (Drury, 1773); Odonata: Libellulidae) are reported for New Brunswick, Canada, from seven sites along the Bay of Fundy coast in the southern part of the province. The species joins a suite of several other Odonata species of southern affinity that have been newly documented for New Brunswick over the past 15 years, and its occurrence may represent range expansion resulting from warming climate.

**Key words:** Seaside Dragonlet; Érythrodiplax côtier; *Erythrodiplax berenice*; New Brunswick; climate warming

Seaside Dragonlet (*Erythrodiplax berenice*) is a dragonfly species strongly associated with saline habitats and the only truly marine dragonfly, with larvae commonly occurring in salinities exceeding that of seawater (Corbet 1999). In North America, the species is found in salt marshes along the Gulf of Mexico and the Atlantic coast from Florida to Nova Scotia (Paulson 2011). It is also found in saline lakes in the southwestern United States (Nikula *et al.* 2003). In Canada, Seaside Dragonlet has been reported from Nova Scotia and Quebec (Catling *et al.* 2005). In Nova Scotia, it was first recorded in Yarmouth County in 1957 and has since been found from localities scattered along the Atlantic coast of the southwestern part of the province, between Digby and Halifax Counties (Bridgehouse 2007; Brunelle 2010). A single inland collection from southern Quebec was made in 1911; it occurred away from suitable habitat, and the voucher specimen has since been lost (Skinner *et al.* 2012). Seaside Dragonlet has been found in Maine along the coast north to Washington County, just 2.8 km from the nearest coastline in New Brunswick (Abbott 2006–2022).

On 3 and 8 July 2012, we visited salt marshes at Belliveau Cove and Rossway, Digby County, Nova

Scotia, and found Seaside Dragonlet to be abundant. Specimens were identified using Paulson (2011). These sites are 82 km and 68 km, respectively, directly across the Bay of Fundy from mainland New Brunswick, and these observations prompted us to undertake subsequent directed surveys of the species in New Brunswick. On 11 July 2012, we searched five salt marsh sites in the South Musquash to Dipper Harbour areas of St. John County, New Brunswick (Table 1). An additional survey was undertaken at the South Musquash site on 4 September 2012. Seaside Dragonlet was not detected at any of the New Brunswick sites.

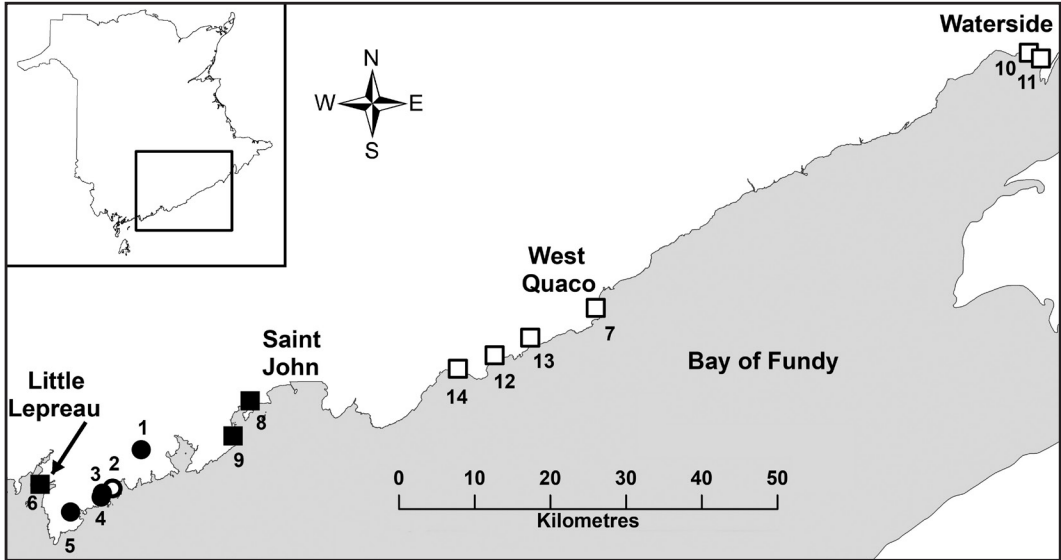
On 25 July 2020, we detected Seaside Dragonlet during a visit to a salt marsh at Little Lepreau, Charlotte County, New Brunswick (45.12867°N, 66.48373°W; Figure 1). Three males and one female were observed; two males were collected and deposited in the New Brunswick Museum invertebrate collections (NBM-IN-070583). We revisited the site on 1 August 2020, when a further nine males and four females were observed, and again on 7 August 2020, when another male and female were recorded. At this site, Seaside Dragonlet was generally associated with high marsh areas containing salt pannes and pools

**TABLE 1.** Locations surveyed for Seaside Dragonlet (*Erythrodiplax berenice*) in New Brunswick (NB) and Nova Scotia (NS), Canada. Site numbers for New Brunswick are listed in order of initial survey and correspond to Figure 2.

Site no.	Location	Latitude, °N	Longitude, °W	No. Seaside Dragonlet observed*			NB Museum accession number
				2012	2020	2021	
	Belliveaus Cove, Digby Co., NS	44.3842	66.0797	200+	—	—	
	Rossway, Digby Co., NS	44.5799	65.9345	10	—	—	
1	South Musquash, St. John Co., NB	45.1699	66.3135	0	4	—	NBM-IN-070586
2	Chance Harbour, St. John Co., NB	45.1241	66.3620	0	0	—	
3	Moose Creek, St. John Co., NB	45.1183	66.3791	0	1	—	NBM-IN-070587
4	Round Meadow Cove, St. John Co., NB	45.1137	66.3808	0	6	2	NBM-IN-070585; NBM-IN-070593
5	Dipper Harbour, St. John Co., NB	45.0961	66.4324	0	1	—	NBM-IN-070590
6	Little Lepreau, Charlotte Co., NB	45.1287	66.4834	—	19	8	NBM-IN-070583; NBM-IN-070584; NBM-IN-070588; NBM-IN-070591
7	West Quaco, St. John Co., NB	45.3344	65.5468	—	0	—	
8	Saint's Rest Marsh, St. John Co., NB	45.2275	66.1302	—	0	3	NBM-IN-070592
9	Lorneville Creek, St. John Co., NB	45.1857	66.1589	—	3	—	NBM-IN-070589
10	Newfoundland Creek, Albert Co., NB	45.6290	64.8082	—	—	0	
11	Long Marsh Creek, Albert Co., NB	45.6220	64.7880	—	—	0	
12	Gardner Creek, St. John Co., NB	45.2796	65.7183	—	—	0	
13	Tynemouth Creek, St. John Co., NB	45.3001	65.6581	—	—	0	
14	Emerson Creek, St. John Co., NB	45.2639	65.7802	—	—	0	

\*— = site not surveyed that year.

**FIGURE 1.** Male Seaside Dragonlet (*Erythrodiplax berenice*) photographed at Little Lepreau, Charlotte County, New Brunswick, Canada, on 25 July 2020. Photo: D.L. Sabine.



**FIGURE 2.** Sites surveyed for Seaside Dragonlet (*Erythrodiplax berenice*) on the Bay of Fundy in southern New Brunswick, Canada. Site numbers correspond to locations listed in Table 1. ● = species not detected in 2012 but present in 2020; ○ = species not detected in 2012 or 2020; ■ = site surveyed and species detected in 2020 and/or 2021; □ = site surveyed but species not detected in 2020 and/or 2021.

(Figure 3) and was typically detected by walking and flushing individuals perched on cordgrass (*Spartina* sp.). The Little Lepreau site is situated 5.3 km north-west of the nearest site previously surveyed in 2012 (Table 1).

This discovery prompted a survey of eight additional salt marshes, primarily between Little Lepreau and Saint John, with one survey to the east at West Quaco, during the first week of August 2020. Seaside Dragonlet was detected at five additional sites, four of which had been surveyed unsuccessfully in 2012 (Table 1, Figure 2). In July and August 2021, we directed a further search effort to six sites northeastward from Saint John, to Waterside, Albert County, in the upper Bay of Fundy. Seaside Dragonlet was discovered at only one additional site, Saint's Rest Marsh in Saint John, which was surveyed unsuccessfully in 2020, and is the easternmost population discovered thus far (Figure 2). In addition, two of the occupied sites discovered in 2020 were re-surveyed in 2021, both in mid-July and again in late August. Seaside Dragonlet was present during all visits at both sites, confirming at least short-term persistence of these populations. Voucher specimens from all sites have been deposited in the New Brunswick Museum invertebrate collections (Table 1).

Over the past 15 years, a number of Odonata species have been newly documented for New Brunswick, including Southern Pygmy Clubtail (*Lanthus vernalis* Carle, 1980; Harding 2007); Martha's Pen-



**FIGURE 3.** Salt marsh habitat at Little Lepreau, Charlotte County, New Brunswick, Canada, on 25 July 2020. Photo: D.L. Sabine.

nant (*Celithemis martha* Williamson, 1922; Klymko 2007); Halloween Pennant (*Celithemis eponina* (Drury, 1773)) and Citrine Forktail (*Ischnura hastata* (Say, 1839); Makepeace *et al.* 2017); Scarlet Bluet (*Enallagma pictum* Morse, 1895; McAlpine *et al.* 2017); Lilypad Forktail (*Ischnura kellicotti* Williamson, 1898; Klymko *et al.* 2019); and Black Saddlebags (*Tramea lacerata* Hagen, 1861) and River Bluet (*Enallagma anna* Williamson, 1900; Makepeace and Lewis 2020). For most of these species, the New Brunswick records are a northward expansion of the prior known distribution, and the species are being detected in the southwestern quadrant of the province. Three of the species are considered to be associated with the coastal plain

(Martha's Pennant, Scarlet Bluet, and Lilypad Forktail); climate warming has been suggested as a potential reason for the apparent range expansions of those species (McAlpine *et al.* 2017; Klymko *et al.* 2019).

This pattern of recent additions of Odonata species of primarily southern affinity to the southwestern portion of New Brunswick contrasts with the list of 11 Odonata species that were newly documented for the province during the previous decade (Brunelle 1999, 2000; Catling 2002; Sabine *et al.* 2004). These earlier reports were of species of both southern and northern affinities, with most occurring across latitudes either similar to or predominantly north of New Brunswick. Initial records of these earlier species were documented from areas widely scattered throughout the province. Documentation of new Odonata species in New Brunswick appears to have recently shifted from a pattern of detection of species already occurring in the province but previously overlooked, to detection of new species arriving through range expansion from the south.

Determination of whether a newly documented species represents a recent arrival resulting from range expansion or simply lack of prior detection by earlier surveyors can be challenging, because negative survey data are not often documented or reported. Seaside Dragonlet, in particular, occupies a specialized habitat where Odonata species richness and abundance are low and, thus, is seldom visited during general surveys. Hence, existing populations of Seaside Dragonlet are more likely to be undetected than many other Odonata species. However, we suggest that this is not the case in New Brunswick. In the 1990s, P.-M. Brunelle conducted extensive surveys of Odonata in Charlotte County and surrounding areas. Although details of negative search data for this species were not published, Brunelle did state that he found it curious that Seaside Dragonlet had not been found in the Bay of Fundy (Brunelle 2010), implying that a targeted survey had occurred. This is further supported by Bridgehouse (2007), who reported that Brunelle had unsuccessfully searched 27 salt marshes for Seaside Dragonlet in New Brunswick and Prince Edward Island. More significantly, our documentation of unsuccessful, prior, directed surveys in appropriate habitat and flight season, immediately following familiarization with the behaviour of the species in a neighbouring jurisdiction, provides evidence that it was likely not present in 2012. The subsequent discovery of the species at almost all of the same survey sites eight years later is strongly suggestive of range expansion during the intervening time.

The capacity of a dragonfly species to colonize new areas will be determined primarily by the ability of adults to migrate or disperse in appropriate numbers and on the suitability of newly colonized habitat

for successful reproduction. Seaside Dragonlet was considered to be a migratory species by Russell *et al.* (1998) and Geijskes (1967). In addition, ship transport has been suggested as a potential cause of vagrant occurrences of this species by Catling *et al.* (2017). Given the apparent capacity of adult Seaside Dragonlet for long-distance flight, dispersal to the Bay of Fundy coast of New Brunswick from nearby populations in Maine and Nova Scotia has likely been a long-term, ongoing process. The ability of this species to complete its life cycle in Bay of Fundy salt marshes, after arrival of vagrant or dispersing adults, is likely the more important factor determining successful population establishment.

Because of its larval habitat requirements, Seaside Dragonlet is unique among Odonata in that changes in ocean water temperatures might conceivably impact population establishment and persistence at the northern edge of its range. Water temperatures in the Bay of Fundy have increased in recent years, both subsurface (Koopman *et al.* 2014) and surface (Koopman *et al.* 2014; Diamond 2021). In the broader Gulf of Maine, continuous slow warming of water over the last five decades, with accelerated warming over the past 10 years, has been documented (Seidov *et al.* 2021). Annual mean air temperatures in Atlantic Canada increased by 0.7°C between 1948 and 2016 and are predicted to increase a further 1.3°C by 2050 (Zhang *et al.* 2019). It seems likely that the ongoing climate and ocean warming trend in the region have aided the apparent expansion of Seaside Dragonlet northward along the Bay of Fundy coastline into New Brunswick. Future expansion of the species to the upper Bay of Fundy, and eventually to the extensive salt marshes of the Gulf of St. Lawrence shoreline of New Brunswick, might be expected.

### Author Contributions

Conceptualization: D.L.S., M.E.J.S., and H.S.M.; Investigation: H.S.M., D.L.S., and M.E.J.S.; Writing – Original Draft: D.L.S., M.E.J.S., and H.S.M.; Writing – Review & Editing: M.E.J.S., H.S.M., and D.L.S.

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## Preliminary estimate of a Gray Treefrog (*Hyla versicolor*) population at a protected site in New Brunswick using photo identification and community science

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### Abstract

We provide a preliminary population estimate ( $n = 120$ , 95% CI 65–722) of (male) Gray Treefrog (*Hyla versicolor*) at the Hyla Park Nature Preserve, New Brunswick, Canada's first amphibian conservation site. As proof of concept, we also demonstrate the efficacy of a minimally invasive photographic identification method (PIM) that uses pattern recognition software for estimating the population of a visually cryptic amphibian that is subject to physiological colour change. Finally, we validate the use of PIM data collected by community participants and the opportunity it provides to engage and educate the local community about amphibian conservation.

Key words: Amphibian conservation; citizen scientists; community scientists; *Dryophytes*; pattern recognition software; urban parks

### Introduction

Mark–recapture studies of amphibian species often rely on invasive tagging or marking techniques (e.g., implanting passive integrated transponders or toe clipping; Sullivan and Hinshaw 1992; Donnelly *et al.* 1994). These methods can be expensive and require experienced personnel. Toe clipping can be problematic because amphibians can grow back the appendages, making it difficult to distinguish recaptures (Ritke and Semlitsch 1991; Sullivan and Hinshaw 1992; Donnelly *et al.* 1994). Furthermore, there is evidence that toe-clipping may reduce survival or alter the behaviour of some species of frogs (McCarthy and Parris 2004; Ginnan *et al.* 2014). To avoid invasive techniques for marking individuals, some amphibian research has used photographic identification methods (PIMs) to identify individuals (Donnelly *et al.* 1994; Schoen *et al.* 2015; Romiti *et al.* 2017). Although the technique is not suitable for all species, PIMs can be

used for the re-identification of species that have individually unique and unchanging epidermal patterns. Such methods can be cost-effective, require fewer permits than other wildlife sampling techniques, and may allow surveyors with a range of experience to assist with data collection and analyses (Morrison *et al.* 2011; Deutsch *et al.* 2017). In studies with large photo libraries, matching photos can become time consuming and increase the probability of visual errors, but with pattern recognition software, this technique can become cost-effective (Gamble *et al.* 2008).

Successful mark–recapture studies require many personnel hours, especially if the survey window is short. Studies that require large study areas or many surveys have used community scientists (also referred to as citizen scientists) to help collect meaningful data (Bonney *et al.* 2009; Weber *et al.* 2016). Studies that take advantage of community science can acquire more data in a shorter time, provide education, and foster communication between researchers and the

community (Cooper 2007; Bonney *et al.* 2009). A negative perception by the public of some amphibian species can present conservation challenges (Prokop and Fančovičová 2012; Weber *et al.* 2016; Vergara-Ríos *et al.* 2021); using community science at the local level can help educate and engage the public about the importance of amphibians (Weber *et al.* 2016).

Many protected areas lack basic population data that are critical for tracking population changes to help direct management practices (Busby and Parmelee 1996). Protected zones in urban areas can be subject to threats, such as roads, climate change, pollution, and invasive species, which can alter the distribution of species of interest (Weber *et al.* 2016). Hyla Park Nature Preserve in Barker's Point, New Brunswick, is a small, protected wetland surrounded by urban development. The presence of Gray Treefrog (*Hyla (Dryophytes) versicolor*; taxonomy according to AmphibiaWeb 2023) resulted in the park being protected in 1995, when it became Canada's first amphibian conservation park (McAlpine and Vail 2005). At the time, evidence suggested that Gray Treefrog had a very restricted range in Maritime Canada, although

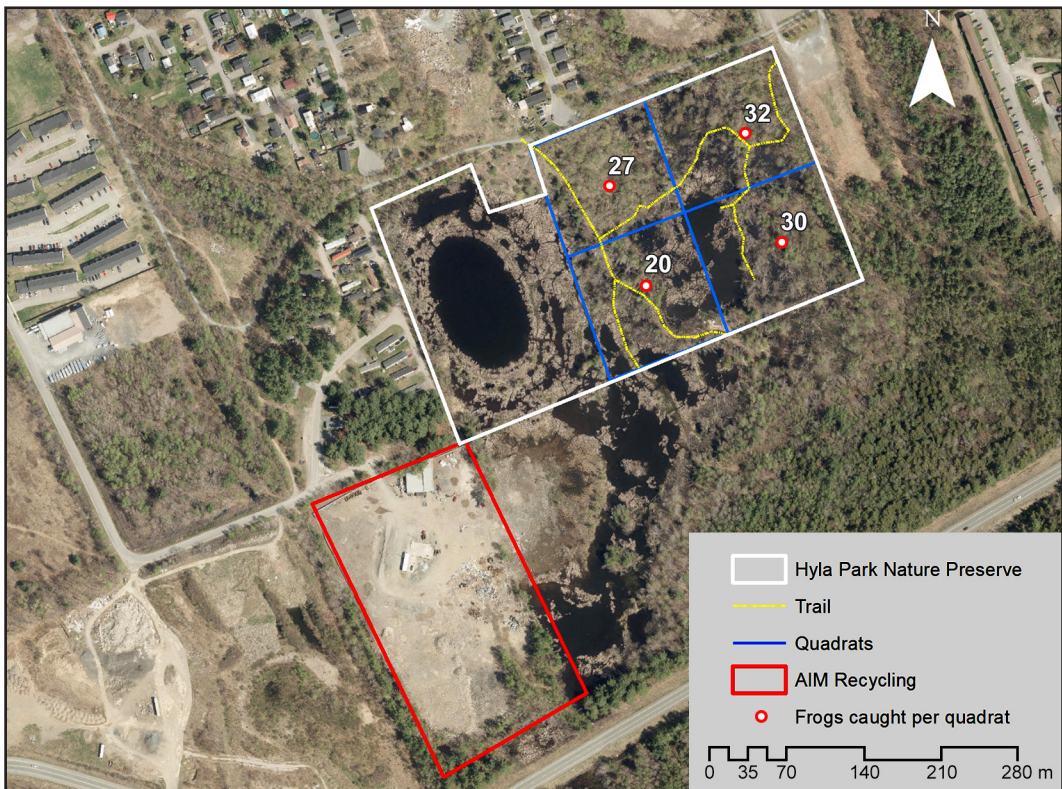
currently it appears to be undergoing a dramatic range expansion in the region (McAlpine *et al.* 2009; McAlpine 2023). The nature preserve is surrounded by housing, invasive species, road networks, and a metal recycling facility (McAlpine and Vail 2009). Because of these outside negative pressures, a baseline study was initiated to monitor the Gray Treefrog population and help with future management decisions. McAlpine *et al.* (1980) emphasized the need for a population estimate of the Hyla Park population.

Our study sought to demonstrate the efficacy of a minimally invasive sampling method for a visually cryptic species subject to diel colour change, validate the use of data collected by community scientists, and provide a preliminary estimate of the population of Gray Treefrogs at Hyla Park Nature Preserve.

## Methods

### *Study area and community scientist training*

We conducted our study in a 7.3-ha area in Hyla Park Nature Preserve (45.951720°N, 66.609181°W) in Barker's Point, New Brunswick, Canada (Figure 1). The nature preserve consists of a provincially



**FIGURE 1.** Aerial view of Hyla Park Nature Preserve, Barker's Point, New Brunswick, Canada, and the surrounding properties, including a metal recycling facility and residential development.

significant wetland, three ponds (~0.49 ha, ~0.22 ha, and ~1 ha, each <2 m in depth), and a young deciduous forest (<50 years). The ponds are mostly accessible by a system of walking trails.

Before the field season, community scientist participants attended a presentation by S.W. on the nature of the Hyla Park site, survey methods, and basic life history of Gray Treefrogs. Participants were taught how to identify a Gray Treefrog (by sight and call), how to capture, handle, and release Gray Treefrogs without injury to the animals and with minimal disturbance, safety precautions required when working the site, and general information about why the study was being undertaken. They were also taught how to use a global positioning system (GPS) free mobile app called Avenza (Avenza Systems Inc., Toronto, Ontario, Canada), which is capable of taking accurate waypoints, and they were encouraged to use this app when they located a Gray Treefrog.

#### Field surveys

During spring 2019, we monitored weekly to pinpoint the onset of the Gray Treefrog breeding season in New Brunswick. Typically, male Gray Treefrogs begin calling in late May to early June at Hyla Park (McAlpine *et al.* 1980). Once calling was detected, we surveyed the site four times from 12 June to 3 July. We conducted surveys when weather conditions were judged favourable for calling by Gray Treefrogs and also for both visual and aural detection by investigators. Conditions included minimal wind (<20 km/h), no precipitation, and an air temperature >20°C. Community scientists ( $n = 7-10$ ) began capturing treefrogs 30 min after sunset (typically around 2100) and surveyed for 1.5 h. The area was split into four quadrats and observers were divided evenly. Participants listened for Gray Treefrogs calling, homed in on a calling frog, and then captured what they believed were calling individuals by hand or with a net. Unfortunately, sex of captured treefrogs was not confirmed, but we believe most or all were males. Participants placed individual treefrogs in translucent plastic containers with air holes. Each container had an identification card that included: participant name, a unique identification code, quadrat, coordinates (from GPS signals received on cell phones) where available, and the type of vegetation or substrate the frog was captured on. Participants then transported the frogs to a photography station established at the field site.

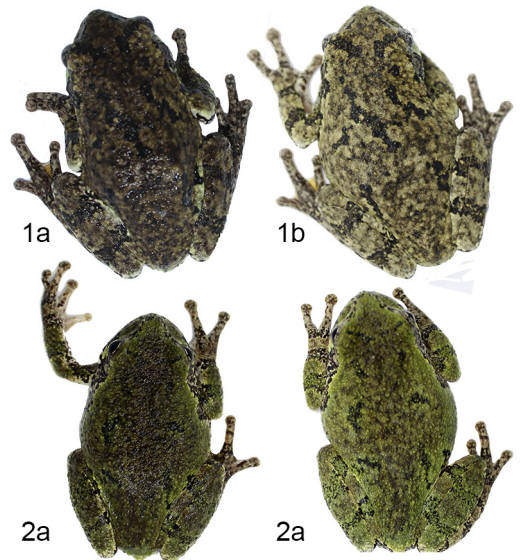
An experienced herpetological researcher was responsible for taking a photo of the dorsal pattern of each Gray Treefrog captured. All individuals were photographed at least twice. Standardized photographs were taken with a Canon EOS Rebel T5i/700D camera (Canon Canada, Brampton Ontario, Canada) using a 0.03 m<sup>3</sup> lightbox photo studio (Amzdeal-US).

The camera was stationed on a tripod, ~1 m over the photo studio. Individual frogs that were dark in colouration at capture (i.e., with dispersed chromatophores) were placed in light blue containers for 2–5 min before being photographed. This prompted pigment in chromatophores to contract, lightening the epidermis and enhancing dorsal pattern recognition when images were later compared (Figure 2). To avoid recaptures, treefrogs were kept in their individual containers until each nightly survey was completed and then released at their capture locations.

To avoid the spread of any potential pathogens among treefrogs, participants washed nets with a 10% bleach solution after each capture and wore latex gloves when handling treefrogs. A clean paper liner was placed on the bottom of the lightbox for each photo, and fresh latex gloves were used before handling each frog for photography. After each nightly survey was completed, frog storage containers were disinfected for 10 min in a bleach solution and participant community scientists never reused a container during a survey.

#### Photographic identification method

We chose the highest quality image to represent captured individuals and cropped each image to



**FIGURE 2.** Photographs demonstrating physiological colour change in Gray Treefrog (*Hyla versicolor*) collected at Hyla Park Nature Preserve, Barker's Point, New Brunswick. Photos 1a and 2a show two different treefrogs with dark epidermis (melanin dispersed in chromatophores) and patterning obscured while the corresponding b photos show the same treefrogs after spending 2–5 min in a light-coloured container. The epidermis is lightened (melanin concentrated in chromatophores) and individually unique patterning is emphasized. Photos: Shaylyn Wallace.

treefrog body length and width. We compared and matched photos using the program Wild-ID (Bolger *et al.* 2012), a graphical interface that automatically presents users with a subset of 20 similar images for comparison. We confirmed recognition of a single individual from this subset, or rejected the entire subset, by visually inspecting the series of contending images. To calculate the accuracy of the matching program, six community scientist participants each analyzed the entire dataset using Wild-ID. Subsequently, we calculated the false acceptance rate (FAR: the probability of matching two images of different individuals) and false rejection rate (FRR: the probability of failing to match two images of the same individual) for each observer to assess error rate (Bendik *et al.* 2013; Cruickshank and Schmidt 2017). The FAR is calculated as the number of false matches divided by the total number of identification attempts. The FRR is calculated as the number of correct matches missed divided by the total number of matching pairs. For comparison, the most experienced participant matched all the images manually and calculated the total time to sort the entire sample without using matching software.

#### Statistical methods

We conducted population estimates in R (v. 4.0.2; R Core Team 2020) using the Schumacher-Eschmeyer (S-E) method in the package “fishmethods” (v. 1.12-1; Nelson 2023) with  $\alpha$  set to 0.05. A Poisson distribution was used to set CIs for Schnabel and a  $t$  distribution for S-E. Abundances were rounded down to the nearest integer.

#### Results

A total of 109 captures were made during the three sampling periods with 80 individual frogs identified (Table 1). From the 109 captures, 24 individuals were captured during two surveys and five were captured during all three surveys (Table 1). Because community scientists located treefrogs largely by call, the population estimates presented here are for males only. An additional 35 treefrog captures were made during the first survey on 12 June, but were excluded from our population estimates and PIM analysis because treefrogs were not subjected to a period of

epidermal lightening (i.e., chromatophore contraction) before photography.

Observer errors using PIMs were rare. While five of the six community scientists each misidentified one pair, yielding a FRR (false rejection rate) of 2.4% (12 mismatched pairs/510 matching pairs), the false acceptance rate (FAR) was zero (0 false pair matches/480 matching attempts). The Wild-ID program scored the recapture photos from 0.005 to 0.25 (mean 0.069; scores range from 0 to 1.0). Using Wild-ID reduced the identification of recaptures to 1.5–2 h per reviewer for our sample; without the software, we estimated ~30 h per reviewer.

The Schumacher and Eschmeyer (1943) population estimator method yielded an abundance of 120 (male) Gray Treefrogs (95% CI 65–722); however, lower and upper CI varied considerably. The inverse SE was 0.0005.

#### Discussion

We used PIMs successfully as a non-invasive mark–recapture technique for male Gray Treefrogs at a site in New Brunswick. Wild-ID software dramatically reduced the number of hours spent identifying recaptures compared with traditional methods that involve searching for matching patterns across all captures manually, which is time-consuming. False acceptance and false rejection rates using the software were low (<2.4%), which validated its use in future Gray Treefrog population studies.

Identifying individuals with PIMs based on their patterns has been used in past amphibian studies (Bendik *et al.* 2013; Elgue *et al.* 2014; Bradley and Eason 2018). However, to our knowledge, PIM has never been tested with a visually cryptic amphibian species capable of diel physiological colour change. Because PIMs require a consistent pattern for identification, software may struggle to recognize individuals among those species that rely on physiological colour change to enhance crypsis. Physiological colour change of individual treefrogs proved to be a problem at the outset of the fieldwork, as some individuals arrived at the imaging station with a heavily pigmented epidermis (i.e., melanin dispersed in chromatophores), making it difficult to distinguish the dorsal pattern. However, we found that we could easily and quickly (<5 min) stimulate the contraction of melanin in chromatophores in individual treefrogs by transferring them to a light blue container. Using this technique, we were able to lighten the epidermal pattern and easily identify individual treefrogs. Note that we did not warm the frogs; the light blue container resulted in the frogs changing their colour.

The sampling effort by community scientists varied across the sampling period. The first survey had

**TABLE 1.** Gray Treefrog (*Hyla versicolor*) captures from Hyla Park, Barker’s Point, New Brunswick, in 2019.

Date	New captures	Recaptures	Total captures
18 June	33	0	33
25 June	35	15	50
3 July	12	14	26
Totals	80	29	109

the most participants (10), whereas the last survey had the fewest (seven). Although limiting the number of community scientists is an option, it reduces community engagement. However, unequal sampling effort also should be considered. Community scientists were not canvassed, but many stated that they volunteered because they were excited to capture treefrogs while contributing to amphibian conservation efforts, and survey dates fit their personal schedules. Vergara-Ríos *et al.* (2021) noted that community science activities that involve a field component are important for developing positive perceptions about amphibians. Providing field opportunities for community scientists is likely to encourage ongoing involvement in projects. By pairing an experienced herpetological researcher with responsibility for Gray Treefrog photography with community scientists who captured treefrogs, we were able to obtain a sufficiently large sample for a preliminary population estimate. We were able to do this on a small budget, while also engaging and educating the local community about amphibian conservation, as well as the value of Hyla Park Nature Reserve and its associated species and wetlands.

Our study provides the first population estimate for male Gray Treefrogs in Hyla Park Nature Preserve, New Brunswick, Canada's first amphibian conservation site. We also present evidence for the utility of PIMs for population estimates of cryptically coloured amphibians subject to physiological colour change and highlight the value of community science for data collection and engagement. One of our objectives was to test the feasibility of using community scientists in monitoring a Gray Treefrog population in an urban park. We successfully maximized our data collection by involving the local community, and we avoided costly or invasive sampling techniques. Although we have demonstrated proof of concept for use of PIMs with cryptic amphibians, we suggest that improvements to future population estimates could be made by confirming the sex of each individual photographed, as well as ensuring the exact geographic coordinates for each individual captured.

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## Evidence of River Otter (*Lontra canadensis*) recolonization of Prince Edward Island, Canada

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### Abstract

River Otter (*Lontra canadensis*) was extirpated from Prince Edward Island (PEI) in the early 1900s as a result of habitat loss and overexploitation. Although there were isolated and sporadic occurrences in PEI coastal and inland waters pre-1975, only anecdotal reports of tracks or sightings of the species had been documented in the 21st century, until an adult male otter was captured in a beaver trap in 2016. Since then, seven additional individuals have been collected opportunistically or as by-catch of beaver trapping, including an adult female and a kit (juvenile). Camera traps have also revealed what appears to be a family group in central PEI. A growing body of evidence strongly suggests a resident River Otter population on PEI. The island is separated from the mainland by the Northumberland Strait, which has a minimum width of 13 km of salt water. River Otters have naturally recolonized PEI by dispersing across the Northumberland Strait.

Key words: River Otter; *Lontra canadensis*; Prince Edward Island; breeding; dispersal

### Introduction

River Otter (*Lontra canadensis*) is native to Prince Edward Island (PEI; Sobey 2007). Two River Otters killed in Pisquid, Queens County, in 1898 (Jenkins 1901) were apparently the last recorded in the province until 1951 when an otter pelt was shipped from PEI to auction (Park 1971). Jenkins stated that 35–45 years earlier (ca. 1858), he had ordinarily seen otter sign, but by 1898 that was unusual. Shortly afterward he saw two otter pelts in a Charlottetown store and concluded that the otter was “nearly extinct” (Jenkins 1901: 40). At that time, 70% of PEI was cleared of forest (Glen 1997; Loo and Ives 2003) and a fisheries inspector two decades earlier had described the rivers as running “for miles ... denuded of trees” (Curley 2016: 118). Sobey (2007: 388) suggested “after 1890” as an extirpation date for otter in PEI (we suggest “after 1898”) and ascribed its loss to unregulated trapping, settler indifference to its decline, and habitat loss. Cameron’s brief reconnoiter of PEI in 1952 and field season in 1954 for the National Museum of Canada closely followed the marketing of the single pelt in 1951, and he regarded the otter as still present, based on conversation with Chief Game Warden Spurgeon Jenkins (Cameron 1958). In the early

1970s, a dead otter was retrieved from an eel trap at Seal River near Cardigan, Kings County (Curley *et al.* 2019a). Since 2012, there have been several credible reports of observations of otters or their tracks in PEI. Here, we provide physical evidence of recolonization of PEI by River Otters and discuss how they might have arrived on the island.

### Methods

We compiled records of River Otter carcasses submitted to government wildlife officials or photographs obtained from remote camera traps. There is no open season for otter on PEI; thus, trappers surrender the carcasses to wildlife officials. We recorded dates and locations of collection and total length (cm) and mass (kg) for all carcasses. We extracted canine teeth for aging by cementum annuli (Stephenson 1977) at a commercial laboratory (Matson’s Laboratory, Manhattan, Montana, USA). Tissue samples from the quadriceps muscle of three River Otters were sent to Trent University, Peterborough, Ontario, Canada for DNA analysis to assess relatedness of the specimens. The samples were amplified at 11 micro-satellite loci (Beheler *et al.* 2004, 2005; Mowry *et al.* 2011) and the laboratory procedures are described in

detail in Klütsch and Thomas (2018). The software package GeneMarker v.1.91 (Soft Genetics LLC, State College, Pennsylvania, USA) was used to determine allele sizes, which were subsequently used to conduct population genetic statistical analysis. The software ML-Relate (Kalinowski *et al.* 2006) was then used to determine whether the three individuals were related to each other (i.e., potentially a dispersing family group) using a pairwise maximum-likelihood test and a likelihood ratio test with 10 000 simulations. We measured local distances within PEI and between PEI and neighbouring provinces using the PEI 2010 Corporate Land Use Inventory, captured at a 1:17 500 scale (PEICLUI 2010).

## Results and Discussion

From 2016 to 2020, seven River Otters were incidentally trapped in sets for American Beaver (*Castor canadensis*) and Muskrat (*Ondatra zibethicus*). An additional River Otter was found dead on a beach. Data for these eight otter specimens are summarized in Table 1 and their locations mapped in Figure 1.

All microsatellite loci amplified properly and resulted in complete genotype profiles. The first three River Otters were likely not closely related as the maximum-likelihood function in ML-Relate retrieved highest pairwise likelihood values for the “unrelated” category, consistent with findings in coastal populations that siblings may not disperse together (Blundell *et al.* 2002). The relationship of these individuals to those subsequently collected is unknown. In addition, in specific hypothesis testing using a likelihood ratio test of all possible pairwise sample comparisons, the hypothesis that the individuals were unrelated was considerably more supported than alternative relationships (i.e., half siblings, full siblings, and parent-offspring); however, we cannot statistically reject the hypothesis that two of the individuals are either half or full siblings with this second test. Ages of 1, 1, and 4 years were assigned to the first three River Otters. The skewed sex ratio of collected specimens

(7:1 males [M] to females [F]) can be expected with a small sample size; males and females disperse at equal rates from natal areas but males exhibit greater breeding dispersal (Blundell *et al.* 2002). Over 6000 adult carcasses in New Brunswick samples showed a sex ratio approaching 1.13 M:1 F (Cumberland and DeVink 2017). The distances between capture locations on PEI ranged from 6.2 to 137.5 km (mean 51 km, SD 41 km), but three of the first four specimens were caught within 16.4 km of each other in two Kings County watersheds.

Reports of River Otter observations from the public have increased in recent years, but the discovery of a dead juvenile in Darnley Basin on 23 June 2019 (Table 1) confirms that there is a resident population in PEI. Additional confirmation of a reproducing population comes from a photograph of an adult River Otter with what appears to be two juveniles, taken by a camera trap on 23 July 2021 at a north shore coastal pond (46.53106°N, 63.54217°W).

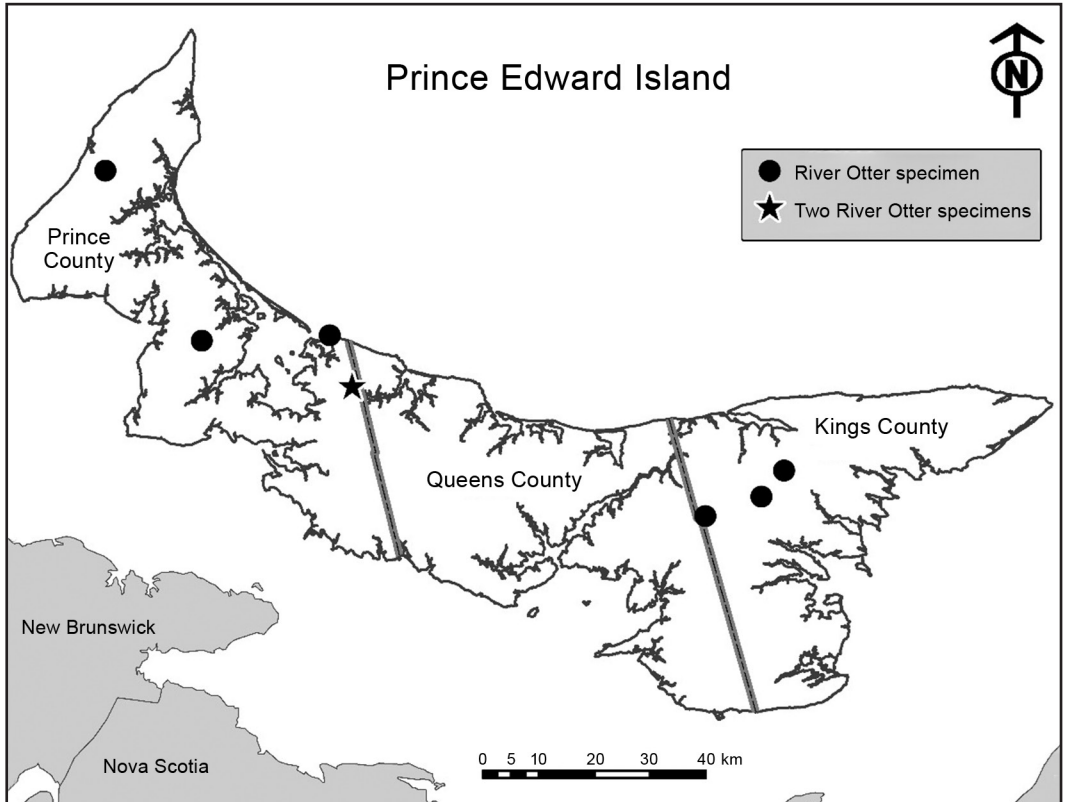
River Otter may have first colonized PEI via a land connection that was in place from 9500 to 5000 years ago across what is now Northumberland Strait (Kranck 1972; Shaw *et al.* 2002). The island is now accessible to River Otter by water or ice. Although they must swim continuously to stay above water (Larivière and Walton 1998), River Otter are exceptional colonizers of islands and are included in depauperate mammalian faunas of Newfoundland and Anticosti Island, Quebec, both in the Gulf of St Lawrence (Cameron 1958).

In coastal Alaska, fewer River Otter females than males disperse, but they frequently move further than dispersing males, over 90 km in one case. River Otters of both sexes crossed 13 km or more of open ocean (Blundell *et al.* 2002), matching the shortest distance across the Northumberland Strait to PEI from New Brunswick or Nova Scotia. Otter dispersal from Nova Scotia could also be facilitated by island hopping 7.5 km to Pictou Island in the mouth of the strait and then navigating 16 km to PEI. The shortest

**TABLE 1.** Description of eight River Otter (*Lontra canadensis*) specimens trapped or found dead on Prince Edward Island, Canada.

Specimen location (county)	Date found	Sex	Age	Total length, cm	Mass, kg
Cardigan River (Kings)	15 Nov. 2016	M	4 years	126	10.76
Morell River (Kings)	14 Mar. 2017	M	1 year	129	11.77
Miminegash River (Prince)	12 Jun. 2017	M	1 year	147	11.2
Morell River (Kings)	8 Nov. 2017	F	Adult	108	7.27
Trout River (Prince)	22 Jun. 2019	M	Adult	124	8.84
Darnley Basin (Prince)	23 Jun. 2019	M	Juvenile	65	—*
Southwest River (Prince)	23 Dec. 2020	M	Adult	125	13.2
Southwest River (Prince)	23 Dec. 2020	M	Adult	121	11.8

\*Carcass was scavenged.



**FIGURE 1.** Locations of specimens of River Otter (*Lontra canadensis*) trapped or found dead in Prince Edward Island, Canada, 2016–2020.

distance from New Brunswick to the western shore of PEI is ~22 km.

River Otters prefer travelling on ice to overland travel and will bound and slide at speed over long distances (Larivière and Walton 1998); however, travel underwater via undulatory propulsion is most efficient (Fish 1994). On average, ice cover in the southern Gulf of St Lawrence extends from January until break-up at the end of March (Bajzak *et al.* 2011), coincidental with the onset of dispersal in young otters in April and May (Larivière and Walton 1998). A combination of travel over ice and swimming is also a possible otter route to PEI. Viable source populations are located in adjacent New Brunswick and Nova Scotia (Scott and Hebda 2004; Gallant *et al.* 2009; Cumberland and DeVink 2017). Source populations are currently stable to increasing in neighbouring Nova Scotia (G. Parsons pers. comm. 11 April 2023) and stable in New Brunswick (J. Cormier pers. comm. 13 March 2023); in the United States, there has been a significant expansion in populations since they were last assessed in 1997 (Roberts *et al.* 2020).

We suggest that the two 20th century reports of otters (Jenkins 1901; Park 1971) reveal sporadic River Otter dispersal from neighbouring New Brunswick or Nova Scotia, ending as failed colonization attempts. Currently, River Otter numbers appear to be increasing in PEI, and 21st century improvements in PEI habitat may have increased their survival. PEI is 44% forested and there are 3279 km of marine coastline (Davies 2011). Beginning in 2000, streams were protected with a 10-m vegetated riparian buffer zone on agricultural land (Statutes of Prince Edward Island 1999), and in 2008 the buffer was extended to 15 m (Statutes of Prince Edward Island 2008). Otter presence in PEI likely indicates that suitable habitat is present, and otters are widely distributed although the central portion of the province is known to have fewer wetlands including beaver dams (Curley *et al.* 2019b) and, thus, may support fewer River Otters. The human desire to maintain beaver populations at moderate levels in accordance with a beaver policy (Anonymous 2011) may influence otter survival. River Otters have an affinity for beaver dams (Gallant *et al.* 2009), and the susceptibility of otters to

traps set within dams (Gorman *et al.* 2008) may make it difficult for them to establish or maintain a resident population. The provincial wildlife agency has developed best-management practices to avoid by-catch of River Otters from beaver trapping and may consider area-specific regulatory changes to achieve this outcome while maintaining beavers at appropriate densities.

### Author Contributions

Writing – Original Draft: R.C.; Writing – Review & Editing: R.C., C.K., and G.G.; Conceptualization: G.G.; Investigation: G.G., C.K., and R.C.; Methodology: G.G. and C.K.; Formal Analysis: G.G. and C.K.; Funding Acquisition: G.G.

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## Population genetic structure of the provincially endangered mainland Eastern Moose (*Alces americanus americanus*) in Nova Scotia, Canada

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### Abstract

Eastern Moose (*Alces americanus americanus* (Clinton, 1822)) on mainland Nova Scotia (MNS) are declining and experience limited immigration across the Isthmus of Chignecto from the larger population in neighbouring New Brunswick. Provincially Endangered, the recovery strategy for MNS Moose involves mitigating various threats that may lead to local extirpation. We examine genetic diversity of MNS Moose using microsatellite markers and mitochondrial (mtDNA) control region sequences. Genetic similarities with the *Alces a. americana* population in New Brunswick and the introduced Northwestern Moose (*Alces americanus andersoni* (= *Alces alces andersoni*) Peterson, 1952) population on Cape Breton Island are also analysed. Observed heterozygosity for microsatellites for MNS Moose was low and there was also evidence of limited gene flow between Nova Scotia and New Brunswick across the narrow Isthmus of Chignecto that connects these provinces. Consistent with relatively recent colonization of North America by Moose dispersing across the Bering Land Bridge <15 000 years ago, mtDNA haplotypes of MNS Moose were identical or extremely similar to haplotypes found across North America. However, mtDNA diversity was lower in Nova Scotia and New Brunswick than in more central regions of the species' range. Active measures to maintain habitat that promote connectivity across the Isthmus of Chignecto would likely be valuable for Moose in terms of maintaining genetic variation in the region and reducing inbreeding.

Key words: *Alces americanus americanus*; Isthmus of Chignecto; microsatellites; mitochondrial DNA control region; population genetic structure; provincially Endangered Moose

### Introduction

The likelihood of population persistence can be compromised by genetic drift in small and isolated populations that experience decreased genetic diversity and increased inbreeding (Grueber *et al.* 2008; Frankham *et al.* 2010). Although inbreeding depression (ID) may not have sufficient time to affect rapidly declining populations, O'Grady *et al.* (2006) concluded in their meta-analysis that the effect of ID is a major extinction threat to small and moderate-sized populations (less than a few thousand individuals). Decreased genetic diversity and ID is related to reduced population fitness (Reed and Frankham 2003; Poirier *et al.* 2019) with an expectation of low

potential for small populations to adapt to environmental changes (Vander Wal *et al.* 2012; Willi *et al.* 2022), although such outcomes are not necessarily a certainty (Teixeira and Huber 2021).

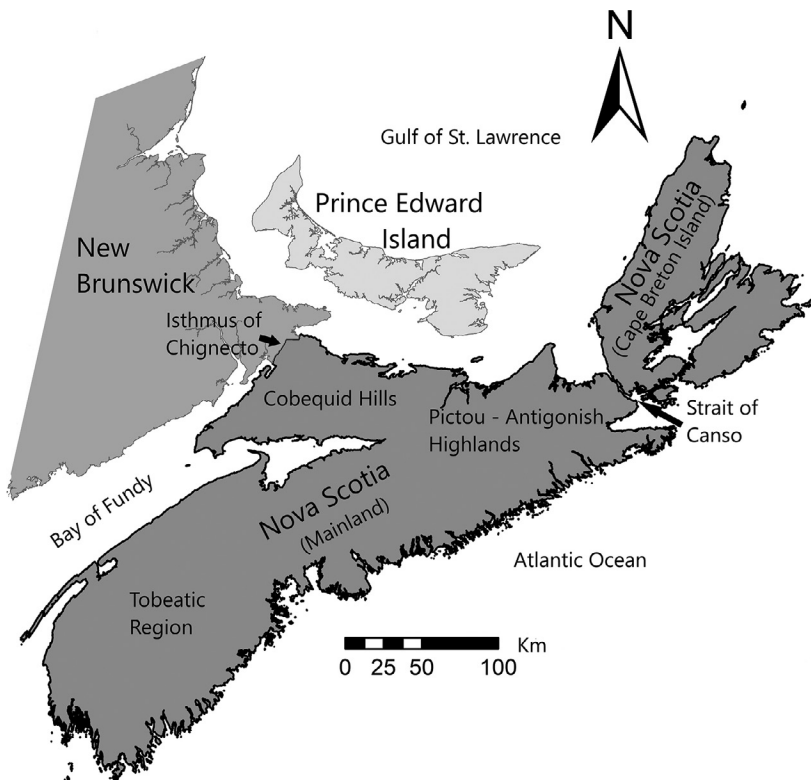
Deterministic threats (e.g., habitat loss, fragmentation, mortality) and stochastic factors (e.g., demography, genetic and environmental stochasticity, disease) associated with population bottlenecks in small, fragmented, and declining populations can lead to local extirpation of a species (O'Grady *et al.* 2004; Brook *et al.* 2008; Frankham 2015, 2016). Populations should have an effective population size ( $N_e$ ), or be connected by gene flow to subpopulations with a total  $N_e$  that exceeds 1000 individuals (Weeks *et al.*

2011). An  $N_e = 1000$  is described as the minimum threshold to maintain adaptive potential and evolutionary resilience in a broad array of organisms from plants to insects to mammals (Willi *et al.* 2006). Eastern Moose (*Alces americanus americanus* (Clinton, 1822) = *Alces alces americana*) on the mainland of Nova Scotia, Canada may be experiencing a population bottleneck and potentially changes in their genetic diversity compared to the larger population in neighbouring New Brunswick. The taxonomic name used here follows Bradley *et al.* (2014) citing Boeskorov (2003) that differentiates *Alces americanus* (Moose) as distinct from *Alces alces* (Eurasian Elk).

The Isthmus of Chignecto (Figure 1) links mainland Nova Scotia to continental North America and is the most probable historical migration route into the province for Moose following the deglaciation of the Laurentide Ice Sheet in Atlantic Canada and New England ~12000 years before present (BP; Shaw *et al.* 2002, 2006). Combined glacio-isostatic, eustatic, and hydro-isostatic processes maximized the width of the isthmus between 10000–8000 years BP (Shaw *et*

*al.* 2002), the latter period corresponding to the scenario proposed by Hundertmark and Bowyer (2004) for Moose colonization of eastern North America from a centrally located population (Hundertmark *et al.* 2003). Increased tidal amplitudes in the Bay of Fundy (~7000 years BP), opening of the Northumberland Strait (~6000 years BP), and formation of extensive tidal marshes at the head of Chignecto Bay (beginning ~3000 years BP) reduced the isthmus close to its current 21 km width (Shaw *et al.* 2002, 2010). Dyking of the extensive salt marsh for agriculture in the late 1600s, harvesting on adjacent forested uplands, and urban/rural development have significantly altered the habitat of the isthmus such that modelled connectivity corridors for terrestrial-based species between the Nova Scotia border and the rest of continental North America are confined to a narrow, 5 km link (Nussey and Noseworthy 2018).

Before European contact, Moose were the most abundant cervid species in Nova Scotia and New Brunswick (Francis 2018). Native Moose were apparently extirpated from Cape Breton Island (Nova



**FIGURE 1.** The Maritime provinces of Canada, showing features identified in the text. The locations of the three localized groups identified in the “Recovery Plan for the Moose (*Alces alces americana*) in Mainland Nova Scotia” (NSDNRR 2021b) are indicated as the Cobequid Hills near the Nova Scotia-New Brunswick border, the Pictou-Antigonish Highlands in north-eastern Nova Scotia, and the Tobeatic Region in southwestern Nova Scotia, respectively.

Scotia) in the late 1800s–early 1900s (Corbett 1995; Pulsifer and Nette 1995). The population of Eastern Moose on Mainland Nova Scotia (MNS), is distinct from the introduced subspecies of Northwestern Moose (*Alces alces andersoni* Peterson, 1950) present on Cape Breton Island (CBI). According to Boyer (1950) cited in Bridgland *et al.* (2007), eight Moose were translocated from Elk Island National Park, Alberta, to the east side of Cape Breton Highlands National Park in 1947 and 10 more were introduced to the same location in 1948. The Nova Scotia Department of Natural Resources and Renewables (NSDNRR) estimates that there are currently ~5000 Moose on CBI (NSDNRR 2021a). Moose on MNS have experienced a dramatic decline and the current population is likely less than the minimum sustainable  $N_e$  threshold described by Willi *et al.* (2006). Parker (2003) estimates the pre-European contact population of MNS Moose at ~15000 animals. A significant decline in numbers by the mid 1970s (Parker 2003 and references therein) continued through the 1990s. Although estimated to be ~1000–1200 animals when listed as provincially Endangered in 2003 under the *Nova Scotia Endangered Species Act*, Brannen (2004) estimated the mainland population at fewer than 700 individuals distributed primarily among three localized groups (a group in the Cobequid Hills of Cobequid and Cumberland counties near the border of Nova Scotia and New Brunswick, a northeastern group in the Pictou-Antigonish Highlands, and a southwestern group in the Tobeatic Region; see Figure 1; Pulsifer and Nette 1995; Parker 2003; Snaith and Beazley 2004). Surveys and coverage have been insufficient, coupled with very low animal densities, to provide a statistically valid estimate of the current population among the three areas isolated by anthropogenic habitat alterations, major highways, and urban and agricultural development (NSDNRR 2021b).

The MNS Moose is increasingly isolated from the larger population in New Brunswick that could be used for genetic rescue or genetic restoration (*sensu* Weeks *et al.* 2011) as a conservation strategy where the risk of outbreeding depression is low (Ralls *et al.* 2018). The harvestable population on CBI is separated from the MNS Moose population by the narrow Strait of Canso which may not be a barrier to the two populations interbreeding as Moose have been reported swimming between parts of CBI and MNS (Bridgland *et al.* 2007). We examine the genetic diversity in nuclear and mitochondrial (mt) DNA within NSM Moose from the Cobequid Hills and Pictou-Antigonish Highlands, and we assess similarity with the *A. a. americanus* population in New Brunswick and the introduced *A. a. andersoni* population on Cape Breton Island.

## Methods

### *Sample collection and processing*

We obtained all tissue samples from necropsied Moose specimens collected by provincial government agencies and so, in accordance with Category of Invasiveness A of the Canadian Council on Animal Care, no separate animal care protocol was required for the genetic analyses we conducted. For our study, no samples were available from the Tobeatic Region localized group; all samples of MNS Moose were from either the Cobequid Hills or the Pictou-Antigonish Highlands localized groups. As will be noted in our Results, we found no evidence of significant genetic differentiation between Moose from the Cobequid Hills and Pictou-Antigonish Highlands so these localized groups are simply referred to as northeast MNS Moose hereafter in this analysis. We collected samples for CBI from ear tissue of 87 Moose harvested in 2018 and skeletal muscle tissue from nine necropsied Moose stored at  $-20^{\circ}\text{C}$  at the Atlantic Veterinary College (AVC). We obtained tongue samples from 32 Moose harvested in 2018 in southern New Brunswick (NB). Skeletal muscle tissue from 66 necropsied Moose stored at  $-20^{\circ}\text{C}$  at the AVC provided the samples for northeast MNS Moose.

We processed ear tissue as follows. Ears arrived whole from which we removed hair using a sterile razor blade. A  $3\times 3\times 3$  mm triangle was cut and a layer of skin was removed and used as tissue for DNA extraction. Skeletal muscle tissue collected from the quadriceps muscle were delivered from the AVC as  $5\times 5\times 5$  mm cubes of muscle tissue stored in ethanol. Small interior sections of tissue were used for the DNA extraction. We obtained tongue samples by dissecting through the tongue mucosa and submucosa and collecting portions of the underlying skeletal muscle. We stored scalpel blades and razors in 10% bleach solution between uses. Prior to use we immersed them in 100% ethanol, rinsed with distilled water, and held over a flame to prevent sample cross contamination.

We used a DNeasy Blood and Tissue kit (Qiagen, Germantown, Maryland, USA) to perform DNA extractions following manufacturer's protocol. We conducted polymerase chain reactions (PCRs) on 10 microsatellite loci amplified in two multiplexes as described by Ball *et al.* (2011): Multiplex 1: MAP2C, RT9, RT24, BM1225, BM4513 and Multiplex 2: RT30, FCB193, BM888, BM848, BL42. The 10  $\mu\text{L}$  reaction mix for Multiplex 1 contained 3  $\mu\text{L}$  of DNA template, 0.5 U of taq and  $1\times$  concentration of PCR buffer (Invitrogen, Frederick, Maryland, USA), 0.2 mM of dNTPs, 1.5 mM of  $\text{MgCl}_2$ , 0.2  $\mu\text{g}$  of BSA, with primers and fluorescent dyes at the following concentrations: 500 nM of MAP2C primers with Fam

label, 500 of RT9 (Hex), 400 nM of RT24 (Hex), 200 nM of BM1225 (Fam), and 200 nM of BM4513 (Fam). The 15  $\mu$ L reaction mix for Multiplex 2 contained 3  $\mu$ L of DNA template, 1 $\times$  concentration of Multiplex Mastermix (Qiagen) with primers and fluorescent dyes at the following concentrations: 400 nM of RT30 with NED label, 300 nM of FCB193 (NED), 300 nM of BM888 (Fam), 500 nM of BM848 (Fam), and 500 nM of BL42 (Ned). Cycling conditions were 95°C for 15 min, followed by 30 cycles of 94°C for 30 s, 60°C for 90 s, 72°C for 60 s with a final extension at 60°C for 30 min.

We amplified the hypervariable domain of the mtDNA control region with primers LGL283 and ISM015 (Hundertmark *et al.* 2002). The 20  $\mu$ L reaction mix contained 2  $\mu$ L of DNA template, 1 U of taq (Invitrogen), 1.5 mM MgCl<sub>2</sub>, 0.2 mM dNTPs, 200 nM of primers, and 0.2  $\mu$ g of BSA. Cycling conditions were 94°C for 5 min, 30 cycles of 94°C for 30 s, 56°C for 30 s, 72°C for 30 s with a final extension of 72°C for 2 min. We visualized amplified products on a 1.5% agarose gel and purified with ExoSAP; the Sanger sequencing reactions were performed at the McGill University and Génome Québec Innovation Centre.

Polymerase chain reactions and genotyping were completed at Trent University in the Natural Resources Wildlife DNA Profiling and Forensic Centre. All microsatellite amplifications were analyzed on an ABI 3730 genetic analyzer (Applied Biosystems, Foster City, California, USA) using Genescan ROX500 size standard (Applied Biosystems).

#### Microsatellite data analyses

A list of all programs that we used in the microsatellite data analyses is provided in Table 1. Allele peaks were scored with Genemarker v1.95. We used Cervus to estimate frequency of null alleles in each locus and to estimate the probability of identity using both the probability a genotype at a locus is identical between unrelated individuals (PID) as well as between full siblings (PIDSib). We also used Cervus

to estimate regional mean observed and expected heterozygosity for: 1) CBI, 2) MNS, 3) NB, and 4) Moose from all regions combined, and to calculate the Polymorphic Information Content value (PIC) for each microsatellite locus, where PIC is a measure of the utility of a polymorphic molecular marker to infer relatedness and other population genetic parameters. We used the program *FSTAT* to estimate allelic diversity ( $N_A$ ), allelic richness ( $A_s$ ), which corrects for sample size to facilitate comparisons across different studies (Goudet 2003), and inbreeding coefficient ( $F_{IS}$ ) for each regional grouping.

We initially investigated population structure using the Hardy-Weinberg Exact Test and default settings in the package “Genepop” written in R (R Core Team 2023). We did this for: 1) each region/localized group separately, 2) MNS and NB Moose combined, and 3) for the entire data set. We used *FSTAT* to estimate genetic differentiation between each region using  $F_{ST}$  values. Two separate runs applying the same settings in STRUCTURE were used to assess population structure in the data set for 1) all regions, and 2) NB and MNS Moose. Admixture was assumed with a Burn-in Period Length of 100 000 and 100 000 Markov chain Monte Carlo (MCMC) repetitions using the Allele Frequencies Correlated Model. We set the number of potential populations ( $K$ ) to 1–10 with 10 iterations of each value. The most likely number for populations was evaluated using both the Evanno Method (Delta  $K$ ) through the Structure Harvester web interface as well as assessing at which value of  $K$  that Posterior probability [ $\ln P(D)$ ] begins to stabilize. To examine for evidence of potential barriers to population movement across the Isthmus of Chignecto, the presence of the isolation by distance (IBD) pattern was first assessed across the geographical scale of NB to MNS Moose. We also completed an IBD assessment between the Cobequid Hills and Pictou-Antigonish Highlands localized groups of MNS Moose. For samples from southern New Brunswick, we used the centroids of the management zones

**TABLE 1.** Programs used in microsatellite and mitochondrial DNA analyses.

Program	Website
Genemarker	<a href="https://genemarker.software.informer.com/1.9/">https://genemarker.software.informer.com/1.9/</a>
Cervus	<a href="http://www.fieldgenetics.com">http://www.fieldgenetics.com</a>
FSTAT	<a href="https://www2.unil.ch/popgen/softwares/fstat.htm">https://www2.unil.ch/popgen/softwares/fstat.htm</a>
Genepop	<a href="https://cran.r-project.org/web/packages/genepop/index.html">https://cran.r-project.org/web/packages/genepop/index.html</a>
STRUCTURE 2.3.4	<a href="https://web.stanford.edu/group/pritchardlab/structure.html">https://web.stanford.edu/group/pritchardlab/structure.html</a>
GenAIx 6.5	<a href="https://biology-assets.anu.edu.au/GenAIEx/Download.html">https://biology-assets.anu.edu.au/GenAIEx/Download.html</a>
DNAsp	<a href="http://www.ub.edu/dnasp/">http://www.ub.edu/dnasp/</a>
Arlequin	<a href="http://cmpg.unibe.ch/software/arlequin35/">http://cmpg.unibe.ch/software/arlequin35/</a>
MEGAX	<a href="https://www.megasoftware.net/">https://www.megasoftware.net/</a>

from which the animals were harvested as their location when this was the only available geographic information. For the Nova Scotia samples, their precise geographic location information was available. We conducted these assessments in GenAlx 6.5 using a Mantel test with 99 permutations.

#### Mitochondrial DNA data analyses

The list of programs we used in the mtDNA data analyses is provided in Table 1. We used MEGAX to visualize electropherograms, to manually assess the quality of each sequence, and to trim and align sequences. We used DNAsp and Arlequin to identify polymorphic sites in the dataset and to assess genetic diversity for all regions as well as each region individually. Measures included the number of haplotypes (h), haplotype distribution, haplotype diversity ( $H_d$ ), nucleotide diversity ( $P_n$ ), and average number of nucleotide differences between individuals (k). We used DNAsp to compare the number of nucleotide differences between regions ( $K_{xy}$ ) and estimate genetic differentiation between populations ( $G_{ST}$ ). We also used DNAsp to perform a  $\chi^2$  permutation test with 1000 replicates to test for genetic differentiation between population pairs.

## Results

### Microsatellite data—genetic diversity estimates and population structure

In total, 55, 32, and 96 samples were used for microsatellite genotype analyses from MNS, NB, and CBI Moose, respectively. Although the number of samples varied, all regions had samples of over 30. According to Hale *et al.* (2012), 25–30 individuals is sufficient for accurate analysis of population structure using microsatellites. The average frequency of null alleles was 0.103, with the highest being 0.3113 for locus MAP2C (Table 2). PIC ranged from 0.260 to 0.805, with an average of 0.575 (Table 2).

CBI Moose samples had slightly higher observed heterozygosity,  $H_o$  ( $0.547 \pm 0.123$ ), than either MNS ( $0.488 \pm 0.163$ ) or NB ( $0.460 \pm 0.119$ ) Moose (Table 3). All regions had a similar average number of alleles per locus (range ~4–4.5 alleles/locus) and

similar allelic richness (range ~3.8–4.3 alleles/locus). All regions had  $F_{IS}$  values close to zero, with the NB Moose samples having the highest  $F_{IS}$ , and MNS Moose samples having a slightly negative value. Genotypes in the sample set had low probability of being identical ( $PID = 2.000 \times 10^{-8}$ ;  $PID_{Sib} = 6.832 \times 10^{-4}$ ).

The  $F_{ST}$  was lowest when comparing MNS to NB Moose samples (0.0716). The  $F_{ST}$  comparisons were considerably higher when comparing either MNS to CBI (0.2877) or NB to CBI (0.2473) Moose. Departures from Hardy-Weinberg Equilibrium (HWE) were not significant (i.e.,  $P > 0.05$ ) for samples within their respective regions of MNS ( $P = 0.160$ ), CBI ( $P = 0.089$ ), and NB ( $P = 0.053$ ) Moose. There were, however, significant departures from HWE expectations for combined MNS and NB ( $P = 0.038$ ) and for MNS, NB, and CBI Moose combined ( $P = 0.015$ ). Given that we detected null alleles, and that null alleles for microsatellites may lead to departures from HWE (Brookfield 1996), null alleles could be a factor in our analyses. However, because there were not statistically significant departures from HWE within regions but only between regions, we interpret this result as evidence of true genetic differentiation between regions. When STRUCTURE was run with all regions combined, nLnap(D)f began leveling off

**TABLE 2.** Estimates of null allele frequencies and Polymorphic Information Content (PIC) of microsatellite loci estimated using Cervus.

Locus	Est. freq. null alleles (Cervus)	PIC
MAP2C	0.3113	0.504
BM4513	0.1296	0.703
BM1225	0.0567	0.626
RT9	0.1175	0.784
RT24	0.0610	0.501
BM888	0.0143	0.260
BM848	0.1466	0.572
FCB193	0.0109	0.634
RT30	0.1653	0.359
BL42	0.0210	0.805

**TABLE 3.** Microsatellite genetic diversity measures ( $H_o$  = observed heterozygosity,  $H_e$  = expected heterozygosity,  $F_{IS}$  = Inbreeding Coefficient) for Moose (*Alces alces*) in mainland Nova Scotia (MNS), Cape Breton Island (CBI), and New Brunswick (NB).

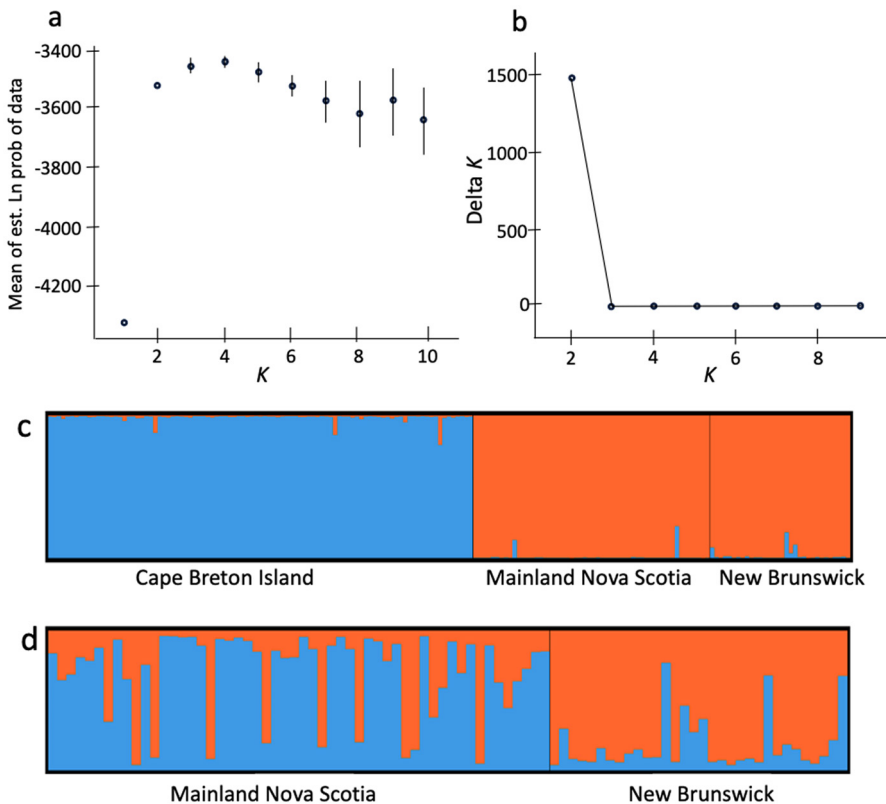
Region	Mean $H_o$ (Cervus)	Mean $H_e$ (Cervus)	Avg. # of Alleles/locus (FSTAT)	Allelic richness (FSTAT)	$F_{IS}$ (FSTAT)
CBI	$0.547 \pm 0.123$	$0.550 \pm 0.115$	$4.4 \pm 0.837$	$3.825 \pm 0.715$	0.007
MNS	$0.488 \pm 0.163$	$0.476 \pm 0.159$	$4.0 \pm 1.700$	$3.816 \pm 0.963$	-0.024
NB	$0.460 \pm 0.119$	$0.500 \pm 0.144$	$4.4 \pm 1.313$	$4.380 \pm 1.305$	0.081
Overall	$0.510 \pm 0.110$	$0.619 \pm 0.109$	$6.0 \pm 1.307$	$5.144 \pm 1.068$	

at  $K = 2$  (Figure 2a). A similar result was found using the Evanno Method, with Delta  $K$  being the largest ( $> 1500$  on the y-axis indicating a strong level of population differentiation) at  $K = 2$  (Figure 2b). The Q plot derived from STRUCTURE when  $K = 2$  divided individuals into two groups: 1) samples from CBI, and 2) MNS and NB (Figure 2c). The pattern of Ln P(D) over values of  $K$  when only samples from MNS and NB were included indicated  $K = 1$  (Figure 3a). Although Delta  $K$  was highest at  $K = 2$ , the Delta  $K$  value was low at 25, consistent with limited differentiation (Figure 3b). In the Q plot for NB and MNS Moose alone with  $K = 2$ , NB samples were predominately grouped together and MNS samples were predominately grouped together, with some individuals from each region showing genetic signatures from the opposite region (Figure 2d). Evidence of a weak but significant presence of IBD ( $r^2 = 0.019$ ,  $P = 0.03$ ) occurred between all samples from NB and MNS

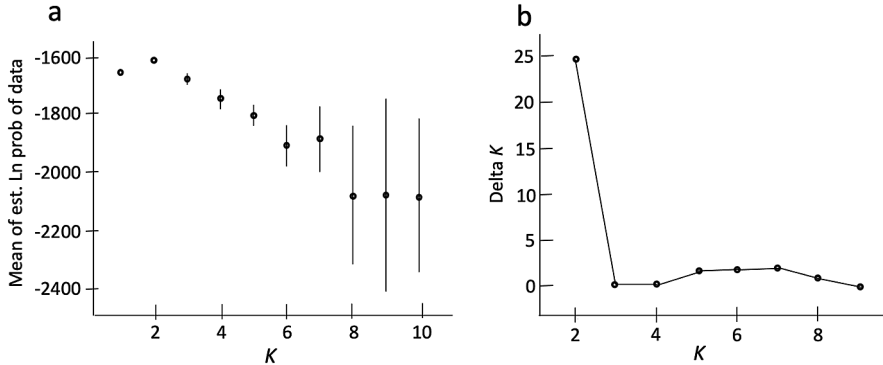
but not between samples from the Cobequid Hills and Pictou-Antigonish Highlands localized groups of MNS Moose, respectively ( $r^2 = 0.002$ ,  $P = 0.23$ ).

#### Mitochondrial DNA data

After assessing quality, 50, 30, and 85 mtDNA sequences were usable from MNS, NB, and CBI Moose, respectively. After sequences were trimmed of primers and uncertain nucleotides adjacent to the primers, they were 479 nucleotides long. The sample set from MNS tended to show somewhat higher levels of haplotype diversity when compared to the other regions within our study (Table 4). Six haplotypes (referred to here as Hap 1 to Hap 6) were found in this region, with the haplotypes in CBI being distinct from those found in the other two regions (Table 5). Each of these six haplotypes was compared to sequences available in the GenBank database using NCBI Blast ([blast.ncbi.nlm.nih.gov](http://blast.ncbi.nlm.nih.gov)) for comparison with haplotypes identified in Hundertmark *et al.* (2003). Hap 1



**FIGURE 2.** a. Change in mean Posterior probability [LnP(D)] in Moose (*Alces alces*) as a function of the number of subpopulations  $K$  over values 1–10 for all regions together (Cape Breton Island [CBI] + Mainland Nova Scotia [MNS] + New Brunswick [NB]), with SD bars calculated by STRUCTURE. b. Evanno Method (Delta  $K$ ) results when all regions (CBI+MNS+NB) are combined in STRUCTURE. c. Q plot for STRUCTURE run with all regions combined when  $K = 2$ . d. Q plot for STRUCTURE run with genotypes from mainland Nova Scotia (MNS) and New Brunswick (NB) combined when  $K = 2$ .



**FIGURE 3.** a. Change in mean Posterior probability [ $\text{LnP}(D)$ ] in Moose (*Alces alces*) as a function of the number of subpopulations  $K$  over values 1–10 when samples from mainland Nova Scotia (MNS) and New Brunswick (NB) were analyzed, with SD bars calculated by STRUCTURE. b. Evanno Method (Delta  $K$ ) results for New Brunswick (NB) and mainland Nova Scotia (MNS) in STRUCTURE.

**TABLE 4.** Mitochondrial DNA genetic diversity measure outputs from DNAsp ( $h$  = number of haplotypes,  $H_d$  = haplotype diversity,  $P_i$  = nucleotide diversity,  $k$  = average number of nucleotide differences within a population, ‘ $\pm$ ’ is SD) for Moose (*Alces alces*) in mainland Nova Scotia (MNS), Cape Breton Island (CBI), and New Brunswick (NB).

Region	$h$	$H_d$	$P_i$	$k$
CBI	2	$0.430 \pm 0.039$	$0.90 \times 10^{-3} \pm 0.8 \times 10^{-4}$	0.430
MNS	4	$0.520 \pm 0.044$	$2.17 \times 10^{-3} \pm 1.9 \times 10^{-4}$	1.042
NB	3	$0.441 \pm 0.098$	$1.50 \times 10^{-3} \pm 0.4 \times 10^{-3}$	0.717
Overall	6	$0.750 \pm 0.014$	$2.65 \times 10^{-3} \pm 0.9 \times 10^{-4}$	1.269

**TABLE 5.** Haplotype distribution of Moose (*Alces alces*) samples from Cape Breton Island (CBI), mainland Nova Scotia (MNS; including the Cobequid Hills and Pictou-Antigonish Highlands localized groups), and southern New Brunswick (NB).

Haplotype	CBI	MNS	NB
Hap 1	0.694	0.000	0.000
Hap 2	0.306	0.000	0.000
Hap 3	0.000	0.600	0.135
Hap 4	0.000	0.020	0.135
Hap 5	0.000	0.360	0.733
Hap 6	0.000	0.020	0.000

and Hap 2 were identical or nearly identical (differing by only a single nucleotide) to the haplotype referred to as “Alaska1” (accession no. AF412235.1) on GenBank that references Hundertmark *et al.* (2002). Hap 1 and Hap 2 are also identical or nearly identical to a series of haplotypes from a study by DeCesare *et al.* (2020) from various states, provinces, and territories in western North America. Hap 3 was identical to the haplotypes referred to as “Central3” (AF412242.1) and “Central4” (AF412244.1) on GenBank. In Hundertmark *et al.* (2003), “Central” samples were from northeastern and northcentral

Minnesota, southwestern Ontario, Isle Royale, Michigan, northeastern North Dakota, and the Lake Winnipeg area of Manitoba, which cover the range of subspecies *A. a. andersoni*. Hap 4 and Hap 5 were identical to haplotypes “East2” (AF412243.1) and “East1” (AF412239.1), respectively. Lastly, Hap 6 was nearly identical to haplotypes Central3 and Central4. The “Eastern” haplotypes of Hundertmark *et al.* (2003) were from New Hampshire and New Brunswick and represent *A. a. americana*. Note: the reason that a haplotype from the present study, e.g., Hap 6, could be identical to two different haplotypes on GenBank is because the length of the haplotype sequences presented here is slightly shorter than the haplotype length in Hundertmark *et al.* (2003). NB and CBI Moose had the largest average difference in nucleotides (Table 6). Chi-square results supported significant differentiation in haplotype frequencies for all pairwise regional comparisons (CBI–MNS:  $\chi^2_3 = 135$ ,  $P < 0.05$ ; CBI–NB:  $\chi^2_4 = 115$ ,  $P < 0.05$ ; MNS–NB:  $\chi^2_3 = 19.288$ ,  $P < 0.05$ ).

## Discussion

Consistent with values obtained for microsatellites obtained by Ball and Wilson (2003) that are summarized in Table 7, the Moose on CBI had the highest

**TABLE 6.** Nei's measure of genetic diversity ( $G_{ST}$ ; Hudson *et al.* 1992) and DNAsp output for average number of differences between nucleotides among Moose (*Alces alces*) individuals ( $K_{xy}$ ) of mainland Nova Scotia (MNS), Cape Breton Island (CBI), and New Brunswick (NB).

Region	$K_{xy}$	$G_{ST}$
CBI-MNS	1.734	0.346
CBI-NB	1.827	0.336
NB-MNS	1.344	0.142

level of observed heterozygosity in our analysis, followed by MNS and then NB. The observed heterozygosity for microsatellites for MNS Moose was lower than values typically observed in populations from larger geographic regions such as northwestern Ontario, Manitoba, Finland, and Poland (Table 7). Comparatively, the lower heterozygosity level for MNS Moose is more typical of island or peninsular populations such as Isle Royale, Michigan (Sattler *et al.* 2017) and the Kenai Peninsula, Alaska (Wilson *et al.* 2015; see Table 7), which likely experience restricted gene flow as was noted by the authors of these studies. Similar to both the Isle Royale and Kenai Peninsula populations, mainland Nova Scotia is geologically nearly an island, but it is technically a peninsula as it is connected to New Brunswick by the narrow Isthmus of Chignecto (MacDonald and Clowater 2005). Samples from Nova Scotia and

New Brunswick had similar, relatively low numbers of alleles (between ~4.0 and 4.4), which are considerably lower than the value observed in Ontario and Manitoba that ranged between 6.3 and 9.5 (Table 7). Genetic diversity levels in our study are higher than that observed for insular Newfoundland (Broders *et al.* 1999).

The Newfoundland Moose population was introduced from extremely small numbers of individuals, specifically, one male and one female from Nova Scotia in 1878, and two males and two females from New Brunswick in 1904. Not surprisingly, this founder event resulted in a considerable loss of genetic variation in that population (Broders *et al.* 1999). While the genetic diversity of Newfoundland Moose continues to be low, its population is estimated to be 110000 individuals and remains stable with only a 4% decline over 10 years between 2012 and 2022 (NLDFFA 2022). While there may be similarities in several of the factors affecting mortality and health of Newfoundland and MNS Moose, unlike Newfoundland Moose that are not exposed to White-tailed Deer (*Odocoileus virginianus*), MNS Moose and White-tailed Deer are sympatric species. This is significant because White-tailed Deer in Nova Scotia are the natural host of the endoparasite Brainworm (*Parelaphostrongylus tenuis*) that is well known to cause significant mortality in Nova Scotia Moose populations, but does not harm White-tailed Deer (Benson

**TABLE 7.** Studies reporting estimates of genetic diversity measures in Moose (*Alces alces*) populations.

Region	Reference	Mean $H_o$	Mean $H_e$	$N_A$	$F_{IS}$
Cape Breton Island, NS	Ball and Wilson 2003	0.6073	0.6008	4.5	-0.110
Guysborough County, NS	Ball and Wilson 2003	0.4405	0.5888	3.3	0.267
Cumberland County, NS	Ball and Wilson 2003	0.4265	0.4833	4.1	0.121
Tobeatic, NS	Ball and Wilson 2003	0.3889	0.4908	3.6	0.218
New Brunswick	Ball and Wilson 2003	0.4500	0.5246	3.8	0.146
Cape Breton Island, NS	Ball <i>et al.</i> 2011	0.6136	0.5968	4.5	
Mainland, NS	Ball <i>et al.</i> 2011	0.4446	0.5207	4.4	
New Brunswick	Ball <i>et al.</i> 2011	0.4793	0.5355	3.7	
Newfoundland	Wilson <i>et al.</i> 2003		0.3780	2.2	0.017
Northwestern Ontario	Price 2016	0.5860	0.6512	8.8	0.112
Northeastern Ontario	Price 2016	0.5367	0.5751	9.5	0.062
Southcentral Ontario	Price 2016	0.4810	0.5131	7.2	0.063
Manitoba	Price 2016	0.7014	0.6982	6.3	0.005
Northern Yellowstone, USA	Koitzsch <i>et al.</i> 2014	0.4885	0.4979	3.9	
Isle Royale, Michigan, USA	Sattler <i>et al.</i> 2017	0.4700	0.4800	4.1	0.160
Anchorage, Alaska, USA	Wilson <i>et al.</i> 2015	0.5200	0.5200	4.1	0.010
Kenai Peninsula, Alaska, USA	Wilson <i>et al.</i> 2015	0.4200	0.4300	3.2	0.031
Finland, Europe	Kangas <i>et al.</i> 2013		0.7400	4.7	-0.004
Poland, Europe	Świslocka <i>et al.</i> 2015	0.7690	0.7810	6.4	0.112

$X_i$  = Allelic Richness rather than Avg. # of Alleles/Locus.

1958a,b; Smith *et al.* 1964; Smith and Archibald 1967; Thomas and Dodds 1988; Beazley *et al.* 2006). Additionally, White-tailed Deer in Nova Scotia are the natural host of the ectoparasite Winter Tick (*Dermacentor albipictus*), and while White-tailed Deer are unaffected by Winter Tick, this parasite is also reported to be a significant mortality factor in north-eastern North American Moose populations (Jones *et al.* 2019). Winter Ticks have been reported on MNS Moose and Winter Tick infestations have been found as a cause of MNS Moose mortality (Beazley *et al.* 2006; Canadian Wildlife Health Cooperative unpubl. data, accessed 20 May 2023).

The viability of individuals and populations is not affected by the loss of genetic variation alone, but through its interactions with demographic and ecological processes (Lacy 1997). The decline of MNS Moose is believed to be multifactorial, likely the consequence of several direct and indirect factors (Beazley *et al.* 2006; NSDNR 2021b). Therefore, while Newfoundland and MNS Moose both have low genetic diversity, there are other significant factors that lack commonality. Morbidity and mortality of MNS Moose associated with these parasites of sympatric White-tailed Deer are examples of potential cumulative effects that, in conjunction with low genetic diversity, could be facilitating or causing the continued decline of the MNS Moose population. In comparison, freedom of Newfoundland Moose from these parasites could potentially prevent or reduce the consequences of decreased genetic variation in their population.

The  $F_{IS}$  values indicated potential inbreeding in the NB Moose population. This result is somewhat surprising given that Moose appear to be abundant in New Brunswick numbering around 29 000 (Nature Conservancy of Canada 2023) and because of the long land borders between New Brunswick, Maine, and Quebec, dispersal of Moose, and consequently gene flow, should be much greater than in Nova Scotia. However, the samples included in our analysis were from the southern region of New Brunswick, which is the most densely populated part of the province. Analyses of New Brunswick Moose from central and northern regions of the province may present a different pattern.

Moose samples from both CBI and MNS had  $F_{IS}$  values near zero, indicating little evidence of inbreeding. Values of  $F_{ST}$  can range from zero to one, but values for natural mammal populations typically range from near zero to  $\sim 0.25$  (Storz 1999). Unsurprisingly, the CBI population with  $F_{ST}$  values around 0.25 showed little evidence of gene flow with either of the MNS or NB subpopulations. An  $F_{ST}$  value of  $\sim 0.07$  indicated a moderate level of genetic differentiation

between the NB and MNS subpopulations, suggesting only limited gene flow between these locations. Ball and Wilson (2003) examined patterns of gene differentiation among three regions of Nova Scotia: Cumberland County (adjacent to New Brunswick and comparable to the Cobequid Hills localized group referred to in the Recovery Plan for Nova Scotia's Endangered mainland Moose), Guysborough County (comparable to the Pictou-Antigonish Highlands group in north-eastern MNS), and the Tobeatic Wilderness Area (the central, southwestern region of MNS near Kejimikujik National Park; NSDNR 2021b). Ball and Wilson (2003) found the Tobeatic and Guysborough regions to be highly similar, but identified moderate to high levels of differentiation between Cumberland and Guysborough, and Cumberland and Tobeatic regions, respectively. Based on their findings, Ball and Wilson (2003) also suggested that levels of gene flow in the region generally were low to very low, although levels of differentiation were lower between New Brunswick and either Cumberland or Guysborough Counties compared to New Brunswick versus the Tobeatic Region.

When CBI, MNS, and NB Moose were considered together, STRUCTURE analysis indicates two genetic populations, with CBI grouping separately and NB and MNS grouping together (Figure 1c). There is additional support for weak population structure between MNS and NB when CBI is removed, and these two regions are analyzed together in STRUCTURE (Figure 2d). Although STRUCTURE results did suggest that MNS and NB Moose are genetically slightly distinct, the low degree of distinctiveness could be due, in part, to the uneven sample sizes for these two regions (i.e., 55 and 32 for MNS and NB, respectively). According to simulation studies performed by Puechmaille (2016), uneven sample sizes can cause STRUCTURE to tend to merge subpopulations that are actually distinct. Future studies of population genetic structure of Moose in Atlantic Canada should aim to use similar sample sizes for all regions where possible.

Significant deviations in HWE occurred when all populations were combined and when the MNS and NB populations were compared to one another. The IBD assessment indicated a significant but weak pattern of IBD between NB and MNS suggesting some restriction to animal movement and thus limited gene flow across the Isthmus of Chignecto. Within MNS, however, IBD results indicate there are no barriers to dispersal between the Cobequid Hills and Pictou-Antigonish Highlands localized groups, but the pattern may simply be the result of the geographic scale being too small to detect IBD in such a large-bodied mammal.

In terms of general trends for mtDNA diversity in Moose, Hundertmark *et al.* (2002, 2003) found

that haplotypes were similar across North America, which was indicative of recent colonization of the continent across the Bering land bridge <15 000 years ago. Colonization of the continent likely consisted of episodes of small numbers of dispersers moving into unoccupied regions with eastern North America being colonized from the central region of the continent more recently than 8000 years ago following the retreat of several proglacial lakes that would have impeded expansion of Moose populations eastward. Despite low overall diversity, populations in central North America tend to have higher diversity than Moose populations closer to the east and west coasts. Our results are consistent with this finding, with lower measures of mtDNA diversity in CBI, MNS, and NB than was found by Hundertmark *et al.* (2003) for Moose populations located nearer to the centre of the species range. However, the Hundertmark *et al.* (2003) study only included 13 Moose from eastern North America, including samples from only New Brunswick and New Hampshire. Haplotype and nucleotide diversity measures for the eastern North American samples in that study were lower than our estimates, likely due to the extremely small sample sizes in Hundertmark *et al.* (2003). Both our results and those of Hundertmark *et al.* (2003) indicated that haplotypes from eastern North America (representing subspecies *A. a. americana*) were identical or extremely similar to haplotypes from other regions (and subspecies) such as *A. a. andersoni* from central Canada and North Dakota, Minnesota, and northern Michigan, and Alaskan Moose (*Alces alces gigas* Miller, 1899) from Alaska. As expected, our finding that the CBI Moose population has a different set of haplotypes than those found in MNS and NB is consistent with these Moose being descendants of individuals introduced from Alberta. That there are no shared haplotypes between the CBI and MNS samples is consistent with no genetic exchange occurring between these two Moose populations. Although we found a total of four haplotypes in NB and MNS, they were all nearly identical in sequence, and NB and MNS had the lowest number of nucleotide differences between their populations resulting in low values for  $K_{xy}$  and  $G_{ST}$ . Despite the near identity in DNA sequence of these haplotypes, the statistically significant  $\chi^2$  differences in haplotype frequencies among Moose in these three geographic locations is an indication that it is not a single homogeneous population for mtDNA. Although MNS and NB Moose shared three of four haplotypes found in the region, the statistically significant  $\chi^2$  test indicated that haplotype frequencies are not homogenous across mainland Nova Scotia and New Brunswick, and female-mediated gene flow (for mtDNA) is limited between these

two Maritime provinces. Again, because mtDNA is only transmitted by females, this phylogeographic pattern is consistent with female natal philopatry as documented in Moose and cervids generally (e.g., Colson *et al.* 2016).

#### *Management implications*

An objective of the Recovery Plan for Nova Scotia's Endangered mainland Moose is to "enhance connectivity to improve genetic health and demographic parameters..." by improving connectivity with the larger subpopulation in New Brunswick and among local breeding individuals (NSDNR 2021b: 34). Action to improve connectivity through landscape management may, in time, reduce the weak IBD between NB and MNS. However, our results indicate the Moose localized groups in NB and MNS exhibit moderate genetic differentiation with limited gene flow between subpopulations. Further, the two subpopulations have heterogenous mtDNA suggesting limited genetic exchange since their founding. This pattern is partially consistent with phylogeographic patterns documented for Maritime Shrew (*Sorex maritimensis*; Dawe *et al.* 2009). Maritime Shrew is a Canadian endemic species that only occurs in Nova Scotia and New Brunswick (Stewart *et al.* 2002). Both nuclear and mitochondrial markers are consistent with the hypothesis that Maritime Shrew diverged into two subpopulations in Nova Scotia and New Brunswick, respectively, as a consequence of post-Wisconsin glacial ebbs and flows (Dawe *et al.* 2009). Although obviously a much smaller animal with much less dispersal ability than is the case for Moose, Maritime Shrew is adapted to the coastal wetland habitats that connect Nova Scotia and New Brunswick, and populations on either side of the Isthmus of Chignecto appear to be genetically connected. Active measures to maintain appropriate habitat that ensures connectivity across the Isthmus of Chignecto would likely be valuable for Moose, as well as for other species such as Maritime Shrew. While some recent studies have questioned the value of maintaining genetic diversity and reducing inbreeding in management plans for species conservation (e.g., Teixeira and Huber 2021), other studies argue that there is "overwhelming evidence that inbreeding depression is often substantial in natural populations" and that "[s]mall populations suffer from reduced mean performance due to the accumulation of deleterious mutations" (Willi *et al.* 2022: 4).

Augmenting gene flow through translocations is a conservation method recommended for threatened species programs to alleviate detrimental genetic effects that arise in small, fragmented populations (Weeks *et al.* 2011; IUCN 2013; Ralls *et al.* 2018; García-Dorado and Caballero 2021). This maintains

genetic diversity at levels similar to large locally adapted populations (Weeks *et al.* 2015). Although Frankham (2015) reports the out-crossing of inbred populations in his meta-analysis resulted in beneficial effects, the translocation of individuals from genetically distinct populations and the concerns over outbreeding depression (Frankham *et al.* 2011) remains controversial due to cultural, taxonomic, and legislative barriers (Love Stowell *et al.* 2017). Ralls *et al.* (2018) argues the hesitancy in outcrossing/gene pool mixing (Weeks *et al.* 2015) by agencies stressing preservation of genetic uniqueness and taxonomic integrity (Love Stowell *et al.* 2017) does not recognize that many small and at-risk populations:

... will not be well-adapted to their current environment, due to fixation of deleterious alleles by random drift and changing local conditions due to human alteration of the environment, including global climate change". (Ralls *et al.* 2018: 2)

Another consideration is uncertainty in the causes of the numerical decline of the MNS Moose (NSD-NRR 2021b); there are several additional factors other than low genetic variability implicated as contributing to this decline. Thus, the concern remains that augmenting the MNS Moose population with individuals from other geographic locations might not have the desired effect of maintaining the population through improved genetic diversity and could simply result in the death of the introduced animals as a potential animal welfare issue (see Guideline 40 of the Canadian Council on Animal Care document on the Care and Use of Wildlife; <https://www.ccac.ca/Documents/Standards/Guidelines/Wildlife.pdf>). In summary, maintaining the natural gene flow between MNS and NB should be a high priority and, if necessary, genetic rescue—the introduction of individuals to supplement low levels of genetic variability and inbreeding depression—may be another effective conservation strategy to consider (Willi *et al.* 2022) while balancing the concerns noted above. As noted by Hedrick and Fredrickson (2010), one of their 10 guiding principles for genetic rescue is that the donor population should be closely related and ideally from a nearby area to minimize the likelihood of outbreeding depression. We suggest that Moose populations in New Brunswick, because of their high degree of genetic similarity, could be a source for genetic rescue of mainland Moose in Nova Scotia should the need arise. Although the data analyzed herein are likely indicative of neutral genetic variation, and so do not allow us to make any direct inferences about patterns of adaptive genetic variation in this region, using neutral variation for informing management strategies is

still useful in lieu of alternative sources of information as part of a strategy to preserve as much genetic diversity as possible (García-Dorado and Caballero 2021).

### Author Contributions

Writing – Original Draft: G.R.M., B.S., and D.T.S.; Writing – Review & Editing: G.R.M., B.S., S.M., and D.T.S.; Conceptualization: G.R.M., B.S., and D.T.S.; Investigation: B.S. and S.M.; Formal Analysis: B.S. and D.T.S.; Funding Acquisition: S.M., G.R.M., and D.T.S.

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Guest Editor: G.J. Forbes

# 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

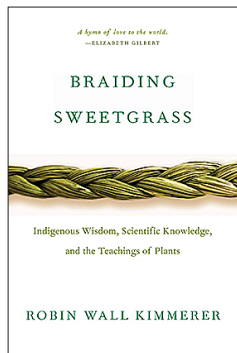
#### **Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants**

By Robin Wall Kimmerer. 2013. Milkweed Editions. 408 pages, 23.89 CAD, Paper. Also available as an E-book and Audio-book. Hardcover Special Edition published in 2020.

Reviewing this incredible book is difficult, not because I disagree with the praise that others have laid upon it—I agree entirely—but due to the depth of this book and its message. Dr. Kimmerer is a trained botanist and enrolled member of the Citizen Potawatomi Nation. *Braiding Sweetgrass* weaves together Western scientific knowledge with Indigenous ways of knowing through the lens of an Indigenous woman navigating these sometimes disparate realms.

With a narrative based primarily in her own life and experiences, Dr. Kimmerer employs her poetic and eminently readable writing style to explore relationships with non-human elements of the natural world. Each chapter is a more or less self-contained story, with the central theme of reciprocity woven throughout. This book is at once deeply personal and broadly relevant. Justified critiques of the modern Western scientific perspective are accompanied by positive and forward-looking ways of using science to address current challenges.

This book encourages readers to develop a deeper



appreciation for and close observation of natural processes and seasonal changes, and to consider different ways of knowing the world around us. I read this book in winter, and it made me ache for spring and summer when I could get my hands in the soil and feel the thrum of life around me.

I have both read this book and listened to the audiobook, which is narrated by the author, and I will be reading it again. *Braiding Sweetgrass* is a book that you come back to, reflect on, and find new knowledge in each time. Will you learn plant facts? Yes, absolutely. And they are excellent plant facts. The value of this book is expansive; when you read it—and you should, or listen to it, or possibly do both—you will take something different away than I did, and likely find something different again when you read it a second time. I recommend this book to anyone and everyone. For younger readers, there is also a 2022 adaptation by Monique Gray Smith, *Braiding Sweetgrass for Young Adults* (Zest Books). It includes additional information and illustrations by Nicole Neidhardt.

Ultimately, *Braiding Sweetgrass* and its messages are hopeful and necessary. If you've been looking for a reason to read this book, take this as your sign.

HEATHER CRAY  
Halifax, NS, Canada

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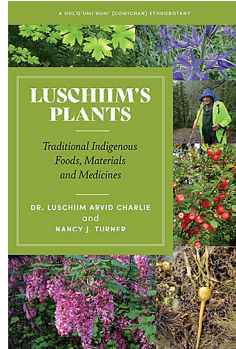
## Luschiim's Plants: Traditional Indigenous Foods, Materials and Medicines

By Luschiim Arvid Charlie and Nancy J. Turner. 2021. Harbour Publishing. 288 pages, 29.95 CAD, Paper.

This field guide containing Indigenous cultural knowledge is different than anything I've read, although this is not really my field. For those living in or visiting Canada's West Coast, it is intended as a historical record and a model for future books. Dr. Luschiim Arvid Charlie combines his extraordinary knowledge of more than 140 Canadian West Coast plants with the writing skills of co-author and ethnobotanist Nancy J. Turner. As a Cowichan Tribes Elder, his knowledge comes from his grandparents and the Elders he grew up with, as well as his own life experience. The aim of the book is to share knowledge about the existence of these plants so they are not forgotten, and to stress their cultural importance for future generations. Animals are also discussed in a few instances.

The term "plants" is used loosely. Seaweeds (algae)—which are not really plants—are included in the book, as well as lichens and fungi, which are definitely not plants. But that's alright, because I cannot think of a better term to group these taxa. "Life forms" would not have worked as well.

As per the title, the book focusses on the physical (and psychological) uses of plants as foods, materials (such as tools), and medicines. Each species, or group of species, is given names in the languages of Hul'q'umi'num', English, and Latin. Too bad the French names are not given. A Description is followed by a Where to Find section for each species account. There are colour photographs for every entry. The heart of the book is the Cultural Knowledge section of each species entry. Much of this comes directly from Luschiim. Vertical lines in the left-hand margins seem to identify his words. The rest of the text, without the vertical lines, seems to be Turner's interpretation of Luschiim's words.



Many of the plants featured are edible or can be used as "thirst quenchers" in a pinch in the bush, especially the many berries described. Many medicinal plants are also described, including those used for treating wounds, curing colds, increasing energy, and cleansing blood. Most of the plants featured have multiple uses.

The book also discusses the material uses for plants, which can include indicating the presence of other species in the area and being used as dyes. Kelp beds may even be used to anchor boats. Different Coast Salish tribes use plants for different purposes.

Introduced plants are identified with the caveat that it's difficult to be certain whether some species were introduced or not.

The book provides descriptions of how to use plants, prepare them, and even grow them. A key theme throughout *Luschiim's Plants* is that plants must be treated with respect before collecting and using them. The ritual applications of a plant in Hul'q'umi'num' ceremonial contexts may be noted, but any other information on the plant is kept private. In some cases, its use is given, but without any other information regarding the plant being shared—and in my opinion, rightly so. I wouldn't share all my secrets with the public, either.

Some plants can be used for predicting the weather. Luschiim describes looking for "echoes", but he doesn't explain how echoes are used to make predictions about the weather.

Many readers will enjoy the numerous stories shared in the book. Luschiim and Turner write about the care that must be taken to select the appropriate part of a plant at the right time of year in the right conditions, and then prepare and use it properly. Some plants can be harmful. I enjoyed the fact that the last plant described is potentially deadly Death Camas!

I don't know whether you should add this book to your list, but I hope that this review will help you decide.

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## Rare Vascular Plants of Alberta. Second Edition

Edited by Gina Fryer, Jane Lancaster, Kimberly Ottenbreit, Christina Metke, Donna Cherniawsky, Amy Griffiths, Kristen Foreman, and Jenalee Mischkolz. 2022. Alberta Native Plant Council. Distributed in Canada by UBC Press. 664 pages, 548 colour photos, 508 illustrations, and 934 maps, 47.95 CAD, Paper.

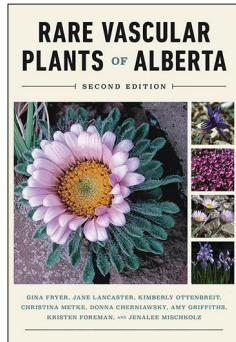
Alberta is a biodiverse province with an array of terrestrial and aquatic ecosystems including boreal forest, grassland, parkland, foothills, the Canadian Shield, and the Rocky Mountains. There are upwards of 2000 vascular plants that have been detected provincially (including subspecies and varieties), and this tally continues to grow as the flora

of the province is documented, the ranges of North American plants change, and our understanding of taxonomy advances. *Rare Vascular Plants of Alberta, Second Edition*, includes nearly 500 species profiles, with about 150 being new to this edition. Fryer *et al.* emphasize that a fifth of the province's native vascular plants are rare, and with this prevalence tools to identify rare plants are invaluable.

The book's beautiful cover has images of many rare plants and prominently features a charismatic photo of *Townsendia condensata* Parry on a rocky alpine slope. However, all the cover species occur in southwestern Alberta where there is a high concentration of rare plants that reach the northern and eastern extent of their ranges. It would have been beneficial to see province-wide representation on the cover to highlight vascular plant diversity in other ecological regions; Alberta's rare plants are not restricted to the southwestern Rocky Mountains, and rare plant occurrences are possible province-wide, including in human-impacted environments.

The guide opens with a comprehensive introduction of what rare plants are, the types of rare plants typically found within the province, a description of species conservation rankings, and a brief history of the published records of rare plants in Alberta. There is also guidance on how to conduct rare plant surveys and document occurrences in the province, highlighting the importance of reporting rare plant populations to the Alberta Conservation Information Management System (ACIMS).

Each species profile describes the rare plant's habitat and vegetative and reproductive features, with key attributes highlighted. Summaries of plant traits are written in common vernacular, making it easier for novice botanists to understand the diagnostic features of each rare species. Considering that many



of the species summaries were initially crafted by numerous individual volunteers, the primary authors did a great job ensuring plant morphology language was stylistically unified throughout the book. The Habitat descriptions provide detail on the soils, substrates, moisture regimes, plant community associations, and disturbance responses for many species, which are diagnostic for rare species that occupy a narrow niche. Every profile includes a short Notes section with interesting information on species ecology, contrasts with similar species, and other facts like the etymology of nomenclature. For rare plants that are federally listed as Endangered or Threatened under the *Species at Risk Act* (SARA), their statuses and threats are described in the Notes; however, these statuses are not boldly presented.

In addition, all species profiles include detailed illustrations. For most species, there are also high-quality photos of the plants (often in their natural environments) and additional photos of important diagnostic plant organs referenced in taxonomic keys, such as perigynia for *Carex* L. and fruits, leaves, and bulbs, etc. for other plants. There are a few cases where photos are out of focus or do not focus on diagnostic features. This occurs primarily in the section on Poaceae, which would have benefitted from diagnostic photos of spikelets and florets, much like the detailed photos included for Cyperaceae. However, with many of these species being rare and often inaccessible, it is understandable that access to ideal photos is limited. In the absence of photos, the illustrations that have been chosen highlight the diagnostic traits well.

For most species profiles, the guide also includes occurrence maps of the species across Alberta's main natural regions. These are valuable references for understanding where rare plant populations are known to occur, and the maps often illustrate how disjunct and widely distributed the occurrences of populations can be. Further context on a species' North American range is also provided; this is important as many rare plants in Alberta are at the extreme extent of their ranges. These maps can aid in confirming a species' identity in conjunction with its habitat and ecological description and alert botanists who detect novel populations to the importance of reporting occurrences.

To aid in the identification of some taxonomically challenging taxa—such as *Boechera* Á. Löve & D. Löve, *Eleocharis* R. Brown, *Carex* L., and *Potentilla* L.—the authors have compiled useful Conspectus

Tables to help compare key traits of similar species. These tables are useful tools to use in conjunction with dichotomous keys and pressed reference materials.

Noting that the species profiles are very well put together, there are some small drawbacks. The conservation status of each species is not described in the profiles; however, the authors do acknowledge in the introduction that ACIMS (2022) should be consulted for the current list and statuses of rare plants in Alberta. This will be apparent to people who have experience working with rare plants in the province, but it may be a barrier to novice botanists or people reviewing the guide from outside of Alberta. Further, the guide appears to have a complete inclusion of species ranked provincially as S1 (Critically Imperilled) and S2 (Imperilled), while species with an S3 (Vulnerable) status appear to be included at the discretion of the authors. An appendix of rare plants in Alberta, notations on whether species are included or excluded, and their statuses at the time of publication would have been beneficial.

*Rare Vascular Plants of Alberta* compliments the recent publication of *Vascular Flora of Alberta: an Illustrated Guide* by Linda Kershaw and Lorna Allen (2020), an illustrated dichotomous key that also indicates the conservation status of rare vascular plant species. Detailed species descriptions and range maps

are lacking in the illustrated key, which are important for confirming the keying of rare plants. The *Rare Vascular Plants of Alberta* guide fills this information gap well.

*Rare Vascular Plants of Alberta, Second Edition*, is an excellent resource for anyone working with plants in Alberta. With the comprehensive inclusion of Alberta's rarest plants, it empowers the people who monitor and manage the province's vegetational resources and ecosystems to detect and understand the ecology of rare plants. High-quality illustrations, photos, and plant summaries in common vernacular make this guide accessible to both novices and experienced botanists.

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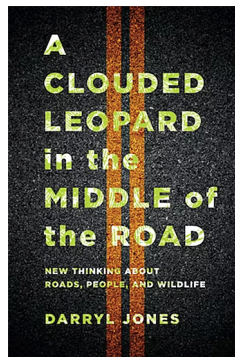
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## CONSERVATION AND CLIMATE CHANGE

### A Clouded Leopard in the Middle of the Road: New Thinking about Roads, People, and Wildlife

By Darryl Jones. 2022. Cornell University Press. 272 pages, 26.95 CAD, Paper, 10.99 CAD, E-book.

The rather evocative title of this book (especially if you happen to like Clouded Leopards) refers to the time the author and his students observed this secretive jungle cat standing in the middle of a logging road in Borneo. To see a Clouded Leopard is a rare event, and to see one out in the open is rarer still. But, of relevance to the book, Darryl Jones notes that by the next year the same site had become a major highway, and the likelihood of a Clouded Leopard successfully crossing the new, busy road, or even surviving in the proceeding development, was doubtful. This anecdote captures the dual threats of transportation networks. Logging (or dirt or resource) roads,



common in many regions and particularly in Canada, represent the threat of overharvesting, either legally or illegally, whereas paved highways represent the additional threat of direct mortality, commonly referred to as roadkill. More vehicles can travel at faster speeds on paved roads, and with ever-increasing human density and the concurrent footprint, roads are becoming a significant conservation issue for many wildlife species.

*A Clouded Leopard in the Middle of the Road* summarizes the problems of roads. These include increased annual levels of animal mortality (e.g., 14 million birds in Canada, 365 million mammals in the United States, and 5 million frogs in Australia [p. 20]); the creation of barriers to movement; and vibration, dust, and noise that can affect mammals and breeding birds. Two of seven chapters present a history of mitigation efforts. In particular, the book recounts the early days of engineering for human safety but also wildlife

movement, when large and expensive initiatives in the 1980s and 1990s erected extensive fencing bisected by wildlife underpasses and overpasses. Jones also discusses research and monitoring by Parks Canada along a 60-km stretch of the Trans-Canada Highway in Banff National Park. A proposal to twin the national highway in Banff—an iconic Canadian place known for Grizzly Bear, Elk, and Bighorn Sheep—warranted a solution to the problem of roadkill and barriers to wildlife movement. As a result, few places in the world have a better understanding than Banff of the impacts of vehicles and roads on wildlife, and how to mitigate these impacts. In later chapters, Jones explores more recent approaches, such as canopy crossings and glider poles, and the value of innovative signage (i.e., the number of dead animals to date), educating drivers, and working with municipal governments. Much work appears underway in Australia, particularly with canopy crossings, which are networks of ropes and bridges that allow arboreal species like Koalas to safely cross a road by walking along ropes high above the cars. In treeless spaces, glider poles are a line of spaced structures, like telephone poles, that permit Sugar Gliders and similar species in Australia to cross roads and the adjacent rights-of-way.

Jones is a professor in urban ecology at Griffith University, Queensland, Australia, who works mainly on urban birds and road ecology—a term that broadly

relates to the impact of roads on wildlife. He has been involved in numerous mitigation initiatives, notably the assessment of canopy overpasses. In this book, Jones combines the experiences gained from mitigation projects, researchers, and managers in locations including Mongolia, North America, Brazil, and Australia to promote the idea of road ecology and show how planners, road engineers, and the public can achieve success. *A Clouded Leopard in the Middle of the Road* is not a technical product containing specifics on how wide a highway underpass for wildlife should be or, for example, where and how to erect a rope bridge. Instead, by providing numerous examples of ideas put into action, it is more of a call-to-arms for the conservation community to make roads less of a problem for wildlife. Some mitigation measures such as highway overpasses and underpasses—which cost tens of thousands of dollars—are only possible with considerable political will and financing. However, local communities working with transportation officials can apply some of these success stories, such as rope bridges and narrow tunnels for snakes. This focus on small and diverse projects in cooperation with, rather than in conflict against development is the ‘new thinking’ referred to in the title.

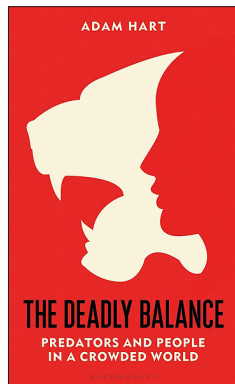
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## The Deadly Balance: Predators and People in a Crowded World

By Adam Hart. 2023. Bloomsbury Sigma. 368 pages, 37.00 CAD, Hardcover, 25.90 CAD, E-book.

*The Deadly Balance* is an authoritative, well-researched account with 33 pages of references. It documents the relationships that humans have with the wild animals around the world that kill and sometimes eat us: Lions, Tigers, crocodiles, hyenas, bears, canids (wild dogs), other species of cats (especially leopards), and Chimpanzees—our closest relatives. We are both fascinated by and terrified of many wild animals, even on an increasingly urbanized planet. This book will interest many readers—including the general public, people interested in or studying carnivores, human dimensions researchers, and journalists—and help them gain a better understanding of the relative dangers from the world’s carnivores.



I found the book easy to read despite it being bogged down in detailed accounts and statistics of animal attacks by all the species previously mentioned (and then some). Ultimately, all these creatures have much more to fear from us, and most of these species have decreased tremendously in both numbers and ranges in the past century or two. That being said, there are many areas of the world where people are still regularly killed and consumed by predators. Rural, impoverished people are generally more susceptible to predator attacks—a major theme in the book that Hart repeatedly discusses (pp. 33, 49, 85, 87–88, 95, 110, 132, 136, 151, 189, and 318). He describes how it is easy for folks in high-income countries to support carnivore conservation, but the reality is that they are generally not the ones affected by predators. He also notes that the media is often heavily biased toward reporting stories about animal attacks on North Americans, specifically white people (p. 39); a Cougar, bear, or wolf non-lethally attacking a white person, for instance, is covered in much more

depth than many people dying (sometimes in the dozens or hundreds) from animal attacks in other parts of the world, such as India or Nepal (e.g., pp. 39, 51, 55, and 228). I generally agree with that statement.

I learned many new things from this book and was mostly surprised at how many people are regularly killed in other parts of the world (remember the media bias mentioned above). For example, an astonishing 373 000 people have been killed by Tigers in India in the past ~200 years (p. 83), which amounts to ~1800 deaths a year. And that is just one country in Tiger's large (but shrinking) range. In just 20 years, over 1000 Tanzanians were attacked by Lions, and two-thirds of those were killed and eaten (p. 35). Lion and Tiger attacks are covered the most in this book, but there are other species that leave behind many victims. For example, there were 892 people killed by Saltwater Crocodiles in over 21 years, up to 2021 (p. 145). Also, in just two Indian states, 289 people were killed by Leopards (*Panthera pardus*) in only seven years (p. 245). Leopards have a vast range and are quite adaptable to living in human-dominated areas; they survive there by killing feral dogs and other domestic animals (pp. 247–248). Furthermore, all those above statistics are likely underestimates given that rural, impoverished people often disappear undocumented. Those numbers are literally orders of magnitude higher than the kill totals for species—such as Cougars (p. 222), wolves (p. 295), sharks (p. 308), American Black Bears (p. 259), and even Brown Bears (p. 266)—that North Americans often hear about in the media. Despite news reports of their potential danger, some predatory animal families, like canids, actually pose little to no statistical threat to humans worldwide (p. 304).

Throughout the book, Hart discusses the importance of involving local communities in conservation decisions and not imposing carnivore conservation strategies on them (e.g., pp. 73, 251, 306, and 322). While I agree that is intuitively important, I also tired of repeatedly reading it. Hart also mentions multiple times that he stands firmly behind protecting habitats rather than focussing on animal rights (p. 115), but it became similarly tiresome to read him bemoaning animal rights groups (pp. 89, 117, 160, 214, and 247), even though I understood his intention. However, his main conclusions that good conservation is complex (pp. 322–323) and empathetic (p. 323), and it's about people not animals (p. 320), listening to communities (p. 321), and supporting rather than imposing conservation frameworks on local people (p. 322) are well-researched and detailed throughout the tome.

A few other things are notable in the book. First, many people survive attacks with the help of others, even when the attacks are by animals like Lions (e.g.,

pp. 14 and 37). Yellowstone National Park recommends that visitors hike in groups, and this strategy likely saves many people from most predator attacks. Also, I had always thought that anacondas (specifically Green Anacondas) were relatively dangerous to people, and of course that viewpoint has been aided by sensationalist media sources (i.e., movies). I was shocked to read that there are no recorded accounts of them killing people (p. 190)—but there are for pythons (pp. 188–189). In fact, more people are killed each year by often unheard-of (for North Americans) Mugger Crocodiles than are attacked by snakes (p. 162 and Chapter 5). Finally, I was pleased to read in the bear section about the importance of using bear spray in saving people from bear attacks (p. 2), but I was shocked that Hart doesn't mention using bear spray against other species, especially in other parts of the world where animal attacks are more frequent. While surprise predatory attacks by ambush species like Tiger and Leopard might be difficult to avoid even with bear spray, it surely would prevent numerous other tragedies.

*The Deadly Balance* is well-written and thoroughly researched with the author providing detailed background information on the majority of animals that can harm us. Hart is from the United Kingdom, so some words are spelled differently than I am used to (e.g., learnt versus learned; pp. 182 and 231). In addition, some of the phrases he uses were also new to me, such as: “was to hand” (pp. 66–67); “take an age” (p. 97); “rough sleepers” (p. 206); “loaded for bear” (p. 252); and “I was at pains” (p. 261). Neither of these issues distracted from the book, however; I simply googled the meaning of those passages that didn't make sense to me. There are a few minor errors in the book. Interestingly, the most glaring omission has to do with one of the animals I study, Coyotes (pp. 289–290). In that passage, Hart neglects to mention the two humans killed by Coyotes, which surprised me as they have been covered in-depth (Carbyn 1989; Timm *et al.* 2004; Gehrt *et al.* 2022). Otherwise, I think that maps and other visuals would have been helpful to include, as there is only text throughout the book's lengthy 368 pages.

This is an important publication. While maybe not as captivating as a book focussed on the individual trials and tribulations of a specific species (e.g., wolves in Yellowstone; Way 2021), it is nonetheless an important contribution to science. With most wildlife populations declining (despite recent increases for wolves, Cougars, and Tigers in certain areas), it is important to frame the relatively low chance of injury that most people have from most species. In that sense, *The Deadly Balance* will surely interest and surprise most readers, especially those of us from North America.

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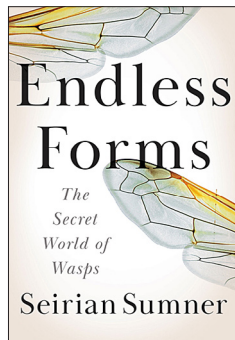
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## ENTOMOLOGY

### Endless Forms: the Secret World of Wasps

By Seirian Sumner. 2022. HarperCollins. 400 pages, 35.99 CAD, Hardcover, 14.99 CAD, E-book.

I have read several wasp books lately (who knew there were so many?), and this one stands out. It's not necessarily better than the others, but it is a good book with a different take on the subject. Although the content of the book is science-based, the tone is that of a storyteller delivering a message that is more consumable by a broader audience.



The classic taxon book (e.g., sharks, hover flies, dinosaurs, wasps) will typically include a few introductory chapters (e.g., evolution, adaptations, relationships to people). Then the bulk of the book will cover taxonomic groups—a family-by-family or species-by-species approach to looking at diversity. Classic books also have a lot of photographs ... rarely a page goes by without one or two pictures. Sumner's book is essentially all text, with two eight-page sections of beautiful pictures. She does not do the taxonomy thing; her book is eight chapters of perspectives on wasps and the entomologists who study them.

Aristotle was the first published entomologist who expounded on honeybees, but he also devoted many lines of his scrolls to wasps. Despite this, he posited that wasps were of no obvious value, especially compared with honeybees. This clear oversight had to be corrected, and Sumner does so in a chapter that describes a fantastical dinner between herself and the philosopher. This chapter is used to explain, in a lyrical fashion, some of the biology that Aristotle missed, including both older (but not as old as him) and modern advances. By doing this, Sumner brings the

non-entomologist reader up to speed as well. The creativity in this chapter alone makes the book an interesting read ... not to say the taxon-by-taxon approach isn't interesting. But Sumner's take is interesting in a different way, and, dare I say, it's refreshing.

Another brilliant chapter covers pollination. Move over bees, because wasps contribute as well (although not likely as much as the true flies [Diptera] do!)

Solitary male wasps are perfect for [pollination], as they have no sooner mated with one female (or attempted to do so with a female wasp mimic orchid) than they're off looking for the next. (p. 326)

Sumner reviews the literature on this and other topics and eloquently simplifies the findings for the non-specialist.

The two eight-page inserts of colour plates represent essentially all the non-text components of the book. The photographs are top quality and show a diversity of wasps in several facets of their lives, such as foraging for nectar, transporting prey, roosting, and ovipositing. My only wish here would be that there were more images.

There are times that diagrams would have been very useful. For example, Sumner uses a paragraph of text to describe the sting (often colloquially called “the stinger”) when a diagram of that moderately complex, charismatic feature would have more easily enhanced the understanding of this structure in the reader's mind. There are a number of small errors in the book, such as equating eukaryotes with multicellular organisms (when, actually, eukaryotes also include some single-celled organisms, e.g., amoebas) and describing a newly hatched wasp (which is a larva arising from an egg) when referring to a newly eclosed wasp (which is the transition from pupa to adult). These errors give the knowledgeable

reader mental hiccups, but thankfully there are only a few.

A final, modest criticism I could raise is that of the deceptive title, *Endless Forms*. There are more than 90 families of wasps, with the 100 000+ species truly reflective of the epithet “endless forms”. However, this book dominantly uses examples from only one family, the Vespidae (which includes the familiar yellow

jackets, hornets, and paper wasps). Certainly a few others are mentioned, but too few to justify the title.

Overall, a splendid book!

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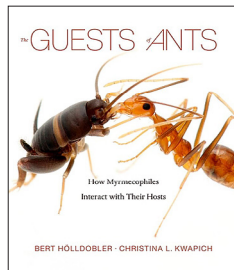
## The Guests of Ants: How Myrmecophiles Interact with Their Hosts

By Bert Hölldobler and Christina L. Kwapich. 2022. Belknap Press. 576 pages, 205 colour photos, and 16 colour illustrations, 90.95 CAD, Hardcover.

I had high expectations for *The Guests of Ants* given that Bert Hölldobler and E.O. Wilson’s *The Ants* (Belknap Press, 1990) won a Pulitzer Prize in 1991 and their subsequent ant-related books were great reads. I was not disappointed. And I certainly wasn’t surprised, as Dr. Hölldobler is one of the world’s leading authorities on ants, and Dr. Kwapich also has an impressive publication record on ants and myrmecophiles. But just what is a myrmecophile?

A myrmecophile is literally an “ant-lover”, an organism that spends at least part of its life cycle with ant colonies. To narrow the scope somewhat, *The Guests of Ants* does not attempt to discuss ants that exploit other ant societies, nor the interactions between ants and honeydew-producing insects such as aphids. That still leaves a staggering diversity of actors, with thousands of known myrmecophiles. Most are typically arthropods, but there are also myrmecophile bacteria, fungi, worms, and vertebrates. Their relationships with ants run the gamut from living in or on ant bodies (symbiotically or otherwise), stealing booty from foraging ants outside the colony, living in the margins of ant nests while feeding on discarded refuse, or even penetrating the inner sanctum of the nest to prey upon ant eggs and larvae. How myrmecophiles take advantage of ant colonies is a big part of the book, which includes discussions of risks to the myrmecophiles as well as costs to the ant colonies.

The diversity of taxa and relationships poses a challenge for how to best synthesize and present the information without overwhelming the reader. Fortunately, the first chapter is a primer on how ant societies work, from reproduction to division of labour. A much-needed glossary (with more than 200



definitions) introduces the reader to new terms—such as mermithergate, “an aberrant worker form in ants, caused by infection with nematode parasites in the genus *Mermis*” (p. 489)—and serves as a memory jog for others. This large format (24 cm × 24.5 cm) book is brought to life by more than 200 spectacular full-colour macro photographs, scanning electron microscope images, and illustrations of tiny organisms that we rarely get to see up close. More than mere eye candy, many photos even capture intimate interactions between myrmecophiles and their ant hosts, both in the lab and nature.

Myrmecophiles have diverse morphological, behavioural, chemical, and other mechanisms that allow them to exploit ant societies. For example, adults of the aptly-named phorid fly *Vestigipoda myrmolarvoidea* lack functional legs (and wings) and are dead ringers for the larvae of *Aenictus* army ants, whose colonies they inhabit. In contrast, despite not resembling their host, the ant cricket *Myrmecophilus albicinctus* uses its legs and palps to drum on the mouthparts of host *Anoplolepis* ants to induce them to regurgitate the liquid food (in an exchange called trophallaxis) upon which it depends. Even more remarkable is the chemical subterfuge used by myrmecophiles to hijack the olfactory communication used by ant societies in order to take advantage of them for room and/or board. Some guests have cuticular scent profiles that mimic those of host ant colonies (often acquired from living in close proximity to ants or from consuming ants) that allow them to hide in plain sight. Some staphylinid (rove) beetles produce appeasement chemicals that can temporarily distract ant workers while the beetles make their getaway, or they spray noxious compounds as a deterrent of last resort. Yet other myrmecophiles have larvae that are preferentially fed by their host ants to the detriment of their own ant broods, similar to avian cuckoos. The final chapter of the book is on vertebrate myrmecophiles and covers more well-trodden

ground, like the relationship between army ants and antbirds (which eat the invertebrates flushed by the ants, rather than the ants themselves). There were still surprises, such as Painted Ant-nest Frog (*Lithodytes lineatus*) laying its eggs deep inside leafcutter ant nests or snapping turtles nesting in *Formica* ant mounds and enjoying the added benefit of leech removal services.

One minor quibble: over 1000 references are cited in the main text using the author-date (Harvard) format. This format makes for rather dense reading at times, compared to using superscripted numerals for in-text references. The references are essential if the reader wishes to dive deeper into the primary literature, which is made all the more useful by Hölldobler and Kwapich's critiques (where appropriate) of the cited study designs or findings. As the authors

point out, there is still much to learn about numerous myrmecophile species and the nature of their relationships with host ants.

While books on ants seem almost as numerous as their subjects, the same cannot be said about books on myrmecophiles. *The Guests of Ants* fills this niche and is an essential reference for any myrmecologist or entomologist. It is also an interesting read for any naturalist interested in social insects and their ecology. This book serves as an inspiration to further explore myrmecophiles; after all, a journey of a thousand steps begins with a single ant column.

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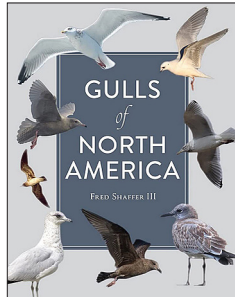
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## ORNITHOLOGY

### Gulls of North America

By Fred Shaffer III. 2022. Schiffer Publishing. 288 pages and 540 colour images, 28.99 CAD, Paper.

This quiet little gem of a book can be added to the plethora of gull-devoted websites and gull identification texts. *Gulls of North America* offers a different enough slant on the topic that will make it a good addition to the libraries of inexperienced gull-watchers and larophiles alike.



At a glance, the format is typical for these kinds of guides. It includes sections on Gull Terms and Topography (with good photos that have arrows pointing out various features), a glossary, and species treatments organized into the usual sections: Hooded Gulls; Large White-Headed Gulls; Medium-Sized White-Headed Gulls; White-Hooded Gull; and Arctic Species, Pelagic Species, and Vagrants. Twenty-seven species are covered.

An example of Shaffer's different approach is the manner in which he treats gull ages. While generously acknowledging the terminology and precise utility of the main gull identification books, Shaffer uses older terms such as breeding, non-breeding, juvenile, first-winter, second-winter, and adult. For the purposes of his intended readership, he says these terms should suffice. He strays from his terminology at times, as even a supposed simple system does not cover all the variations in gull moults.

The biggest difference in his approach—and what to me is attractive about this book—is that it is, in large part, a personal account of his observations and experiences with his beloved gulls. Shaffer worked in an office building across the street from School House Pond, a small conservation area in Maryland, where he studied gulls before work, at lunchtime, and after work for more than 20 years. In an appendix he includes number counts of all the gulls he tallied there, but he also conveys his excitement at the rare and unusual gulls that appeared.

Two other appendices are accounts of a major East Coast fallout of Franklin's Gulls in 1998 and an Ivory Gull invasion of the Northeast in 2009. Again, in these he captures the excitement of those observers.

The best part of the species accounts are not the descriptions of plumages but the Background sections that begin each account. There he liberally quotes passages from Arthur Cleveland Bent's *Life Histories of North American Gulls and Terns: Order Longipennes* (Government Printing Office, 1921). Shaffer clearly loves the lyrical style of those old naturalists who captured the living essence of their subjects. In fact, he does a fair job with his own impressionistic writing:

Kittiwakes spend the majority of their lives in a vast watery world far removed from land, and they are well adapted to thriving in the harsh pelagic environment. It is a thrill to see one of these birds on a winter boat trip, as they navigate strong winds and ocean swells with

the utmost of skill and grace. (p. 224)

In addition to such writing, this book is a photo guide. The Herring Gull account contains 27 photographs, and on pages comparing gull species are more Herring Gull images. The smaller gulls with fewer plumages have, appropriately, fewer photos in their accounts. For example, Black-headed Gull has 19 photos (plus two more photos of a hybrid Ring-billed Gull and Black-headed Gull). Two fold-out pages offer a very nice, quick guide to identifying those pesky gulls.

The 16-page Bibliography is much more than a list of references. Almost all entries are annotated with Shaffer's comments. They make the reader keen to look up the references and read them for her/himself. Two examples:

1) Of J. Dewey Soper in *The Auk* (Volume 63, 1946):

This is a delightful and detailed account of the explorations and ornithological findings of Baffin Island. It provides a detailed inventory of the birdlife of the island and incorporates both Soper's personal observations and observations from the local Inuit population. It provides insights into the birds and natural history of a region seldom visited by birders or researchers. (p. 282)

2) Of Niko Tinbergen's *The Herring Gull's World* (Basic Books, 1960):

This delightfully written book covers the social behavior of Herring Gulls. Tinbergen in-

cludes many firsthand diary accounts of gull interactions and social behaviors, many rendered in black-and-white drawings. This book is not written with a detached scientific viewpoint; Tinbergen's enthusiasm for gulls comes through in the text and the animated descriptions of their behavior. (p. 283)

There are a few shortcomings. Scientific names are not used, except for Short-billed Gull (*Larus brachyrhynchus*). These names are helpful in understanding the taxonomic affinities of gull species. However, the most glaring omission is the lack of a species account for Common Gull (*Larus canus*). *Gulls of North America* was published in 2022, and although Shaffer describes and depicts Short-billed Gull—noting that it was formerly considered a subspecies of Mew Gull (*Larus canus*)—he does not include a separate species account of Common Gull (formerly the Old World subspecies of Mew Gull). Written descriptions and photographs in eBird enable the occurrence of Common Gull to be traced back at least 30 years. Surely Shaffer was aware of this, so why he did not include it as a separate species (with occurrences quite close to his Maryland home) is a mystery.

This omission notwithstanding, *Gulls of North America* is a book for gull-watchers to stuff in winter jacket pockets and use as a quick photo reference guide in the field. It will make a nice addition to their larid bookshelves.

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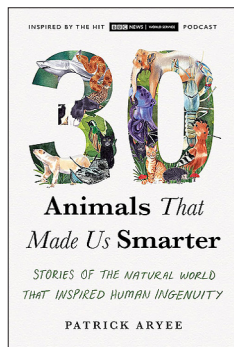
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## OTHER

### 30 Animals that Made Us Smarter: Stories of the Natural World that Inspired Human Ingenuity

By Patrick Aryee. 2022. Island Press. 384 pages and 42 illustrations, 30.95 CAD, Paper, 24.99 CAD, E-book.

From robotics to health care to transportation to preventing brain injuries, humans have turned to the non-human animal world to inspire and shape technologies. Animals have adapted and evolved over millions of years to not only survive, but to also function better within their environments. For example, Polar Bears have evolved to keep warm in the Arctic, while mosquitos have developed mouthparts that allow their bites to go undetected.



By studying animals both large and incredibly small, we have been able to make advancements and create technologies that make human lives easier, safer, and more efficient. This process of learning from systems and designs in nature is also known as biomimicry.

What originally began as a BBC podcast of the same name hosted by Aryee, *30 Animals that Made Us Smarter* takes readers through 30 case studies that describe how specific animal adaptations and abilities have inspired technologies to improve human life. Readers will learn how studying a cow's digestive system inspired water filtration systems, how a kingfisher's beak inspired more aerodynamic transportation in Japan, and how studying *Stenocara gracilipes* beetles to improve water collection may

teach humans better ways to harvest water droplets from fog. There are so many examples of biomimicry, some that you'd expect and others that will leave you in awe of human ingenuity.

When I first began reading this book, I expected to learn more details about the historical ways that animals have shaped our knowledge. However, *30 Animals* instead details more recent discoveries. For example, Aryee describes how studying woodpeckers helped to develop helmets and the 'black box' used in airplanes. Several of the technologies he mentions were recently developed, are still in the process of being developed, or are being tested. I learned how studying snake movements are helping to develop robots that can move more easily in rugged terrain and search earthquake rubble for victims. It was enjoyable to get more in-depth stories about some examples of biomimicry that I already knew, while also learning about some that won't impact my life for years to come.

I also really enjoyed learning about the various

research labs throughout the globe and how different disciplines take lessons from nature. It's truly amazing that all these disciplines—including medicine, engineering, transportation, and sports—have taken ideas from the natural world. This really highlights how much humans have to learn from the other beings around us!

The author's writing style is easy to read, quite conversational, and he has a great sense of humour. While some of the chapters can be a bit tedious, Aryee's storytelling abilities make the information accessible to a wide audience. His enthusiasm for the natural world and science storytelling is obvious throughout the book. Combined with his wit, *30 Animals* is sure to educate and entertain anyone who is interested to learn.

TIANNA BURKE

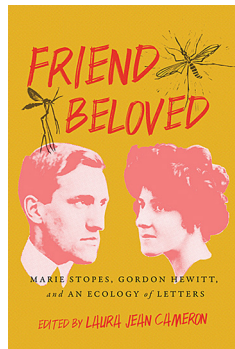
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## Friend Beloved: Marie Stopes, Gordon Hewitt, and an Ecology of Letters

Edited by Laura Jean Cameron. 2021. McGill-Queen's University Press. 224 pages, 40.95 CAD, Hardcover. Also available as an E-book.

Naturalists will likely be drawn to this book for its possible insights into the enigmatic Canadian superstar biologist, Charles Gordon Hewitt (1885–1920). Hewitt was the British-trained entomologist hired in 1909 by the Canadian Department of Agriculture's Central Experimental Farm. He was to fill the entomological part of James Fletcher's research position made vacant by Fletcher's early death the year before at the age of 56. In the decade before Hewitt shockingly died at the even earlier age of 35, he completed a number of the nationally significant economic entomology projects initiated by Fletcher and undertook game-changing national and continental conservation initiatives that remain in force today. Among his many organizational commitments and associations, Hewitt was deeply involved in the Ottawa Field-Naturalists' Club (OFNC), especially during the existentially difficult World War I period, and he served as president in the last year of his life (1918–1919; see OFNC Collection, City of Ottawa Archives). He had no heirs nor long-time



professional associates to compile a full account of him personally or his approach to his work, however. There is virtually nothing but brief, formally published records to tell us how he managed to do so much, so quickly.

*Friend Beloved* is based upon the correspondence between Hewitt and British palaeobotanist, controversial social activist, and notorious eugenicist Marie Charlotte Carmichael Stopes (1880–1958). The letters were written almost entirely between 1907 (in England) and 1911 (after Hewitt came to Canada). Stopes and Hewitt were close friends as students and staff at the University of Manchester, England, from 1907 to 1909. There was little contact between them, however, in the last decade of Hewitt's life.

The speculations on feelings and motives that populate *Friend Beloved*, both in the correspondents' own words and in those of editor and author Cameron, paint a picture of two very bright but entitled and rather self-absorbed individuals. Their often jocular, flirtatious exchanges frequently exude youthful intellectual smugness.

*Friend Beloved*, however, fails its stated objective "not ... to cast judgment" (p. 141), because the author acknowledges having a problem with Hewitt's professional record and personal judgement. In places, it reads as if Cameron has a personal axe to grind with

him. This objectivity problem is exacerbated by a pattern of loaded personal characterizations in defense of various questionable actions and statements by Stopes. While Stopes's important role in women's suffrage and as a pioneer of birth control is appropriately lauded, her controversial darker side is virtually unmentioned in *Friend Beloved*. How can it not be pertinent to our understanding of the values being explored in this brief (three- to four-year) correspondence that Stopes was a strong believer in eugenics as a tool for preventing "inferior women of the lower classes" from having too many children (Britannica 2022) and advocated for forced sterilization (Williams 2011)? Similarly, how could it not be pertinent to note that in the years leading up to World War II she proclaimed these and other fascist views? It is not known (to this writer at least) if she was a card-carrying member and supporter of the British Union of Fascists (although her prominent brother-in-law, Alliott Verdon Roe, certainly was), but she clearly was at least a 'fellow traveller'.

While the personal shortcomings of Hewitt are prominently dissected and pinned out (to use entomological terminology) for all to see, Stopes's more odious social views and pronouncements (including her blatant anti-Semitism [Williams 2011] and correspondence with Hitler [Falcon-Lang 2010]) are barely examined. And while Stopes's subsequent achievements are heralded, Hewitt's groundbreaking advances in economic entomology are not celebrated, if mentioned at all.

For a biologically informed reader, the imprecise use of technical language is distracting. Perhaps most critically, the term 'ecology' is used almost entirely in a social rather than biological context. Notwithstanding whatever "an Ecology of Letters" is intended to

mean, 'ecology' is sometimes employed as a synonym for 'home' and at other times for 'relationships'.

So what can the naturalist or biologist looking to the Hewitt–Stopes correspondence for insights into the thinking and development of celebrated scientist and conservationist Hewitt expect to find here? The annotated letters provide a selective insight into the thinking of both Hewitt and Stopes over that period, which is of some value when clarified or supported by other more objective assessments of their world and those times. In her copious footnoting of the reproduced letters, Cameron has done an excellent job of identifying the people, places, and often the context mentioned in the letters that otherwise are identified only through personal short-hand and/or abbreviations.

Beyond these particulars, *Friend Beloved* exemplifies a major challenge for historical retrospectives: how difficult it is to fairly judge the worthiness of past achievements and achievers through the lens of our own times. And to achieve balance in our treatment of the cast of characters being examined.

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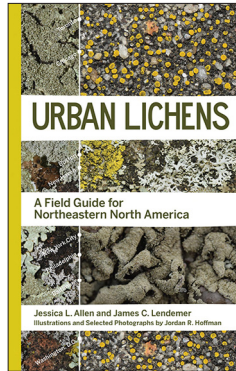
## Urban Lichens: a Field Guide for Northeastern North America

By Jessica L. Allen and James C. Lendemer. Illustrations and Selected Photography by Jordan R. Hoffman. 2021. Yale University Press. 168 pages and 121 colour illustrations, 33.95 CAD, Paper.

This book is a field guide to 61 of the most common urban lichens found in the Northeast. The authors based their fieldwork in New York City, but the guide will be useful for most large urban areas in northeastern North America, including Toronto. The book is divided into three sections. The first section is a 26-page introduction to lichens and their cultural relevance (e.g., for use as dyes). The short description of lichen biology in this section is the most technical part of the book, but understanding it is not critical to successfully using the field guide. The other parts of the introductory material are very accessible to a broad audience. Part Two, pages 27–108, contains the illustrated species descriptions followed by a 23-page dichotomous key. Part Three includes a complete list of New York City lichens, a partly illustrated nine-page glossary of terms, a bibliography, and a suggested reading list.

Species descriptions are sorted first by growth form and then by colour. Within each colour category, species are sorted alphabetically by scientific name, although this is not immediately apparent because the common names appear first in larger, bold font. Each species entry consists of a photo, common name, Latin name, species authority, physical description, Where to Find It, and abundance level in urban areas. For 14 species, there is also an Air Quality Rating, which identifies sensitivities to acidic pollution and fertilizing nitrogen, and overall sensitivity, if known. Species photos are high-quality and illustrate key features; importantly, all photos were taken in urban areas. Delightfully, some lichens have charming common names, such as Curly Biscuits, Rei of Sunshine (*Cladonia rei*), and Bruce's Lucky Dust.

Why does this book exist? According to the authors, many lichens have distinct city morphologies compared to similar species established in areas with better air quality. This book was a response to popular demand for a field guide of species that can survive or thrive in urban areas. The authors' goal was to create a guide that would be accessible to anyone—from a novice to an expert—with an interest in lichens. With



so many of us living in urban areas, it is nice to see a field guide that intentionally supports urban naturalists in their adventures.

I tested the dichotomous key and species descriptions in downtown Halifax, Nova Scotia, to assess its accessibility and ease of use. Get your hand lenses or dissecting microscopes ready: lichen features are very small. Although not exactly beginner-friendly, the photo glossary helped with parsing the dichotomous key, and with some time and backtracking I could arrive at an educated guess for the species in question. As this book covers only a subset of lichen species, it suffers from the drawback of all guides of its type: when you arrive at a species identification, you cannot be sure if you have indeed keyed correctly or if the species that you have in hand is simply not included or mentioned in the guide. Species pages do offer useful advice on what distinguishes look-alikes, but without a more involved follow-up an accurate identification is not guaranteed.

There is an unfortunate error in the dichotomous key where one of the main options (lead 10) is trichotomous, leading to some early confusion keying species. The dichotomous key is also missing page numbers referencing the species entries in the book, so you have to open the Index and attempt to find your result there. Flipping through the book until you land on the correct photo is an alternative to searching the Index, but in either case you will discover that several species included in the key are not described in the book. There is also no indication in the key which species are or are not covered. This can prove frustrating, and if your objective is to positively identify lichen species this book is best used in combination with a secondary source.

This field guide is a good fit for those looking to appreciate lichen diversity and the unique morphologies in northeastern North American urban areas. While urban lichen aficionados with prior experience using dichotomous keys and field guides will probably get the best utility from this book, it is also suitable for a general audience. If the cost of misidentification is low, the process of keying out lichen species provides many of us with a much closer and more intimate view of these taxa than we would otherwise have, and the more folks out appreciating lichens the better.

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## Voles, Not Moles: a Personal Journey Connecting with Nature

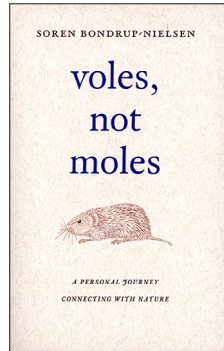
By Soren Bondrup-Nielsen. 2021. Gaspereau Press. 240 pages, 29.95 CAD, Paper.

This book, the fifth the author has published with Gaspereau Press, is essentially an autobiography interspersed with rather clichéd admonitions about how Western society has lost its way and become disconnected from nature. These tiny sermons—possibly drawn from Bondrup-Nielsen's lecture notes from a long career as a biology professor—include comments on evolution, ecology, conservation, and the joys of living alone, or close to it, in the northern forests of Canada, Scandinavia, and Russia.

I should clarify that I have a particular interest in this book, because Bondrup-Nielsen's career is eerily parallel to mine. I am slightly older, but we had similar academic careers, both spending time at the University of Toronto and the University of Guelph, both working on birds for our Master of Science degrees and microtine (i.e., voles, lemmings, and muskrats) rodent ecology for our Doctor of Philosophy degrees, and both spending time at the Algonquin Wildlife Research Station. We also both attended meetings with fellow microtine researchers in Scandinavia, and we have both ended up living only a few kilometres apart in retirement in Nova Scotia. I am sure we must have met, but although I immediately recognized his name and face, I can't recall meeting him. These connections made me eager to read this book as the title reflects an amusing misconception we vole guys face.

*Voles, Not Moles* begins with Bondrup-Nielsen's early life in Denmark where his parents gave him the freedom to roam the outdoors (or what remains of it in Denmark). Eventually, his family emigrated to the United States, but they returned to Denmark after a year. When Bondrup-Nielsen was 13 they moved to Canada. At the end of this brief family history, he digresses into a discussion of human overpopulation and an outline of some principles of genetics.

Bondrup-Nielsen then outlines how he became a biologist, attending the University of Guelph where he was initially interested in becoming a veterinarian. His description made me realize that he missed being a student in my first year teaching the Animal Kingdom course by one semester. Although he correctly extols the importance of evolution, he never took this subject at Guelph, and the professor he



praises as a great teacher was an outspoken denier of evolution.

Bondrup-Nielsen's writing style is unusually dry and serious. He includes details like the name of the ship he took, the kind of truck he was driving, the details of setting up his trapping grid, the materials with which he built his pens, and how he placed and joined the sections. Yet he describes meeting his future wife and their romance in one sentence: "Pia and I went to the Zoological Museum where 'events took a turn'. The next fall Pia gave birth to our daughter" (p.130).

He describes very nicely how he built his study pens, and how he designed and tested his hypotheses. But I have done these things—making trapping grids, setting mouse traps, measuring voles—and these activities are not exciting. I studied ecology of collared lemmings (an animal that spends much of its time underground) and attached radio-transmitters to them so I could at least occasionally watch them gallop about and socially interact on the earth's surface. Red-backed Voles, Bondrup-Nielsen's study species, are rarely visible in the wild, and he seems uninterested in describing them beyond inferred reproductive strategy. Even if one loves nature, it is difficult to get attached to microtines if you can't see them.

This book gives good descriptions of how to design field experiments, but poor descriptions of how to connect with nature. Too often, Bondrup-Nielsen describes shooting birds for dinner, but he never describes the birds, the voles, or anything else, except his owls. He seems to have no interest in biology beyond his own research. He kills or traps large numbers of voles and shoots other things in passing. Getting in touch with nature seems to be about roughing it in the bush, hiking, chopping trees, skiing, building shelters, and occasionally killing animals for food. I like these things too; however, as a reader, I want to know what it is about nature that grabs his attention and makes him feel a part of it.

Overall, the book has some charm, but it is also dull and pedantic. There is no clear connection between Bondrup-Nielsen's clichéd environmentalism and his research. He has written four other books and two of them have titles matching chapter titles of this book. I would guess that *Voles, Not Moles* might be in some parts condensed from the earlier works.

This book reminds me of my uncle George. Every year, George went on a family trip and took many slides. Months later, our family would be subjected to a slide presentation. What I remember most was how George would create text slides to describe shots

or places. Somehow, this book reminds me of those slideshows. Charming, sometimes interesting, but always plodding and often skipping over details I expect would be of importance to the reader.

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Guelph, ON, Canada

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## New Titles

Prepared by Jessica Sims

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

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

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

### BIOLOGY

**Evolution and the Machinery of Chance: Philosophy, Probability, and Scientific Practice in Biology.** By Marshall Abrams. 2023. University of Chicago Press. 304 pages, 136.50 CAD, Hardcover, 45.50 CAD, Paper, 34.99 CAD, E-book.

**Evolution “On Purpose”: Teleonomy in Living Systems.** Vienna Series in Theoretical Biology. Edited by Peter A. Corning, Stuart A. Kauffman, Denis Noble, James A. Shapiro, Richard I. Vane-Wright, and Addy Pross. 2023. MIT Press. 390 pages and 29 black and white illustrations, 99.00 CAD, Paper, 78.99 CAD, E-book.

†**Evolutionary Quantitative Genetics.** By Stevan J. Arnold. 2023. Oxford University Press. 496 pages, 130.00 USD, Hardcover, 60.00 USD, Paper. Also available as an E-book.

**Evolvability: a Unifying Concept in Evolutionary Biology?** Vienna Series in Theoretical Biology. Edited by Thomas F. Hansen, David Houle, Mihaela Pavličev, and Christophe Pélabon. 2023. MIT Press. 406 pages and 49 black and white illustrations, 86.00 CAD, Paper, 67.99 CAD, E-book.

**The Foundations of Population Genetics.** By Daniel M. Weinreich. 2023. MIT Press. 254 pages and 50 colour illustrations, 66.00 CAD, Hardcover, 51.99 CAD, E-book.

**The New Biology: a Battle between Mechanism and Organicism.** By Michael J. Reiss and Michael Ruse. 2023. Harvard University Press. 320 pages, 58.50 CAD, Hardcover, 44.99 CAD, E-book.

**Properties of Life: Toward a Theory of Organismic Biology.** Vienna Series in Theoretical Biology. By Bernd Rosslénbroich. 2023. MIT Press. 326 pages and 40 black and white illustrations, 79.00 CAD, Paper, 63.99 CAD, E-book.

**Species, Science and Society: the Role of Systematic Biology.** Routledge Studies in Conservation and the Environment Series. By Quentin Wheeler. 2023. Routledge. 246 pages, 239.95 CAD, Hardcover, 60.95 CAD, Paper, 53.99 CAD, E-book.

**Understanding Species.** Understanding Life Series. By John S. Wilkins. 2023. Cambridge University Press. 150 pages, 22.95 CAD, Paper.

**The Voices of Nature: How and Why Animals Communicate.** By Nicolas Mathevon. Foreword by Bernard L. Krause. 2023. Princeton University Press. 392 pages and 32 black and white illustrations, 40.00 CAD, Hardcover, 31.99 CAD, E-book.

### BOTANY

**The Biology of Aquatic and Wetland Plants.** By Gary N. Ervin. 2023. CRC Press. 394 pages, 241 co-

four illustrations, and 40 black and white illustrations, 225.95 CAD, Hardcover, 87.99 CAD, E-book.

**Darwin and the Art of Botany: Observations on the Curious World of Plants.** By James T. Costa and Bobbi Angell. 2023. Timber Press. 380 pages, 38.00 CAD, Hardcover, 25.99 CAD, E-book.

**Demystifying Orchid Pollination: Stories of Sex, Lies and Obsession.** By Adam P. Karremans. 2023. Royal Botanic Gardens, Kew. Distributed by University of Chicago Press. 442 pages and 120 colour photos, 65.00 CAD, Hardcover.

**Ecological Guide to the Mosses and Common Liverworts of the Northeast.** By Sue Alix Williams. 2023. Cornell University Press. 208 pages and 1000 colour photos, 37.95 CAD, Paper.

†**The Evolutionary Ecology of Plant Disease.** By Gregory Gilbert and Ingrid Parker. 2023. Oxford University Press. 336 pages, 130.00 USD, Hardcover, 50.00 USD, Paper. Also available as an E-book.

**The Herbarium Handbook. Fourth Edition.** Edited by Nina M.J. Davies, Claire Drinkell, and Timothy M.A. Utteridge. 2023. Royal Botanic Gardens, Kew. 256 pages, 24.99 GBP, Paper.

**In Search of the Old Ones: an Odyssey among Ancient Trees.** By Anthony D. Fredericks. 2023. Smithsonian Books. 248 pages, 36.95 CAD, Hardcover, 27.99 CAD, E-book.

**Kew Pocketbooks: Trees.** By Kevin Martin. 2023. Royal Botanic Gardens, Kew. Distributed by University of Chicago Press. 96 pages and 40 colour illustrations, 19.50 CAD, Hardcover.

**The Kew Temperate Plant Families Identification Handbook.** Edited by Gemma Bramley, Anna Trias Blasi, and Richard Wilford. 2023. Royal Botanic Gardens, Kew. Distributed by University of Chicago Press. 240 pages, 1200 colour photos, and 100 maps, 45.50 CAD, Paper.

**A Lab for All Seasons: the Laboratory Revolution in Modern Botany and the Rise of Physiological Plant Ecology.** By Sharon E. Kingsland. 2023. Yale University Press. 400 pages, 110.50 CAD, Hardcover, 40.00 USD, Paper, 39.99 CAD, E-book.

**An Ocean Garden: the Secret Life of Seaweed. Second Edition.** By Josie Iselin. 2023. Oregon State University Press. 144 pages, 30.95 CAD, Paper. Hardcover edition published in 2014.

**Orchid.** By Dan Torre. 2023. Reaktion Books. Distributed by University of Chicago Press. 256 pages,

106 colour plates, and 15 halftones, 35.50 CAD, Hardcover.

**Plant Strategies: the Demographic Consequences of Functional Traits in Changing Environments.** By Daniel C. Laughlin. 2023. Oxford University Press. 464 pages, 130.00 USD, Hardcover, 50.00 USD, Paper. Also available as an E-book.

**Rare Trees: the Fascinating Stories of the World's Most Threatened Species.** By Sara Oldfield and Malin Rivers. 2023. Timber Press. 400 pages, 48.00 CAD, Hardcover, 24.99 CAD, E-book.

**Rowan.** By Oliver Southall. 2023. Reaktion Books. Distributed by University of Chicago Press. 248 pages, 84 colour plates, and 19 halftones, 35.50 CAD, Hardcover, 26.99 CAD, E-book.

**Sexus Botanicus: the Love Lives of Plants.** By Joanne Anton. Translated by Erik Butler. 2023. MIT Press. 184 pages and 61 colour illustrations, 36.95 CAD, Paper.

**Things to Do with Plants: 50 Ways to Connect with the Botanical World.** By Emma Crawforth. 2023. Royal Botanic Gardens, Kew. Distributed by University of Chicago Press. 168 pages and 80 colour photos, 32.50 CAD, Hardcover.

**Vegetal Entwinements in Philosophy and Art: a Reader.** Edited by Giovanni Aloï and Michael Marder. 2023. MIT Press. 656 pages and 22 black and white illustrations, 86.00 CAD, Hardcover.

**Yew.** By Fred Hageneder. 2023. Reaktion Books. Distributed by University of Chicago Press. 208 pages, 70 colour plates, and 30 halftones, 29.50 CAD, Paper, 26.99 CAD, E-book. Hardcover edition published in 2013.

#### CONSERVATION AND CLIMATE CHANGE

**The Book of Wilding: a Practical Guide to Rewilding, Big and Small.** By Isabella Tree and Charlie Burrell. 2023. Bloomsbury. 560 pages, 53.00 CAD, Hardcover, 29.99 CAD, E-book.

**Canopy of Titans: the Life and Times of the Great North American Temperate Rainforest.** By Paul Koberstein and Jessica Applegate. 2023. OR Books. 416 pages, 34.95 CAD, Hardcover. Also available as an E-book.

**Carbon Colonialism: How Rich Countries Export Climate Breakdown.** By Laurie Parsons. 2023. Manchester University Press. 248 pages, 37.99 CAD, Hardcover.

**The Case for Nature: Pioneering Solutions for the Other Planetary Crisis.** By Siddarth Shrikanth. 2023. Duckworth Overlook. 304 pages, 39.22 CAD, Hardcover, 9.99 CAD, E-book.

**Climate Change 2022—Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.** By Intergovernmental Panel on Climate Change (IPCC). 2023. Cambridge University Press. 3000 pages, 260.00 USD, Paper. Also available as an E-book. PDF freely available from [https://report.ipcc.ch/ar6/wg2/IPCC\\_AR6\\_WGII\\_FullReport.pdf](https://report.ipcc.ch/ar6/wg2/IPCC_AR6_WGII_FullReport.pdf).

**Climate Resilience: How We Keep Each Other Safe, Care for Our Communities, and Fight Back against Climate Change.** By Kylie Flanagan. 2023. North Atlantic Books. 352 pages, 25.95 CAD, Paper, 20.99 CAD, E-book.

**Climate Travels: How Ecotourism Changes Minds and Motivates Action.** By Michael M. Gunter, Jr. 2023. Columbia University Press. 360 pages, 120.00 USD, Hardcover, 39.00 CAD, Paper. Also available as an E-book.

**The Conversation on Water.** Critical Conversations Series. Edited by Andrea K. Gerlak. 2023. Johns Hopkins University Press. 264 pages, 10 black and white photos, and 10 black and white illustrations, 22.95 CAD, Paper, 16.99 CAD, E-book.

**Cry of the Wild: Eight Animals under Siege.** By Charles Foster. 2023. Doubleday. 256 pages, 16.99 GBP, Hardcover. Also available as an E-book.

**The Domination of Nature. New Edition.** McGill-Queen's Studies in the History of Ideas Series No. 89. By William Leiss. 2023. McGill-Queen's University Press. 306 pages, 130.00 CAD, Hardcover, 37.95 CAD, Paper. Also available as an E-book. First published in 1972.

**The Ghost Forest: Racists, Radicals, and Real Estate in the California Redwoods.** By Greg King. 2023. PublicAffairs. 480 pages, 40.00 CAD, Hardcover, 24.99 CAD, E-book.

**Humanity's Moment: a Climate Scientist's Case for Hope.** By Joëlle Gergis. 2023. Island Press. 336 pages, 37.95 CAD, Hardcover, 29.99 CAD, E-book.

**Ignition: Lighting Fires in a Burning World.** By M.R. O'Connor. 2023. Bold Type Books. 384 pages, 38.00 CAD, Hardcover, 22.99 CAD, E-book.

**Kings of Their Own Ocean: Tuna, Obsession, and the Future of Our Seas.** By Karen Pinchin. 2023.

Knopf Canada. 320 pages, 36.00 CAD, Hardcover, 16.99 CAD, E-book.

**Lacandón Maya in the Twenty-First Century: Indigenous Knowledge and Conservation in Mexico's Tropical Rainforest.** By James D. Nations. 2023. University Press of Florida. 320 pages, 125.00 CAD, Hardcover, 43.95 CAD, Paper.

**The Living Planet: the State of the World's Wildlife.** Edited by Norman Maclean. 2023. Cambridge University Press. 446 pages, 137.95 CAD, Hardcover, 57.95 CAD, Paper. Also available as an E-book.

**Message in a Bottle: Ocean Dispatches from a Seabird Biologist.** By Holly Hogan. 2023. Knopf Canada. 304 pages, 32.95 CAD, Hardcover, 15.99 CAD, E-book.

**Mnemonic Ecologies: Memory and Nature Conservation along the Former Iron Curtain.** By Sonja K. Pieck. 2023. MIT Press. 290 pages and 16 black and white illustrations, 60.00 CAD, Paper, 47.99 CAD, E-book.

**Nature-Made Economy: Cod, Capital, and the Great Economization of the Ocean.** By Kristin Asdal and Tone Huse. 2023. MIT Press. 280 pages and 31 black and white illustrations, 60.00 CAD, Paper, 47.99 CAD, E-book.

†**Nature that Makes Us Human: Why We Keep Destroying Nature and How We Can Stop Doing So.** By Michel Loreau. 2023. Oxford University Press. 168 pages and 11 black and white illustrations, 34.95 USD, Hardcover. Also available as an E-book.

**The Octopus in the Parking Garage: a Call for Climate Resilience.** By Rob Verchick. 2023. Columbia University Press. 288 pages, 42.00 CAD, Hardcover. Also available as an E-book.

**One Planet, Many Worlds: the Climate Parallax.** The Mandel Lectures in the Humanities at Brandeis University Series. By Dipesh Chakrabarty. 2023. Brandeis University Press. Distributed by University of Chicago Press. 144 pages, 99.00 USD, Hardcover, 34.46 CAD, Paper, 23.99 CAD, E-book.

**Organizing Nature: Turning Canada's Ecosystems into Resources.** By Alice Cohen and Andrew Biro. 2023. University of Toronto Press. 282 pages, 12 black and white illustrations, and 13 black and white maps, 80.00 CAD, Hardcover, 36.95 CAD, Paper, 29.95 CAD, E-book.

**Over the Seawall: Tsunamis, Cyclones, Drought, and the Delusion of Controlling Nature.** By Ste-

phen Miller. 2023. Island Press. 264 pages, 43.95 CAD, Hardcover. Also available as an E-book.

**The Parrot and the Igloo: Climate and the Science of Denial.** By David Lipsky. 2023. W.W. Norton. 496 pages, 42.50 CAD, Hardcover, 30.99 CAD, E-book.

**Pluralist Politics, Relational Worlds: Vulnerability and Care of the Earth.** By Didier Zúñiga. 2023. University of Toronto Press. 240 pages, 95.00 CAD, Hardcover, 35.95 CAD, Paper. Also available as an E-book.

**Protecting the Coast and Ocean: a Guide to Marine Conservation Law in British Columbia.** By Stephanie M. Hewson, Linda Nowlan, Georgia Lloyd-Smith, Deborah Carlson, and Michael Bissonnette. 2023. UBC Press. 300 pages, 39.95 CAD, Hardcover. Also available as an E-book.

**The Quickening: Creation and Community at the Ends of the Earth.** By Elizabeth Rush. 2023. Milkweed Editions. 424 pages, 44.95 CAD, Hardcover.

**Rare Air: Endangered Birds, Bats, Butterflies, and Bees.** By Sarah Kaizar and A. Scott Meiser. 2023. The Mountaineers Books. 152 pages, 32.95 CAD, Hardcover.

**Reflections: What Wildlife Needs and How to Provide It.** By Mark Avery. 2023. Pelagic Publishing. 248 pages, 36.00 CAD, Paper, 27.99 CAD, E-book.

**The Return of Wolves: an Iconic Predator's Struggle to Survive in the American West.** By Eli Francovich. 2023. Timber Press. 240 pages, 35.00 CAD, Hardcover, 19.99 CAD, E-book.

**River Notes: Drought and the Twilight of the American West—a Natural and Human History of the Colorado. Edition, Revised and Updated.** By Wade Davis. 2023. Greystone Books. 184 pages, 22.95 CAD, Hardcover.

**Sea Change: an Atlas of Islands in a Rising Ocean.** By Christina Gerhardt. 2023. University of California Press. 320 pages, 11 figures, and 38 maps, 49.50 CAD, Hardcover. Also available as an E-book.

**A Sense of Urgency: How the Climate Crisis is Changing Rhetoric.** By Debra Hawhee. 2023. University of Chicago Press. 272 pages and 32 halftones, 128.95 CAD, Hardcover, 37.67 CAD, Paper, 26.99 CAD, E-book.

**The Shotgun Conservationist: Why Environmentalists Should Love Hunting.** By Brant MacDuff. 2023. Timber Press. 256 pages, 35.00 CAD, Hardcover, 19.99 CAD, E-book.

**Smoke on the Water: Incineration at Sea and the Birth of a Transatlantic Environmental Movement.** Global America Series. By Dario Fazzi. 2023. Columbia University Press. 272 pages, 182.00 CAD, Hardcover, 46.00 CAD, Paper. Also available as an E-book.

**Solving the Climate Crisis: Frontline Reports from the Race to Save the Earth.** By John J. Berger. Introduction by Russ Feingold. 2023. Seven Stories Press. 480 pages, 38.95 CAD, Paper, 20.99 CAD, E-book.

**Streams of Consequence: Dispatches from the Conservation World.** By Lorne Fitch. 2023. Rocky Mountain Books (RMB). 232 pages, 25.00 CAD, Paper, 10.99 CAD, E-book.

**The Three Ages of Water: Prehistoric Past, Imperiled Present, and a Hope for the Future.** By Peter Gleick. 2023. PublicAffairs. 368 pages, 38.00 CAD, Hardcover, 24.99 CAD, E-book.

**Traffication: How Cars Destroy Nature and What We Can Do About It.** By Paul Donald. 2023. Pelagic Publishing. 294 pages, 37.00 CAD, Hardcover, 27.99 CAD, E-book.

**Tree by Tree: Saving North America's Eastern Forests.** By Scott J. Meiners. 2023. Cornell University Press. 246 pages, 33.95 CAD, Paper. Also available as an E-book.

**Wasteland: the Secret World of Waste and the Urgent Search for a Cleaner Future.** By Oliver Franklin-Wallis. 2023. Hachette Books. 400 pages, 38.00 CAD, Hardcover, 19.99 CAD, E-book.

**Wildlife Disease and Health in Conservation.** Edited by David A. Jessup and Robin W. Radcliffe. 2023. Johns Hopkins University Press. 496 pages, 71 colour photos, and 109 colour illustrations, 77.95 CAD, Hardcover. Also available as an E-book.

#### ECOLOGY

**Animals under Logs and Stones.** Naturalists' Handbooks Series. By C. Philip Wheeler, Helen J. Read, and Charlotte E. Wheeler. 2023. Pelagic Publishing. 352 pages, 130 photos, and 280 line drawings, 55.00 CAD, Paper, 41.99 CAD, E-book.

**The Blue Machine: How the Ocean Works.** By Helen Czerski. 2023. W.W. Norton. 416 pages, 42.50 CAD, Hardcover, 30.99 CAD, E-book.

†**Carnivoran Ecology: the Evolution and Function of Communities.** By Steven W. Buskirk. 2023. Oxford University Press. 288 pages, 105.00 USD, Hardcover, 50.00 USD, Paper. Also available as an E-book.

**Crossings: How Road Ecology is Shaping the Future of Our Planet.** By Ben Goldfarb. 2023. W.W. Norton. 384 pages, 40.00 CAD, Hardcover, 30.99 CAD, E-book.

**Deep Water: from the Frilled Shark to the Dumbo Octopus and from the Continental Shelf to the Mariana Trench.** By Riley Black. 2023. University of Chicago Press. 224 pages, 100 colour plates, and 100 halftones, 45.50 CAD, Hardcover. Also available as an E-book.

**The Ecology of Collective Behavior.** By Deborah M. Gordon. 2023. Princeton University Press. 184 pages, 125.00 CAD, Hardcover, 38.00 CAD, Paper, 29.99 CAD, E-book.

**How to Do Ecology: a Concise Handbook. Third Edition.** By Richard Karban, Mikaela Huntzinger, and Ian S. Pearse. 2023. Princeton University Press. 232 pages, 35.00 CAD, Paper, 27.99 CAD, E-book.

**Our Ancient Lakes: a Natural History.** By Jeffrey McKinnon. 2023. MIT Press. 336 pages, 39.95 CAD, Hardcover, 31.99 CAD, E-book.

**Paths of Pollen.** By Stephen Humphrey. 2023. McGill-Queen's University Press. 272 pages and 51 photos, 39.95 CAD, Hardcover. Also available as an E-book.

**River Ecology: Science and Management for a Changing World.** By Michael A. Mallin. 2023. Oxford University Press. 416 pages, 130.00 USD, Hardcover, 50.00 USD, Paper. Also available as an E-book.

#### ENTOMOLOGY

**Alien Worlds: How Insects Conquered the Earth, and Why Their Fate Will Determine Our Future.** By Steve Nicholls. 2023. Princeton University Press. 496 pages and 179 colour photos, 56.50 CAD, Hardcover, 39.99 CAD, E-book.

**Beetles of the World: a Natural History.** A Guide to Every Family Series No. 7. By Maxwell V.L. Barclay and Patrice Bouchard. 2023. Princeton University Press. 240 pages, 300 colour photos, and 150 colour illustrations, 42.50 CAD, Hardcover, 29.99 CAD, E-book.

**Butterflies of Maine and the Canadian Maritime Provinces.** By Phillip G. deMaynadier, John Klymko, Ronald G. Butler, W. Herbert Wilson Jr., and John V. Calhoun. Foreword by Ernest H. Williams. 2023. Cornell University Press. 456 pages, 168 colour photos, 20 black and white halftones, and 127 maps, 47.95 CAD, Paper.

**The Complete Insect: Anatomy, Physiology, Evolution, and Ecology.** Edited by David A. Grimaldi. 2023. Princeton University Press. 368 pages and 150 colour illustrations, 49.50 CAD, Hardcover, 34.99 CAD, E-book.

**Hairy-Foot, Long-Tongue: Solitary Bees, Biodiversity and Evolution in Your Backyard.** By David J. Perkins. 2023. Whittles Publishing. 224 pages and 250+ colour photos and illustrations, 18.99 GBP, Paper.

**Honey Bee Biology.** By Brian R. Johnson. Foreword by Thomas D. Seeley. 2023. Princeton University Press. 512 pages, 16 colour illustrations, 101 black and white illustrations, and 13 tables, 57.00 CAD, Hardcover, 44.99 CAD, E-book.

**\*Hymenoptera: the Natural History and Diversity of Wasps, Bees and Ants.** By Stephen A. Marshall. 2023. Firefly Books. 640 pages, 95.00 CAD, Hardcover.

**\*The Jewel Box: How Moths Illuminate Nature's Hidden Rules.** By Tim Blackburn. 2023. Island Press. 288 pages and 10 photos, 37.95 CAD, Hardcover. Also available as an E-book.

**Shieldbugs.** New Naturalist Series. By Richard Jones. 2023. William Collins. 496 pages, 135.99 CAD, Hardcover, 50.00 USD, Paper, 87.99 CAD, E-book.

**Solitary Bees.** New Naturalist Series. By Ted Benton and Nick Owens. 2023. William Collins. 496 pages, 135.99 CAD, Hardcover, 50.00 USD, Paper, 60.99 CAD, E-book.

#### HERPETOLOGY

**Frogs of the United States and Canada. Second Edition.** By C. Kenneth Dodd Jr. 2023. Johns Hopkins University Press. 992 pages, 410 colour photos, 35 black and white illustrations, and 110 maps, 258.95 CAD, Hardcover. Also available as an E-book.

**Of Time and Turtles: Mending the World, Shell by Shattered Shell.** By Sy Montgomery. Illustrations by Matt Patterson. 2023. HarperCollins. 304 pages, 35.99 CAD, Hardcover.

**Pocket Guide to the Amphibians and Reptiles of Costa Rica.** By Twan Leenders. 2023. Cornell University Press. 336 pages and 600 colour photos, 37.95 CAD, Paper.

**Saving Snakes: Snakes and the Evolution of a Field Naturalist.** By Nicolette L. Cagle. 2023. University of Virginia Press. 210 pages, 37.95 CAD, Paper, 27.99 CAD, E-book.

**Tadpole Hunter: a Personal History of Amphibian Conservation and Research.** By Arnold Cooke. 2023. Pelagic Publishing. 305 pages and 106 colour photos, 55.00 CAD, Paper, 41.99 CAD, E-book.

#### ORNITHOLOGY

**Alfie and Me: What Owls Know, What Humans Believe.** By Carl Safina. 2023. W.W. Norton. 352 pages, 42.50 CAD, Hardcover, 30.99 CAD, E-book.

**Better Living through Birding: Notes from a Black Man in the Natural World.** By Christian Cooper. 2023. Random House. 304 pages, 37.99 CAD, Hardcover, 16.99 CAD, E-book.

**Bird Day: a Story of 24 Hours and 24 Avian Lives.** Earth Day Series. By Mark E. Hauber. Illustrations by Tony Angell. 2023. University of Chicago Press. 168 pages and 24 halftones, 23.50 CAD, Hardcover. Also available as an E-book.

**Ecology and Conservation of Mountain Birds.** Ecology, Biodiversity and Conservation Series. Edited by Dan Chamberlain, Aleksii Lehtikoinen, and Kathy Martin. 2023. Cambridge University Press. 450 pages, 51.95 CAD, Paper. Also available as an E-book.

**In a Class of Their Own: a Detailed Examination of Avian Forms and Functions.** By Gary Ritchison. 2023. Springer Nature. 2513 pages, 1482 colour illustrations, and 1022 black and white illustrations, 222.50 CAD, Hardcover.

**One Midsummer's Day: Swifts and the Story of Life on Earth.** By Mark Cocker. 2023. Jonathan Cape. 352 pages, 20.00 GBP, Hardcover. Also available as an E-book.

**Owls: the Majestic Hunters.** By Stan Tekiela. Photography by Stan Tekiela. 2023. Adventure Publications. 160 pages, 29.95 CAD, Paper.

**The Purple Sandpiper.** By Ron W. Summers. Foreword by Jeremy J.D. Greenwood. 2023. Ron W. Summers. 352 pages, 150+ photos, and 100+ illustrations, 29.99 GBP, Hardcover.

**The Screech Owl Companion: Everything You Need to Know about These Beneficial Raptors.** By Jim Wright and Scott Weston. 2023. Timber Press. 192 pages and 150 photos, 31.99 CAD, Paper, 16.99 CAD, E-book.

**Ten Birds that Changed the World.** By Stephen Moss. 2023. Basic Books. 416 pages, 38.00 CAD, Hardcover, 22.99 CAD, E-book.

**Terns of North America: a Photographic Guide.** By Cameron Cox. 2023. Princeton University Press. 208 pages and 350 colour illustrations, 35.00 CAD, Paper. Also available as an E-book.

**What an Owl Knows: the New Science of the World's Most Enigmatic Birds.** By Jennifer Ackerman. 2023. Penguin Press. 352 pages, 41.00 CAD, Hardcover, 18.99 CAD, E-book.

**Yellowstone's Birds: Diversity and Abundance in the World's First National Park.** Edited by Douglas W. Smith, Lauren E. Walker, and Katharine E. Duffy. 2023. Princeton University Press. 304 pages and 168 colour illustrations, 44.00 CAD, Hardcover. Also available as an E-book.

#### ZOOLOGY

**All the Mammals of the World.** Foreword by Ara Monadjem. Introduction and Appendix by Connor J. Burgin. Illustrations by Toni Llobet, Ilian Velikov, Lluís Sogorb, Faansie Peacock, Francesc Jutglar, Àlex Mascarell, Blanca Martí, and Jesús Rodríguez-Osorio. 2023. Lynx Edicions. 800 pages, 7349 colour illustrations, and 6459 colour distribution maps, 89.00 EUR, Hardcover.

**Around the Ocean in 80 Fish and Other Sea Life.** By Helen Scales. Illustrations by Marcel George. 2023. Laurence King Publishing. 200 pages, 37.99 CAD, Hardcover, 19.99 CAD, E-book.

**The Curious World of Seahorses: the Life and Lore of a Marine Marvel.** By Till Hein. Translated by Renée Von Paschen. 2023. Greystone Books. 224 pages, 34.95 CAD, Hardcover.

**Eight Bears: Mythic Past and Imperiled Future.** By Gloria Dickie. 2023. W.W. Norton. 336 pages, 40.00 CAD, Hardcover, 30.99 CAD, E-book.

**Hydroids of the World.** By Elena Kupriyanova, Yanan Sun, Eunice Wong, and Harry A. ten Hove. 2023. CRC Press. 282 pages and 80 colour illustrations, 282.50 CAD, Paper.

**The Lives of Octopuses and Their Relatives: a Natural History of Cephalopods.** The Lives of the Natural World Series. By Dana Stauf. 2023. Princeton University Press. 288 pages and 150 colour illustrations, 49.50 CAD, Hardcover, 34.99 CAD, E-book.

**The Lives of Sharks: a Natural History of Shark Life.** The Lives of the Natural World Series. By Daniel C. Abel and R. Dean Grubbs. 2023. Princeton University Press. 288 pages and 150 colour illustrations, 49.50 CAD, Hardcover, 34.99 CAD, E-book.

**Many Things under a Rock: the Mysteries of Octopuses.** By David Scheel. Illustrations by Laurel “Yoyo” Scheel. 2023. W.W. Norton. 288 pages, 38.95 CAD, Hardcover, 26.99 CAD, E-book.

**North American Mammals: Systematics and Taxonomy.** By Sergio Ticol Alvarez-Castañeda. 2023. Springer. 700 pages, 314.55 EUR, Hardcover.

**North American Survivors.** By Dave Taylor. 2023. Fitzhenry & Whiteside. 96 pages, 40.00 CAD, Hardcover.

†**Oar Feet and Opal Teeth: about Copepods and Copepodologists.** By Charles B. Miller. 2023. Oxford University Press. 536 pages, 137.00 USD, Hardcover. Also available as an E-book.

**Ocean Bestiary: Meeting Marine Life from Abalone to Orca to Zooplankton.** By Richard J. King. 2023. University of Chicago Press. 320 pages and 93 halftones, 29.50 CAD, Hardcover, 21.99 CAD, E-book.

†**Orangutans: Their History, Natural History and Conservation.** By Ronald Orenstein. 2023. Firefly Books. 352 pages, 49.95 CAD, Hardcover.

**Sea Mammals: the Past and Present Lives of Our Oceans’ Cornerstone Species.** By Annalisa Berta. 2023. Princeton University Press. 224 pages and 150 colour illustrations, 42.50 CAD, Hardcover, 29.99 CAD, E-book.

**Whale Music: Thousand Mile Songs in a Sea of Sound. Edition, Revised and Updated.** By David Rothenberg. Foreword by Scott McVay. 2023. Terra Nova Press. 376 pages, 30 colour illustrations, and 45 black and white illustrations, 36.95 CAD, Paper, 29.99 CAD, E-book.

†**Wildlife of the North: Animals of the High Latitudes of North America and Europe.** By Hålle Flygare, Valerius Geist, Geoffrey Holroyd, and Wayne Lynch. 2023. Firefly Books. 264 pages and 240 colour photos, 29.95 CAD, Paper.

#### OTHER

**Across a Waking Land: a 1,000-Mile Walk through a British Spring.** By Roger Morgan-Grenville. 2023. Icon Books. 368 pages, 42.95 CAD, Hardcover.

**The Best American Science and Nature Writing 2023.** Edited by Carl Zimmer and Jaime Green. 2023. HarperCollins. 272 pages, 23.99 CAD, Paper, 11.99 CAD, E-book.

**Born of Ice and Fire: How Glaciers and Volcanoes (with a Pinch of Salt) Drove Animal Evolution.** By

Graham Shields. 2023. Yale University Press. 352 pages and 27 black and white illustrations, 36.50 CAD, Hardcover.

**Brave the Wild River: the Untold Story of Two Women Who Mapped the Botany of the Grand Canyon.** By Melissa L Sevigny. 2023. W.W. Norton. 304 pages, 40.00 CAD, Hardcover, 30.99 CAD, E-book.

**Cabin: How to Build a Retreat in the Wilderness and Learn to Live with Nature.** By Will Jones. 2023. Abrams Image. 256 pages and 50 black and white illustrations, 37.95 CAD, Hardcover, 30.99 CAD, E-book.

**Canada’s East Coast Seashore: a Visual Guide to Starfish, Shellfish, Seashells, Plants, Insects, Birds and More!** By Jeffrey C. Domm. 2023. Formac. 96 pages, 24.95 CAD, Paper.

**The Comfort of Crows: a Backyard Year.** By Margaret Renkl. Illustrations by Billy Renkl. 2023. Spiegel & Grau. 288 pages and 52 colour illustrations, 41.99 CAD, Hardcover, 33.99 CAD, E-book.

**The Deepest Map: the High-Stakes Race to Chart the World’s Oceans.** By Laura Trethewey. 2023. Goose Lane Editions. 336 pages, 24.95 CAD, Paper, 15.99 CAD, E-book.

**Disputed Inheritance: the Battle over Mendel and the Future of Biology.** By Gregory Radick. 2023. University of Chicago Press. 568 pages and 60 halftones, 146.50 CAD, Hardcover, 48.95 CAD, Paper, 36.99 CAD, E-book.

†**The Earth in Our Hands: Photos from the International Space Station.** By Thomas Pesquet. 2023. Firefly Books. 384 pages, 49.95 CAD, Hardcover.

**Elemental: How Five Elements Changed Earth’s Past and Will Shape Our Future.** By Stephen Porder. 2023. Princeton University Press. 240 pages, 35.00 CAD, Hardcover, 27.99 CAD, E-book.

**Embrace Fearlessly the Burning World: Essays.** By Barry Lopez. Introduction by Rebecca Solnit. 2023. Random House. 352 pages, 24.95 CAD, Paper, 16.99 CAD, E-book. Hardcover edition published in 2022.

**Finding W.H. Hudson: the Writer Who Came to Britain to Save the Birds.** By Conor Mark Jameson. 2023. Pelagic Publishing. 360 pages and 39 black and white illustrations, 42.00 CAD, Paper, 31.99 CAD, E-book.

**Fire Weather: the Making of a Beast.** By John Vailant. 2023. Knopf Canada. 432 pages, 38.00 CAD, Hardcover, 16.99 CAD, E-book.

**George Meléndez Wright: the Fight for Wildlife and Wilderness in the National Parks.** By Jerry Emory. 2023. University of Chicago Press. 248 pages and 26 halftones, 36.50 CAD, Hardcover, 27.99 CAD, E-book.

**Into the Amazon: the Life of Cândido Rondon, Trailblazing Explorer, Scientist, Statesman, and Conservationist.** By Larry Rohter. 2023. W.W. Norton. 480 pages, 51.00 CAD, Hardcover.

†**Kingdoms, Empires, and Domains: the History of High-Level Biological Classification.** By Mark A. Ragan. 2023. Oxford University Press. 856 pages, 165.00 USD, Hardcover. Also available as an E-book.

†**Lichens: the Macrolichens of Ontario and the Great Lakes Region of the United States.** By R. Troy McMullin. 2023. Firefly Books. 608 pages, 49.95 CAD, Paper.

**Life Sculpted: Tales of the Animals, Plants, and Fungi that Drill, Break, and Scrape to Shape the Earth.** By Anthony J. Martin. 2023. University of Chicago Press. 360 pages and 56 halftones, 35.95 CAD, Hardcover, 26.99 CAD, E-book.

**The Man Who Organized Nature: the Life of Linnaeus.** By Gunnar Broberg. Translated by Anna Paterson. 2023. Princeton University Press. 512 pages, 18 colour illustrations, and 55 black and white illustrations, 50.00 CAD, Hardcover, 39.99 CAD, E-book.

**Meetings with Remarkable Mushrooms: Forays with Fungi across Hemispheres.** By Alison Pouliot. 2023. University of Chicago Press. 320 pages and 16 colour plates, 33.95 CAD, Hardcover, 25.99 CAD, E-book.

**Methuselah's Zoo: What Nature Can Teach Us about Living Longer, Healthier Lives.** By Steven N. Austad. 2023. MIT Press. 320 pages and 22 black and white illustrations, 39.95 CAD, Hardcover, 29.95 CAD, Paper, 31.99 CAD, E-book.

**Mountains of Fire: the Menace, Meaning, and Magic of Volcanoes.** By Clive Oppenheimer. 2023. University of Chicago Press. 352 pages, 20 colour plates, and 15 halftones, 35.95 CAD, Hardcover. Also available as an E-book.

**Move Like Water: My Story of the Sea.** By Hannah Stowe. 2023. Tin House Books. 272 pages, 33.95 CAD, Hardcover, 25.99 CAD, E-book.

**Mushrooms: a Natural and Cultural History.** By Nicholas P. Money. 2023. Reaktion Books. Distributed by University of Chicago Press. 224 pages, 90 colour plates, and 10 halftones, 29.50 CAD, Paper, 22.99 CAD, E-book.

**The Mushroom Hunters: a Hidden World of Food, Money, and (Mostly Legal) Adventure.** By Langdon Cook. 2023. Ballantine Books. 320 pages, 24.95 CAD, Paper, 14.99 CAD, E-book.

**Natural Allies: Environment, Energy, and the History of US–Canada Relations.** Brian Mulroney Institute of Government Studies in Leadership, Public Policy, and Governance Series No. 14. By Daniel Macfarlane. 2023. McGill–Queen's University Press. 280 pages, 130.00 CAD, Hardcover, 37.95 CAD, Paper, 30.99 CAD, E-book.

**Organized Environmental Crime: Black Markets in Gold, Wildlife, and Timber.** By Daan van Uhm. 2023. Bloomsbury. 304 pages and 63 black and white illustrations, 90.50 CAD, Hardcover. Also available as an E-book.

**A Philosophy for the Science of Animal Consciousness.** By Walter Veit. Foreword by Nicola S. Clayton. 2023. Routledge. 162 pages, 239.95 CAD, Hardcover, 69.50 CAD, Paper, 61.99 CAD, E-book.

**The Phoenix Complex: a Philosophy of Nature.** By Michael Marder. 2023. MIT Press. 308 pages, 60.00 CAD, Paper, 47.99 CAD, E-book.

**Pitfall: the Race to Mine the World's Most Vulnerable Places.** By Christopher Pollon. 2023. Greystone Books in association with the David Suzuki Institute. 304 pages, 39.95 CAD, Hardcover.

**Reconfiguring the Museum: the Politics of Digital Display.** By Ana-Maria Herman. 2023. McGill–Queen's University Press. 272 pages and 58 photos, 80.00 CAD, Hardcover. Also available as an E-book.

**Shells: a Natural and Cultural History.** By Fabio Moretzsohn. With M. G. Harasewych. 2023. Reaktion Books. Distributed by University of Chicago Press. 176 pages and 114 colour plates, 35.95 CAD, Hardcover, 27.99 CAD, E-book.

†**Stoneworts of Newfoundland and Labrador: an Introductory Guide.** By Henry Mann. 2022. Henry Mann in association with Grenfell Campus Herbarium (SWGCH), Memorial University. 216 pages, free PDF available at <https://www2.grenfell.mun.ca/herbarium/download.html>.

**Times Flies: an Environmental History of Prince Edward Island from the Air.** By Joshua MacFa-

dyen. 2023. Island Studies Press. 250 pages, 49.95 CAD, Paper.

**The Two-Headed Whale: Life, Loss, and the Tangled Legacy of Whaling in the Antarctic.** By Sandy Winterbottom. 2023. Greystone Books. 256 pages, 34.95 CAD, Hardcover.

**The Underworld: Journeys to the Depths of the Ocean.** By Susan Casey. 2023. Knopf Doubleday. 352 pages, 42.00 CAD, Hardcover, 18.99 CAD, E-book.

**The Voyage of Sorcerer II: the Expedition that Unlocked the Secrets of the Ocean's Microbiome.** By J. Craig Venter and David Ewing Duncan. Foreword by Erling Norrby. 2023. Harvard University Press. 336 pages, 36.50 CAD, Hardcover.

**Water Beings: from Nature Worship to the Environmental Crisis.** By Veronica Strang. 2023. Reaktion Books. Distributed by University of Chicago

Press. 280 pages and 126 colour plates, 58.50 CAD, Hardcover, 44.99 CAD, E-book.

**Wild Track: Sound, Text and the Idea of Birdsong.** By Seán Street. 2023. Bloomsbury. 240 pages, 166.95 CAD, Hardcover, 120.99 CAD, E-book.

**Wind: Nature and Culture.** By Louise M. Pryke. 2023. Reaktion Books. Distributed by University of Chicago Press. 240 pages, 84 colour plates, and 21 halftones, 32.50 CAD, Paper, 24.99 CAD, E-book.

**Women, Environment, and Networks of Empire: Elizabeth Gwillim and Mary Symonds in Madras.** Edited by Anna Winterbottom, Victoria Dickenson, Ben Cartwright, and Lauren Williams. 2023. McGill-Queen's University Press. 400 pages and 103 illustrations, 75.00 CAD, Hardcover. Also available as an E-book.

**Women in the History of Science: a Sourcebook.** Edited by Hannah Wills, Sadie Harrison, Erika Lynn Jones, Farrah Lawrence-Mackey, and Rebecca Martin. 2023. UCL Press. Distributed by University of Chicago Press. 474 pages and 53 colour plates, 104.00 CAD, Hardcover, 50.00 USD, Paper.

# The Canadian Field-Naturalist

## News and Comment

Compiled by Amanda E. Martin

### Upcoming Meetings and Workshops

#### **The Society for Integrative & Comparative Biology Annual Meeting**

The annual meeting of the Society for Integrative and Comparative Biology to be held 2–6 January 2024 at the Seattle Convention Center, Seattle, Washington. Reg-

istration is currently open. More information is available at <https://www.xcdsystem.com/sicb/program/11Kr23t/index.cfm>.

#### **Midwest Fish & Wildlife Conference**

The 84th Midwest Fish & Wildlife Conference, hosted by South Dakota Game, Fish & Parks, to be held 28–31 January 2024 at the Denny Sanford PREMIER Center & Sheraton Sioux Falls, Sioux Falls,

South Dakota. The theme of the conference is: 'Habitat: Working Today to Benefit Tomorrow'. Registration is currently open. More information is available at <https://www.midwestfw.org/>.

#### **Society for Range Management Annual Meeting**

The annual meeting of the Society for Range Management to be held 28 January–1 February 2024 at The Nugget, Sparks, Nevada. Registration is currently

open. More information is available at <https://rangeands.org/annual-meeting-2024/>.

#### **Stewardship Network Conference**

The 17th Stewardship Network Conference to be held 29–30 January 2024 at The Kellogg Hotel & Conference Center, East Lansing, Michigan. Registration

is currently open. More information is available at <https://conference.stewardshipnetwork.org/>.

#### **Wetland Science Conference**

Wisconsin Wetlands Association's 29th annual Wetland Science Conference to be held 20–22 February 2024 at the Radisson Hotel & Convention Center,

Green Bay, Wisconsin. More information is available at <https://conference.wisconsinwetlands.org/>.

#### **Society for Canadian Aquatic Sciences Annual Meeting**

The second annual meeting of the Society for Canadian Aquatic Sciences to be held 21–24 February 2024 at the Fredericton Convention Centre, Fredericton,

New Brunswick. Registration is currently open. More information is available at <https://www.scas-scsa.ca/CONFERENCE>.

#### **Forests Ontario Annual Conference**

The annual conference of Forests Ontario to be held 28 February 2024 in Vaughan, Ontario. More infor-

mation is available at <https://forestsontario.ca/en/event/annual-conference>.

## James Fletcher Award for *The Canadian Field-Naturalist* Volume 136

The James Fletcher Award is awarded to the authors of the “best” paper published in a volume of *The Canadian Field-Naturalist* (CFN). The award is in its seventh year. The award honours James Fletcher, founder of the Ottawa Field-Naturalists’ Club (OFNC) and the first editor of CFN’s earliest iteration, *Transactions of the Ottawa Field-Naturalists’ Club*. The editorial team of CFN sifted through all papers in Volume 136 of CFN and came up with a list of the top seven papers. From these, the committee ranked the papers and, because of the difficult decision and high quality of the papers, selected the two, tied, top papers. The joint award for Volume 136 of CFN goes to:

**Noémie Pelletier, Janice E. Arndt, Rachel Darvill, and Marc-André Cyr.** Natural and human-made nesting habitat use by Bank Swallow (*Riparia riparia*) in Canada. *Canadian Field-Naturalist* 136(3): 228–236. <https://doi.org/10.22621/cfn.v136i3.2779>

- Analysis of data collected from a range of sources, revealing a reversal in the dominant nesting habitat type for the Threatened Bank Swallow, from human-made to natural habitats.

**Marjorie Wonham, Catherine Gerstle, and Colin Bates.** Combining current and historical biodiversity surveys reveals order of magnitude greater richness in a British Columbia marine protected area. *Canadian Field-Naturalist* 136(4): 348–360. <https://doi.org/10.22621/cfn.v136i4.2903>

- A combination of historical and current survey data, covering three intertidal habitats and 43 years, are used to increase the list of taxa observed in the Átl’ka7sem/Howe Sound United Nations Biosphere Reserve (British Columbia, Canada) by an order of magnitude (to 99).

Congratulations to Noémie and Marjorie and co-authors for their excellent papers.

### *Honourable Mentions (in chronological order):*

**Richard J. Staniforth and Daniel F. Brunton.** A synopsis of lycophytes in Manitoba, Canada: their status, distribution, abundance, and habitats. *Canadian Field-Naturalist* 136(2): 107–121. <https://doi.org/10.22621/cfn.v136i2.2669>

- A synthesis of information on the abundance, distribution, and habitats of Manitoba’s lycophytes, based on collections made throughout the province since 2008 in combination with more than 1000 herbarium specimens.

**Cassandra A.B. Simone, Erica A. Geldart, Christina A.D. Semeniuk, Oliver P. Love, H. Grant Gilchrist, and Andrew F. Barnas.** Conspecific nest

attendance behaviour of Common Eider (*Somateria mollissima*) in response to Polar Bear (*Ursus maritimus*) foraging activity: error or intent? *Canadian Field-Naturalist* 136(3): 247–253. <https://doi.org/10.22621/cfn.v136i3.2807>

- Interesting observations of female eiders attending nests of other females when a predator was present.

**Michael J. McTavish, Alexandra Rossi, Robert S. Bouchier, and Sandy M. Smith.** Quantifying seeds egested by field-collected earthworms: a dynamic and overlooked pool in forest soil seed banks. *Canadian Field-Naturalist* 136(3): 262–267. <https://doi.org/10.22621/cfn.v136i3.2873>

- A novel pairing of field collection and laboratory assay to determine the importance of including plant seeds ingested by earthworms when studying the soil seed bank.

**Cherisse Du Preez, Heidi N. Gartner, Hawilh-Wayanis (Joshua Watts), Lindsay Clark, Shelton Du Preez, and Tammy Norgard.** Salmon Shark (*Lamna ditropis*) scratching behaviour using floating anthropogenic debris. *Canadian Field-Naturalist* 136(3): 274–280. <https://doi.org/10.22621/cfn.v136i3.2949>

- A novel observation of Salmon Sharks scratching themselves, but with an interesting twist, because they were using human debris, which has some obvious conservation concerns regarding marine litter; the study also went a step further to compare their findings with traditional ecological knowledge.

**Sage Raymond, Julius Strauss, and Nancy Flood.** Observations of Grizzly Bear (*Ursus arctos*) associated with abundance of spawning Kokanee (*Oncorhynchus nerka*) at an inland river, British Columbia, Canada. *Canadian Field-Naturalist* 136 (4): 337–347. <https://doi.org/10.22621/cfn.v136i4.2559>

- Combining citizen observations of Grizzly Bears and government aerial surveys expands our understanding of the close interaction between salmon and bears previously observed in coastal systems.

Congratulations to these finalists. We would also like to show our appreciation to all authors who chose to share their interesting and valuable field-based studies with the readers of Volume 136 of *The Canadian Field-Naturalist*.

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

## In Memoriam for four long-standing Ottawa Field-Naturalists' Club members

The year 2023 has seen the passing of four long-standing Ottawa Field-Naturalists' Club (OFNC) members.

Robert (Bob) W. Nero, 26 December 1922–23 January 2023. Bob was an OFNC member since 1961 (Keith 2023) and an Honorary Member since 1987 (OFNC 2023). A short tribute to Bob will appear in the January–March 2024 issue of *Trail & Landscape* (T&L), the Ottawa Valley regional publication of OFNC. Nature Manitoba's tribute to Bob can be found at <https://www.naturemanitoba.ca/news-articles/tribute-robert-w-nero>.

Ron Pittaway, 2 June 1947–7 August 2023. Ron was an OFNC member since 1964 (Keith 2023). A tribute to Ron will appear in the January–March 2024 issue of T&L. Some of his contributions to birding can be found at the Finch Research Network's tribute at <https://finchnetwork.org/a-passing-of-a-legend>.

Linda Jeays, 27 June 1944–10 September 2023. Linda was an OFNC member since 1993 and a prolific contributor of poems to T&L. She was awarded the OFNC Anne Hanes Natural History Award in 2006 (OFNC 2007). A “farewell” poem will appear in the January–March 2024 issue of T&L. Her obituary is available at <https://ottawacitizen.remembering.ca/obituary/linda-jeays-1088851799>.

Allan Reddoch, 19 January 1931–10 October 2023. Allan and his wife Joyce were OFNC members since 1967 (Keith 2023) and Honorary Members since 2000 (OFNC 2023). Their *Canadian Field-Naturalist* Special Issue publication on the orchids of Ottawa (Reddoch and Reddoch 2010) is available at the Biodiversity Heritage Library. His obituary is available at <https://beechwoodottawa.ca/en/services/allan-harvey-reddoch>.

### Literature Cited

- Keith, K.** 2023. “Golden Anniversary” membership list 1943-2023. *Trail and Landscape* 57: 164–165.
- OFNC (Ottawa Field-Naturalists' Club).** 2007. Linda Jeays, Anne Hanes Natural History Award 2006. Accessed 7 December 2023. <http://ofnc.ca/wp-content/uploads/2017/11/LindaJeays.pdf>.
- OFNC (Ottawa Field-Naturalists' Club).** 2023. Honorary members. Accessed 7 December 2023. <https://ofnc.ca/about-ofnc/awards/honorary-members>.
- Reddoch, J.M., and A.H. Reddoch.** 2010. The orchids in the Ottawa District: floristics, phytogeography, population studies and historical review. *Canadian Field-Naturalist Special Issue* 111: 1–181. Accessed 7 December 2023. <https://www.biodiversitylibrary.org/page/32418417>.

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

# The Canadian Field-Naturalist

## Draft Minutes of the 144th Annual Business Meeting (ABM) of the Ottawa Field-Naturalists' Club, 10 January 2023

Held by Zoom meeting during COVID-19 pandemic.  
Chairperson: Jakob Mueller, President

The Zoom meeting was attended by 50 participants. The minutes of the 2022 ABM, the financial statements, Treasurer's Report, and Annual Reports of the Ottawa Field-Naturalists' Club (OFNC) Committees for 2021–2022 had previously been available on the Club's website. During the meeting, relevant documents were projected on the screen for the audience's reference.

Jakob Mueller called the meeting to order at 7:35 p.m. and welcomed the participants.  
The Zoom host, Ken Young, explained how the Zoom meeting and voting would work.

### 1. Approval of the Agenda

It was moved by Elizabeth Moore, seconded by Diane Lepage, that the Agenda be accepted as distributed.

**Carried**

### 2. Minutes of the Previous Annual Business Meeting (ABM)

It was moved by Elizabeth Moore, seconded by Ken Young, that the minutes of the 143rd ABM be accepted as distributed and published in *The Canadian Field-Naturalist* (CFN).

**Carried**

### 3. Business Arising from the Minutes

None

### 4. Treasurer's Report by Ann MacKenzie

The treasurer, Ann MacKenzie, presented the financial statements to the members. These statements had been reviewed by the accountants, Welch LLP, and were available prior to the meeting on the website. They show that the OFNC is in a good financial position with revenues exceeding expenses again this year.

While the current situation looks positive, Ann pointed out that it was not likely to be the case in future years. The revenue in 2021–2022 was particularly high because of three 'extra', non-recurring items. One was a bequest of \$9470 from the estate of Betty Marwood. Another was a \$5000 donation for Safe Wings to upgrade their computer systems and a third was the transfer of assets from a charity which was folding. As a result, revenues in 2021–2022 were higher than they are likely to be in subsequent years.

Looking ahead there are several areas where expenses are forecast higher. One big item is the cost of producing the two publications, CFN and *Trail & Landscape*. Research grants are increasing from \$15 000 per year to \$20 000 per year. The OFNC has also resumed its Memorandum of Understanding with the school board to provide \$5000 to pay for additional buses for students to visit the Outdoor Education Centre. Various administrative expenses are also increasing. In total, expenses are forecast to be considerably greater in future years.

With lower revenues and higher expenses the OFNC is expected to have a deficit next year and in the following years. The substantial asset base the Club enjoys should allow it to continue to offer its full range of activities and services to the Ottawa community and naturalists farther afield in keeping with its mission and objectives.

It was moved by Ann MacKenzie, seconded by Ken Young, that the Financial Statements be accepted as a fair representation of the financial position of the Club as of 30 September 2022.

**Carried**

Approved financial states available online at: <https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/3335/3083>

### 5. Nomination of the Accounting Firm

It was moved by Ann MacKenzie, seconded by Ken Young, that the accounting firm of Welch LLP be contracted to conduct a review of the OFNC's accounts for the fiscal year ending 30 September 2023.

**Carried**

**6. Committee Annual Reports**

It was moved by Elizabeth Moore, seconded by Janette Niwa, that the Committee Annual Reports be accepted as distributed.

**Carried**

**7. Report of the Nominating Committee by Diane Lepage (Chair)**

The Board has small changes from last year. Bob Cermak, until recently Chair of the Birds Committee, and Diane Kitching, Macoun Club Representative, have indicated that they wish to step down from the Board.

Two new additions to the slate are Derek Dunnett, new Chair of the Birds committee, and Morgan McAteer, a member of the Macoun Club.

**Relevant Excerpts from the OFNC Constitution (revised February 2000)**

Article 8 –The Council shall consist of the officers of the Club and up to eighteen additional members, all members of the Club.

Article 12 –The officers of the Club and other members of the Council shall be elected annually at the Annual Business Meeting. The nomination of sufficient persons for election to the various offices and membership of the Council shall be the responsibility of the Nominating Committee, which shall act in the manner prescribed in the By-Laws.

The Council shall, at the earliest possible date, appoint chairs and members of Standing and ad hoc committees and Editor and Business Managers, as required for club publications.

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

<b>Officers</b>	<b>Position</b>
Jakob Mueller	President
Owen Clarkin	1st Vice President
(vacant)	2nd Vice President
Elizabeth Moore	Recording Secretary
Ann MacKenzie	Treasurer

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

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

It was moved by Diane Lepage, seconded by Ann MacKenzie, that the slate of nominees be accepted as Officers and other Members of the Board of Directors of the OFNC for 2023.

**Carried**

**Nominating Committee suggestions to the Board of Directors for Chairs of Committees and Other Positions**

At its first meeting after the ABM, the newly-elected Board of Directors will appoint people to various positions, in particular to be chairs of standing committees. For some standing committees, the Board will appoint a director to represent the committee on the Board. The Nominating Committee suggests that directors be appointed to the following positions:

Awards Committee, Chair	Eleanor Zurbrigg
Birds Committee, Chair	Derek Dunnett
Conservation Committee, Chair	Owen Clarkin
Education & Publicity Committee, Chair	Gordon Robertson
Events Committee, Chair	Jakob Mueller
Finance Committee, Chair	Ken Young
Fletcher Wildlife Garden Committee, Representative to the Board	Edward Farnworth
Investment Manager	Catherine Hessian
Macoun Field Club, Representative to the Board	Morgan McAteer
Membership Committee, Chair	Kerri Keith
Ontario Nature Representative	Jakob Mueller
Publications Committee, Representative to the Board	Annie Bélair
Safe Wings Ottawa, Representative to the Board	Janette Niwa
Trail & Landscape, Editor	Annie Bélair

**Other Positions, of People Not on the Board of Directors**

Not all positions are filled by directors. The Nominating Committee suggests that the Board appoint the following people to the positions named:

<i>Canadian Field-Naturalist</i> , Editor	Dwayne Lepitzki
Macoun Field Club, Chair	Rob Lee
Publications Committee, Chair	Jeff Saarela
Webmaster	Sandra Garland

Note: The Fletcher Wildlife Garden Committee and Safe Wings Ottawa do not have a permanent chair. The responsibility rotates among senior members of these committees.

**Carried**

Jakob acknowledged the significant contributions of several members who have stepped down from the Board this year:

- Anouk Hoedeman – founder and previous chair of Safe Wings Ottawa
- Henry Steger – long-time chair of the Membership Committee

Diane Kitching – Macoun Club representative for many years

Bob Cermak – previous chair of Birds Committee

### **8. New Business and General Discussion**

Gord Robertson drew the attention of the meeting to the social media icons on the Club's web page. In addition to its previously existing Facebook and Twitter accounts, the Club has recently added Instagram.

Morgan McAteer noted that the Instagram page shows mainly wildlife pictures from the Fletcher Wildlife Garden and inquired whether there are any plans to expand this to for example, Club trips. Henry Robertson suggested that it would be nice to be able to submit any wildlife photos from the area. Jakob responded that the account is new and its role is still being figured out. Deb Doherty suggested a link with the University of Ottawa students who are involved with Safe Wings.

Patrick Jarmuske inquired whether the Club has a relationship with the Ottawa Wildflower Seed Library. Owen Clarkin responded that the Club does have some recent contact through its collaboration with Canadensis Botanical Garden.

### **9. Adjournment**

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

**Carried**

ELIZABETH MOORE  
Recording Secretary

### **Post-business presentations**

After the meeting was adjourned, Diane Lepage presented a multiple choice identification quiz based on some of her lovely wildlife photographs.

# The Canadian Field-Naturalist

## Annual OFNC Committee Reports for 2022

### Awards Committee

The Awards Committee manages the process to annually recognize and thank those Ottawa Field-Naturalists' Club (OFNC) members and other qualified persons who, by virtue of their efforts and talents, are deserving of special recognition. In late 2021, nominations were received and evaluated (see awards criteria at [ofnc.ca/about-ofnc/awards](http://ofnc.ca/about-ofnc/awards)), and recommended to the Board of Directors for approval. Biographies were written for the award recipients for inclusion in the Club's publications and posting on the website. The awards were announced in December 2021 on the website. An awards appreciation event was held by Zoom in February 2022. The recipients' names, type of award, and short rationale for recognition follow below.

- Ken Young—Honorary Membership, for his extensive contributions to the successful operation of the Club over many years, particularly on financial aspects.
- Deborah Doherty—Member of the Year, for her contribution to Safe Wings' bird-friendly initiatives in 2021 and her success in engaging new volunteers.
- Jeff Saarela—George McGee Service Award, in recognition of his leadership on *The Canadian Field-Naturalist* transition to fully digital and initiating the OFNC research grant program.
- Janet Mason—Conservation Member Award, for outstanding contributions to the conservation work of several community organizations in the Ottawa area.
- Tammy MacKenzie—Conservation Non-member Award, for remarkable efforts in turtle conservation in Lanark County.
- Owen Clarkin—Anne Hanes Natural History Award, for his independent field investigation to find and document Red Spruce in remnant habitat in eastern Ontario.

ELEANOR ZURBRIGG, Chair

### Birds Committee

Birds Committee (12 members), Bird Records Subcommittee (11 members including recording secretary and alternate voting members), and Bird Feeders Sub-committee (Chair coordinates and fills in when

needed and five volunteers) coordinated OFNC bird-related activities and directed and encouraged interest in birds within and outside the OFNC area.

A committee member, Nina Stavlund, administered the OFNC's Facebook group, currently 2600 members, which is a place for OFNC members and non-members to discuss ideas and exchange information relating to all aspects of natural history, club outings, and club initiatives, as well as for prospective members to get a feel for what the OFNC is about.

A committee member, Derek Dunnett, provided weekly reports of OFNC area (Ottawa-Gatineau) bird sightings which, with photos by local photographers, was provided on OFNC Facebook and the OFNC website.

Committee members provided articles on a variety of subjects in *Trail & Landscape*, led OFNC field trips, improved Birds content on the website, responded to bird-related enquires from members and the public, and provided the OFNC Board with birding-related advice and guidance.

The OFNC Birds Committee and the Club des ornithologues de l'Outaouais (COO) organized the 103rd Ottawa-Gatineau Christmas Bird Count (CBC) on 19 December 2021. Temperatures ranged from  $-11.3$  to  $-7.4^{\circ}\text{C}$ , with some light snow on and off throughout the day. A total of 142 field observers plus 26 feeder watchers found 71 species and 41 842 individual birds. Highlights included the third record for Yellow-bellied Sapsucker, two Green-winged Teal, a White-winged Scoter, and a Northern Harrier. Record highs were set for Wild Turkey (334), Common Raven (147), and White-throated Sparrow (44). Two other record highs were tied: Winter Wren (two) and Gray Catbird (two). As usual, American Crow was the most abundant species with a roost estimated at 23 000. Thanks to OFNC compiler Bernie Ladouceur, COO compiler Daniel Toussaint, sector leaders, and all participants.

The "OFNC Rare Bird Data Project", led by Jeff Skevington, entered documentation of historically important OFNC rare bird sightings into eBird. This project provides a permanent record of OFNC rare bird sighting on eBird for worldwide birders, science, and conservation.

Birds Committee has supported the third Ontario

Breeding Bird Atlas, 2021–2025, which will map the distribution and relative abundance of Ontario's approximately 300 species of breeding birds. As of September 30 this year, 237 atlas participants have found 181 bird species in Region 24's 86, 10 × 10 km squares. Of all Ontario regions at this time our region ranks: Total Hours No. 1, Total Participants No. 2, Total Records No. 2, Total Checklists No. 2, and Total Species No. 4. Thanks to region 24 coordinator Aaron Hywarren for his enormous effort and highly successful leadership and thanks to all Region 24 participants for their remarkable contribution.

As a result of trees felled by the derecho storm on 21 May 2022, two of the five OFNC bird feeders had to be moved. The Davidson Road Pine Grove Trail feeder has been moved to the opposite side of the trail. The Jack Pine trail feeder has been moved to the Stony Swamp Beaver Trail just west of what was the Ottawa Valley Wild Bird Care Centre building. Thanks to Lorraine Elworthy, Chair of the Bird Feeders Sub-committee, for coordinating these efforts.

BOB CERMAK, Chair

### Conservation Committee

Our activities started in January at the OFNC Annual Business Meeting (ABM), with the presentation "Elm Zigzag Sawfly in Eastern Ontario" summarizing our work in 2021 tracking the spread of this new invasive species across our region. In 2022 we continued tracking Elm Zigzag Sawfly (EZS) finding it throughout eastern Ontario as far northwest as Arnprior, and also along the St. Lawrence River to Kingston and as far west along the north shore of Lake Ontario as the eastern edge of the Greater Toronto Area. Also to our knowledge we found the first record in Vermont during a trip in October. In December, we discussed EZS and its spread with the Canadian Food Inspection Agency (CFIA).

The plans we had for spring fieldwork were impacted by the powerful 21 May derecho, which caused widespread destruction and lengthy (week+) power outages. The strongest winds unfortunately overlapped closely with valuable habitats in the Greenbelt and east of the city, and significant damage was still being surveyed by our members at the end of 2022.

Our committee surveyed Voyageur Provincial Park for salamander and moth biodiversity in 2022; this was led by Jakob Mueller (salamanders) and Diane Lepage (moths).

Starting in April, we collaborated with the Canadensis Botanical Garden to lead public events demonstrating how and why to grow native plants via seed collection. This collaboration will continue in 2023.

Just before the 21 May derecho, we completed a year-long bioinventory at Lavigne Natural Park with a final guided tour on 14 May.

In June, we heard of a report of Swamp White Oak (*Quercus bicolor*) being noticed as a wild tree growing near the appropriately-named Oak Valley south of Winchester. We conducted several surveys, and found the species growing apparently wild along an approximately 11 km stretch of the South Nation River from roughly Brinston to Cass Bridge. These populations of Swamp White Oak in and near Oak Valley appear to be previously unknown.

In July and August, we led biodiversity tours in partnership with Parks Canada geared toward families learning how to camp for the first time. The tours took place at Manotick and Newboro.

In August, we started a year-long bioinventory at Morris Island Conservation Area which combines surveys of biodiversity by experts with public education tours. This project will continue until the end of summer 2023 and is a combined effort of the OFNC, the Macnamara Field Naturalists' Club, and Ontario Power Generation.

In December, we discussed with the CFIA the spread of the invasive Hemlock Woolly Adelgid (HWA) across Lake Ontario to the edge of eastern Ontario at Grafton. This winter we will be surveying for HWA in Ottawa, and south of Ottawa from roughly Cornwall to Oshawa.

Also in December we discussed the biology of Rock Elm (*Ulmus thomasi*) with the United States Department of Agriculture, as it is becoming a species of increasing conservation interest and we have led fieldwork efforts documenting extant populations and growing seedlings for restoration.

We led or participated in a number of conservation policy events as well, notably related to the Alfred Bog Provincial Park proposal, and Bill 23.

Our group also led many other conservation-themed tours and biodiversity surveys throughout the year with individuals, community groups, and other organizations such as the Dominion Arboretum, Eco East, Ontario Woodlot Association, and Mississippi Madawaska Land Trust.

OWEN CLARKIN, Chair

### Education and Publicity Committee

The Committee welcomed five new members: Kaitlyn Sjonnesen, Joan Harrison, Deb Doherty, Leo Vander Wouden, and Sheena Parsons. Joseline Beau-lieu is taking a brief leave.

The Ottawa-Carleton District School Board's Science Fair was held online again. Fenja Brodo, Lloyd Mayeda, and myself judged the five applications (six students) for the OFNC nature prizes. Four

projects were deemed excellent and were awarded \$100 per project with certificates of recognition to each member.

Dean Beeby continues as our Twitter administrator (join at [twitter.com/ottawafieldnat](https://twitter.com/ottawafieldnat)). Jakob Mueller hosts a YouTube page for the OFNC (look for it at [youtube.com/channel/UCHryjAyoDoz7qnanrVaTJ\\_w](https://youtube.com/channel/UCHryjAyoDoz7qnanrVaTJ_w)). Sandy Garland maintains our Friends of the Fletcher Wildlife Gardens Facebook page ([facebook.com/groups/48901132335](https://facebook.com/groups/48901132335)), while Nina Stavlund administers our OFNC Facebook page ([facebook.com/groups/379992938552](https://facebook.com/groups/379992938552)).

Two new wildlife quests for Mud Lake and the Fletcher Wildlife Garden (FWG) were created by myself. More quests are planned for next year. Find them at [ofnc.ca/quests](https://ofnc.ca/quests).

A few “News Flashes” have been posted around the FWG this spring and summer to highlight recent wildlife occurrences, for example, the spring flowers, avian flu, and Ash Flower Gall Mite.

Groups of Beavers and Cubs came to the FWG on 21 and 29 September. Over 50 children showed up from both groups. They were divided into two sections and shown the Backyard Garden and Amphibian Pond. Lloyd Mayeda and Gord Robertson led the tours with assistance from Sheena Parsons. Fenja Brodo and Lloyd Mayeda led tours to Vietnamese immigrants at Mud Lake on 16 October. Fletcher Wildlife Garden tours were also given with help from FWG people to the Canadian Federation of University Women, Ottawa branch.

With the addition of three new storyboards (now at 13) members of the committee (Sheilagh Stacey, Sarah Wray, Fenja Brodo, Kaitlyn Sjonnesen, and myself) have created new stories for the various seasons. Thanks to Jean-Michel Weber, Louise Dumouchel, and Diane Lepage for checking the French translations. Find copies at <https://ofnc.ca/stories>.

There were no applicants for the Youth Summit this year that was to be online. Macoun Club members were contacted but none responded. Greater outreach is necessary for this event to be successful.

Several new initiatives have begun. One is to tag trees in the FWG to identify and provide links to our Flora and Fauna pages, which have information about each species (see <https://ofnc.ca/education/tags>). Another is to add Algonquin/Anicinàbemowin names where possible to the trees, vines, and shrubs in our database. Joan Harrison is seeking names from Kitigan Zibi elders. We are also planning to dedicate a storyboard to highlight an Indigenous garden that is being added to the FWG by Marlene Souliere. A fourth is to start an Instagram page in the new year (2023) hosted by Robyn Molnar and Hannah Dillion. Finally, Leo Vander Wouden is creating a poster that

illustrates the history of the FWG to be displayed on the bulletin board at the FWG.

GORDON ROBERTSON, Ph.D., Chair

## Events Committee

The year started with a burst of excitement for spring events, as May activities in 2020 and 2021 were curtailed by COVID-19. On 21 May, a severe thunderstorm produced a derecho, which caused a historic level of damage across the region. As a result, many natural areas became inaccessible due to fallen trees and many sectors of the Ottawa Greenbelt were closed to the public for months. This disrupted some planned events and limited opportunities to hold others throughout the year.

Due to the lingering effects of COVID-19, monthly meetings continued to be held virtually on Zoom for the duration of the year.

In total, the committee coordinated 52 events, including field trips, workshops, presentations for monthly meetings, and digital events. General interest and overall biodiversity was the most common focus (15), with specific topics including birding (10), botany (nine), entomology (four), mycology (four), conservation (four), herpetology (two), geology (one), astronomy (one), aquatic macro-invertebrates (one), and bats (one).

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

JAKOB MUELLER, Chair

## Finance Committee

This report covers financial matters during our last fiscal year (FY) 2021–2022, which extended from 1 October 2021 through 30 September 2022. It also discusses the budget for the current fiscal year.

The effect of the COVID-19 pandemic on the Club’s finances continues to be minimal. Compared with many other small charities, we are fortunate. We have a sizeable reserve that enables us to purchase things such as a Zoom licence to help us cope with the pandemic. The Club was using electronic methods for most financial transactions before the pandemic hit, so it has not affected our financial operations.

The primary task of the Finance Committee is to prepare a draft budget for consideration by the Board of Directors. The committee receives suggestions, and estimates of committee revenues and expenses, from directors and committee chairs. Our process is that the Finance Committee presents a draft budget for discussion at the September meeting of the Board of Directors. After amendment, it is adopted at the October meeting.

The budget for FY2021–2022 was approved at

the Board of Directors meeting of October 2021. The draft budget for FY2022–2023 was presented to the Board's September 2022 meeting and after revision, was approved at the October 2022 Board meeting. The budget forecasts revenues of \$169 200 and expenses of \$222 811, for a deficit of \$53 611. A copy of the budget is included as an appendix to the minutes of the October 2022 Board of Directors meeting. These minutes are posted on the OFNC website (<https://ofnc.ca/wp-content/uploads/2023/03/OFNC-BoD-Meeting-October-17-2022-Minutes.pdf>).

Concern about the amount of our expenditures has been expressed at different times by Club members at Annual Business Meetings, by Directors, and by the Finance Committee. Two different concerns have been raised—that we are spending too much and spending too little.

The Club has a large investment account, as a result of a large bequest some years ago. If we spend more than our revenues, eventually the investment account will be exhausted. Not in the near future—perhaps in 20 years or so at current rates. The Board of Directors is concerned about the size of our projected deficit for this fiscal year, and has directed the Finance Committee to advise it on possible changes to our operations.

On the other hand, some people think that we should spend more on our objectives, for example conservation or natural history education. The Board of Directors reviews proposals for spending, during the budget process and on an *ad hoc* basis during the year. Proposals are evaluated based on the Club's objectives and policies. The Board is responsive to proposals, but also prudent.

KEN YOUNG, Chair

### **Fletcher Wildlife Garden Committee**

The FWG had a very successful year. Again this year, we saw an increase in the number of visitors to the Fletcher. Compliments about the work we do came from walkers, bird watchers, photographers, and dog walkers, many of whom were regular visitors to the Fletcher. Visitor safety became an issue when two storms left half-fallen trees on or near visitor pathways. Agriculture Canada had to be called to safely remove the trees. As a result of this, a Fletcher volunteer offered to take a chain saw safety course, so that in the future we can do more storm clean-up ourselves.

The FWG is a tenant of Agriculture and Agri-Food Canada and so we have to abide by their rules. At the start of the year, entrance to the Resource Centre was restricted due to COVID-19; over the summer restrictions were eased. Safety of our volunteers and our visitors was always a priority.

Again this year the annual plant sale was a pre-order, pre-pay, curbside pick-up format. Due to the hard work of the plant sale team, the number and variety of plants for sale were increased and this resulted in our most profitable sale yet. The plant nursery that is used by the plant sale group was expanded and made more secure. The team has begun the transition from fluorescent lights to LED lights for their seedling growing tables as a way of conserving energy.

A Fletcher volunteer has started a garden to grow plants that were traditionally cultivated by Indigenous peoples that lived in the Ottawa area. Plants that have medicinal use and those used in spiritual ceremonies are being grown.

The number of “story boards” located throughout the property has been increased as a way of educating visitors about the flora and fauna they can observe while walking around the Fletcher. A program has been started to identify trees throughout the property using a link to a website that gives the name of the tree and information about the tree.

The Fletcher continued to co-operate with local university researchers who were looking for sites to carry out experiments, especially those involving the study of pollinators. One experiment of note evaluated which flowering native plants were better at preparing the migrating generation of Monarch Butterflies for their long trip south.

Our volunteer group was not as large as we would have liked, but our work teams were able to maintain and even expand some parts of the property. Unlike years past, we received very few requests by outside organizations to come to the Fletcher to do a volunteer service activity. We are hopeful that more people will become volunteers in the future. We will continue our outreach to recruit and retain volunteers.

Again this year the Fletcher was the site of a “Jane's Walk”. We gave tours to groups such as the Canadian Federation of University Women, the Bird Friendly Ottawa Group as well as several Sparks, Brownie, and Cub groups. Fletcher volunteers who served as guides were able to provide information, answer questions, and tell stories that help our visitors understand better what we are trying to do at the FWG.

There is a growing concern of our volunteers and visitors about the future of the Fletcher Wildlife Garden as construction of the new Ottawa hospital starts up. Also, our relationship with our neighbour, the *Canadensis* botanical garden, continues to evolve.

TED FARNWORTH, FWG Representative

### **Macoun Field Club**

The Macoun Field Club, which is for kids aged eight to 18, is in its 74th year. Traditionally, the Club

has provided a weekly program of indoor meetings alternating with outdoor field trips. During this third year of the COVID-19 pandemic, the Committee judged that indoor public health restrictions were still too onerous for us to resume meetings. Outdoor activities, however, were not only permissible, but were publicly encouraged.

In this year, Committee members led 30 field trips, half of them to the Macoun Club Nature Study Area in Ottawa's western Greenbelt, and half into wilder places in Lanark County. We took part in one field trip held jointly with the OFNC, at Brewer Park Pond. At the end of the school year, one indoor meeting was attempted, but it was not a success, owing to the unnatural spacing of a necessarily restricted number of children, properly masked, 2 m apart in every direction. An account of each activity was posted on the Macoun Club's home page on the OFNC website.

We went into the autumn of 2021 with Ontario's limit on the size of outdoor gatherings standing at 100 people. During December, the Omicron variant of the virus arrived in Ottawa and cases surged; within a month authorities admitted that they had lost control. The limit for outside gatherings was reduced to 25 persons; ours did not exceed 20. In January, members' families began to experience household-based infections with SARS-CoV-2 and withdrew from upcoming field trips; this spared us all from the self-isolation required of close contacts. Thanks to widespread vaccination, cases were mild. The province restored the limit to 100 people in mid-February.

By the summer of 2022, with not a word of promotion, without even the usual call-up of existing membership, we had taken 44 children out into the safety of the natural world, more than double the Club's membership in the last pre-pandemic year.

ROBERT E. LEE, Chair

### Membership Committee

Club participation includes:

1. Membership:
  - a. Those who pay Club fees
  - b. Honorary members
  - c. Members who participate in the Macoun Club
2. *Trail & Landscape* (T&L) Subscribers
3. An aggregate called Other which represents individuals and organizations that receive complimentary copies of T&L. The groups are reported separately.

The distribution of Club membership on 30 September 2021 and on 30 September 2022 is shown in Table 1.

TABLE 1. OFNC membership by type.

	2022	2021
Individual	434	415
Family	349	340
Student	14	19
Honorary	24	24
Life	38	38
Macoun Club	21	23
USA	11	11
Other International	1	1
Total	892	871

The increase in membership for 2022 was 21. As Henry Steger, past Chair of the Committee, notes, "This increase is consistent with the volatility in membership that the Club experiences from year to year".

Members within 50 km of Ottawa comprised 757 of the total membership of 892.

The number of T&L Subscribers and Other on 30 September 2021 and on 30 September 2022 is shown in Table 2. The numbers do not vary greatly on a year-to-year basis.

TABLE 2. Non-member counts.

	2022	2021
T&L Subscriber	4	2
Other	25	25
Total	29	27

KERRI KEITH, Chair

### Publications Committee

The Publications Committee manages publication of CFN, T&L, and Special Publications. The committee also advises the Club with respect to issues relating to research, including managing the research grants program. We published four issues of T&L (55[4] and 56[1–3]) and four issues of CFN: 135(2) (published 3 October 2021), 135(3) (21 January 2022), 135(4) (28 April 2022), and 136(1) (29 July 2022).

The CFN book review editor Barrie Cottam stepped down from the Committee, and we welcomed new book review editor, Jessica Sims, to the Committee. Due to the impacts of the COVID-19 pandemic, the Committee continued to conduct its meetings virtually.

This was the eighth year of the OFNC Research Grants program. Research grants support field-based research activities that reflect and promote the Club's objectives within eastern Ontario and/or western Quebec, focussed particularly upon the Club's study area. The application deadline for the upcoming year's program was 15 January 2022. A subcommittee compris-

ing Jeff Saarela (chair), Carolyn Callaghan, and Paul Catling reviewed all proposals and submitted funding recommendations to the Board of Directors. We published the recipients of 2022 Research Grants in T&L 56(3): 135–136.

JEFFERY M. SAARELA, Chair

### Safe Wings Ottawa Committee

This was a year of change for the organization.

In July our founder, Anouk Hoedeman, moved to the Netherlands with her husband. Her departure necessitated a rethink of the organization's structure and led to some changes in not only how we operate but also on what services we would continue to provide. As a result we divided the organization into key areas, in line with our core principles of "research, rescue, and prevention", and looked at ways to streamline our focus. As part of that shift, we reduced the hours that our volunteers answered the emergency line and re-directed, during the day, all incoming calls about injured birds to the Ottawa Valley Wild Bird Care Centre (OVWBCC). We continue to respond to calls from 6 am to 8 am and from 4 pm to 10 pm.

It was also a year of challenges.

The emergence of the HPAI (highly pathogenic avian influenza) in the spring was unexpected. As we had done when COVID-19 became prevalent in 2019, we reworked our protocols for all volunteers as they related to patrolling, rescuing, and reporting to ensure that they would remain safe. We also worked closely with the OVWBCC to ensure that our messages to the public were consistent especially as they were unable to take in waterfowl without risking the other birds in their care to the effects of the virus.

Despite it all, we continued with our work in rescue, outreach and advocacy.

#### *Rescue*

- Our volunteers documented more than 2000 window collisions (exact number not yet available).
- They provided care to 783 live birds representing 125 species (not including domestics). Of these, 456 (82%) were window collision victims.
- Added eight new species to our list of collision victims, bringing our cumulative total to 148, including 15 Species-at-Risk.

Besides losing one centrally located rehabilitation location, the other significant impact to our rescue team was the limitations that were imposed as a result of avian influenza. Not being able to help rescue or rehabilitate waterfowl was hard on everyone, but none more so than our phone volunteers who were left explaining to the public why we couldn't help. To fill

this gap, Safe Wings Ottawa partnered with Holly's Haven Wildlife Rescue and, in collaboration with the Canadian Wildlife Health Cooperative and the Ministry of Natural Resources, put together a plan to help rescue and rehabilitate orphaned ducklings (waterfowl that were deemed low risk as it related to HPAI). Safe Wings Ottawa would take in the ducklings, isolate them and track their progress. After about four weeks, they would be transferred to Holly's Haven where they were placed in large, protected outdoor pens until they were old enough to fly away on their own. Once Holly's Haven was at capacity, ducklings would be transferred to Sandy Pines in Napanee.

Over the span of seven weeks this past spring, we received 68 orphaned ducklings (57 Mallards and 11 Wood Ducks). Nine of those were released with a foster mom, 19 were transferred to Holly's Haven, and 34 were transferred to Sandy Pines.

We continued fostering relationships with other rehabilitation facilities in the area, including Holly's Haven, Sandy Pines and The Owl Foundation, and the OVWBCC. Our open dialogue with OVWBCC, not only on window collisions, but in best practices as well, has resulted in improved outcomes and the willingness to help each other when needed. Safe Wings Ottawa is looking forward to strengthening these relationships in the upcoming year.

#### *Outreach*

Collaboration with the University of Ottawa continued. As a follow-up to their May 2021 report which included mitigation strategies for both the short-term and long-term retrofitting of key buildings identified to be the most lethal, February 2022 saw the launch of the Bird-Safe Campus program at the University of Ottawa. This group is busy patrolling buildings and raising awareness of this environmental issue on campus. They are currently working with the Office of Sustainability on the location of another collision-prevention mural similar to the one that was done on the corridor between Morriset and Jock Turcott.

Safe Wings Ottawa was also approached by a group of Grade 8 students looking for an organization that they could partner with as part of their community project. These students have learned about rescue, rehabilitation, and reporting and are looking forward to volunteering this spring during migration season. The goal is a year-end presentation that will focus on what we do and how the public can help.

#### *Advocacy*

This year the advocacy committee grew by several members, which allowed us to expand our efforts. We provided comments on many proposed developments, pushing for them to be bird-friendly, and were rewarded by seeing many new projects planning to

use bird-friendly glass in at least some areas. With the passing of the province's Bill 23, we will have to change our approach for new buildings as the city no longer has to approve exterior design. We additionally saw bird-safe retrofitting installed at several buildings, and new construction with bird-friendly elements, notably Stage 2 stations of the Light Rapid Transit.

Changes to the federal Migratory Bird Regulations this summer have made it clear that failing to address window collisions contravenes the *Migratory Bird Convention Act*, and may prove to be a tool for convincing building owners to take action. The advocacy committee is working with other collision prevention groups to push for the inclusion of bird-friendly design guidelines in Ontario's building code, and more progress at a national level.

We continue to use our social media to push homeowners to address collisions at their houses; some of our most popular posts show how collision prevention methods look when installed. We have additionally drawn attention to the loss of Ottawa's bird-safe design guidelines with the passing of Bill 23, and suggested ways for our supporters to voice their opposition.

Finally, Safe Wings Ottawa, along with a number of other groups, has representation on the Ottawa Bird Friendly City group. Developed by Nature Canada, the Bird Friendly City designation is given to cities that have met a set of specific standards, standards which ensure that our urban environments are a safe haven for birds.

As a result of our activities and outreach we were able to strengthen our relationship with other rehab facilities. While Holly's Haven, Sandy Pine, and The Owl Foundation have all reached out for help with calls in our area, the most notable change has been with the OVWBCC.

JANETTE NIWA, Safe Wings Board Member

### **Treasurer's Report 2021–2022**

This year we are fortunate to again have our revenues exceed our expenses by about \$8000. The financial statements show that we are in a good financial position going into the next year. This situation enables us to maintain our operations and fulfil our objectives without undue concern.

There are some unusual aspects to this year's financial picture that must be noted because of their implications for upcoming years. Revenues were higher as a result of a \$9470 bequest from the Estate of Betty Marwood. Safe Wings also received a one-off donation of \$5000 for computer system upgrades

raising their donation total from about \$10000 to about \$15000.

On the expense side the Board approved an increase to the payments to those providing services to the club's two publications, CFN and T&L. This will raise our costs by about \$15 000 per year. Because the new schedule only started in May, it had very little impact on the 2021–2022 fiscal year that ended 30 September 2022. The full impact will be felt in the 2022–2023 year.

During the year we only made one donation and it was \$1000 to the Nature Conservancy to support the purchase of property at Wolf Grove. Now that school activities are back to normal, we have re-instated our agreement with the Ottawa-Carleton District School Board to provide \$5000 per year for busing to the Outdoor Education Centre. Consequently, next year our donation expenses will definitely be higher.

Inflation has started to impact our operations. Services such as bookkeeping, payment processing, and accounting services have all increased. We have rented a storage facility to accommodate material that was being kept in members' basements, especially publications and Safe Wings displays. Ontario is now charging us to keep our records up-to-date and there are other instances of having to pay for previously free goods. Again, the full impact of these cumulative changes will be felt in the upcoming years.

The finances of the FWG are managed in a separate fund. Like the general fund, they have also seen higher than normal revenues this past year and increased expenses. Another charitable organization, The Civic Hospital Area Parks, had to dissolve because of the relocation of the Civic Hospital. Fortunately, they transferred their remaining assets of \$4500 to the Fletcher because it is another charity with similar goals. In addition, there were several donations to the FWG in memory of Alex Johnson. Total donations were over \$9000 compared to less than \$4000 the previous year. The plant sale continues to grow and hopefully that will continue. However, the expenses related to the sale have jumped as we switched to LED lights and had to buy pots that previously were donated.

Overall, we do not anticipate being able to maintain the same relative levels of revenues and expenses into the future.

ANN MACKENZIE, Treasurer

Approved financial statements available online at:  
<https://www.canadianfieldnaturalist.ca/index.php/cfn/article/view/3335/3083>

# The Canadian Field-Naturalist

## The Ottawa Field-Naturalists' Club Awards for 2022, presented April 2023

ELEANOR ZURBRIGG, BETHANY ARMSTRONG, IRWIN BRODO, CHRISTINE HANRAHAN, KAREN MCLACHLAN HAMILTON, and LYNN OVENDEN

The 2022 Ottawa Field-Naturalists' Club (OFNC) awards were presented at the Club's Awards Night on 1 April 2023. Awards are given to members or non-members who have distinguished themselves by accomplishments in the field of natural history and conservation or by extraordinary activity within the Club. Three awards were conferred for 2022, one for long time service in bird-related matters and two for conservation efforts of local natural areas.

### George McGee Service Award: Chris Traynor

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

Chris Traynor is a long-time member of the OFNC and well-known in the birding community for his passionate interest in birds, particularly owls about which he is especially knowledgeable. It is no surprise then that he served for 26 years on the Club's Birds Committee, much of that time as Chair (18 years). As Chair he dealt with innumerable issues that arose regarding birds and birdwatching in the Ottawa region. A key issue that arose during his tenure was developing the OFNC Code of Conduct for birding. The document was a group effort, but Chris was the person who steered it through appropriate OFNC channels to approve the finished product. The Code of Conduct emphasises the welfare of birds and delineates ways that birders can pursue their interests while safeguarding birds. Another significant achievement was negotiating with the Department of National Defence for birding access to Shirleys Bay for OFNC members, when such access was still allowed.

For over a decade Chris was also Chair of the Bird Feeders Sub-committee. This involved a prodigious amount of work, for example: making sure there was a ready supply of seed for the feeders, finding volunteers to take responsibility for the OFNC-run bird feeders at the various National Capital Commission Greenbelt locations, being available should someone be unable to continue with maintaining the feeders, including replacing old ones, and finding new volunteers as necessary, as well as handling all questions and details about the feeders.

Furthermore, Chris was a member of the Bird Records Sub-committee for over a decade, either as a voting member or as an alternate. This sub-committee is responsible for documenting and verifying all occurrences of rare birds within the Ottawa district. An extensive database of records is maintained permanently and used for updating the two bird checklists for the region.

As a member of the OFNC Board for more than a decade, Chris reported on the various committees and sub-committees on which he sat or chaired. While Chris did not offer comments on every item discussed, when he did, they were astute, perceptive, and to the point.

As a member of the OFNC's Facebook group, Chris provides extensive and significant contributions to the birding community by helping with identification and addressing various bird-related questions or concerns, always available to offer his expertise and knowledge.

There is more to Chris than birds and birding. He has a long-standing interest in dragonflies and damselflies and has spent considerable time studying, pursuing, and documenting the various species inside and outside the Ottawa district. He has written extensively on Odonata for *Trail & Landscape*, preparing species profiles for each issue (an ongoing project). These are detailed, well-documented, informative articles that provide valuable information and aid with identification. The identification tips and the sections on "possible confusables" are particularly helpful and much appreciated by the growing number of odonate enthusiasts in the region.

Chris has been a stalwart and key member of the OFNC for decades, and we are delighted to acknowledge and celebrate all the work he has done on be-

half of the Club. He is a very worthy recipient of the George McGee Service Award.

*(Prepared by Christine Hanrahan)*

### **Conservation Award—Member: Sharon Boddy**

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

We are pleased to award Sharon Boddy for her conservation work with two Friends groups in west Ottawa where she lives. Sharon co-founded the Friends of Carlington Hill in 2016 (renamed Friends of Carlington Woods in 2021) and founded the Friends of Hampton Park in 2019. She continues to lead both groups. In October, Sharon led OFNC members on a tour of Carlington Woods.

Carlington Woods is a 22 ha upland deciduous forest with some mature trees, adjacent to Carlington Park and the former quarry. Hampton Park is located just 2 km away, north of the Queensway beside Island Park Drive. The park is almost 100 years old with a good variety of native plant species, including trees more than 200 years old. Both Friends groups raise awareness of the natural value of their forests and work to preserve them.

Carlington Woods and Hampton Park are both Environmental Protection Zones of the city, a designation that prohibits off-leash dogs, mountain biking, and building forts. Nevertheless, these urban forests face pressure from these activities and other recreational use. In 2021, Sharon obtained a City of Ottawa Community Protection grant on behalf of both groups, to commission a Natural Heritage and Impact Study on both parks ([https://carlingtonparkhome.files.wordpress.com/2021/02/report\\_carlingtonhampton\\_final\\_dec21.pdf](https://carlingtonparkhome.files.wordpress.com/2021/02/report_carlingtonhampton_final_dec21.pdf)).

The study identified significant features and concerns in each forest and recommended specific restoration projects, removal of invasive species, and formalizing a reduced trail network. It confirmed the Friends' concerns and goals. Both Friends groups host

guided walks, organize clean ups, and maintain lively Facebook pages with cartoons, photos, conservation advice, and invitations to work parties and walks. They have established pollinator gardens at the edge of each forest. In Hampton Park, they blocked some informal trails, planted native species on them, and collaborated with the National Capital Commission on removal of Japanese Knotweed colonies. In 2021–2022, Sharon coordinated a major project in Carlington Woods to replace dense buckthorn in a small area, with native species. For this, she collaborated with both Friends groups, Tree Fest Ottawa, local residents, and local students to gain funds to buy plants, grow native plants from seeds, remove the buckthorn, and plant the native species. She presented the project to the Invasive Plant Council's conference in January 2023.

Sharon Boddy is a writer, an environmental researcher, and community leader on conservation issues in west Ottawa. She communicates tirelessly with positive messages via a large email distribution list, Twitter, and the newsletters for each Friends group. She writes the newsletters, applies for grants, and liaises with city and National Capital Commission officials on behalf of the Friends groups. She organizes and leads most of their activities. The *Ottawa Citizen* has published her articles about Carlington Woods and Hampton Park Woods. Recently, she hosted eight virtual presentations by local experts on urban forests; this was a joint project of Tree Fest Ottawa and the Friends groups.

Sharon's colleagues confirmed: "she is the right person to receive this award ... two urban natural areas will be sustained and conserved because of her amazing efforts, diligence, communicating skills and ... experience". Congratulations, Sharon, and thank you.

*(Prepared by Lynn Ovenden)*

### **Conservation Award—Non-Member: John Sankey**

*This award recognizes an outstanding contribution by a non-member in the cause of natural history conservation in the Ottawa Valley.*

John Sankey was recognized for his extraordinary stewardship and advocacy of Hunt Club Creek, one of the many small but biologically rich tributaries of the Rideau River. Curiosity may be a curse for cats, but it is a blessing when bestowed on bright, well-educated human beings. It is what drives research scientists to make breakthrough discoveries and what makes naturalists explore the natural world,

wherever they find it. It is not surprising therefore that John Sankey has filled both these roles, first as a physicist with the National Research Council for 30 years and, especially since his retirement in 1995, as a keen observer of natural history and tireless conservationist.

John became active in the Hunt Club Community Association (HCCA) soon after moving into Hunt Club Woods, a development just north of the Hunt Club Golf Course and east of Riverside Drive. He soon discovered the small creek winding its way

through the community, finally passing under Riverside Drive near the Rivergate high-rise apartments and cascading down to the Rideau River. Fascinated by the rich biological life of the creek, he explored its banks and its biota from one end to the other, writing numerous articles on his website about what he found, all the while advocating for the creek's preservation and enhancement. His volunteer work as a "stream watcher" began in 2013 as a project of the HCCA. John established a working relationship between the Association and the Rideau Valley Conservation Authority by joining in the latter's City Stream Watch Program, assessing the biodiversity and pollution levels of the creek, getting rid of garbage (almost entirely by himself over a period of three years), and raising local awareness of the creek's value and history through his many articles in the HCCA newsletters. John also enjoyed taking a few people at a time on discovery walks along portions of the creek. At his suggestion, the city placed a sign at one of the access points to the creek in Hunt Club Woods to explain the creek's importance to residents and visitors to the neighbourhood. It was, in fact, John himself who gave the creek its currently accepted name by submitting "Hunt Club Creek" to the official custodians of Geographical Names in Canada.

John's interest in conservation also extends to growing and tracking nut-bearing trees in the Ottawa

region. He spent his early years in the Niagara region where nut and fruit trees abound. After moving to Ottawa in the mid 1960s to take up a job with the National Research Council, he was curious to see if he could grow nut trees here. Despite the scepticism of some, he persisted and went on to plant hundreds of oak, Shagbark Hickory, and Black Walnut trees in the Ottawa region, for example as part of the Sawmill Creek recovery project, as well as documenting rare populations of these nut trees in the region. In recognition of this important work, he received a Lifetime Achievement Award from the Eastern Chapter Society of Ontario Nut Growers in 2011.

A glance at John's website ([johnsankey.ca](http://johnsankey.ca)) will reveal the breadth and depth of his knowledge of natural history, human history, nut-growing, conservation, and even music. (He is an accomplished harp-sichordist and violinist, among his other talents.) Clicking the link for "An Ottawa Valley Naturalist" will open an array of useful and interesting articles including some on gardening, learning about birds, a guide to the identification of dragonflies, and even a recording of a singing deer mouse. The Ottawa Field-Naturalists' Club is grateful to have such a dedicated and energetic conservationist in the Ottawa community, and we recognize John Sankey for his efforts with the Conservation Award for 2022.

*(Prepared by Irwin M. Brodo)*

# The CANADIAN FIELD-NATURALIST

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