COSEWIC
Assessment and Status Report

on the

White-rimmed Shingle Lichen
Fuscopannaria leucosticta

in Canada

THREATENED
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2019. COSEWIC assessment and status report on the White-rimmed Shingle Lichen *Fuscopannaria leucosticta* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 85 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Production note:
COSEWIC would like to acknowledge Sean R. Haughian, Stephen R. Clayden, Robert Cameron, Frances Anderson, and Samuel R. Brinker for writing the status report on the White-rimmed Shingle Lichen (*Fuscopannaria leucosticta*) in Canada, prepared under contract with Environment and Climate Change Canada. Funding and in-kind support also provided by the New Brunswick Wildlife Trust Fund, the New Brunswick Department of Energy and Resource Development, the Nova Scotia Department of Natural Resources, and the Ontario Ministry of Natural Resources and Forestry. This report was overseen and edited by David Richardson, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur la Fuscopannaire à taches blanches (*Fuscopannaria leucosticta*) au Canada.

Cover illustration/photo:
White-rimmed Shingle Lichen (*Fuscopannaria leucosticta*); photo by Sean R. Haughian.

Catalogue No. CW69-14/783-2019E-PDF
ISBN 978-0-660-32394-7

COSEWIC
Assessment Summary

Assessment Summary – May 2019

Common name
White-rimmed Shingle Lichen

Scientific name
Fuscopannaria leucosticta

Status
Threatened

Reason for designation
This rare lichen in Canada grows in wet forests of Nova Scotia, New Brunswick and Ontario, with three known subpopulations. The main threat to the species in Canada is logging of host trees Eastern White Cedar and Red Maple. As with other cyanolichens, this species is sensitive to atmospheric pollution in the form of acid rain and to climate change including more extreme weather events leading to blowdown of host trees. The decline in number of mature individuals observed over the past ten years is expected to continue, with about 45% of the population expected to be lost over the next three generations.

Occurrence
Ontario, Quebec, New Brunswick, Nova Scotia

Status history
Designated Threatened in May 2019.

COSEWIC
Executive Summary

White-rimmed Shingle Lichen
Fuscopannaria leucosticta

Wildlife Species Description and Significance

White-rimmed Shingle Lichen, *Fuscopannaria leucosticta,* is a rare lichen that grows on trees in wet forests of eastern Canada. The lichen consists of many small, overlapping lobes (like shingles). These lobes typically have a dark olive-grey colour on their upper surface, and a noticeable white rim on the edges. Mature colonies produce many brownish-coloured discs (fruiting bodies) on their upper surface.

Distribution

White-rimmed Shingle Lichen has a disjunct global distribution. It occurs primarily in eastern Canada, the southeastern United States, and also in Europe and the Asia-Pacific region. In Canada, it is found in New Brunswick, Nova Scotia, and a small area in western Ontario. In the U.S.A., it has not been detected in any New England states for at least 30 years.

Habitat

The White-rimmed Shingle Lichen lives almost exclusively on the bark of trees in wet forests. It is most commonly found on Red Maple in Nova Scotia, and on Eastern White Cedar in New Brunswick and Ontario. It usually occurs on the uppermost surface of tree trunks that lean away from the vertical position, and it avoids the southwestern sides of trunks. The preferred habitat of this species ranges from open swamps, with persistent standing water throughout the year, to dense riparian (stream or lakeside) corridors or transitional habitats near peatlands.

Biology

Lichens are symbiotic organisms, formed by the association of a fungus and a photosynthetic green alga or cyanobacterium. In the White-rimmed Shingle Lichen, the photosynthetic partner is a cyanobacterium belonging to the genus *Nostoc*. The fungus is an ascomycete in the family Pannariaceae.

This lichen is thought to disperse over long distances by spores but may colonize nearby patches of tree bark if fragments break off the main body (thallus). Because the spores contain only fungal DNA, a compatible cyanobacterium must already be present if new habitats are to be colonized. The generation time of this species is unknown, but related lichen species require between 5 and 22 years to reach maturity. Available data suggest the generation time is at least 12 years.

Population Sizes and Trends

Based on surveys, 1,663 thalli of the White-rimmed Shingle Lichen have been enumerated and found on 502 trees in 88 occurrences, in Canada. Of the known thalli, about 45% are in New Brunswick, about the same percentage are in Nova Scotia, and less than 10% are in Ontario. Based on the information provided by distribution models and developed for this report, the population in Canada is estimated to be approximately 9,265 thalli in total.

Threats and Limiting Factors

The main threat to White-rimmed Shingle Lichen in Canada is logging of Eastern White Cedar and Red Maple. This species is also sensitive to atmospheric pollution in the form of acid rain. Climate change is also a threat particularly in the form of warmer dryer summers to which this lichen is sensitive as its photosynthetic partner is a cyanobacterium. Hence, it requires liquid water to initiate photosynthesis, unlike lichens associated with green algae that become metabolically active with humid air. Climatic changes not only stress the lichen but may also result in an increase in the incidence of forest fires. Furthermore, the predicted increase in the frequency of extreme weather events is likely to cause blowdown of host trees. Grazing by invasive slugs is another threat but currently it seems to be limited to Nova Scotia. Overall, it is predicted that 45% of the population of White-rimmed Shingle Lichen could be lost over the next three generations (36 years) as a result of threats.

Protection, Status, and Ranks

White-rimmed Shingle Lichen has a national rank of N2N3 – Imperilled to Vulnerable and a General Status rank of N3 (Vulnerable). The Natural Heritage Information Centre (Ontario) ranks the species as S1S2 (Critically Imperilled to Imperilled), and the Atlantic Conservation Data Centre ranks it as S2S3 (Imperilled to Vulnerable) in New Brunswick and Nova Scotia.

TECHNICAL SUMMARY

Fuscopannaria leucosticta

White-rimmed Shingle Lichen

Fuscopannaire à taches blanches

Range of occurrence in Canada (province/territory/ocean): Ontario, Quebec, New Brunswick, Nova Scotia

Demographic Information

Generation time based on other studied cyanolichen species	12 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, both observed and projected
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations] 36% in 24 years (2 generations)	36%
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. The estimate is that at least nine occurrences were lost since 2007, but at least one additional site in ON and one in NB were lost in the last 30 years and were not included in this total.	9.3% decline over last ten years
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. 45% projected over 3 generations if logging continues at the current rate.	45% projected reduction over the next three generations
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. 9.3% lost over last ten years plus 36% losses projected over the next 2 generations.	45% reduction
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. no, not in the short-term unless logging is curtailed and climate change is controlled b. yes c. no
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	576,652 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	344 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. possibly: 78% of sites have fewer than 15 mature individuals (colonies,) and 49% have fewer than 5. b. Long-distance dispersal by ascospores is possible but has a very low probability of success.
Number of "locations" (use plausible range to reflect uncertainty if appropriate) Threats from forestry activities, fires, and alien slug infestation operate at the occurrence/stand level, which would translate into 88 locations. Climate change threats operate at a regional level. The number of locations could be as low as three, one for each subpopulation, but likely more than 10.	>10 to 88
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes - Inferred if the small Ontario subpopulation is lost as a result of forestry activities, air pollution or habitat disturbance.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes - projected
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes - Inferred if the small Ontario subpopulation is lost as a result of forestry activities, air pollution or habitat disturbance.
Is there an [observed, inferred, or projected] decline in number of "locations"? Yes – a reduction from 88 to 71 locations is expected over the next 3 years for sites with active logging during the preparation of this report; further declines in locations are projected on the basis of further harvesting rates.	Yes - Projected decline
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – In all three subpopulations, projected on the basis of forestry activities and climate change.
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"?	No
Are there extreme fluctuations in extent of site?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals (thalli)
Ontario	77 thalli on 31 trees (known) Total estimated 639 (no confidence estimates)
New Brunswick	764 thalli on 247 trees (known) Total estimated 4,315 thalli (±1 SD = 2,474-6,206)
Nova Scotia	822 thalli on 224 trees (known) Total estimated 4,311 thalli (±1 SD = 3,196-5,599)
Total population	1,663 thalli on 502 trees (known) Total estimated 9,265 (±1 SD = 6,386-12,521)

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not done

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes (draft Appendix 1). 27 February 2018.

Major threats include:

1. Logging & Wood Harvesting
2. Climate Change & Severe Weather
3. Air Pollution
4. Invasive & Other Problematic Species (invasive slugs)

What additional limiting factors are relevant?

In the long-term, there may also be impacts from shifting bioclimatic envelopes on host trees and further acidification of habitats.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The nearest occurrences to the Ontario subpopulation are in Minnesota, Wisconsin, and Michigan, where the species has largely disappeared and not been collected within the last 15 years. The species has also not been found since 1986 in Pennsylvania and since 1953 in Maine.
Is immigration known or possible?	It is possible but unlikely given the distance involved.
Would immigrants be adapted to survive in Canada?	Probably, as long as suitable strains of the cyanobacterium are available for capture by the germinating lichen spores.
Is there sufficient habitat for immigrants in Canada?	Probably if forestry activity and air pollution levels are reduced.

Are conditions deteriorating in Canada?	Yes – Eastern White Cedar and Red Maple swamps are being logged for lumber and biomass. Such old-growth forests are not regenerating rapidly enough to compensate for losses.
Are conditions for the source population deteriorating?	Yes – Collections in northern U.S.A. states are less frequent, suggesting reduced prevalence.
Is the Canadian population considered to be a sink?	Unlikely
Is rescue from outside populations likely?	Unlikely
Is this a data sensitive species?	No – There is a possibility that owners of private or unprotected forests might wish to proceed with logging if this lichen were known to occur. However, with consultation between government, industry, and the public, knowledge about the presence of this lichen species is more likely to prove beneficial, as a result of increased awareness about endangered organisms.

Status History

COSEWIC: Designated Threatened in May 2019.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** A3c+4c
Reasons for designation: This rare lichen in Canada grows in wet forests of Nova Scotia, New Brunswick and Ontario, with three known subpopulations. The main threat to the species in Canada is logging of host trees Eastern White Cedar and Red Maple. As with other cyanolichens, this species is sensitive to atmospheric pollution in the form of acid rain and to climate change including more extreme weather events leading to blowdown of host trees. The decline in number of mature individuals observed over the past ten years is expected to continue, with about 45% of the population expected to be lost over the next three generations.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Threatened, A3c, as there is a projected future reduction in the total number of mature individuals in the lichen population of 45% over the next three generations (36 years), based on projected loss habitat as a result of logging activities and extreme weather events, as the loss of occupied sites over the past few years is expected to continue at similar rates in the future. Also meets Threatened A4c, as the observed reduction in the availability of host trees over the past few years due to forest harvesting is projected to continue into the future over a total period (past and future) of at least three generations (36 years) with an overall population reduction of about 45%.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria as the EOO exceeds the limit and there are more than 10 locations.
Criterion C (Small and Declining Number of Mature Individuals): May meet Threatened, C1 as the total estimated population may be less than 10,000 mature individuals and there is an estimated continuing decline that may exceed 10% of the number of mature individuals over three generations.

Criterion D (Very Small or Restricted Population): Does not meet criteria as the total population exceeds 1000 individuals and the IAO exceeds the threshold.
Criterion E (Quantitative Analysis): Not done.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2019)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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Fuscopannaria leucosticta

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2019

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Fuscopannaria leucosticta* (Tuck.) P.M. Jørg. (1994)

Synonym: *Parmelia leucosticta* Tuck. (1853); *Pannaria leucosticta* (Tuck.) Tuck. ex Nyl. (1859); *Pannularia leucosticta* (Tuck.) Stizenb. (1887)

Common Name: White-rimmed Shingle Lichen, Fuscopannaire à taches blanches

Family: Pannariaceae

Major Group: Lichens (Lichenized Ascomycetes) *Fuscopannaria leucosticta* (Tuck.) P.M. Jørg. is a cyanobacterial lichen in the family Pannariaceae.

Morphological Description

Fuscopannaria leucosticta has a sub-foliose to squamulose growth form, usually forming irregularly shaped colonies of 1-8 cm across. The upper surface (cortex) of the thallus ranges from mineral grey to a rust-brown or even blackish colour but is most often a medium olive-grey. Squamules are usually small, less than 0.5 mm across, but lobes of some thalli can reach up to 2 mm across (Figure 1). Both squamules and larger lobes typically display a distinct white colour along the margins that is formed by closely appressed white hairs called the tomentum. *Fuscopannaria leucosticta* has a prothallus, consisting of a blue-black fibrous mat of hyphae that underlies the thallus or body of the lichen and extends several millimetres beyond its edges. This prothallus is well-developed in *F. leucosticta*, up to 0.5 mm thick, or slightly greater than the thallus itself.

The photosynthetic partner in *F. leucosticta* is a cyanobacterium in the genus *Nostoc.* This photobiont is also common in many other lichens of the Pannariaceae.

Fruiting bodies (apothecia) in *F. leucosticta* have a broad brown disc that extends above the surface of the cortex and is surrounded by a thallus-coloured margin consisting of both the fungus and cyanobacterium. These apothecia are 0.5-1.5 mm across. When wet, apothecia appear swollen, with the disc often protruding beyond the edges of the exciple and appearing light brown or peach-coloured. When dry, the disc is typically sunken and dark brown or rust-brown. The absence of asexual reproductive structures (e.g., soredia) is a diagnostic feature of the species.

The spores of *F. leucosticta* are colourless, elliptical, 19-23 x 9-11 µm, and surrounded by a clear gelatinous layer (perispore) that is smooth, 23-27 µm long, and usually tapered to a point at both ends (Jørgensen 2000). This is a useful distinction from morphologically similar species. Two similar species can be distinguished by their spores. *Protopannaria pezizoides* has spores that are slightly larger, and with a perispore that has a warty surface and blunt tips. *Pannaria rubiginosa* spores have a roughened surface and are often pointed at only one end. However, these spore-based features are only necessary for the identification of atypical specimens.

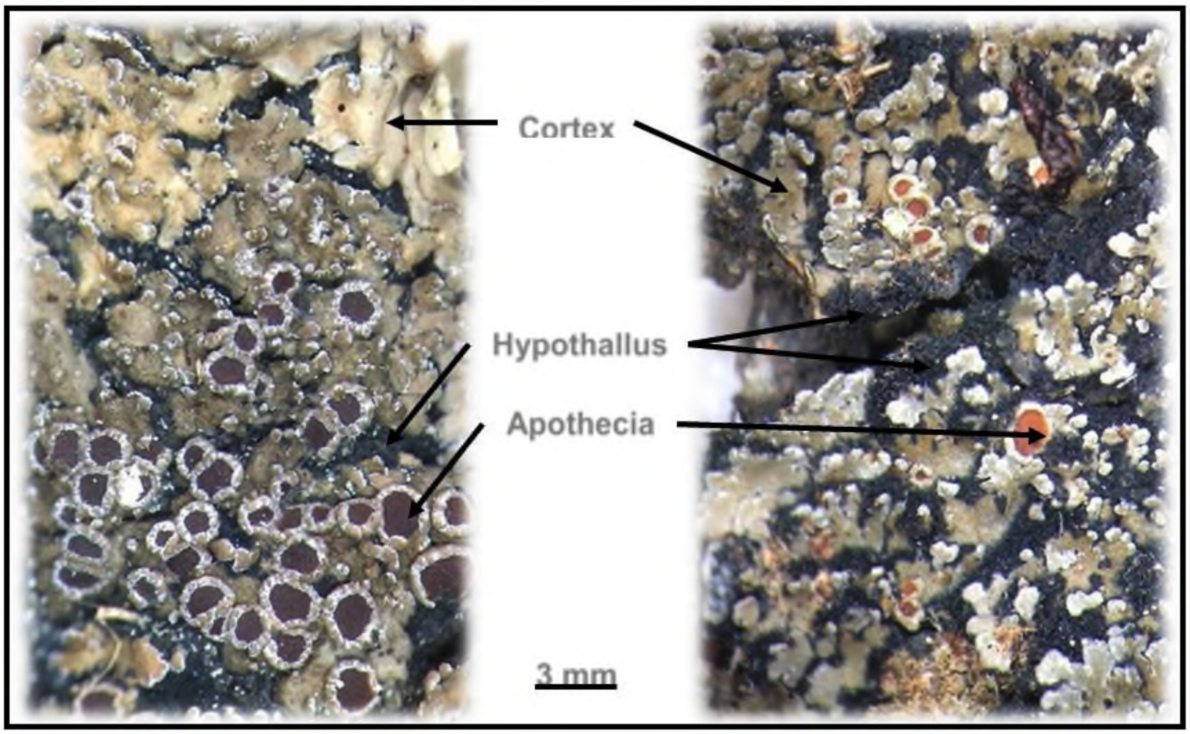

Figure 1. Fertile *Fuscopannaria leucosticta* thalli showing apothecia and white fringed thallus margins. Photos by S. Haughian.

Chemistry

Fuscopannaria leucosticta can also be distinguished from other species by its chemistry. The interior layer (medulla) of *F. leucosticta* does not react when spot-tested with PD (para-phenylenediamine), whereas the medulla of *Pannaria rubiginosa* will usually turn orange (Jørgensen 1978). The asci of *F. leucosticta* react with a potassium iodide solution; they possess an apical amyloid ring structure, which will turn blue when iodine solutions are added. Neither *Protopannaria pezizoides,* nor *Pannaria rubiginosa* have such structures. Nevertheless, while *Protopannaria pezizoides* shows no reaction with exposure to iodine solutions, in *Pannaria rubiginosa* both asci and paraphyses will react blue.

Designatable Units

There is considerable geographic separation between occurrences in Ontario and those in New Brunswick and Nova Scotia. *Fuscopannaria leucosticta* colonizes Eastern White Cedar, *Thuja occidentalis*, in Ontario and New Brunswick, and Red Maple, *Acer rubrum*, in Nova Scotia. These differences in host associations are likely due to the prevalence of particular host species in the wet forests where the lichen thrives (Haughian *et al.* 2018), rather than to any incipient ecotypification or population divergence. There appear to be no morphological differences in the samples collected from the three subpopulations. No molecular work has been done on thalli from different areas. Thus, there is no information to warrant more than one designatable unit.

Special Significance

Fuscopannaria leucosticta is one of a group of rare cyanolichens that are largely dependent upon Eastern White Cedar or Red Maple swamp forests. This group includes *Erioderma mollisimum* (endangered; COSEWIC 2009, 2014), *Pannaria lurida* (threatened; COSEWIC 2016), and *Degelia plumbea* (special concern; COSEWIC 2010). All of the above species were detected during surveys of high-probability *F. leucosticta* habitats. *Fuscopannaria leucosticta* appears to be a valuable indicator of old, undisturbed forests (Haughian *et al.* 2018), an increasingly rare type of ecosystem in Atlantic Canada (Loo and Ives 2003). Other At risk species, like the Canada Warbler (*Wilsonia canadensis*; COSEWIC 2008) and the Olive-sided Flycatcher (*Nuttallornis borealis*; COSEWIC 2007), are also associated with these ecosystems and were detected during the recent surveys.

DISTRIBUTION

Global Range

Fuscopannaria leucosticta is a species of temperate forests with a disjunct distribution, primarily in eastern North America and northern parts of the Asia Pacific region (Jørgensen 1978; Jørgensen and Sipman 2007; GBIF Secretariat 2017). In the eastern United States, it has been reported as an infrequent species on several lichen inventories (Perlmutter 2006; Keller *et al.* 2007; Lendemer and Tripp 2008) (Figure 2). There appears to be a disjunct western component of the range around Lake Superior. *F. leucosticta* is uncommon in Africa (Alstrup and Christensen 2006), South America (Jørgensen and Sipman 2007) and Europe (Spribille 2009).

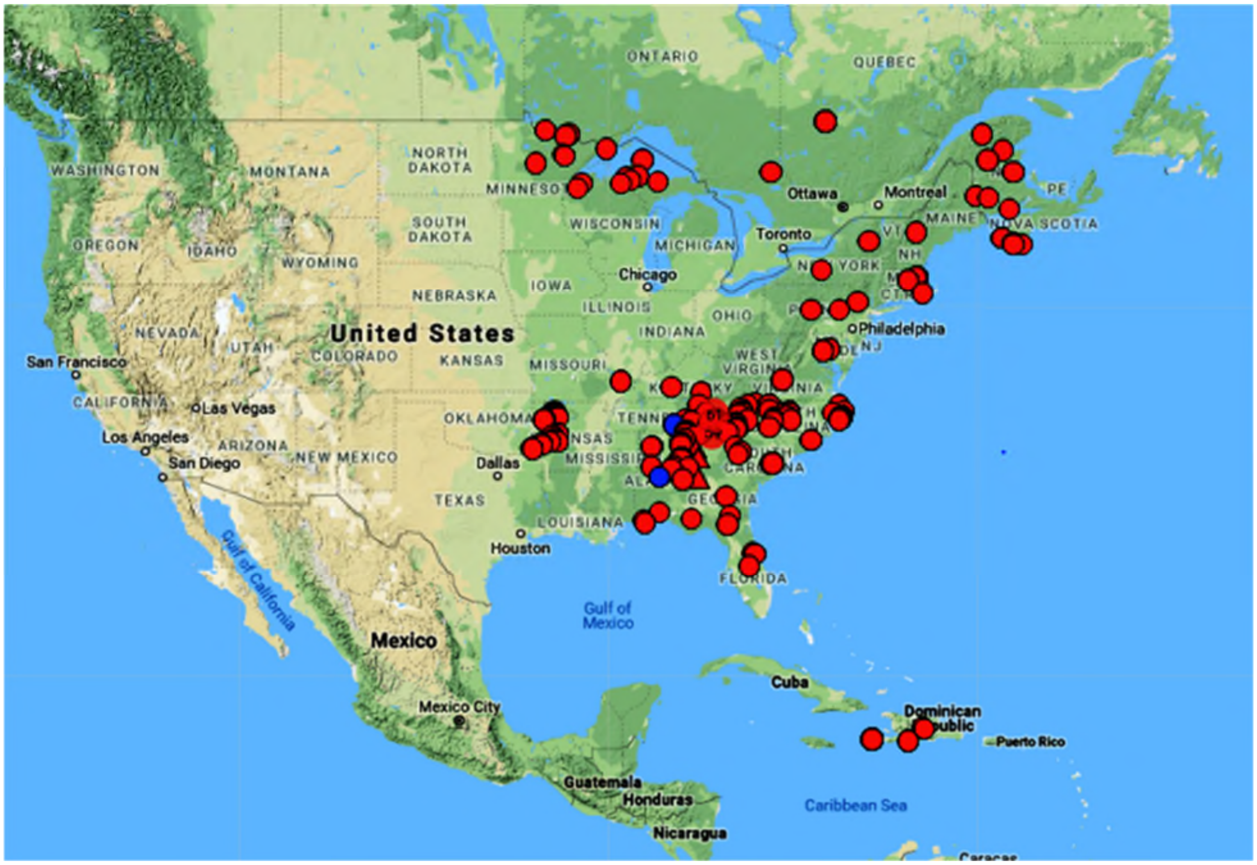

Figure 2. The distribution of *Fuscopannaria leucosticta* in Canada, the USA and the Caribbean. The map is based on specimens in Consortium of North American Lichen Herbaria in 2019). There are also records for this lichen in the CNALH from the west coast of North America and Lake Temagami, Ontario. These records have been examined and proved to be a different species, *Fuscopannaria leucostictoides*. The red dot south of James Bay in Quebec is incorrectly mapped and is actually the historical Lac Clair record, 50 km north of Montréal (Map © Google, 2019).

The global distribution pattern of *F. leucosticta* suggests that it is a Tertiary relict because it is primarily found in places that served as interglacial refuges throughout Europe, Asia, and North America (Jørgensen and Sipman 2007).

Canadian Range

In Canada, *F. leucosticta* is currently limited to New Brunswick and Nova Scotia, with a small cluster of occurrences in western Ontario. There was an early record from Quebec, just north of Montréal in the 1880s, although the exact site could not be verified. The lichen is assumed to no longer be present in this area, as satellite imagery indicates that there is no suitable habitat in the general area. Other surveys in Quebec have, to date, failed to discover *F. leucosticta* in the province.

The species is considered to consist of three subpopulations in Canada. The first is largely restricted to a broad SW-NE band across the mid-latitude of New Brunswick, running from Fredericton to Bathurst with sporadic sites elsewhere (Figures 3 and 7). The second subpopulation in Nova Scotia occurs mainly on the east coast of southwestern Nova Scotia (in Shelburne and Queens counties), with sporadic sites throughout the eastern mainland. The Ontario subpopulation consists of a small cluster of sites from Thunder Bay west to the Quetico region in Rainy River District. Records from western Canada have been determined to be other species. There is very little likelihood of movement between the three subpopulations as the distances are large and both the Bay of Fundy and a large amount of land separate NS and NB occurrences, and a very large distance separates ON from others (see Life Cycle and Reproduction).

Extent of Occurrence and Area of Occupancy

The calculated extent of occurrence (EOO) was 67,652 km^2 and the index of area of occupancy (IAO) was 344 km^2.

Search Effort

Pre-2016 searches

Search effort is summarized in several ways. The pre-2016 sites for *F. leucosticta* in each province as well as the sites that have been visited in other surveys for lichens in the Pannariaceae but where *F. leucosticta* was not recorded are shown in Figures 3 to 6. A second set of maps shows the recently verified (2016-2017) occurrences in each province as well as sites where the lichen was not found, although the habitat appeared to be suitable (Figure 7 to 10). Note that the place where the lichen is found is termed a site. If one or more trees are colonized close together at the site, they are counted as a single occurrence. If one or more trees are colonized at a distance greater than one kilometre (a distance greater than propagules are generally disseminated on a regular basis) from the first site, the tree or group of trees would be counted and regarded as a separate occurrence. Where occurrences are found at greater distances than the propagules ever normally disperse, e.g., between Ontario and New Brunswick, the lichens are regarded as belonging to separate subpopulations in the sense used by IUCN.

The search effort is also summarized as the number of person-hours spent searching. In total, 785 hours were spent searching for *F. leucosticta* in 2016-2017; Nova Scotia had the most person-hours followed by New Brunswick, Ontario, and Quebec (Table 1). In total, 25 people contributed to these searches.

Table 1. Summary of the number of observed occurrences, trees, and thalli (for 2016-2018 surveys). Data are taken from Table 3 and indicate the projected number of thalli, and the total search effort (person-hours and observers) in each province. Projected population totals were estimated using the method in Appendix 2.

	Observed population			Projected population (No. Thalli)			Search effort	
	Number of occurrences	No. Trees	No. Thalli	-SD	Mean	+SD	No. Person-Hours	No. Observers
NB	26	247	764	2474	**4315**	6206	207	10
NS	57	224	822	3196	**4311**	5599	433	9
ON	5	31	77		639		123	4
QC	0	0	0		N/A		22	2
TOTAL	88	502	1663	6,386	9,265	12,521	785	25

Thirdly, the search effort is summarized as the number of trees examined in New Brunswick and part of Nova Scotia (Table 2). In New Brunswick, almost 10,000 trees were inspected; in Nova Scotia, 761 trees were inspected. In this report, observers are shown by initials: CP = Chris Pepper, CV = Cole Vail, DS = Dwayne Sabine, EH = Eleni Hines, FA = Frances Anderson, JG = Jean Gagnon, KD = Kendra Driscoll, RB = Richard Blacquiere, RC = Robert Cameron, SB = Samuel Brinker, SC = Stephen Clayden, SH = Sean Haughian, SS = Steven Selva, TN = Tom Neily, CS = Chad Simmons.

Table 2. Search effort and species prevalence in all New Brunswick and several Nova Scotia sites (surveyed in 2016-2018), shown in terms of the number of detected host trees or thalli, and the number of trees that were inspected. Note: only those NS sites at which completed data sets were collected are shown here.

Prov.	Occurrences	Trees			Thalli		
		Hosts	Searched	Ratio	Total	/host tree	/searched trees
Nova Scotia	Little Bon Mature Lk N	17	50	0.340	173	10.18	3.460
	Little Bon Mature Lk S	14	28	0.500	113	8.07	4.036
	Burnaby Lake SE	9	140	0.064	31	3.44	0.221
	Blue Hill Mud Lake C	6	40	0.150	27	4.50	0.675
	Little Bon Mature Lk C	4	63	0.063	26	6.50	0.413
	Blue Hill Mud Lake S	5	32	0.156	22	4.40	0.688
	Blue Hill Mud Lake E	3	24	0.125	33	11.00	1.375
	Malay Falls NW	2	20	0.100	11	5.50	0.550
	Ash Brook	2	24	0.083	3	1.50	0.125
	Blue Hill Mud Lake N	2	120	0.017	2	1.00	0.017
	Crane Lake SE	1	20	0.050	5	5.00	0.250
	Ian's Road SE	1	100	0.010	1	1.00	0.010
	Pleasant River Lake Rd	1	100	0.010	1	1.00	0.010
	NS TOTAL	**67**	**761**	**0.088**	**448**	**6.69**	**0.589**
New Brunswick	Goodfellow Brook	59	635	0.093	204	3.46	0.321
	Eel River	31	1280	0.024	81	2.61	0.063

Prov.	Occurrences	Trees			Thalli		
		Hosts	Searched	Ratio	Total	/host tree	/searched trees
	Southeast of Napan Bay	24	642	0.037	83	3.44	0.129
	South of Saint Margarets	17	1091	0.016	56	3.26	0.051
	Pineville (North of HWY 108)	17	373	0.046	50	2.91	0.133
	Spednic Lake, North Mosq. Bk.	14	421	0.033	45	3.21	0.107
	North of Fraser-Burchill Rd	10	283	0.035	35	3.50	0.124
	Munsons Landing (North of HWY 108)	10	322	0.031	14	1.40	0.043
	Southeast of Peaked Mountain	9	374	0.024	44	4.89	0.118
	Clark Point	8	481	0.017	26	3.25	0.054
	Blissfield (S of HWY 108)	7	196	0.036	34	4.86	0.173
	Near Bronson Bog	6	586	0.010	12	2.00	0.020
	Kelly’s Creek 1	6	68	0.088	7	1.17	0.103
	Spednic Lake, South Mosq. Bk.	5	194	0.026	29	5.80	0.149
	Beaverbrook headwaters	4	30	0.133	5	1.25	0.167
	NE of Lawrence Station	4	908	0.004	7	1.75	0.008
	Kouchibouguac	3	160	0.019	15	4.83	0.091
	Near Brockway Airport (HWY 3)	3	296	0.010	8	2.67	0.027
	NW Miramichi River	3	282	0.011	3	1.00	0.011
	West of Red Pine Knoll	1	569	0.002	2	2.00	0.004
	Mount Carleton P. Park	1	234	0.004	1	1.00	0.004
	Jacquet River Gorge (S Antinouri Lake Brook)	1	175	0.006	1	1.00	0.006
	Upper Tetagouche Lake S	1	150	0.007	1	1.00	0.007
	East of Harcourt	1	118	0.008	1	1.00	0.008
	Jacquet River Gorge (S of Belledune Pond)	1	107	0.009	1	1.00	0.009
	Pokiok Settlement	1	24	0.042	1	1.00	0.042
	NB TOTAL	**247**	**9999**	**0.025**	**764**	**3.09**	**0.076**

Until 2016, *F. leucosticta* was not regularly targeted for specific searches in Canada, but considerable effort has been expended to monitor related cyanolichens, especially members of the Pannariaceae. Consequently, a “Target Group Sampling” approach (Ponder *et al.* 2001) can be applied to infer historical search effort. Search effort before 2016 has varied among provinces, based on the availability of naturalists, biologists, or lichenologists. For example, between 2003 and 2012, lichenologists estimate that they spent over 3000 hours searching for *Erioderma pedicellatum* (Boreal Felt Lichen) in Nova Scotia (COSEWIC 2014). *E. pedicellatum* grows on Balsam Fir in wetlands. Extensive preharvest surveys are done on Crown lands by experienced lichenologists as part of the Special Management Practice (Nova Scotia Department of Natural Resources 2018). En route to and from the Balsam Fir habitats, the lichenologists passed through Red Maple and other wet habitats, where they recorded rare lichens, especially the cyanolichens. In New Brunswick, Stephen Clayden has conducted general inventories of Eastern White Cedar swamp forests for over a decade.

In New Brunswick (NB), prior to recent survey efforts, *F. leucosticta* was collected 23 times from 13 sites (Figure 3). The collections are held at the New Brunswick Museum (NBM). One was made from a single site in each of Charlotte and Saint John counties, two collections were made in Restigouche County, two were made in Kent County (at two sites), eight were made in York County (at five sites), and eight were made in Northumberland County (in Goodfellow Brook Protected Natural Area). These were all made in the course of more generalized macrolichen surveys in lichen-rich habitat. The oldest collection was made by Wolfgang Maas in 1986; most others were made after 2005 by SC (often with SS or KD), or by DS. For details of many of these records see Consortium of North American Lichen Herbaria (2017). The CNALH records also include 297 records of other cyanolichens, and there are a further 63 collections from intensive mycological forays that took place in New Brunswick, where observers could reasonably have been expected to detect *F. leucosticta*, if it was present. The collected Pannariaceae specimens are at the New Brunswick Museum.

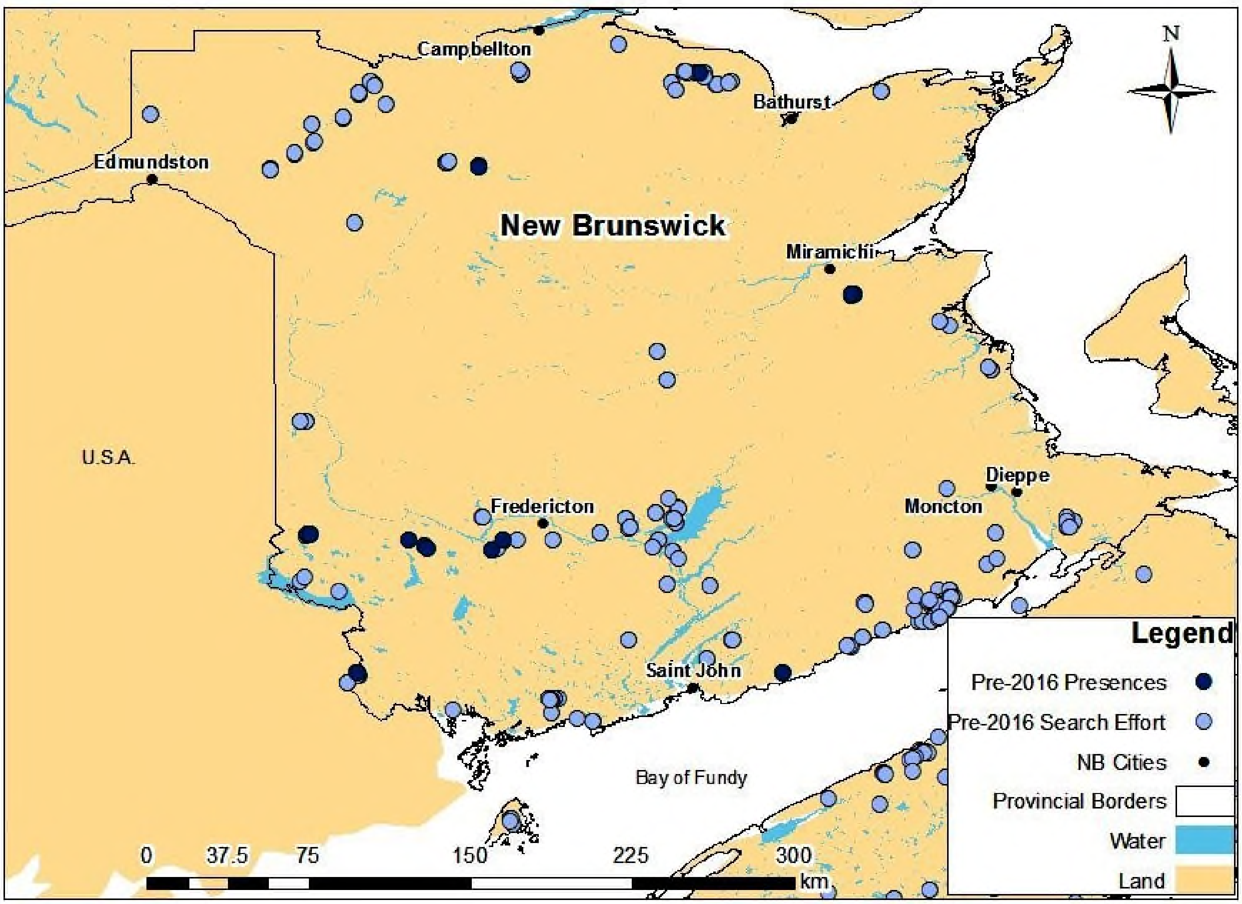

Figure 3. Dark blue dots are sites of *Fuscopannaria leucosticta* discovered in New Brunswick between 1880 and 2015. Pale blue dots are sites searched successfully for lichens belonging to the Pannariaceae, over the same period but where *F. leucosticta* was not recorded.

In Nova Scotia, 63 records from 24 sites documented *F. leucosticta* prior to 2016 (Figure 4), but not all were accompanied by collected material. These records were predominantly from Shelburne County, with 38 observations from 13 sites. All have multiple collections associated with them. Another 15 observations and collections were from three sites in Queens County. Four collections were from four sites in Halifax County, and three records were from two sites in Digby County. The other two records were from a single site in Annapolis and Lunenburg counties. The earliest collection of *F. leucosticta* was made by Hinds and Hinds (1999). The majority of observations in NS were made after 2005 by SC, TN, CP, RC, and FA. Some were recorded opportunistically, but most were made during contracted surveys for other At risk species as part of pre-cutting assessments. There are approximately 1400 records of other At risk cyanolichens in the extensive database maintained by the Mersey Tobeatic Research Institute, and there are 139 cyanolichen records from the province that are held by other herbaria (Consortium of North American Lichen Herbaria 2017).

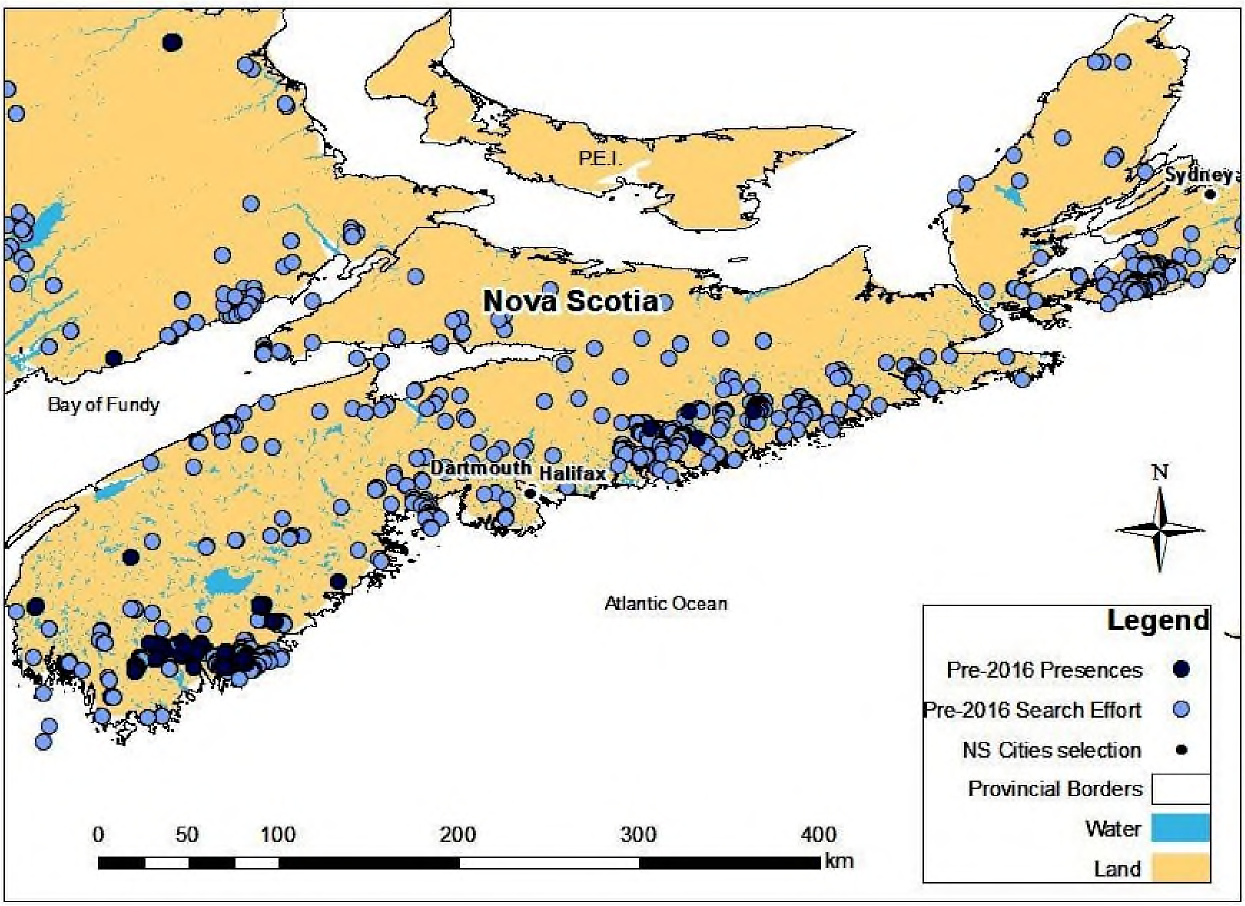

Figure 4. Dark blue dots are sites of *Fuscopannaria leucosticta* discovered in Nova Scotia between 1880 and 2015. Pale blue dots are sites searched successfully for lichens belonging to the Pannariaceae, over the same period but where *Fuscopannaria leucosticta* was not recorded.

In Ontario, three sites of *F. leucosticta* were reported prior to 2016. One was from Algoma District in Lake Superior Provincial Park with a single 1993 collection by S. Sharnoff on the Nokomis Trail near Old Woman Bay. The second area is from the Rainy River District in western Ontario, where it was collected by early American lichenologist Bruce Fink, who visited the Emo area in July of 1901 and made over 20 *F. lecucosticta* collections (most are replicates of material from one area with the same collection number), all labelled "on cedar in swamps". A third specimen was collected in the Nipissing District in central Ontario. This collection was made by Roy Cain in 1935 on a decayed log along the Gull Lake Portage, Lake Temagami. It was originally identified as *F. leucosticta* by Albert William Herre. The specimen at the Canadian Museum of Nature appears to have gone missing but there is a duplicate collection in the Field Museum in Chicago which was re-examined in 2017 by R.T. McMullin and found to be misidentified. There are 234 other Pannariaceae records (Consortium of North American Lichen Herbaria 2017) and notable collectors include C. Wetmore and I.M. Brodo.

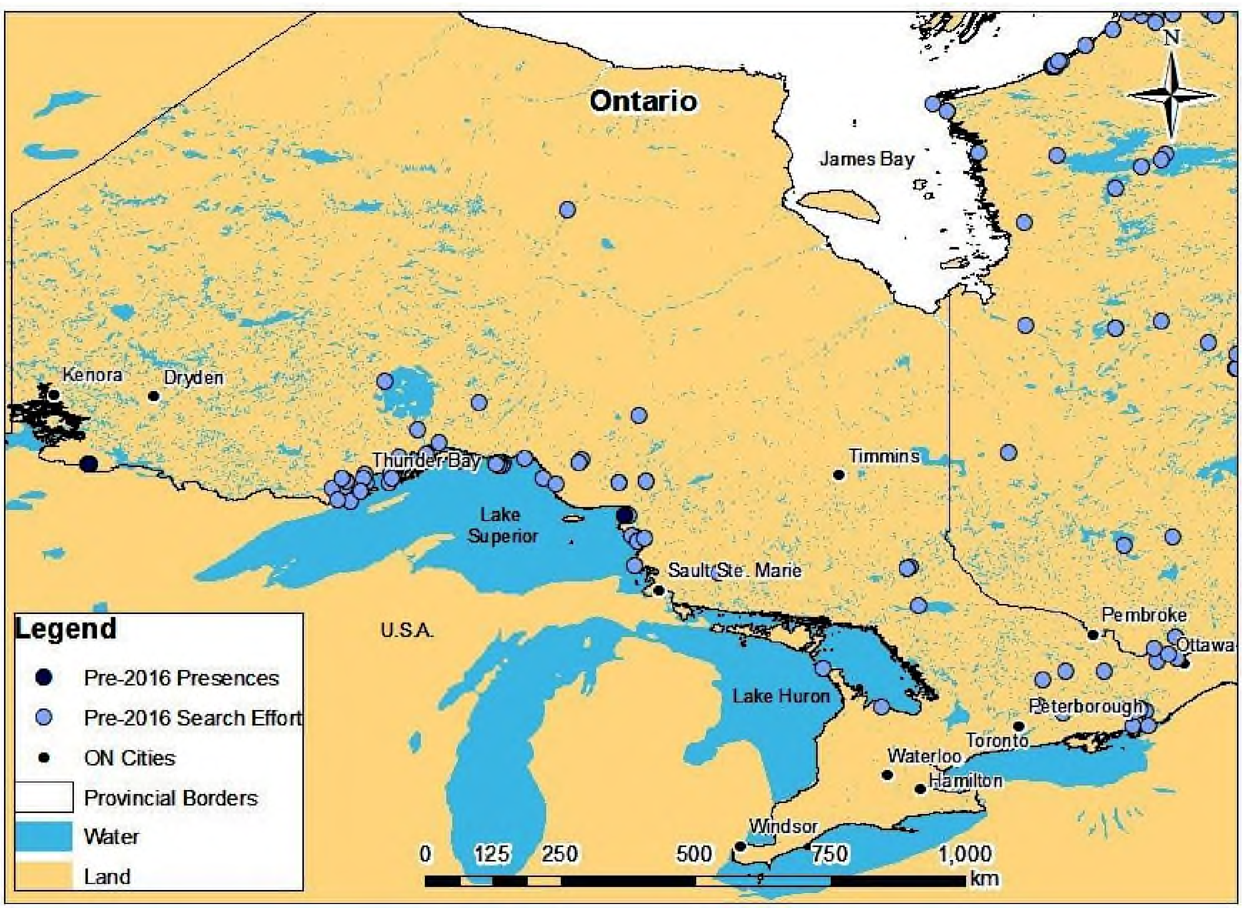

Figure 5. The two dark blue dots are sites of *Fuscopannaria leucosticta* discovered in Ontario between 1880 and 2015. The pale blue dots are sites searched successfully for lichens belonging to the Pannariaceae, over the same period but where *Fuscopannaria leucosticta* was not recorded.

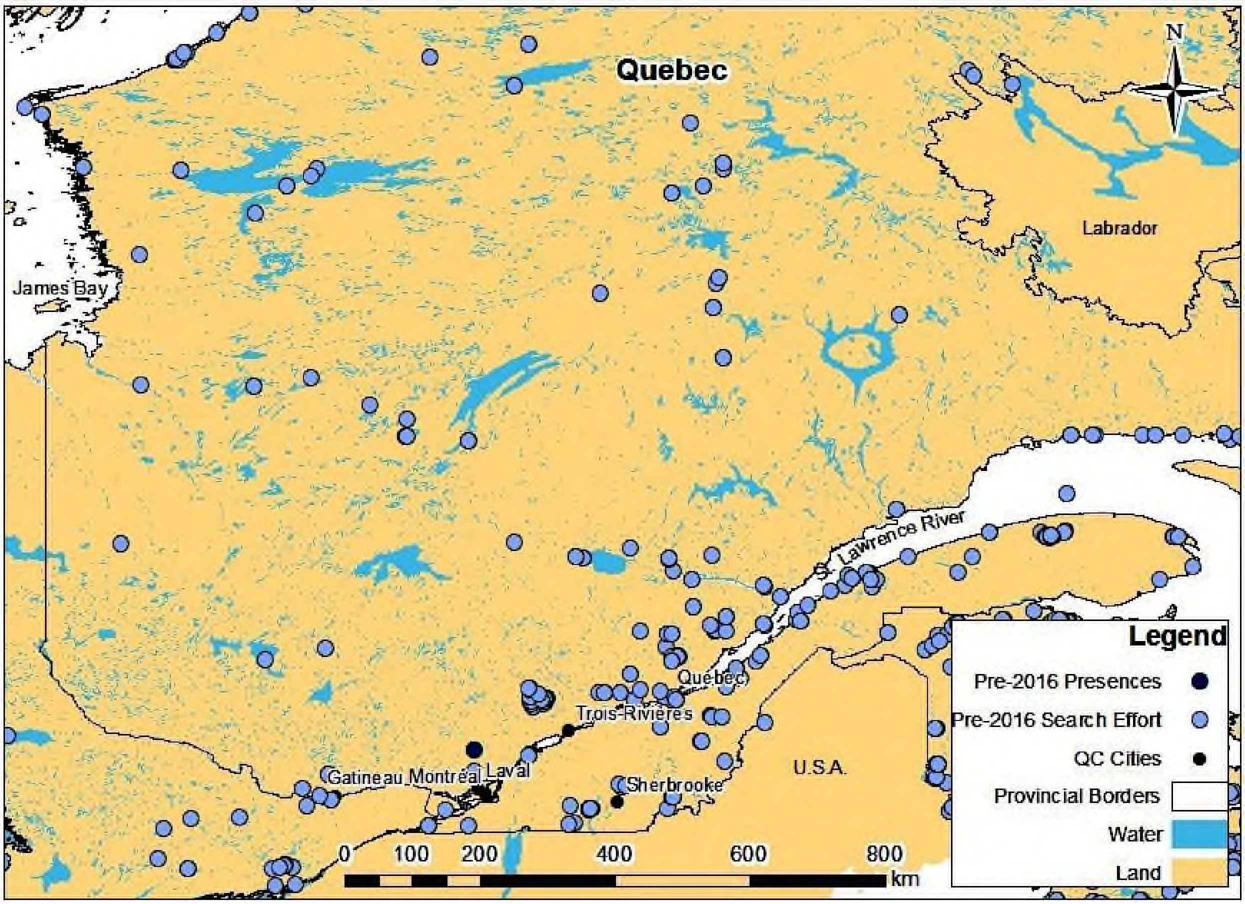

Figure 6. The dark blue dot, north of Montréal, is the historical site of *Fuscopannaria leucosticta* discovered in Quebec in 1888. The pale blue dots were sites searched successfully for lichens belonging to the Pannariaceae in Quebec between 1880 and 2015, but where *Fuscopannaria leucosticta* was not recorded.

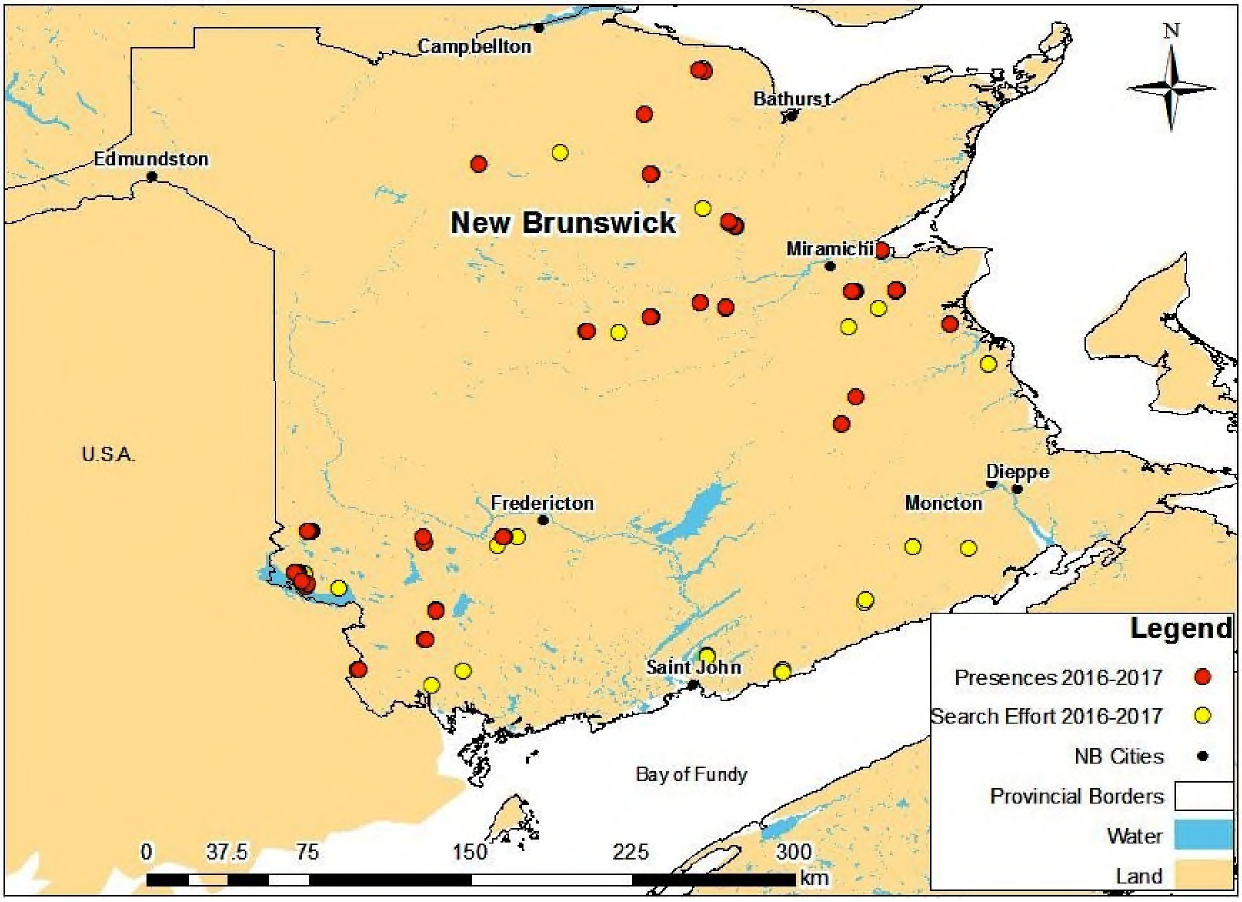

Figure 7. The orange dots show the sites of *Fuscopannaria leucosticta* in New Brunswick, found during the lichen surveys carried out in 2016 and 2017. The yellow dots show sites where this lichen was not detected in the surveys over the same period.

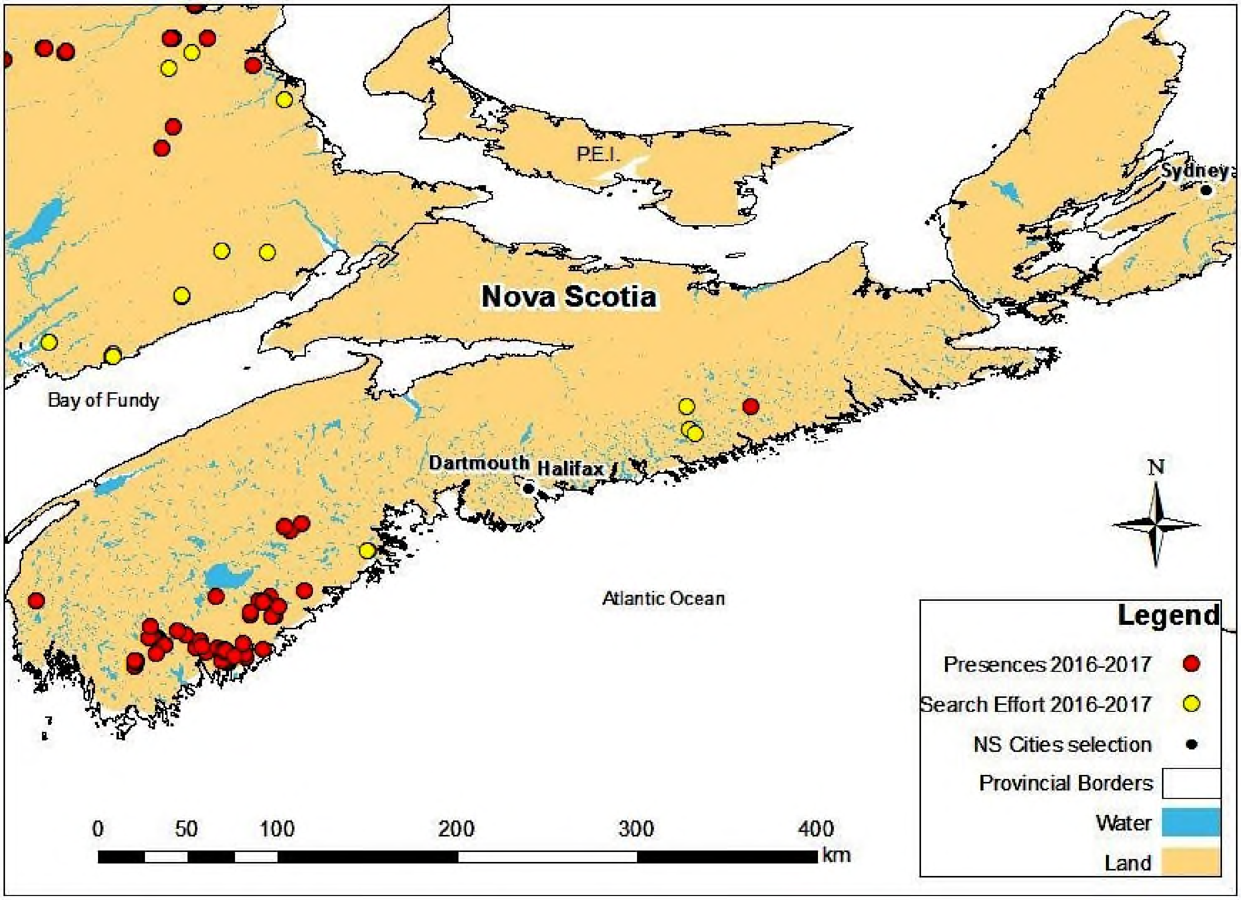

Figure 8. The orange dots show the sites of *Fuscopannaria leucosticta* in Nova Scotia, found during the lichen surveys carried out in 2016 and 2017. The yellow dots show sites where this lichen was not detected in the surveys over the same period.

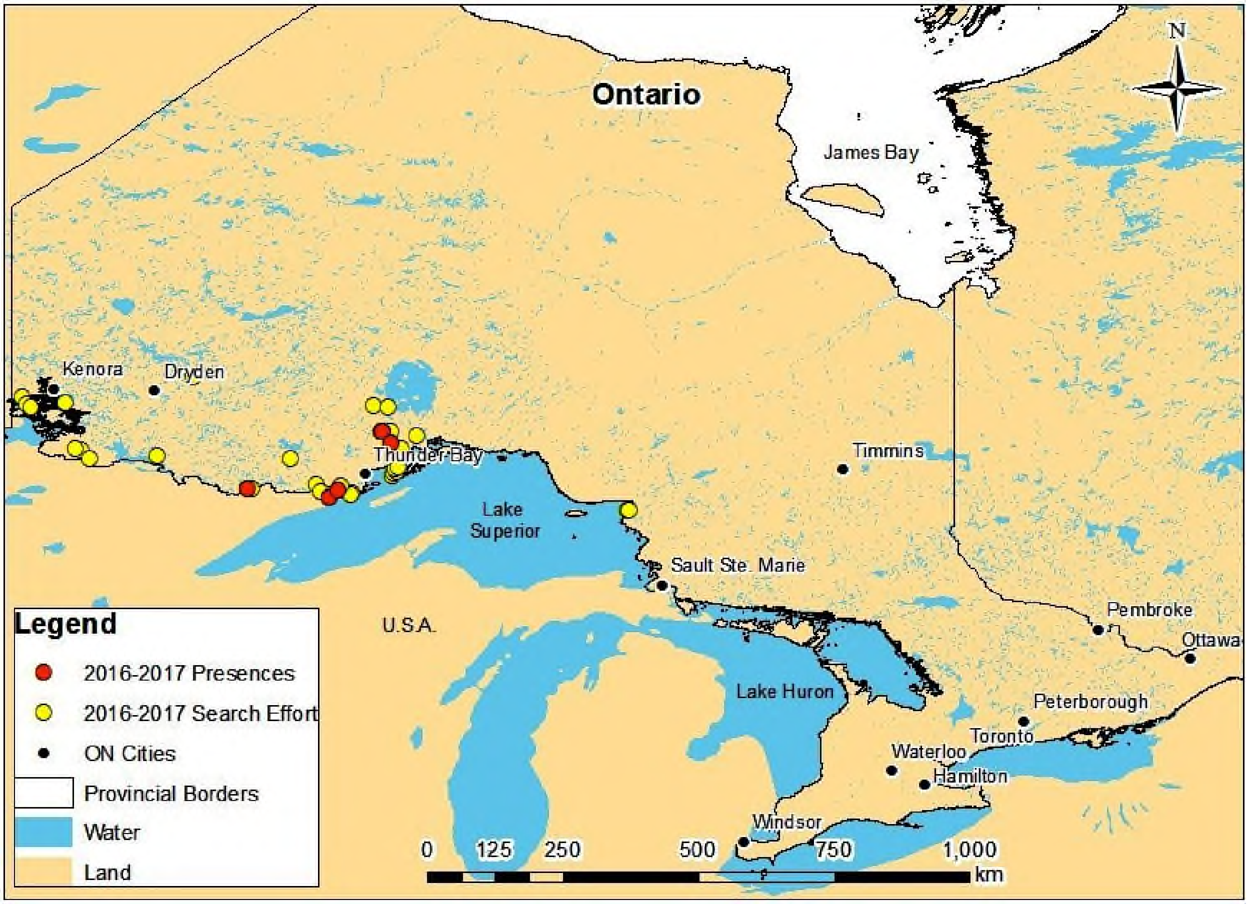

Figure 9. The orange dots show the sites of *Fuscopannaria leucosticta* in Ontario, found during the lichen surveys carried out in 2016 and 2017. The yellow dots show sites where this lichen was not detected in the surveys over the same period .

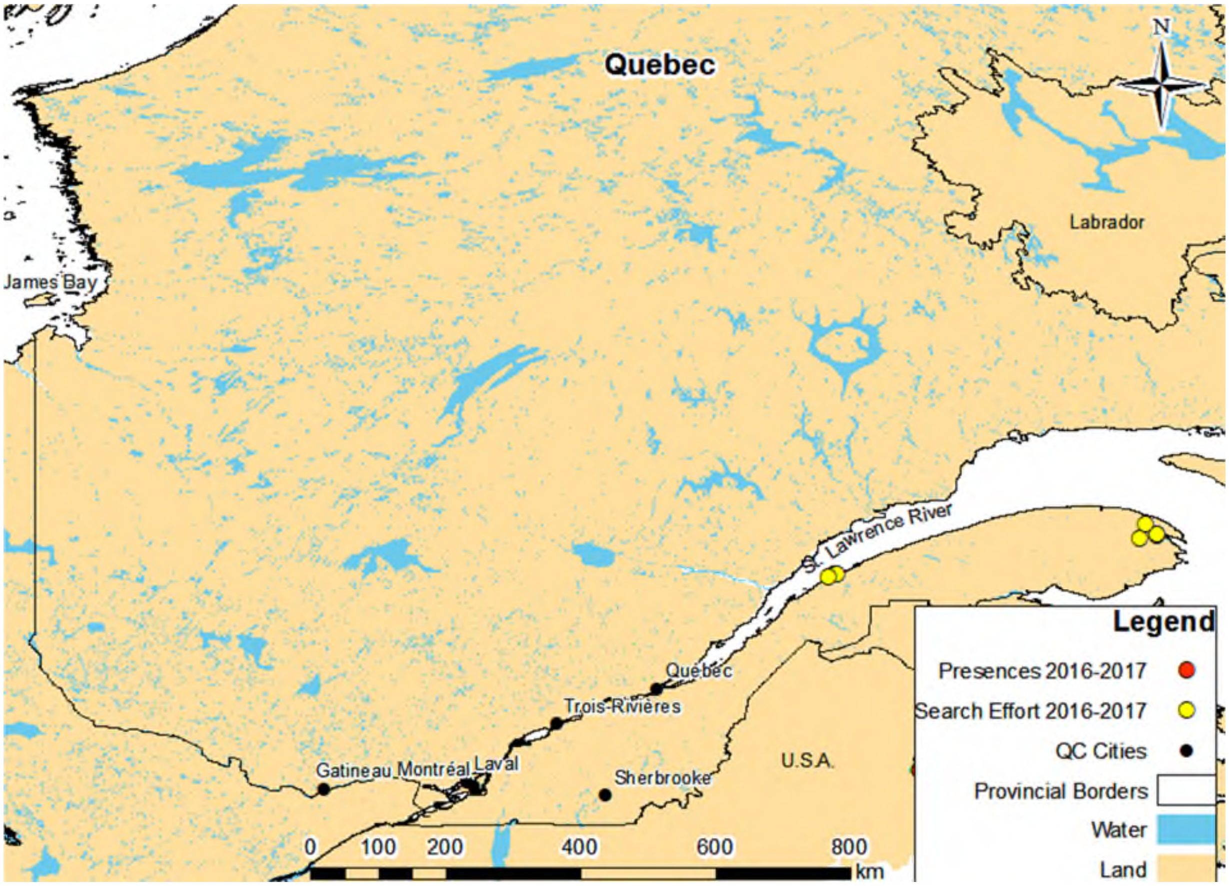

Figure 10. The yellow dots show searched sites, along the south shore of Quebec, that failed to discover *Fuscopannaria leucosticta* during the lichen surveys carried out in 2016 and 2017.

In Quebec, three collections were reported (Consortium of North American Lichen Herbaria 2017), but all are older than 65 years, and two were found to have been misidentified. There were two records in the Field Museum, Chicago. In 1943, E. Lepage purportedly collected *F. leucosticta*, along with several other lichens, on a day trip spent collecting along the Rimouski River, near the Rapide du Bois Brûlé. This specimen was recently re-examined by FA and found to have been misidentified. The second Field Museum collection was made in 1939, by Brother Marie-Anselme in the vicinity of Saint-Félicien, in Comté de Lac-St-Jean (Accession No. C1005165F). When photographs of the herbarium label and annotations were examined (Consortium of North American Lichen Herbaria 2017), it appeared to be a different species. Originally it was recorded as *Pannaria microphylla*, but in 2000 the name was revised to *Fuscopannaria leucophaea* (Vahl) P.M. Jørg. The only other record from Quebec was made in 1888 near Lac Clair, approximately 50 km north of Montréal but no collector information is listed on the packet (Harvard University 00437227). A possible duplicate collection, also made in 1888, is from the herbarium of H. Willey (Smithsonian 2878810). Again, no collector is listed for this record. Nevertheless, J. Macoun was known to have collected extensively in Canada in 1888 and may have made both collections. No detailed locality notes are available on any of these packets. Possible associated geographic data appear to have been added after the fact by museum staff, making relocation extremely difficult. Moreover, the Lac Clair area has undergone extensive agricultural and residential development since 1888, suggesting that even if the original identifications were correct, suitable habitat is no longer likely to exist. There are 1105 records of lichens in the Pannariaceae (Consortium of North American Lichen Herbaria 2017) indicating significant search effort for cyanolichens in the province.

Several collections of *F. leucosticta* have been reported from other provinces in Canada, but have proved to be misidentified. The single Newfoundland collection from Little Ridge, Trinity Bay, by A. Waghorne (University of Minnesota 017101), identified as *F. leucosticta,* has since been revised to *Pannaria rubiginosa* (by S.R. Clayden). Specimens reported to be *F. leucosticta* from British Columbia and the western United States (Figure 2), have been re-examined by I.M. Brodo and shown to belong to another species, *Fuscopannaria leucostictoides (Ohlsson) P.M Jørg.* A record from the Kananaskis area in Alberta (CANL 102211) was also recently examined by R.T. McMullin at the Canadian Museum of Nature and found to have been misidentified.

Recent searches

In New Brunswick, most of the search effort for *F. leucosticta* consisted of dedicated sampling trips and surveys of potentially suitable sites (Figure 7). Over 207 person-hours were spent in 2016-17 searching for *F. leucosticta* in New Brunswick. SH and KD surveyed former sites and nearby suitable habitat near Clark Point Protected Natural Area, Ten Mile Creek, New River Beach, and Oromocto Lake. Later in the summer of 2017, SH, SC, KD, and FA (with CV or EH - student research assistants from the NBM) spent 5 days, 10 days, 5 days, and 3 days, respectively, searching for *F. leucosticta* and other rare lichens and bryophytes in Spednic Lake Protected Natural Area for the BiotaNB program (cf. Drost 2017). SH and FA also conducted surveys when suitable habitat was encountered when hiking throughout New Brunswick and Nova Scotia. RB and SH spent 7 days surveying high probability sites throughout the northern and eastern parts of New Brunswick. In total, observers scanned an average of 463 potential host trees in sites where *F. leucosticta* was found to be present, and 256 trees in sites where the species was not detected. Once the species was found at a site, the distance walked was extended and estimated to be about (5.4 km) greater than at sites where *F. leucosticta* was not detected (1.9 km). This difference represents the early recognition of poor sites where the lichen was unlikely to be found and economized on available search time.

In Nova Scotia, from winter 2016 to summer 2018, approximately 433 hours were spent conducting extensive surveys for epiphytic cyanolichens. Between winter of 2016 and summer of 2017, 133 hours specifically targeted *F. leucosticta*. The targeted surveys were led by RC and TN in Halifax County, and by FA and TN in Digby, Shelburne, Lunenburg, and Queens counties. Surveys by CP in Queens and Shelburne counties were conducted as part of other floristic surveys over the winter of 2016-2017. All but five previous sites of *F. leucosticta* were revisited during these surveys (Figure 8).

Between March and August 2018, SH recorded the presence and abundance of *F. leucosticta* opportunistically while doing site selection and sampling for a study on the effects of clearcut edges on lichen communities in mixedwood swamps. This included approximately 120 hours (300 person-hours) of extensive surveys during the site-selection phase, 160 hours (320 person-hours) of occasional observation in suitable habitat during the site-installation phase, and an additional 100 hours (100 person-hours) of intensive surveys during the sampling phase. The extensive surveys involved SH and one or two assistants walking much of the extent of approximately 180 potentially suitable (identified as suitable using GIS queries) habitat polygons across the province, with a focus on observing stand structure, lichen community composition, and cut boundary delineation, using a wandering transect method similar to the targeted *F. leucosticta* surveys. Occasional observations during the site-installation phase consisted of infrequent glances at suitable host trees that were previously unnoticed; considerably less effort was spent looking for lichens at this time, so these hours are not included in the search effort totals. Intensive surveys included the recording of all cyanolichen species growing upon the north- and south-facing sides of 21 Red Maple trees in each of 10 study sites, at regular sampling intervals from a clearcut edge. Each tree was observed (by SH) for an average of 20 minutes, depending on the richness of the epiphyte community. Because no thalli of *F. leucosticta* were detected through intensive surveys that had not already been detected during the site-selection phase, this search effort is not included in the search effort totals.

In Ontario, SB has made extensive surveys for rare plants and lichens (Oldham and Brinker 2011; Brinker 2017; Lewis and Brinker 2017). He undertook surveys for *F. leucosticta* during fieldwork that brought him within range of suitable habitat (Figure 9). SB also made several dedicated collecting trips to areas that he or others had previously visited and seemed to be possible *F. leucosticta* habitat. He searched in the general vicinity of two sites where the historical collections had proved to be correctly identified: Emo, and Lake Superior Provincial Park. SB and others also spent 123 person-hours searching for *F. leucosticta* during other field surveys in Ontario.

In Quebec, searches for *F. leucosticta* were carried out by JG or by JG and FA, when doing general lichen surveys in botanically interesting habitats (Figure 10). Efforts were biased towards southeastern Quebec, where habitats of higher quality were presumed to exist for *F. leucosticta*, due to the similarities with northern New Brunswick where the lichen was known to occur. Approximately 22 person-hours were spent searching for the target species in Quebec.

HABITAT

Habitat Requirements

Forest and understorey composition

Suitable habitat for *F. leucosticta* can be identified through the combination of canopy and understorey species. Common canopy and understorey species throughout Canada include *Abies balsamea*, *Alnus incana* ssp. *rugosa*, *Rubus pubescens*, and *Clintonia borealis*. In Atlantic Canada, common understorey associates of *F. leucosticta* include ferns in the genus *Osmundastrum* (e.g., *O. cinnamomeum* and *O. regalis*), hollies (*Ilex verticillata* and *I. mucronata*), and ash (*Fraxinus nigra* and *F. americana*), with peat (*Sphagnum*) mosses dominating the ground cover in depressions and feathermosses (*Hylocomium splendens* or *Rhytidiadelphus triquetrus*) dominating on hummocks. In Ontario, understorey associates include *Acer spicatum*, *Cypripedium reginae, Rhamnus alnifolia, Carex vaginata, Cystopteris bulbifera*, and *Calypso bulbosa.*

Like many cyanolichens, *F. leucosticta* is restricted to rich (*sensu* Bowling and Zelazny 1992; Racey *et al.* 1996), high-moisture ecosystems, such as minerotrophic swamps and riparian forests. This was confirmed in recent modelling work showing that depth to water table and precipitation were two important predictors of its distribution in Nova Scotia after mean annual temperature and distance from the coast (Pearson *et al.* 2018).

Host trees

Fuscopannaria leucosticta grows on the bark of Red Maple trees in Nova Scotia, and on Eastern White Cedars in New Brunswick and Ontario. The reason for the difference in tree preference between Nova Scotia and other regions is not entirely understood. It may result from a need for a bark with certain moisture-holding ability and pH buffering capacity as well as a suitable microclimate. These conditions are provided by Eastern White Cedar forests that are more common in NB, and by Red Maple swamps which are more common in NS (cf. COSEWIC 2002).

Fuscopannaria leucosticta's host trees are usually medium- to large-sized, with a noticeable lean and a diameter at breast height (DBH) of 24.8 cm for Red Maple and 26.5 cm for Eastern White Cedar. Occasionally, the DBH can be less than 10 cm, but such trees are always within stands that contain large-sized trees. This suggests that stand longevity, rather than tree age or size, is important in determining habitat suitability (Boch *et al.* 2013).

In addition to displaying a preference for certain tree species, *F. leucosticta* displays a preference for heights on the tree bole. Colonies are most often found between 1.0 and 1.8 m up the tree (Figure 11). A decline in frequency was detected above this height, but it is difficult to quantify this without ladders or other access to the upper trunks. *Fuscopannaria leucosticta* was rarely found below 0.3 m, perhaps due to greater competition with bryophytes and other lichens.

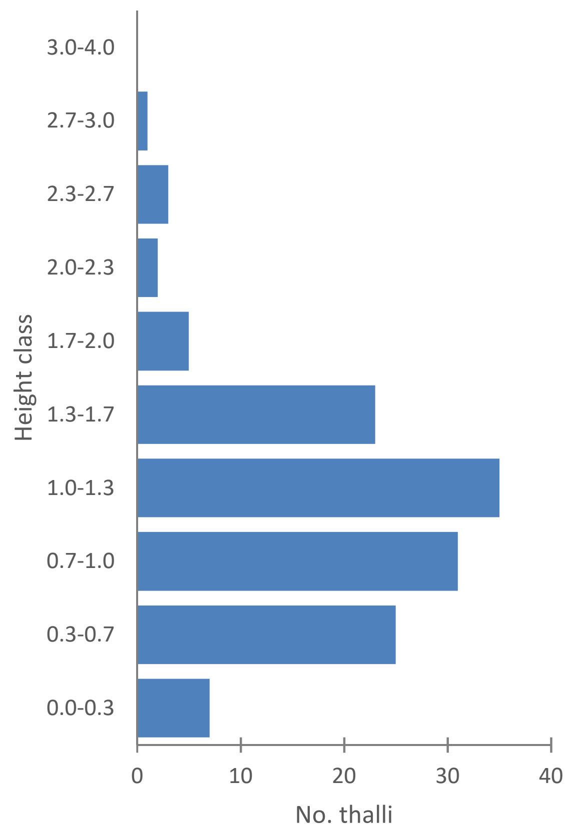

Figure 11. The frequency of sites of *Fuscopannaria leucosticta* thalli in relation to height in metres on tree boles. Data based on surveys in New Brunswick (NB) and Nova Scotia (NS) in 2016 and 2017.

Host trees (both Red Maple and Eastern White Cedar) commonly lean at angles of 20 degrees away from the vertical, with *F. leucosticta* colonies growing exclusively upon the upwards-facing side of the trunks (Figure 12a,b). This is likely because the upper sides of sloped trunks receive more precipitation and light filtering through the canopy than the lower sides. Field data also clearly indicate an aspect bias for *F. leucosticta*, with colony frequency increasing along a SW to NE gradient (Figure 12c). This aspect bias suggests an aversion to microhabitats with high heat loading and desiccation stress. Indeed, the importance of poor drainage was also corroborated by the field surveys in 2017, where sites with *F. leucosticta* tended to be flat and have standing water (Figure 13).

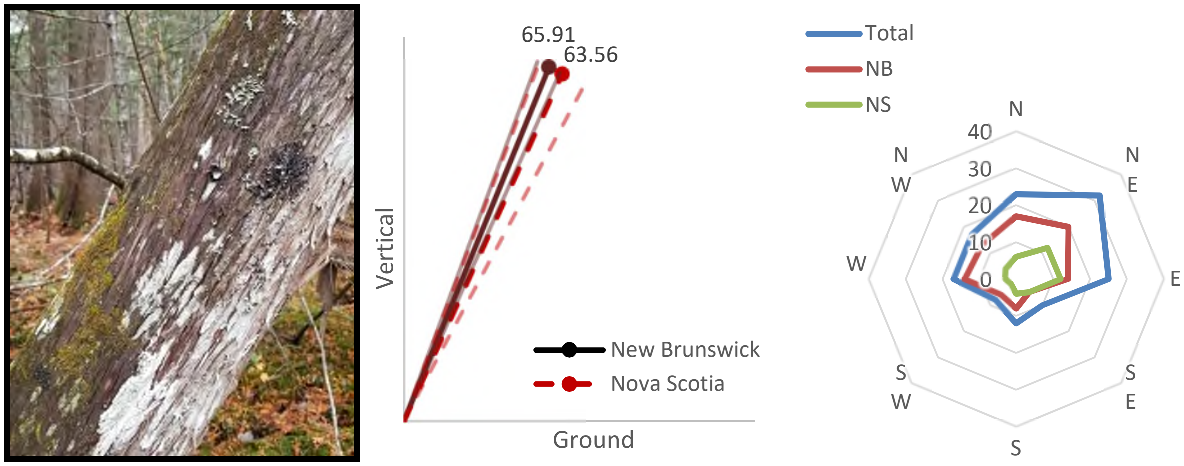

Figure 12. (a) Photograph showing a host tree of *Fuscopannaria leucosticta* that shows the typical leaning habit of its host, and (b) mean (±SE) lean angle of the host tree and (c) aspect on the tree bole, based on 2016 and 2017 surveys in New Brunswick (NB) and Nova Scotia (NS).

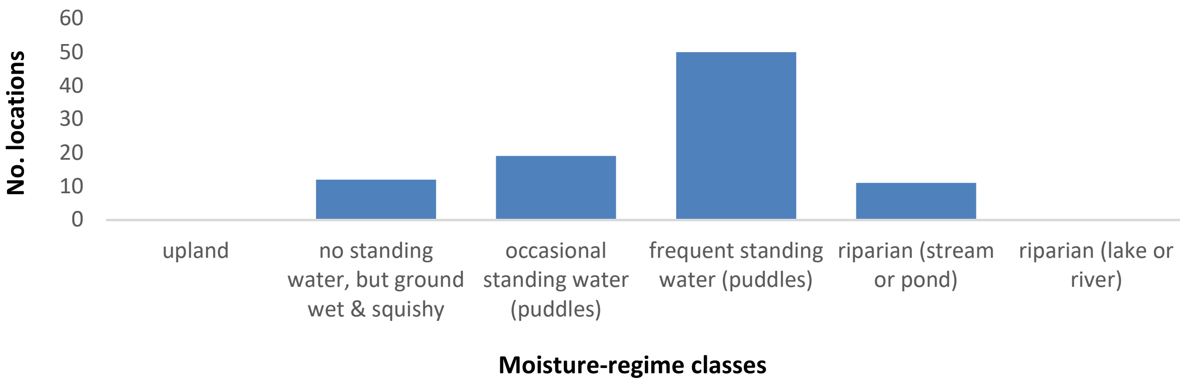

Figure 13. Frequency of moisture-regime classes from 2016 and 2017 field surveys of known and probable *Fuscopannaria leucosticta* sites in New Brunswick.

These lichens are dependent upon old, often leaning trees in old-growth forests, so the number and longevity of host trees should be considered as important as the number of individual thalli, in terms of understanding population size and trends.

Habitat Trends

Almost 50% of the total *F. leucosticta* population in Canada is found in New Brunswick. It appears to be restricted to wet, old-growth forests (*sensu* Mosseler *et al.* 2003; Stewart *et al.* 2003) or undisturbed swamp-forests, provided that they contain Eastern White Cedar. During fieldwork for this report (cf. Haughian *et al*. 2018 and earlier seach efforts), 21 of 22 (95%) of the newly detected sites in New Brunswick showed no evidence of anthropogenic disturbance, i.e., old undisturbed forests. The 22 sites included nine new sites that were discovered before field-testing of the MaxEnt model was done. The number 22 that emerged from that model (Haughian *et al*. 2018) was a coincidence and does not relate to this analysis. In contrast, 56% of the predicted suitable habitats where the lichen was NOT found showed evidence of logging having taken place, probably between 30 and 50 years ago (based on the state of decay of cut stumps that were present). Another 25% showed evidence of dramatic water level changes due to beaver activity.

In New Brunswick, a GIS-based forest inventory was created for the province from aerial photo interpretation (imagery from the 2010s), covering over 80% of the forested area (Crown lands and small private lands). These data indicate that approximately 50% of old cedar-dominated stands in the province are on Crown lands. Approximately 13% (9,748 ha) of these old cedar-dominated stands on Crown lands are in Protected Natural Areas (PNAs) where no harvest is allowed. Other areas are deer-wintering areas, riparian areas or are part of the operationally constrained land base (e.g., steep areas, wet areas). Thus, they are not available for clearcut harvest, but may be available for some level of harvest. Overall, there was about a 17% decline in the amount of old cedar-dominated forest between 1980 and 2010 (NB ERD preliminary analysis). This estimated decline may be an overestimate because some stands that were identified as Eastern White Cedar in the 1980s inventory were actually not cedar. However, some stands that were identified as not containing Eastern White Cedar occasionally do have it, so the errors may be balanced. This decline is likely to continue as forestry extends into Eastern White Cedar and Red Maple swamps, which were previously not much exploited. Indeed, recent changes in forest management strategy in New Brunswick suggest that logging of old forests is likely to continue at higher-than-historical levels (Province of New Brunswick 2014). However, in August 2018, the New Brunswick provincial government released a review of the 2014 forest strategy. One of the commitments was: “over the next five years, designate an additional 150,000 hectares of Conservation forest”. This may include additional old cedar forest. Furthermore, there is a commitment in New Brunswick to set aside more land as protected areas (Pathway to Target 1), which may lead to additional old cedar forest being protected (Province of New Brunswick 2018). Using information from the most recent forest inventory layer (NBERD preliminary analysis 2018), Sabine pers. comm. (2019) calculated that there are 7,863 old, wet cedar stands (37,078 ha). These haven’t had forest harvest activity since at least the early 1980s (beginning of the inventory). The cedar stands are across central New Brunswick, the zone that the Haughian *et al.* (2018) model indicated was more suitable for *F. leucosticta*. When considering a minimum stand size of 12.5 ha (for a circular stand with a 200 m radius), there are 430 stands totalling 8,239 ha. Thus, there may be about 15% more potential habitat for the species in New Brunswick than was estimated for the draft report which used a then available figure of 6,666 stands (“polygons”) of old unmanaged cedar, with an average stand area of 7.7 ha (range: 0.01-154.3 ha) (Clayden, pers. comm. 2019).

In Nova Scotia, there are no long-term harvest plans available to project trends in the harvesting of particular areas or types of forested habitats. Currently, information on planned harvests is only being released county by county and area by area (Bayne 2019). However, at the present time, forestry outputs are well-documented in the province. These suggest that the utilization of species that are common in old-mixedwood swamps for pulpwood and biofuel has been increasing over the last 10 years (Nova Scotia Department of Natural Resources 2017). There are recent amendments to the Province’s Special

Management Practices (SMPs) for forests on Crown land in relation to species at risk and to buffer sizes around these species. These amendments protect several species but exclude *F. leucosticta.* Counter-intuitively, the implementation of these SMPs could lead to an increase in the amount of forest harvesting in Shelburne and Queens counties (Duncan Bayne pers. comm. 2018), where *F. leucosticta* is most common and abundant; this is because the forest sector has been avoiding harvesting in these places in recent years, due to the lack of certainty surrounding SMPs for lichens. On the other hand, these SMPs may confer increased protection to species that often co-occur with *F. leucosticta* (Nova Scotia Department of Natural Resources 2018). This applies where *F. leucosticta* occurs within the bufffer for that protected species. Buffers for these associated lichen species at risk vary from 100 to 200m. *F. leucosticta* would have to occur in the same occurrence as the associated species before effective protection would be achieved. Three of 61 occurrences in Nova Scotia (Table 3) that have large numbers of *F. leucosticta* thalli (80,113, and 173) should be given protection by the presence of other species at risk (Nova Scotia Department of Environment 2018). Nova Scotia's approach to forestry was recently reviewed (Lahey 2018) and the Nova Scotia provincial government has committed to "ecological forestry" in the future. Ecological forestry places a greater emphasis on preserving ecological values over economic ones, and early implementation has already resulted in the doubling of species at risk staff and associated resources (Hurlburt pers. comm., 2019). As in the case of New Brunswick, the outlook seems brighter, but only action to curtail clear cutting will help species at risk such as *F. leucosticta.* One element under development is forest harvest environmental assessments, which should help wildlife species under threat (Nova Scotia Government 2919).

Table 3. Summary of the number of thalli as observed between late 2016 and mid-2018, or inferred from the number of colonized host trees observed in earlier years. The table includes all sites from which *Fuscopannaria leucosticta* has been recorded in Canada. Relevant protections and threats to *F. leucosticta* sites are given by province, region, and site. NB = New Brunswick, NS = Nova Scotia, ON = Ontario, and QC = Quebec; Recr. Dev. = Recreational development; Unk. = Unknown; Lk. = Lake; P. = Park; SARA = *Species At Risk Act*; molli = *Erioderma mollisimum* site; PNA = protected natural area. Sites that could not be revisited (designated as "unk." for observed thalli) were considered to have a single thallus per tree for the purposes of population estimation.

Prov.	Region/ County	Site	Thalli	Trend '07-'17	Trend '18-'28	Protection?	Threats
NB	Charlotte	Clark Point	26	Likely declining	Stable	PNA	Edge effects
NB	Charlotte	NE of Lawrence Station	7	Likely stable	Stable	Riparian buffer	Logging
NB	Kent	E of Harcourt	1	Likely declining	At risk	None	Logging
NB	Kent	Kouchibouguac	14.5	Likely stable	Stable	National Park	Edge influence possible
NB	Kent	Near Bronson Bog	12	Likely stable	At risk	None	Logging
NB	Northumberland	Blissfield (S of 108)	34	Likely declining	Declining	None	Logging - present
NB	Northumberland	Goodfellow	204	Likely stable	Stable	PNA	

Prov.	Region/ County	Site	Thalli	Trend '07-'17	Trend '18-'28	Protection?	Threats
		Brook					
NB	Northumberland	Munsons Landing (N of 108)	14	Likely stable	At risk	None	Logging - imminent
NB	Northumberland	N of Fraser-Burchill Rd	35	Likely declining	At risk	None	Logging - imminent
NB	Northumberland	NW Miramichi River	3	Likely stable	Stable	Riparian buffer	Rec. dev.
NB	Northumberland	Pineville (N of 108)	49.5	Likely stable	At risk	None	Logging
NB	Northumberland	S of Saint Margarets	55.5	Likely declining	At risk	None	Logging - imminent
NB	Northumberland	SE of Napan Bay	82.5	Likely declining	Declining	None	Edge influence, sea level rise
NB	Northumberland	SE of Peaked Mountain	44	Likely stable	At risk	None	Logging
NB	Northumberland	W of Red Pine Knoll	2	Likely stable	At risk	None	Logging - imminent, mining
NB	Restigouche	Jacquet River Gorge (Antinouri Lk Brook)	1	Likely stable	Stable	PNA	
NB	Restigouche	Jacquet River Gorge (Belledune Pond)	1	Likely stable	Stable	PNA	Edge effects (road)
NB	Restigouche	Mount Carleton P. Park	1	Likely stable	Stable	PNA	
NB	Restigouche	Upper Tetagouche Lk	1	Likely stable	Stable	None	Logging, Rec. dev.
NB	Saint John	Ten Mile Creek	0	Extirpated	N/A	Extirpated	Windthrow/logging
NB	York	Beaverbrook headwaters	5	Likely declining	Declining	None	Logging
NB	York	E Branch Longs Creek	0	Extirpated	N/A	None	Logging
NB	York	Eel River	81	Likely stable	Stable	PNA	
NB	York	Kelly's Creek 1	7	Declining	Declining	None	Logging
NB	York	Kelly's Creek 2	0	Extirpated	N/A	Extirpated	Logging
NB	York	Little Pokiok Headwaters	0	Extirpated	N/A	Extirpated	Logging
NB	York	Near Brockway Airport (H 3)	8	Unk.	Declining	None	Logging (present), edge effects
NB	York	Pokiok Settlement	1	Unk.	Declining	None	Logging, edge effects
NB	York	Spednic Lk, N Mosq. Bk.	45	Likely stable	Stable	PNA	
NB	York	Spednic Lk, S Mosq. Bk.	29	Likely stable	Stable	PNA	
NS	Digby	Hectanooga 1	0	Extirpated	N/A	Nature Reserve	Edge influence possible

Prov.	Region/ County	Site	Thalli	Trend '07-'17	Trend '18-'28	Protection?	Threats
NS	Digby	Hectanooga 2	12	Likely stable	Stable	Nature Reserve	Edge influence possible
NS	Digby	Tobeatic	Unk.	Likely stable	Stable	Wilderness Area	Edge influence possible
NS	Guysborough	Ian's Rd. SE	1	Likely declining	Declining	Temporary - research	Edge effects
NS	Halifax	Cross Lk	3	Likely stable	Stable	Nature Reserve	Edge influence possible
NS	Halifax	Kent Lk	0	Extirpated	N/A	None	
NS	Halifax	Malay Falls NW	11	Likely declining	Declining	None	Logging (present), edge effects
NS	Halifax	Shea Lk W	Unk.	Unk.	Declining	None	Logging, mining
NS	Halifax	Tangier Grand Lk	0	Extirpated	N/A	Wilderness Area	Edge influence possible
NS	Lunenberg	Ash Brook	3	Declining	Declining	None	Logging- imminent
NS	Lunenberg	Middlewood	Unk.	Likely stable	At risk	None	Logging
NS	Lunenberg	Pleasant River Lk Rd	1	Likely stable	At risk	None	Logging
NS	Lunenburg	Coade Lk SE	1	Likely stable	At risk	None	Logging
NS	Lunenburg	Mersey River	1	Likely stable	At risk	None	Logging
NS	Lunenburg	Shingle Lk (Medlee Laine)	0	Extirpated	N/A	None	
NS	Lunenburg	Upper Branch Rd	2	Likely stable	At risk	None	Logging
NS	Lunenburg	W of Raddall Park	1	Likely stable	At risk	None	Logging
NS	Queens	Beech Hill	26.4	Likely stable	At risk	None	Logging
NS	Queens	Betw. Toney & Little Bon Mature Lk	2	Likely stable	At risk	None	Logging
NS	Queens	Blue Hill Mud Lk C	27	Likely declining	Declining	None	Logging (present), edge effects
NS	Queens	Blue Hill Mud Lk E	33	Likely stable	Stable	None	Logging
NS	Queens	Blue Hill Mud Lk N	2	Likely stable	Stable	SARA - molli	Logging
NS	Queens	Blue Hill Mud Lk S	22	Likely declining	Declining	None	Logging (present), edge effects
NS	Queens	Bon Mature Lk	2	Likely stable	Stable	None	Logging
NS	Queens	Burnaby Lk SE	31	Likely declining	Declining	None	Logging (present), edge effects
NS	Queens	Crane Lk SE	5	Likely declining	Declining	None	Logging (present), edge effects
NS	Queens	E of Solnow Lk	2	Likely stable	At risk	None	Logging
NS	Queens	Little Bon Mature Lk C	26	Likely declining	Declining	None	Logging (present), edge effects
NS	Queens	Little Bon Mature Lk N	173	Likely stable	Stable	Riparian buffer	Logging, edge effects

Prov.	Region/ County	Site	Thalli	Trend '07-'17	Trend '18-'28	Protection?	Threats
NS	Queens	Little Bon Mature Lk S	113	Likely stable	Stable	SARA - molli	Logging
NS	Queens	Little Bon Mature Lk W	5	Likely declining	At risk	None	Logging
NS	Queens	McGowan Lk E Total	1	Unk.	At risk	None	Logging
NS	Queens	NE of Herring Cove Lk	2	Likely stable	At risk	None	Logging
NS	Queens	S of First Lk	5	Likely stable	At risk	None	Logging
NS	Shelburne	Blue Hill Bog (N of 103)	2.4	Likely stable	At risk	None	Logging
NS	Shelburne	Canada Hill Area	80	Likely stable	Likely stable	None	Logging
NS	Shelburne	Clyde River Rd. SW	10	Likely stable	At risk	None	Logging
NS	Shelburne	Clyde RIver Rd. W	7	Likely stable	At risk	None	Logging
NS	Shelburne	Duck Hole (HL1)	2.4	Likely stable	At risk	None	Logging
NS	Shelburne	E Sable River Rd.	2.4	Likely stable	At risk	None	Rec. dev.
NS	Shelburne	Haley Lk	14	Likely stable	At risk	None	Logging
NS	Shelburne	Harpers Lk NE	2	Unk.	At risk	None	Logging, road expansion
NS	Shelburne	Jordan River S	7	Likely stable	At risk	None	Rec. dev.
NS	Shelburne	Jordan River W	5	Likely stable	At risk	None	Rec. dev.
NS	Shelburne	Lk John Rd.	2.4	Likely stable	At risk	None	Logging, Rec. dev.
NS	Shelburne	Lower Ohio E	5	Likely stable	At risk	None	Logging, Rec. dev.
NS	Shelburne	Misery Brook	2	Likely stable	At risk	None	Edge effects
NS	Shelburne	Misery Lk	8	Likely stable	Stable	Wilderness Area	
NS	Shelburne	Sable River	1	Likely stable	At risk	None	Logging, Rec. dev.
NS	Shelburne	S of Collins Lk	2.4	Likely stable	At risk	None	Logging
NS	Shelburne	S of Wilkins Lk	2.4	Likely stable	At risk	None	Logging
NS	Shelburne	Upper Clyde River E	Unk.	Likely stable	Stable	None	Recreation/Development
NS	Shelburne	Upper Clyde River NE	5	Likely stable	Stable	None	Recreation/Development
NS	Shelburne	Upper Clyde River SE	42	Likely stable	Stable	None	Recreation/Development
NS	Shelburne	Upper Clyde River S	13	Likely stable	Stable	None	Recreation/Development
NS	Shelburne	Upper Clyde River W	2	Likely stable	Stable	None	Recreation/Development
NS	Shelburne	Upper Ohio West	2.4	Likely stable	Stable	Wilderness Area	
NS	Shelburne	Welshtown Lk N	71	Likely stable	Stable	None	Rec. dev., peat mining

Prov.	Region/ County	Site	Thalli	Trend '07-'17	Trend '18-'28	Protection?	Threats
NS	Shelburne	Wentworth Lk NW (SW of Western Beech Hill Lk)	2.4	Likely stable	Stable	Nature Reserve	
NS	Shelburne	Wentworth Lk SW	Unk.	Likely stable	Stable	Nature Reserve	
NS	Shelburne	Western Lk (betw. Western & Harpers Lk)	10	Likely stable	Declining	None	Logging, - imminent Rec. dev.
ON	Rainy River	Emo	0	Extirpated	N/A	Extirpated	Residential/Agricultural dev.
ON	Rainy River	Quetico P. Park (NE of Emerald Lk)	2	Unk.	Stable	Quetico Prov. Park	
ON	Thunder Bay	Albert Lk E	2	Unk.	At risk	Nature Reserve	Logging
ON	Thunder Bay	Albert Lk W	24	Unk.	At risk	None	Logging, Rec. dev.
ON	Thunder Bay	Dorion Cutoff Rd Cedar Swamp	13	Unk.	At risk	None	Logging, Rec. dev.
ON	Thunder Bay	Lk Superior P. Park (by Old Woman Bay)	0	Extirpated	N/A	Extirpated	
ON	Thunder Bay	Lankinen Rd. Cedar Swamp	9	Declining	Declining	Extirpated	
ON	Thunder Bay	N of Pigeon River	27	Unk.	Declining	None	Logging - imminent

In Ontario, the known sites for *F. leucosticta* all fall within the Northwest Region, specifically in the Black Spruce Forest Zone (035) and the Lakehead Forest Zone (796), but it is not yet known whether the recorded sites of *F. leucosticta* fall within stands designated for cutting. The number of old cedar forests and swamps being harvested appears to be increasing in Ontario (personal observation, SB), perhaps due to efforts of the Ontario Ministry of Natural Resources to capitalize on a species it deems to be underutilized (Buda *et al.* 2011).

BIOLOGY

Life Cycle and Reproduction

Fuscopannaria leucosticta's primary mode of reproduction is by ascospores as there are no asexual reproductive structures such as soredia or isidia. Fruit bodies (apothecia), form and asci are formed within these that each have eight spores. Once mature, the asci eject spores into the atmosphere, where they disperse passively by wind currents. It is not known how far these spores travel, or how long they survive aloft in the atmosphere, but studies of deposition in other taxa have shown that deposition drops off to near zero over a distance of several metres, and thereafter exists at a background (landscape) level (Lönnell *et al.* 2012). If ascospores land on a suitable substratum within close proximity to a photobiont (*i.e.,* a *Nostoc* sp.), lichen resynthesis begins (Honegger 2008). If the photobiont strain and mycobiont partners are sufficiently compatible, a lichen will begin to form and differentiate into a thallus. In the case of *F. leucosticta*, development of a hypothallus, which binds the lichen to the substrate, appears to precede other components of the lichen, and is also regularly seen growing through and over the top of bryophytes, suggesting a possible allelopathy.

Thalli as small as 1-2 cm^2 appear to be capable of generating apothecia, but these are typically small apothecia (~0.5 mm in diameter) and produce very few ascospores. Once thalli reach sizes of 40 cm^2 or more, a profusion of apothecia is typically observed in the middle of the colony. *Fuscopannaria leucosticta* is unusual in that spore production within each apothecium appears to be low compared to that of other foliose cyanolichens (personal observation, SH and SC). Although no quantitative data were collected, this can be easily observed by dissecting the apothecia of *F. leucosticta* and comparing spore densities with, e.g., *Protopannaria pezizoides*.

It is not currently known how long it takes *F. leucosticta* to develop from a germinating ascospore to a productive mature colony, nor is the lifespan known. Some common, rapidly growing lichens that associate with green algae like *Trebouxia,* can take as little as 5-10 years, in a temperate maritime climate, to develop a thallus with reproductive bodies on it (Eaton and Ellis 2014). Other lichens require 9-22 years in boreal rainforests (Larsson and Gauslaa 2011). On long-lived trees, epiphytic cyanolichens may live for an average of 40 years (Öckinger and Nilsson 2010). The oldest thallus of *F. leucosticta* that has been relocated in the field was 12 years old. Apothecia form on quite small thalli of *F. leucosticta*, and the generation time is estimated to be 12 years for the purpose of this report, but it may be longer than this.

Fuscopannaria leucosticta has a preference for leaning host trees (mean lean angle of 20°), so the lifespan of a particular thallus may be determined by the longevity of the host tree. Once trees develop a lean of more than 15°, the chance of stem failure increases exponentially; lean angles of 20° or more are at considerable risk of falling (Coder 2000). Such trees may be removed in managed forests for safety reasons (Coder 2000) but are not removed on Crown lands.

The cyanobacterial partner of the lichen symbiosis is a *Nostoc* sp., which can form colonies independent from lichens on soil, tree bark, and in the water-retaining capillary spaces of bryophyte colonies (Dodds *et al.* 1995; Zackrisson *et al.* 2009). Lichen-forming fungi often require particular strains of *Nostoc* and cannot develop unless they are on the bark surface, but no molecular studies have been done with *F. leucosticta* to identify the preferred strain.

Physiology and Adaptability

Lichens like *F. leucosticta*, with a cyanobacterial photobiont, have the capacity to fix atmospheric nitrogen (Nash 1996). Depending on the lichen species and other environmental constraints, such as the availability of phosphorus (Knops *et al.* 1996; Hooper and Vitousek 1998), the fixed nitrogen is largely retained in the lichen until the thallus decomposes (Nash 2008). In cyanolichens such as *F. leucosticta*, both photosynthesis and nitrogen fixation are dependent upon the availability of liquid water to activate the necessary enzymes (Antoine 2004), and to ensure energy inputs from photosynthesis (Dodds *et al.* 1995). *Fuscopannaria leucosticta*, like many other cyanolichens, does not thrive in habitats with a low availability of liquid water (Rikkinen 2015).

Because the photobiont in *F. leucosticta* is a cyanobacterium, this lichen can contribute to nitrogen nutrition of the forests it inhabits. Cyanolichens, in general, are responsible for fixing a significant proportion of the nitrogen that enters cyanolichen-rich ecosystems (Coxson and Nadkarni 1995). In forests of central B.C., for example, trees that host cyanolichens have higher levels of N from atmospheric sources than those that do not (Kobylinski and Fredeen 2015), and increased soil nitrogen has been observed under terrestrial cyanolichens (Knowles *et al.* 2006). While the contribution of *F. leucosticta* would likely be small relative to that of more abundant species, the cyanolichen community as a whole should be considered an important functional component in swamp forests of eastern Canada.

Dispersal and Migration

In lichens: (1) small propagules are dispersed more widely than large ones, and (2) large propagules have a greater chance of growing and producing adult colonies than small ones. In lichens, sexually produced propagules (i.e., ascospores in apothecia) are much smaller than asexual ones (e.g., soredia, isidia, and thallus fragments). Consequently, lichens which rely primarily upon sexual reproduction are expected to disperse widely but be relatively ineffective at colonizing new habitats locally. In contrast, those that rely primarily upon asexual reproduction (isidia or soredia) are expected to occupy most available substrata within a localized habitat but be relatively ineffective at colonizing new habitats (Hedenås and Ericson 2008; Fedrowitz *et al.* 2012). *Fuscopannaria leucosticta* produces apothecia, but no asexual reproductive structures (Jørgensen 2000) and so is hypothesized to be relatively effective in long-distance dispersal, but relatively ineffective at expansion within suitable habitats. This is supported by the low proportion of potential host trees (Eastern White Cedars) upon which *F. leucosticta* was detected during 2017 surveys in New Brunswick (mean = 2.6%, SD = 2.6%).

Fuscopannaria leucosticta appears to compete effectively with other epiphytes on the lower bole of many host trees, and is occasionally found as a sprawling vertically elongated colony covering as much as 50% of the lower bole of a host tree. One out of every 5-10 trees displayed this pattern in New Brunswick, and anecdotal evidence suggests similar frequencies in Nova Scotia. This pattern suggests that a well-developed colony can spread down and perhaps up by scales being broken off and transported very short distances by water movement (Armstrong 1987) or activity of animals (McCarthy and Healy 1978). These thallus scales, if they become re-attached to the bark, can develop into a large secondary colony which may or may not be confluent with the original. In conclusion, it seems likely that *F. leucosticta* is transported to new habitats via wind-blown sexually produced spores, and that the few spores that successfully resynthesize the lichen can form an extended colony on a tree or cluster of trees from locally distributed thallus fragments.

Given this strategy, it is surprising that *F. leucosticta* is not more common across the landscape, or more abundant within apparently suitable habitats. It also surprising that it is less common than many closely related Pannariaceae that reproduce only asexually (e.g., *Pannaria conoplea*). One explanation may be that, in addition to requiring suitable habitat and host trees, colonization of new habitats requires a specific strain of cyanobacterium for resynthesis of the lichen; it may even require a strain used by predominantly asexual cyanolichen species (e.g., *P. conoplea* or *Fuscopannaria sorediata*), or by liverworts like *Frullania* spp., which have water sacks colonized by cyanobacteria (Belinchón *et al.* 2015). Such facilitation has been hypothesized to occur between *Frullania asagrayana* and *Erioderma pedicellatum* (Cornejo and Scheidegger 2016).

Interspecific Interactions

Fuscopannaria leucosticta is often associated with several understorey species, and other epiphytic mosses, lichens, and liverworts. In an inspection of the 19 herbarium collections at the New Brunswick Museum, the three most common associates were *Frullania asagrayana* and *Radula complanata*, two common corticolous liverworts that are most frequently found on hardwoods, and *Ptilidium pulcherrimum*, a generalist corticolous liverwort. In addition, *Parmelia sulcata*, *Sanionia uncinata*, *Dicranum montanum*, and *D. viride* were each found associated with *F. leucosticta* in three herbarium collections from cedar trees. While none of these species are rare, their combination underlines the rich corticolous community of bryophytes and lichens that develops in old, wet to mesic hardwood or cedar forests.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The fieldwork goals for this report were to: (1) visit as many known sites for *F. leucosticta* as possible to verify that the species is still present, (2) visit as many likely sites (based on recommendations from local naturalists and through the use of GIS habitat data) as is possible, given time constraints, (3) obtain accurate counts of the number of thalli, host trees, and sites for the species, (4) photograph and collect voucher specimens, as appropriate, and lodge specimens at the New Brunswick Museum, and (5) to obtain sufficient ecological data to accurately describe the autoecology of *F. leucosticta*.

Surveys in 2017 consisted of timed searches within habitat that was deemed to be suitable for hosting the species. In New Brunswick and Ontario, this generally meant limiting searches to old stands of Eastern White Cedar with a high water table, or a hummock and hollow microtopography that suggested ephemeral flooding. In Nova Scotia, similar habitats were sought, albeit while looking for old Red Maple trees instead of cedar, because cedar is rare in the southern portion of the province. In addition to these trees Black Ash (*Fraxinus nigra*) was inspected in suitable habitat. Both leaning and upright trees were assessed to determine lean angle, but extra attention was paid to leaning trees during searches. During a typical search, observers would walk a wandering transect through the stand for approximately 1-2 hours, at a pace of approximately 0.5-1 km per hour, and spend 2-5 seconds scanning each cedar tree from the ground to approximately 4 m in height. When leaning trees were seen in the distance, observers walked towards them and carefully examined the upper surface.

For those sites in which scanned trees were counted, *F. leucosticta* was detected on an average of four out of every 100 trees, but prevalence varied widely among sites, ranging from 1 thallus per 285 trees (West of Red Pine Knoll) to almost one thallus per ten trees at Goodfellow Brook (Table 2). Given this knowledge, observers doing survey work in the future can be confident that they have suitably assessed a site if they have conducted visual scans of at least 300 trees per site before concluding the species is not present. Depending on the density of the vegetation, this search effort could be realized in approximately one hour by two observers, while walking over approximately 1 km.

In addition to counting thalli and trees, habitat data were collected in New Brunswick and parts of Nova Scotia. Data were recorded at three levels: habitat, substrate, and thallus. Habitat data included dominant canopy species, canopy cover, ground slope and aspect, and a qualitative description of moisture regime. Substrate data included the DBH and species of host tree, the number of colonies per tree, the height range of colonies on the tree, the lean angle of the tree, the aspect of the tree's lean, and the identity of associated epiphytic lichens or bryophytes. Thallus data included the size of the contiguous colony, the median direction the colony was facing, and the percent of the colony that was grazed or necrotic.

Because field surveys were often limited to less than a complete census for logistical reasons, and because data were incorporated opportunistically from multiple sources during the assessment process, several methods were used to improve the realism of population estimates. When complete thallus count data were not available, but tree counts or detections were, the number of colonies was estimated by multiplying the average number of thalli per tree (for a given province) by the number of host trees or detections known for that site. This method was used to estimate the number of thalli for sites visited by CP before the status assessment began, as well as the number of thalli in five sites that could not be revisited in Nova Scotia. Nevertheless, the count of the number of known thalli should be regarded as conservative, because surveys for the most densely populated sites (e.g., Goodfellow Brook Protected Natural Area) in New Brunswick and Little Bon Mature Lake in Nova Scotia) did not include all suitable habitat patches within the site.

To ensure that the primary observers for this study used similar survey and counting methods, two large sampling trips of 2-3 days were made near the beginning of the field season. These trips involved FA, RC, SC, SH, and TN, and focused on standardizing survey techniques and search images. These took place in the Shelburne area of Nova Scotia, and in the Miramichi area of New Brunswick, so those surveying for this lichen could see high-quality sites in each province.

Abundance

Based on survey data collected between 2016 and 2018, the total known population of *F. leucosticta* in Canada is 1663 mature thalli, distributed among approximately 502 host trees in 88 sites (Table 1). The largest known subpopulation is in Nova Scotia (822 thalli known from 224 trees in 57 sites), followed by New Brunswick (764 thalli on 247 trees in 26 sites), then Ontario (77 thalli on 31 trees in 5 sites). The mean number of thalli per tree was 3.1 in New Brunswick, 6.7 in Nova Scotia, and 2.5 in Ontario.

The total possible subpopulation sizes were estimated for both New Brunswick and Nova Scotia using a linear extrapolation, based on recently developed distribution models (Table 1). The projected possible subpopulation size for NB was 4,315 thalli. The projected subpopulation size for NS was 4,311 thalli (see Technical Summary and Appendices 2 & 3 for details). The data from the small subpopulation in Ontario were insufficient to employ the same estimation methods, but using an alternative method, a local expert (SB) estimates the possible subpopulation could be 639 thalli. When combined with the number of observed thalli in Nova Scotia and New Brunswick, the estimate for the total population in Canada is 9,265 individuals.

Survey efforts in Ontario were more limited than in the Atlantic Provinces. Searches by SB in 2017 did not re-locate any *F. leucosticta* individuals in Lake Superior Provincial Park in what appeared to be suitable old-growth or mature forests with little evidence of anthropogenic disturbance. This cedar-dominated forest was found along and adjacent to the trail (which is still present). After searching, it was concluded that this occurrence is no longer present. Suitable habitat may exist elsewhere in the park but could not be searched given time constraints and inaccessibility. Similarly, searches of remnant Eastern White Cedar swamps within a 50 km radius of Emo in 2017 were unsuccessful. Given the likelihood of high nitrogen pollution from extensive agricultural development around Emo, it is unlikely that *F. leucosticta* still occurs nearby. However, SB discovered six new occurrences in Ontario in 2016 and 2017 as part of a combination of routine forest land surveys and dedicated searching.

Fluctuations and Trends

Population trends are currently difficult to assess, because 2017 was the first year that data were collected on the number of thalli and number of colonized trees. The surveys in 2017 yielded new sites, but none showed evidence of past stand-replacing disturbance (*sensu* Pickett and White 1985). Thus, it seems unlikely that any of the new detections represent recent colonizations. Enough previously known sites in New Brunswick and Nova

Scotia were re-visited to identify that there are occurrences where the lichen no longer exists (Figure 14) and to extrapolate average loss rates. The same was done for Ontario for consistency with the other provinces (Table 4).

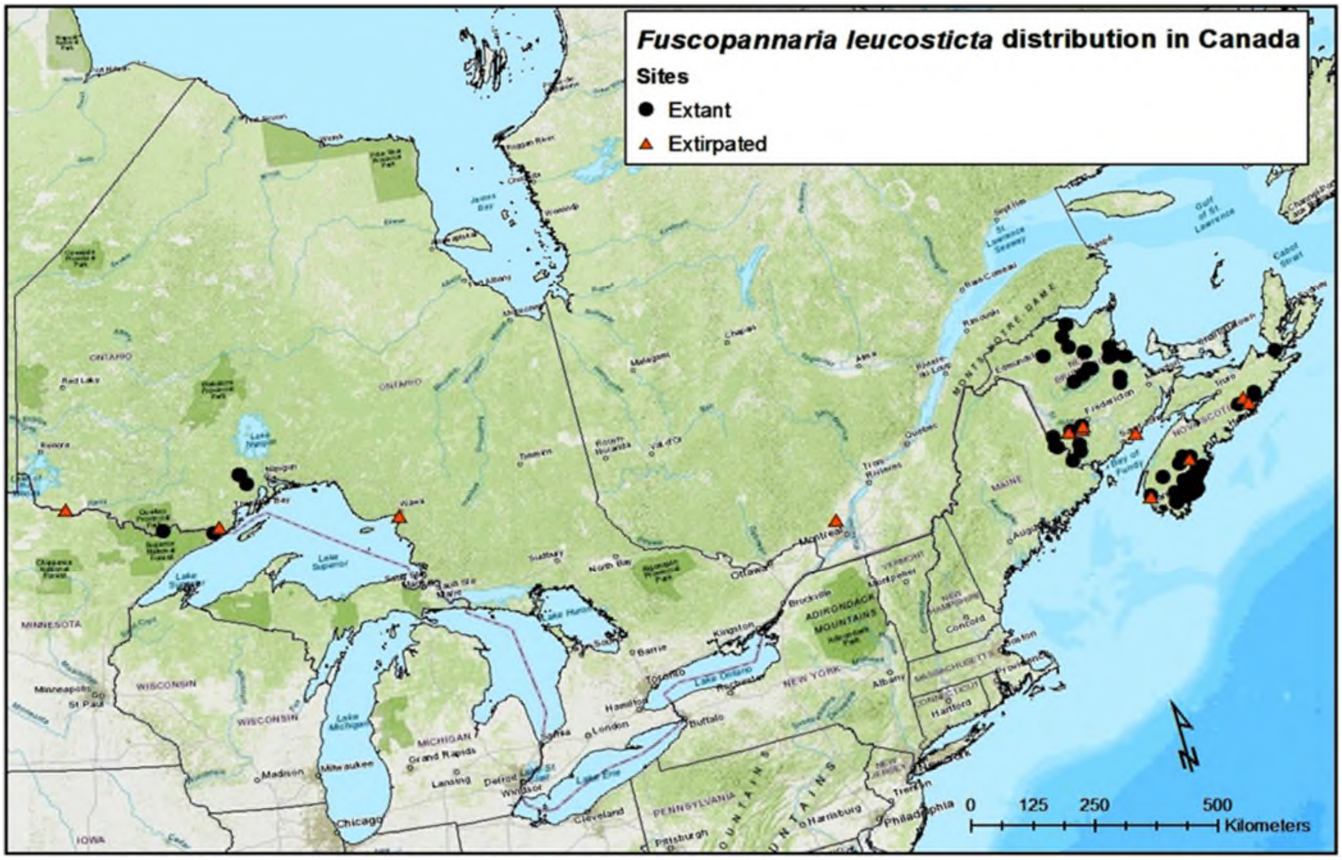

Figure 14. The distribution of *Fuscopannaria leucosticta* showing extant occurrences (black circles) and extirpated occurrences (orange triangles) in Canada. The data are derived from Table 3 and include the historical record from Quebec.

Fuscopannaria leucosticta apparently requires undisturbed old-growth forest to thrive (Haughian *et al.* 2018). From observation, it is assumed that (1) all thalli that were detected on residual trees in recently logged stands will succumb to necrosis and slough off the trees in a short time (i.e., 1-3 years), (2) thalli in stands that were expected to be logged (based on the presence of marking tape during the surveys in 2016 and 2017) will either be directly lost or will succumb to necrosis and slough off the trees shortly after logging takes place (i.e., 2-4 years), and (3) future losses will occur at approximately the same rate as past ones. Using these assumptions, losses were projected, assuming a 0.93% annual reduction in thalli for the next three generations (36 years) in all provinces, for all thalli (Table 5). The decline in the number of thalli over the last 10 years is unknown as thalli were not generally counted prior to 2017 but simply recorded as ‘present’. For this reason, the annual loss rate of thalli is inferred using the proportion of lost sites over the last 10 years, divided by ten, i.e. 0.93%.

The rates of population decline were expected to differ among provinces, and to be lower in protected than unprotected habitats. Unexpectedly, there were differences in the loss rates between protected vs unprotected habitats and between provinces. For example, the estimated annual loss rate (for sites) on unprotected lands in New Brunswick was 1.9%, and no losses were recorded in protected lands. In contrast, unprotected lands in Nova Scotia had losses of 0.41% of sites per year, whereas the loss in protected sites was 1.67%. The differences between provinces for unprotected sites likely results from variations in forest harvesting. The differences between protected sites cannot be readily explained. However, per-province annual loss rates, in protected and unprotected habitats, were used to estimate the overall (national) annual loss rate and so calculate future population sizes (Figure 15, Table 4).

If losses of old, unmanaged forests continue, combined with other sources of mortality, it is estimated that there will be losses of 0.93% per year for the Canadian population (Tables 4, 5). Over three generations (36 years), declines of 45% in mature individuals (thalli) are likely to occur in Canada (Figure 15). This decline was calculated using the methods outlined in Appendices 2 and 3.

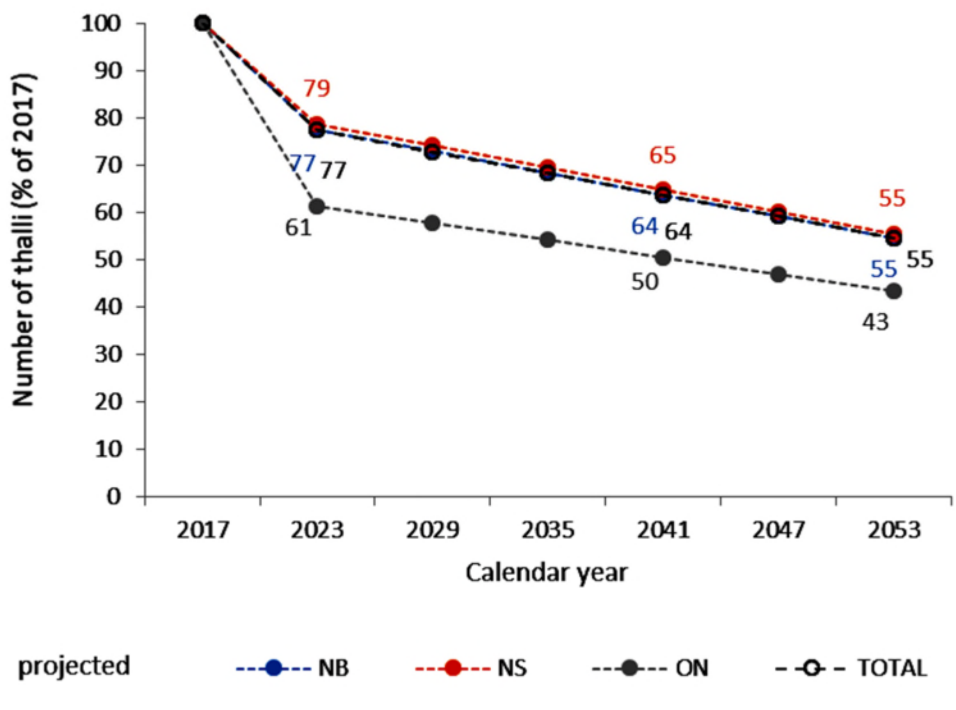

Figure 15. Projected changes in the known population of *Fuscopannaria leucosticta* in Canada by province (three dashed lines). See Tables 4-5. The numbers and projections along the dashed lines represent the proportion of thalli that are likely to remain after each time period. The data show that 55% of thalli will remain after three generations (in 2053), and that there will be a 45% reduction in the total population. See Appendices 2 and 3 for more detail of this calculation.

Table 4. Mean annual changes in the population of *Fuscopannaria leucosticta* (expressed as % of known sites), as estimated over the last 10 years, for unprotected lands, protected lands, or both (All Habitats). Note that the rate used for the projections in Tables 5 and 6, and explained in the Fluctuations and Trends section and Appendix 3, is at bottom right (in bold). This represents the mean annual change in population size for all of Canada.

	Unprotected habitats	**Protected habitats**	**All habitats**
NB	-1.90	0.00	-1.33
NS	-0.41	-1.67	-0.66
ON	-2.00	0.00	-1.67
Canada	-1.05	-0.91	**-0.93**

Table 5. The estimated changes in host trees and the number of thalli (expressed as a percent of 2017 population), over the past 10 years, and as projected for the next 2 or 3 generations (24 and 36 years) for *Fuscopannaria leucosticta* in Canada, by province. The declines are based on a continuing projected decline in host trees. This host tree decline is derived from data collected between 2007 to 2017 and calculated to be 9.3% per year (Table 4). See Figure 15 and Appendix 3 for additional details.

Generation →	**-0.83**		**0**		**2**		**3**	
Calendar year →	**2007**		**2017**		**2041**		**2053**	
Area ↓	Trees	Thalli	Trees	Thalli	Trees	Thalli	Trees	Thalli
NB	102.02	102.51	100.00	100.00	65.25	65.43	56.99	57.14
NS	106.25	100.15	100.00	100.00	68.39	66.48	59.73	58.06
ON	106.45	102.60	100.00	100.00	56.62	51.81	49.45	45.25
Canada	104.18	101.34	100.00	100.00	66.12	65.32	57.75	57.05

Figure 16. Satellite image (left; © Google 2017) and site photo (right; taken from original collection site by SRH) showing the Little Pokiok Headwaters (York Co., NB) site where *Fuscopannaria leucosticta* was detected in 2007.

Because projected population declines depend heavily upon forest harvesting rates, declines could be substantially reduced if additional habitats are protected. In particular, protecting the sites with the largest numbers of thalli (e.g., the Little Bon Mature Lake or Canada Hill sites in Nova Scotia, and Albert Lake or Pigeon River sites in Ontario) could lead to considerably greater population stability. On the other hand, the projected losses may be somewhat greater than estimated, as harvesting in lichen-rich forests has been stalled in Nova Scotia in recent years (while Special Management Practices and Status Assessments have been under development) and harvesting will likely soon increase (**see Habitat Trends**).

On Crown Lands, Special Management practices (SMP) have been introduced in Nova Scotia following ongoing monitoring for the extremely sensitive cyanolichen *Erioderma pedicellatum* (Nova Scotia Department of Natural Resources 2018). Studies have revealed that a buffer zone of 100 m is insufficient, and a Special Management Practice now involves leaving a 500 m buffer around occurrences following pre-harvest surveys on Crown land. Other listed, less sensitive lichens are protected by either a 200 m or 100 m buffer zone around occurrences (Nova Scotia Department of Natural Resources 2018), but *F. leucosticta* was not included in the list. While some protection may be afforded to this species by the presence of the other recognized rare lichens, its somewhat different habitat, and occurrence on White Cedar, means that the current Special Management Practice will not fully protect *F. leucosticta* on Crown land. Furthermore, the Special Management Practice does not apply to forestry activities on privately owned land where many occurrences for *F. leucosticta* have been documented.

Rescue Effect

This is expected to be very low as there are no nearby thalli of *F. leucosticta* growing in the USA. The nearest occurrences to the Ontario subpopulation are in Minnesota, Wisconsin, and Michigan, where the species has largely disappeared and has not been collected within the last 15 years. In addition, this lichen has not been found since 1986 in Pennsylvania. In the past, it was recorded in several New England states, but may be extirpated there, not being found since 1953 in Maine.

THREATS AND LIMITING FACTORS

The threats calculator assessment for *Fuscopannaria leucosticta* is high to medium (Appendix 1). The threats, reviewed below, were categorized following the IUCN-CMP (International Union for the Conservation of Nature – Conservation Measures Partnership) unified threats classification system. This is based on the standard lexicon for biodiversity conservation of Salafsky *et al*. (2008). Threats are presented in decreasing order of severity. The greatest threat to *F. leucosticta* is current and future logging and wood harvesting. However, there are other threats which are also likely to have an impact on *F. leucosticta*. The main potential threats for each occurrence are listed in Table 3. The various threats to *F. leucosticta* are discussed below using the Threats Calculator headings.

Logging & Wood Harvesting (Threat 5.3)

It is uncertain whether harvesting in marginal or wet forests will continue at the current rate. This seems likely given recent trends that project increased pulp and fuelwood harvest in forests that are marginally valuable for timber in three provinces. While there are protected forest areas in each province, 77% of the total known population of *F. leucosticta* in Canada occurs outside these areas and is at risk of being lost due to wood harvesting activities (Table 3).

In New Brunswick, five newly detected occurrences (representing 81 thalli) were already flagged with cutblock-boundary tape during the surveys for this status report, and one (representing 34 thalli) was recently cut. Slightly necrotic thalli were also detected on several trees in retention patches at the Blissfield Clearcuts site. This suggests that edge effects will lead to the loss of further thalli. Losses of 13% of the total known population of *F. leucosticta* in New Brunswick are likely over the next 1-2 years in the cutblocks that have been flagged (flagging usually indicates that logging will take place in 1-2 months). Even if the host trees are retained, thalli will likely only remain alive in retention strips for an uncertain period of time after logging. They will eventually succumb to negative edge influences (*sensu* Harper *et al.* 2005) that include increased heat and desiccation stress. Cyanolichens, like *F. leucosticta,* have been shown to be especially sensitive to stress due to edge effects (Gauslaa *et al.* 2019; Haughian & Harper 2018) as they require liquid water to initiate and maintain photosynthesis and nitrogen fixation. Logging has resulted in the loss of three other occurrences in New Brunswick within the last ten years (Figure 14).

In Nova Scotia, several previously recorded thalli may also have been lost because of adjacent logging activities. In addition, several newly discovered occurrences will likely soon be lost due to logging activities that felled host trees or left residual host trees isolated. This was inferred from the presence of several necrotic thalli on residual trees in four newly detected sites. For example, extensive necrosis (bleaching) was detected on residual trees in or adjacent to clearcuts at the Blue Hill Mud Lake occurrences, on the Crane Lake occurrence, and the occurrence southeast of Burnaby Lake.

In Ontario, one site (discovered in 2016) was noted to have been clearcut in 2017, and another one had considerable logging activity nearby.

Pollution (Threat 9)

Cyanolichens as a group are known to be sensitive to acidification of their habitat (Richardson and Cameron 2004; Hauck and Spribille 2005). Acidification caused by SO_2 emissions and acid rain disrupt photosynthesis (Bertuzzi and Tretiach 2013) and can cause membrane leakage (Häffner *et al.* 2001). Significant reductions in SO_2 and NO_x occurred in Canada and the United States between 1990 and 2014 (Carou *et al.* 2008; International Joint Commission 2016), leading to increased soil pH in some areas (Lawrence *et al*. 2015). However, ecosystem recovery will likely continue to lag behind regulatory changes as soils in other locations have shown only partial recovery or no recovery at all (Lawrence *et al.* 2015). Consequently, persistent acidic conditions may exceed the buffering capacity of host tree bark, making it unsuitable for colonization by cyanolichens like *F. leucosticta* (Nieboer *et al.* 1984). Thus pollution poses a persistent risk to terrestrial ecosystems (Clair and Hindar 2005; Clair *et al.* 2011).

Climate Change & Severe Weather (Threat 11)

Epiphytic cyanolichens can be negatively affected by changes in climate (Bjerke *et al.* 2003; COSEWIC 2016). Expected changes to the climate in eastern Canada over the next century include increased mean annual temperatures and a slight increase in precipitation as well as an increased frequency and severity of extreme high temperatures, heavy precipitation events, and earlier spring thaws. This could lead to earlier peak flows in watersheds (Romero-Lankao *et al.* 2014). In addition, a decline in the frequency of fog events has been detected for recent decades in Atlantic Canada (Wang 2006). Such changes could result in an increasingly negative water balance of thalli, due to increased evaporation and reduced understorey humidity, potentially leading to desiccation stress in cyanolichens (Marini *et al.* 2011).

There remains significant uncertainty with respect to the impacts of climate change on fog, rainfall, and wind in Atlantic Canada (Lemmen 2016; McClearn 2018). However, *F. leucosticta* is sensitive to the availability of liquid water. As a result, reduced frequency of rainfall or fog events, and warmer, dryer summers, as exemplified in Maritime Canada in 2018 (and to a lesser extent in summers since 2013), are likely to have a negative impact on the species. For example, the mean monthly temperature in Yarmouth, Nova Scotia, the general area of the province where *F. leucosticta* is more common, was about two degrees hotter in July and August in the years 2013-2018 compared with the period from 1961-1990. Furthermore, the rain was 20 mm less for these months between the two periods (Environment and Climate Change Canada 2018). These conditions, not only provide more stress for *F. leucosticta,* but also enhance the risk for forest fires.

An additional threat is provided by the predicted increase in the number and severity of weather events including storms and flooding. These are likely to lead to more and widespread tree blowdown events. Windthrow of host trees is also likely if the climate warms as there is less time during the year when soils are frozen. Branches may also be broken during extreme snowfall events (Saad *et al.* 2017). This could reduce the number of suitable host trees for epiphytes like *F. leucosticta*.

Invasive Non-native/Alien Species/Diseases (Threat 8.1)

Gastropod (snail and slug) grazing has been shown to play an important role in structuring epiphyte communities (Asplund and Gauslaa 2008). Expansions of non-native gastropods may negatively impact *F. leucosticta* and other epiphytic cyanolichens, particularly in Nova Scotia (Cameron 2009). During the fieldwork for this report, grazing damage (indicated by the selective removal of cortical layers, exposing the white medulla underneath) was more extensive on thalli in Nova Scotia (mean of 6.32% of each thallus) than in New Brunswick (mean of 0.68% of each thallus). Some grazing is likely sustainable and may even be beneficial for *F. leucosticta*, as it may prevent competitive exclusion in lichen communities (Boch *et al.* 2016) and facilitate the dispersal of lichen colonies via endozoochory (McCarthy and Healy 1978). Nevertheless, the extensive grazing damage detected in Nova Scotia sites may be caused by invasive *Arion* spp., which are known to damage lichen populations (Asplund and Gauslaa 2008, 2010; Cameron 2009; Moss and Hermanutz 2010). The combination of several stressors (e.g., acidification or climate change) may increase cyanolichen susceptibility to grazing damage by limiting the manufacture of anti-herbivory compounds (Baur *et al.* 1994; Lawrey *et al.* 1999). Warmer temperatures may also affect the survival or population growth of invertebrate herbivores (Bjerke *et al.* 2003).

Other Ecosystem Modifications (Threat 7.3)

Rather than allowing natural regeneration after logging, there is an increasing policy to replant with coniferous species to be harvested subsequently for pulp and wood fibre. The New Brunswick government has committed to increasing the size of wood and pulp plantations from 12 to 21% on forested Crown lands over the next 50 years (Province of New Brunswick 2014). Conversion of old cedar-dominated forests to coniferous wood and pulp plantations would make conditions unsuitable for *F. leucosticta*. Fortunately, this threat is currently limited to sites that occupy gentle slopes or upland habitats, and for this reason was not considered in the Threats Calculator Assessment. The bark characteristics (water holding capacity, morphology and pH) of Eastern White Cedar that is colonized by *F. leucosticta* are quite different from pine and spruce bark, which is not suitable for colonization by most cyanolichens. Wood-fibre and timber plantations harbour fewer cryptogamic species than old, structurally complex forests in eastern Canada (Gilliam and Roberts 1995; Ross-Davis and Frego 2002; Veinotte *et al.* 2003). Plantation canopies are also dense, which makes conditions unsuitable for lichen colonization (Porté *et al.* 2004; Carnus *et al*. 2006; Aubin *et al.* 2008; Cole *et al.* 2008; Haughian and Frego 2017).

Limiting Factors

Fuscopannaria leucosticta is found on the bark of Red Maple (*Acer rubrum*) trees in Nova Scotia, and on Eastern White Cedars (*Thuja occidentalis*) in New Brunswick and Ontario. In all three provinces, this lichen grows in mature old wet forests that have been undisturbed for more than 50 years (**see Habitat Trends**). Any combination of threats which affects the habitat requirements are likely to limit the occurrence of this lichen.

Number of Locations

Based on surveys, there are at least 1,663 thalli, distributed among 502 trees in 88 occurrences. The number of locations for the White-rimmed Shingle Lichen in Canada is assessed also as 88. This number is used because logging, fires, and alien snail infestation operate at the individual occurrence or stand level. Climate change impacts may operate at a regional level, so there could be as few as 3 locations for the 3 subpopulations, but the number is probably more than ten.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Global Status

Globally, NatureServe assigns *F. leucosticta* a status of G3G5 - Vulnerable to Secure (last reviewed 2000-12-08). The species is considered endangered in parts of Europe and may have been extirpated when acid rain deposition was at its highest intensity in the mid-to-late twentieth century (Jørgensen 1978; Jørgensen and Sipman 2007). *F. leucosticta*, one of the rarest macrolichens in Europe, was found recently in Greece. It had not been seen on this continent for over a century, when it was recorded from Italy and Slovenia (Spribille 2009).

In the United States, *F. leucosticta* is thought to have been extirpated from most of New England by the mid-20th century, persisting only in southeastern parts of the country (Hinds and Hinds 2007). Only three states have rankings for the species: North Carolina (SNR - unranked), Pennsylvania (SNR), Wisconsin (S1 - critically imperilled).

Status in Canada

Fuscopannaria leucosticta has been given a national rank of N2N3 (2015-0607) – Imperilled to Vulnerable. The species was also assigned a General Status rank of N3 (Vulnerable) by Canadian Endangered Species Conservation Council (2016).

In addition, the species has been given an S rank under the NatureServe/General Status S-ranks system generated by the provinces and territories together with the CDCs. The rank of S1S2 was assigned to this species for Ontario, by the Natural Heritage Information Centre, while the rank of S2S3 – critically imperilled to imperilled, was given for New Brunswick and Nova Scotia, by the Atlantic Canada Conservation Data Centre.

Habitat Protection or Ownership

Currently, 33% of known thalli (24% of sites) are protected by harvest limitations (Table 6). In New Brunswick, these include protected natural areas, riparian buffer strips, and provincial and national parks. Approximately 13% (9,748 ha) of old cedar-dominated stands on New Brunswick Crown lands are in Protected Natural Areas where there is no harvest allowed, although 35% of the areas surveyed for *F. leucosticta* were protected lands. In Nova Scotia, approximately 17.5% of the sites with *F. leucosticta* were protected lands, including nature and wilderness reserves, riparian buffers, provincial parks, and set-aside stands which contain a SARA-designated ‘At risk’ species. In Ontario, protections for *F. leucosticta* include only a single provincial park and a nature reserve, but these represent 33% of sites.

Table 6. The number of host trees and thalli, and the percentage of populations of *F. leucosticta* that are currently within protected habitats. See Habitat Protection and Ownership for more information on protected areas.

Area	Trees		Thalli	
	Number	**%**	**Number**	**%**
NB	123	49.8	403	52.7
NS	36	16.1	145	17.6
ON	2	6.5	4	5.2
Canada	160	31.9	549	33.0

Protected areas confer either partial or full protection, depending in part on the proximity of the protected area boundaries; for example, the best habitat for *F. leucosticta* within Kouchibouguac National Park is along a small section of the southwestern park border. Colonies occur on both sides of this border and even the colonies in the National Park could be affected by altered microclimatic conditions (edge effects) if cutting happened outside this boundary.

While it is not yet known how far clearcuts must be from *F. leucosticta* thalli to ensure survival, it is likely complicated by the landscape context. For example, if clearcut logging and the accompanying road construction results in a drop of the water table, the negative edge influence will likely extend much farther into the wet forest or swamp than it otherwise would. The impacts of adjacent logging may also be more severe in marginal habitat; sites that only support small numbers of thalli may be less optimal ecologically, and therefore would require smaller changes to become unsuitable. For example, one former site in New Brunswick (Ten Mile Creek) was known to have had a single, small thallus, which was lost after a windthrow event, followed by a limited amount of selective cutting. Richer, or more extensive, sites might survive such small-scale disturbances. Removing sites with many host trees and thalli from the harvestable landbase would likely be an effective strategy to reduce losses from logging and unexpected losses from stochastic natural disturbances.

In July 2018, NBERD provided habitat protection (harvest eligibility) information for a number of sites (194 individual points) for species in cedar swamps in SW and NE New Brunswick. Of these sites, 76% (147/194) were on provincial Crown land. Of those, 107/147 (73%) of the points occurred in those parts of the Crown forest where no harvesting can occur. The remaining 39 points (27%) were in forest that is eligible for clearcut harvest (20/147) or partial harvest only (19/147), but they may not be harvested (Sabine, pers. comm. 2019).

Some protection from potential damage caused by recreational development, such as building and using ATV or truck trails, could be achieved through a combination of public education / signage, with restrictions for motorized vehicles in wet habitats, and trail-buffer requirements.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

Acknowledgements

Much of the fieldwork in New Brunswick was supported by a grant from the New Brunswick Wildlife Trust Fund, and both the New Brunswick and Nova Scotia governments contributed significantly (cash and in kind) to the project. The Ontario Ministry of Natural Resources and Forestry provided in-kind support for the Ontario component of the project.

The report writers wish to thank the following individuals for their efforts in collecting or sharing data and verifying records: Chris Pepper, Cole Vail, Dwayne Sabine, Eleni Hines, Frances Anderson, Jean Gagnon, Kendra Driscoll, Richard Blacquiere, Robert Cameron, Samuel Brinker, Stephen Clayden, Steven Selva, Tom Neily, and Chad Simmons. Samuel Brinker (National Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry) and Tom Neily provided extensive assistance in Ontario and Nova Scotia, respectively; Jean Gagnon conducted surveys in southeastern Quebec; Kendra Driscoll, Dwayne Sabine, Cole Vail, and Eleni Hines assisted with data collection in New Brunswick; Kara Pearson shared a pre-publication draft of her habitat modelling study for Nova Scotia. Finally, Dr. R. Troy McMullin (Canadian Museum of Nature) inspected several old specimens and searched for additional records in North American herbaria.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Sean Haughian, PhD, has studied cryptogam ecology and biogeography for over a decade in Canada. His graduate studies focused on the intersection of cryptogam substratum ecology and disturbance in forest ecosystems (Haughian 2010, 2017), giving him experience in physiological ecology and habitat modelling for climate-sensitive species. He is a graduate of the University of Alberta (BSc, 2005), University of Northern BC (MSc, 2011), and the University of New Brunswick (PhD, defended on November 9th, 2016). He has also worked with Ducks Unlimited (2002-03), the Alberta Biodiversity Monitoring Initiative (2004-'05), Wildlife Infometrics Inc. (2008), and the Atlantic Conservation Data Centre (2015). Sean has authored peer-refereed articles, given many public and academic presentations, and taught botany, ecology, and other biology courses at the University of New Brunswick (UNB). He is currently a Research Associate with the New Brunswick Museum (NBM) and a Mitacs Elevate Postdoctoral Fellow at Saint Mary's University.

Stephen R. Clayden, PhD, has studied lichen ecology, systematics, and biogeography in Atlantic Canada (and elsewhere) for over 30 years, and has authored a number of works on rare or endangered lichens (Goward *et al.* 1998, Cameron *et al.* 2011). As curator of the NBM herbarium, Stephen initiated a collection of lichens that has grown to include more than 35,000 specimens, has overseen digitization of the data from these collections, and has enabled public access to these data via the Consortium of North American Lichen

Herbaria. Stephen was responsible for discovering seven of the first eight sites of *F. leucosticta* in New Brunswick. He is a graduate of Mount Allison University (BSc, 1978), the Université de Montréal (MSc 1982), and the University of London, UK (PhD, 2004). Since 1987, he has been Research Curator of Botany and Mycology at the NBM in Saint John, has authored over three dozen refereed articles and has given numerous public and academic presentations. Stephen teaches lichen identification and ecology at the Humboldt Field Research Institute (HFRI; Maine, USA), and is an Adjunct Professor at UNB. He is also a member of the Scientific Advisory Committee on Protected Natural Areas in New Brunswick, and has contributed to conservation organizations such as COSEWIC, the NB Wildlife Council, and the Nature Trust of NB.

Robert Cameron, MSc, has studied environmental planning, and the conservation and biogeography of lichens for over 20 years in Nova Scotia, and has authored many publications on them. He has developed several predictive species distribution models for rare lichens in Atlantic Canada (Cameron *et al*. 2011). Robert is a graduate of UNB (BSc, 1987), and Acadia University (MSc, 1998). Since 2002, he has been an ecologist with the Nova Scotia Department of Environment in Halifax, NS. Robert has worked extensively in both the public and private sector, including the New Brunswick Department of Natural Resources (1987), Cameron Forestry Consulting (‘92-‘00), and the B.C. Ministry of Forests (’00-02), among others. He has authored more than 30 peer-reviewed articles, has given many guest lectures and academic presentations, and taught at several post-secondary institutions, including Dalhousie University, where he is currently an Adjunct. Robert has contributed to advisory bodies such as COSEWIC and the Nova Scotia Lichen Recovery Team.

Frances Anderson, MLS, has studied lichens for over 12 years in northeastern North America, and is an authority on their biogeography and identification. She has contributed to several COSEWIC status reports for lichens, and two extensive works on their identification and biogeography (Anderson 2014, McMullin and Anderson 2015). Frances is a graduate of Boston University (BA, 1969), and Dalhousie (MLS, 1979). Frances was a Research Associate at the Nova Scotia Museum from 2006-2014 and has taught and consulted as an independent with numerous academic, governmental, and private organizations in eastern Canada. Her lichenological training includes many short-courses on lichen identification and ecology from the HFRI.

Samuel R. Brinker, BES, is a provincial botanist with the Natural Heritage Information Centre in the Science and Research Branch of the Ontario Ministry of Natural Resources and Forestry (MNRF). For the last 10 years in this role he has conducted province-wide or regional assessments of vascular plants and lichens, with particular emphasis on documenting the distribution and abundance of rare, threatened and endangered species. He also assists provincial and federal partners with various monitoring and focused inventories, such as vegetation mapping with Parks Canada in Aulavik and Torngat Mountains National Parks. He has previously written COSEWIC status reports on 4 vascular plants and 2 lichens. Prior to this, Sam held a number of positions with the MNRF after spending several years as a consulting botanist. Sam received a Bachelor of Environmental Studies (BES) from the University of Waterloo.

COLLECTIONS EXAMINED

All the known collections of *Fuscopannaria leucosticta* from Canada that could be located by herbarium staff at the holding institutions were examined. Accession numbers are provided in our field summary report (Appendix 4) along with recent observation data.

Appendix 1: Threats Calculator for *Fuscopannaria leucosticta.*

Species or Ecosystem Scientific Name	*Fuscopannaria leucosticta* White-rimmed Shingle Lichen			
Date:	27/02/2018			
Assessor(s):	David Richardson (Co-chair), Dwayne Lepitzki (moderator), Sean Haughian (report writer), Frances Anderson (report writer), Samuel Brinker (report writer), Robert Cameron (report writer), Stephen Clayden (report writer), Julie McKnight, Mary Sabine (NB)			
References:	draft calculator (8 Nov 2017) provided accompanying draft Status Report			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	0	0
	C	Medium	2	0
	D	Low	4	6
Calculated Overall Threat Impact:			High	Medium
Assigned Overall Threat Impact:			**BC = High - Medium**	
Impact Adjustment Reasons:			approximately 49% of known colonies are not protected by natural areas or parks, and may therefore be subjected to wood-harvesting activities.	
Overall Threat Comments			See comments under logging & wood harvest. generation time 5-22 years; 3 gens = 15 - 66 years	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development		Negligible	Negligible (<1%)	Extreme (71-100%)	High - Moderate	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Extreme (71-100%)	High - Moderate	Cottage or residential housing development likely to occur in the next three generations and reduce or remove the amount of suitable habitat where the species is found.
1.2	Commercial & industrial areas						Unlikely to be any commercial developments in areas where the lichen has been found
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Protected recreation and natural areas benefit this species. However, trail construction may remove trees and hence cause loss of the lichen.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling						
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	High (Continuing)	Land-claim tags (related to mineral resources) were found at 2 locations where the species was present or predicted to be present in New Brunswick. There was also one location in Nova Scotia which could not be relocated due to mining road development. An eastern shore gold mine, a former site for this lichen, is being developed and will likely have an impact on the occurrence there.
3.3	Renewable energy						
4	Transportation & service corridors	D	Low	Small (1-10%)	Extreme - Moderate (11-100%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Extreme - Moderate (11-100%)	High (Continuing)	The twinning of the 103 main road to Yarmouth NS will likely cause the loss of the Misery Lake area lichen occurrences. New logging roads elsewhere will likely have a lesser effect.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	CD	Medium - Low	Restricted (11-30%)	Extreme - Moderate (11-100%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.2	Gathering terrestrial plants		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Collection of lichens for scientific studies and part of general lichen surveys will likely have a minor impact on populations of the lichen
5.3	Logging & wood harvesting	CD	Medium - Low	Restricted (11-30%)	Extreme - Moderate (11-100%)	High (Continuing)	Logging is expected to lead to a reduction of 25% of the known colonies over the next ten years; it is uncertain whether this trend will continue, but further loss of the population seems likely given recent trends of increased harvest of forests that were formerly deemed unmerchantable. Up to a 45% loss of the total population of this species could occur when both protected and unprotected lands are considered. The fact that this lichen grows in NB on White Cedar, a slow growing tree, means that recolonization of regenerating sites is likely to be very slow.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance						
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities						
7	Natural system modifications	D	Low	Small (1-10%)	Extreme (71-100%)	Moderate - Low	
7.1	Fire & fire suppression						
7.2	Dams & water management/use						Changes to water use for energy (e.g., dams and reservoirs) particularly the Mactaquac Reservoir in New Brunswick, could change the amount of available habitat for the species. However, it now seems that the dam will not be replaced for the next 30 years.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
7.3	Other ecosystem modifications	D	Low	Small (1-10%)	Extreme (71-100%)	Moderate - Low	Conversion of forests to fibre plantations post-clear cutting is a possible threat, given recent commitments by provincial authorities to increase the extent of plantation forests in New Brunswick. However this will probably be on dryer sites. In Nova Scotia, spraying after clear cutting to prevent deciduous tree re-growth which converts the deciduous forest into coniferous forest, upon which the lichen cannot grow, is ongoing. In addition the Emerald a Ash Borer could affect a small number of lichen thalli which grow very occasionally on ash trees in N.B.
8	Invasive & other problematic species & genes	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Invasive slugs; impacts appear to be primarily limited to the Nova Scotia subpopulation.
8.2	Problematic native species/diseases						
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						Spills from road, especially highways could have an effect on host trees.
9.3	Agricultural & forestry effluents						Herbicides used in forests may affect the lichen but direct effects on this lichen are unknown.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.4	Garbage & solid waste						
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Acid rain has likely had an impact on this species in the past and may overcome the buffering capacity of the host bark, making it unsuitable for colonization by the lichen in the future. In addition nitrogen oxides from vehicles may have a harmful effect over the next three generations. Salt and road dust may also be harmful.
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
11.1	Habitat shifting & alteration						Cedar is not expected to move north in NB as a result of climate change but could move in Quebec, but only outside current timeframe. Currently, thalli growing in protected habitats are small and centered around contiguous stands of host trees; as the climate warms, the suitability of these stands for the host tree species may change, altering the suitability of the habitat for the target species.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	This lichen species is sensitive to the availability of liquid water. Reduced frequency of rainfall events, or increased frequency of extended droughts, is likely to have a negative impact on the species. Current climate projections suggest total precipitation will increase slightly in the Atlantic provinces, but that extreme weather events are also likely to increase.
11.3	Temperature extremes		Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	This species has a disjunct distribution that includes tropical regions, and likely has considerable tolerance for high temperatures, provided that sufficient liquid water is available for photosynthesis. Colder winters could result in increased windfall. Longer warmer summers could stress the lichen.
11.4	Storms & flooding	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	As they relate to the increased frequency of tree blowdown events, the increased frequency of storms and flooding could be problematic for the species. Blowdown and breakage of host trees may increase under a warming climate, due to less time with frozen soils and an increase in extreme snowfall events.
11.5	Other impacts						A reduction in fog frequency could affect this cyanolichen which needs fog droplets or rain (liquid water) unlike green algal lichens that can photosynthesize in humid air. Grazing of slugs may increase as a result of warmer winters.
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							

Appendix 2: Method for Estimating Population Sizes in Each Province.

In this model, potentially suitable habitat was isolated from forest inventory GIS layers polygons by selecting specific characteristics that were chosen differently for NS and NB and a separate approach was used for Ontario.

$$Population\ size = \left[\sum(ENT \times PO)\right] \times OR$$

The population size is the sum of the estimated number of thalli (ENT) x the probability of occurrence (PO) for each polygon within a province, which is then multiplied by an occupancy ratio from field data (Inputs and methods below).
Polygons:

1. NB and NS Polygons for kriging were selected based on
   a. old and unmanaged forests,
   b. forests with Eastern White Cedar in NB, and Red Maple in NS.
2. cddNS polygons were selected based on the additional characteristics of wet, with water table depth of 0-2m, and within 25m of a forested wetland.
3. For NB, there were 6666 polygons with an average size of 78 ± 108 ha.
4. For NS, there were 62,602 polygons with an average size of 56 ± 62 ha.

ENT:

The number of thalli surveyed in observed 50 X 50m cells provides the input for kriging. In general, a 50 x 50 m cell is equivalent to a sampling site.

The ENT is estimated in two steps:
1. The kriging method estimates the number of thalli per 50 x 50 m cell.
2. The ENT (Expected Number of Thalli) for each polygon is the average number of thalli / cell.

PO:

Probability of Occurrence varies from 0 to 1.

The PO assigned to a given polygon was the average PO from all the cells in that polygon.

PO is based on an evaluation of the habitat's ability to support the lichen using:
For NS:
1. Depth to water table
2. Distance to the coast

3. Mean annual temperature
4. Mean annual precipitation

For NB:

1. Absence of disturbance
2. Cedar in the canopy
3. Mean annual rainfall
4. Degree days

ENT x PO:

Estimates the number of thalli that are expected to occur, under ideal conditions, in each NB and NS polygon (suitable habitat patch), based on sampling and the PO covariates.

OR:

OR is the occupancy ratio of promising sites from recent survey efforts in NB and NS. It is a correction required because F.l. does not occupy all suitable habitat patches. The occupancy ratio (OR) of promising sites from recent survey efforts in each province (13/22 for NB, and 37/159 for Nova Scotia).

Because the inclusion of fractions of thalli in the projection seemed unrealistic, only polygons for which *(ENT × PO) >1* were used to calculate the total population size. To provide a range of population sizes that accurately reflected the uncertainty, based on the variability in site data, the standard deviation in PO and ENT were quantified for each polygon, and additional estimates were made using the mean PO and ENT plus or minus 1 SD.

This function was tested on a subset of the data from New Brunswick that included observed and predicted abundances for occurrences with ground-truthed abundance (N=199). The fit was poor ($R^2 = 0.14$), due to high variability in the abundance data, but the relationship was significant ($t = 7.58$, $P < 0.001$).

Using the method outlined above, it was estimated that the estimated approximate size of the population in New Brunswick was 4,315 (+/-1SD =2,474 – 6,206) and for Nova Scotia 4,311 (+/-1SD = 3,196 – 5,599).

For Ontario, the numbers were calculated by considering the three forest management units (FMU).

Lakehead Forest FMUs (Forest Management Units)

- 762,170 ha total size
- Area of old-growth cedar swamp (>120 years old) in FMU: ~1911 ha (or 0.2% of total FMU)
- Area of old-growth cedar swamp within protected areas not accessible to logging activities: ~454 ha (~23%)
- Total number of thalli counted in FMU: 36
- Number of potential thalli (upper limit) assuming every old-growth cedar swamp polygon identified is occupied: 764 (at 0.4 thalli per ha out of the 1911 ha total)
- If we assume that 25% of the polygons are occupied: 191 thalli
- If we assume that 10% of the polygons are occupied: 76 thalli

Black Spruce Forest FMU

- 1.3 million ha total size
- Area of old-growth cedar swamp (>120 years old) in FMU: ~1781 ha
- Area of old-growth cedar swamp in protected areas not accessible to logging activities: ~70 ha (~4%)
- Total number of thalli counted in FMU: 39
- Number of potential thalli (upper limit) assuming every old-growth cedar swamp polygon identified is occupied: 712 (at 0.4 thalli per ha out of the 1781 ha total)
- If we assume that 25% of all the polygons are occupied: 445 thalli
- If we assume that 10% of all the polygons are occupied: 71 thalli

Quetico Provincial Park

- 476,000 ha total size
- Area of old-growth cedar swamp (>120 years old) in FMU: ~31 ha
- Area of old-growth cedar swamp in protected areas not accessible to logging activities: ~31 ha (100%)
- Total number of thalli counted in FMU: 2

- Number of potential thalli (upper limit) assuming every old-growth cedar swamp polygon identified is occupied: 12 (at 0.4 thalli per ha out of the 31 ha total)
- If we assume that 25% of all the polygons are occupied: 3 thalli
- If we assume that 10% of the all the polygons are occupied: 1 thallus

<u>Assumptions Made:</u>

- *Fuscopannaria leucosticta* occurs at roughly 0.4 thalli per hectare in Ontario where it has been found
- Old-growth cedar swamp identified in the analysis = treed stands with >70% cedar in the canopy, are >120 years of age, and are typed as wet (organic soil or saturated mineral soil that is circumneutral). Therefore this total excludes all upland cedar stands and those not likely to be classed as wetlands.
- The Forest Resource Inventory data used was accurate (which we know is not necessarily/always the case).

The amount of the amount of old-growth cedar swamp was identified in the 3 occupied FMUs (~3,723 ha out of ~2.5 million ha).

For this subpopulation, assuming ~0.4 thalli per hectare, the upper limit of the population would be 1,488 thalli. This assumes that every single identified old-growth cedar swamp polygon was occupied in all three 3 FMUs. This is most unlikely and a more realistic assumption based on observations elsewhere is that that 25% of these polygons are colonized at 0.4 thalli per hectare which results in a total estimated population of 639 thalli for Ontario.

Appendix 3: Method for Estimating Future Population Sizes and Declines.

The following model was used to project the number of thalli at all sampled sites over three generations by 6-year intervals.

Population decline Model

$$P_{n,t} = \sum_{i=1}^{n} \left[P_{i,2017} - I_i - 0.0093(t - 2017)(P_{i,2017}) \right]$$

Definitions:

$P_{n,t}$ the number of thalli projected to occur at all sampled sites in year t. These projected numbers of thalli are used to estimate the future population decline in mature individuals

$P_{i,2017}$ = number of thalli at each site in 2017.

I_i = number of thalli expected to be lost from sites that have been recently disturbed or that are expected to be disturbed.

Information on these sites is provided in Table 3. Under the column "Trend (next 3 generations), include:

1. Sites where logging is expected, and all thalli will be lost within 2 -6-year time frame
2. Thalli on residual trees in recently logged stands will die within 1 – 3 years

For example, if:

$P_{i,2017}$ = 20 and the site satisfies either 1 or 2 above I_i = 20, and $P_{i,2017} - I_i = 0$.

The percentage of sites lost between 2007 and 2017 across Canada is 9.3%.and is used as a proxy for decline.

Assumptions: Decline rate for each site:

1. Future losses will occur at the same rate as 2007 to 2017 losses
2. Losses were estimated assuming a 0.93% (9.3%/10) annual reduction in thalli for the next three generations (36 years) in all provinces

The decline after 6 years (0.5 generation) as a result of initial losses is 21%. Once these initial losses are accounted for, the decline over the next 2.5 generations is 30%. Thus, the model above projects a reduction in the number of mature individuals over three generations of 45% (Figure 15).

A consequence of the $0.0093(P_{i,2017})$ model term is that the number of thalli projected to be lost each year is constant and the decline will be a straight line over time. Hence, even if $l_i = 0$ at all sites, the decline over three generations will be 33% and the decline over the last 2.5 generations at each site will be 30% regardless of the value of $P_{i,2017}$.

The $0.0093(P_{i,2017})$ model term differs from the compound interest model that is normally used by COSEWIC when estimating population declines. Back-calculating the 9.3% decline, from 2007 to 2017, to a compound interest rate provides an annual decline rate estimate of 0.0097. The three-generation decline estimates will differ between these two methods. For example, even if $l_i = 0$ at all sites, the decline, using this compound interest rate, is slightly curvilinear and 30% over three generations. In this case, because the annual rate is relatively low, the selection of a constant instead of a compound interest decline rate does not affect conclusions regarding designation status. In addition, the minimum population decline over three generations, ignoring initial losses, $l_i = 0$ at all sites, is 30%. However, because of initial losses, a decline over three generations >30% is well supported.

Note that based on field evidence (e.g., nearby clearcuts, new logging roads, or presence of cut-boundary tape), sites were classified as “likely stable”, “likely declining”, “declining”, or “extirpated” for the last 10 years (Table 3). Additional columns indicate whether the site was protected or not (“Habitat protection?”) and what the likely trend would be in the future, based on the combination of recent disturbance on or adjacent to the site (=declining), the existence of habitat protection (stable), or the absence of habitat protection, but with no obvious active threats in the vicinity (at risk). A single rate of change was applied to all sites, trees, and thalli, regardless of their protection status, after the ‘inferred’ losses were accounted for. This was considered to be reasonable primarily based on simplicity and statistical considerations

Based on the number of lost sites between 2007 and 2017 (9 sites = 9.3%), the annual loss rate was estimated to be 0.93% for the entire population. This annual loss rate was multiplied by the number of years passed for each time column and subtracted from the observed number of sites (as a proportion of a single whole), trees, or thalli in 2017 for each site. The sum of the remaining sites, trees, and thalli were then calculated for each province, and for the Canadian population as a whole to generate the numbers used in the Technical Summary of this report.

Appendix 4: Field Summary Data.

Table 7: Summary of *Fuscopannaria leucosticta* observations, by year, province, county, and locality; Provinces shown as NB = New Brunswick, NS = Nova Scotia, ON = Ontario, QC = Quebec; Observers shown by initials are CP = Chris Pepper, CV = Cole Vail, DS = Dwayne Sabine, EH = Eleni Hines, FA = Frances Anderson, KD = Kendra Driscoll, RB = Richard Blacquiere, RC = Robert Cameron, SB = Samuel Brinker, SC = Stephen Clayden, SH = Sean Haughian, SS = Steven Selva, TN = Tom Neily; accession number provided for specimens that have been catalogued; 2017 and 2018 collections have accessioning pending for at least 1 specimen per locality at the NBM. (*Editorial note: Lat/Lon coordinates have been removed to remove precise location information. Please contact the COSEWIC Secretariat if you require this information.)

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	Clark Point PNA	2006	SC			FL-09932
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	Clark Point PNA	2017	SH,KD			
NB	Charlotte	NE of Lawrence Station	2017	SH,KD			
NB	Charlotte	NE of Lawrence Station	2017	SH,KD			
NB	Charlotte	NE of Lawrence Station	2017	SH,KD			
NB	Kent	E of Harcourt	2017	SH,RB			
NB	Kent	Kouchibouguac National Park	2017	SH,RC			
NB	Kent	Kouchibouguac National Park	2017	SH,FA			
NB	Kent	Kouchibouguac National Park	2017	SH,SC			
NB	Kent	Near Bronson Bog	2017	SH,RB			
NB	Kent	Near Bronson Bog	2017	SH,RB			
NB	Kent	Near Bronson Bog	2017	SH,RB			
NB	Northumberland	Blissfield (S of 108)	2017	SH,RB			
NB	Northumberland	Blissfield (S of 108)	2017	SH,RB			
NB	Northumberland	Blissfield (S of 108)	2017	SH,RB			
NB	Northumberland	Blissfield (S of 108)	2017	SH,RB			
NB	Northumberland	Blissfield (S of 108)	2017	SH,RB			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	Northumberland	Blissfield (S of 108)	2017	SH,RB			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2007	SC			FL-10886
NB	Northumberland	Goodfellow Brook PNA	2006	SC			FL-08746
NB	Northumberland	Goodfellow Brook PNA	2006	SC			FL-08747
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2006	SC			FL-08808
NB	Northumberland	Goodfellow Brook PNA	2006	SC			FL-08807
NB	Northumberland	Goodfellow Brook PNA	2006	SC			FL-08809
NB	Northumberland	Goodfellow Brook PNA	2006	SC			FL-08810
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Goodfellow Brook PNA	2017	SH,FA,SC,RC,TN			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	Munsons Landing (N of 108)	2017	RB,SH			
NB	Northumberland	Munsons Landing (N of 108)	2017	RB,SH			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	Munsons Landing (N of 108)	2017	SH,RB			
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			
NB	Northumberland	N of Fraser-Burchill Rd	2017	RB,SH			
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			
NB	Northumberland	N of Fraser-Burchill Rd	2017	SH,RB			
NB	Northumberland	NW Miramichi Rvr	2017	SH,RB			
NB	Northumberland	NW Miramichi Rvr	2017	SH,RB			
NB	Northumberland	NW Miramichi Rvr	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	RB,SH			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	Pineville (N of 108)	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			
NB	Northumberland	S of Saint Margarets	2017	SH,RB			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	Northumberland	S of Saint Margarets	2017	RB,SH			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	RB,SH			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	RB,SH			
NB	Northumberland	SE of Napan Bay	2017	RB,SH			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Napan Bay	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	SE of Peaked Mountain	2017	SH,RB			
NB	Northumberland	W of Red Pine Knoll	2017	RB,SH			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	Northumberland	W of Red Pine Knoll	2017	SH,RB			
NB	Restigouche	Jacquet Rvr Gorge PNA (S of Belledune Pond)	2017	SH,RB			
NB	Restigouche	Jacquet Rvr Gorge PNA (W of Quarry Rd)	2017	SH,RB			
NB	Restigouche	Jacquet Rvr Gorge PNA (S of Antinouri Lk Brook)	2010	SC/KD/SS			FL-12943
NB	Restigouche	Mt. Carleton Provincial Park	2006	SC/SS			FL-09994
NB	Restigouche	Mt. Carleton Provincial Park	2017	SH,RB			
NB	Restigouche	Upper Tetagouche Lk (S. shore)	2017	SH			
NB	Saint John	Ten Mile Creek	2006	SC/RW			FL-10643
NB	York	Beaverbrook headwaters	2006	DS			
NB	York	Beaverbrook headwaters	2006	DS			
NB	York	Beaverbrook headwaters	2005	DS			
NB	York	Beaverbrook headwaters	2017	SHDS			
NB	York	E Branch Longs Creek	2005	DS			FL-10612
NB	York	Eel Rvr PNA	2017	CV,SH			
NB	York	Eel Rvr PNA	2017	SHCV			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2006	SC			FL-08511
NB	York	Eel Rvr PNA	2006	SC			FL-08512
NB	York	Eel Rvr PNA	2006	SC			FL-08480
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH/CV			
NB	York	Eel Rvr PNA	2017	SH			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Eel Rvr PNA	2017	SH			
NB	York	Kelly's Creek	2017	SH,DS			
NB	York	Kelly's Creek	2017	SH,DS			
NB	York	Kelly's Creek	2017	SH,DS			
NB	York	Kelly's Creek	2006	DS			
NB	York	Kelly's Creek	2017	SH,DS			
NB	York	Kelly's Creek	2017	SH,DS			
NB	York	Little Pokiok Headwaters	2007	DS			
NB	York	Near Brockway Airport	2017	SH,KD			
NB	York	Near Brockway Airport	2017	SH,KD			
NB	York	Near Brockway Airport	2017	SH,KD			
NB	York	Pokiok Settlement	2017	SH,DS			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SHCV			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SHCV			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, N Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, S Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, S Mosquito bk	2017	SH/EH			
NB	York	Spednic Lk PNA, S Mosquito bk	2017	SH			
NB	York	Spednic Lk PNA, S Mosquito bk	2017	SH			
NS	Digby	Hectanooga Nature Reserve	2009	SC			FL-17977
NS	Digby	Hectanooga Nature Reserve	2009	SC			FL-17982
NS	Digby	Hectanooga Nature Reserve	2017	FA,TN			
NS	Digby	Hectanooga Nature Reserve	2005	TN			226904
NS	Digby	Hectanooga Nature Reserve	2017	FA,TN			
NS	Digby	Hectanooga Nature Reserve	2017	FA,TN			
NS	Digby	Hectanooga Nature Reserve	2011	TN			130576
NS	Digby	Tobeatic Wilderness Area between Sporting Lk and Whitesand streams	2010	Clapp			208310
NS	Guysborough	Ian's Road SE	2018	SH			
NS	Halifax	Cross Lk	2017	RC,TN			
NS	Halifax	Cross Lk	2011	TN			130579
NS	Halifax	Kent Lk	2011	RC			130285
NS	Halifax	Malay Falls NW	2018	SH			
NS	Halifax	Shea Lk W of	2007	TN			64716
NS	Halifax	Tangier Grand Lk Wilderness Area	2013	RC			451014
NS	Lunenberg	Pleasant Rvr Lk Rd	2018	SH			
NS	Lunenburg	Middle LaHave, near Grimm Rd,	2008	FA			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Lunenburg	Ash Brook	2008	FA			
NS	Lunenburg	Beck's Lk	2010	FA			
NS	Lunenburg	Chelsea Road	2014	FA			
NS	Lunenburg	Coade Lk SE	2017	FA			
NS	Lunenburg	Mersey Rvr	2017	FA			
NS	Lunenburg	near Middlewood	2011	FA			450984
NS	Lunenburg	near Shingle Lk	2015	FA			
NS	Lunenburg	Shingle Lk (Medlee Laine)	2016	DR,FA			
NS	Lunenburg	Upper Branch Rd	2008	FA			
NS	Lunenburg	Upper Branch Rd	2017	FA,TN			
NS	Lunenburg	W of Raddall Park	2017	FA			
NS	Queens	Ash Brook	2017	FA			
NS	Queens	Beech Hill	2017	FA,TN			
NS	Queens	Beech Hill	2017	FA,TN			
NS	Queens	Beech Hill	2017	FA,TN			
NS	Queens	Beech Hill	2017	FA,TN			
NS	Queens	Beech Hill	2007	TN			64695
NS	Queens	Beech Hill	2007	TN			64694
NS	Queens	Beech Hill	2007	TN			64698
NS	Queens	Beech Hill	2007	TN			64696
NS	Queens	Beech Hill	2007	TN			64697
NS	Queens	Between Toney & Little Bon Mature Lk	2017	CP			
NS	Queens	Big Bon Mature Lk	2017	CP			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Blue Hill Mud Lk C	2018	SH			
NS	Queens	Bon Mature Lk	2007	TN			64700
NS	Queens	Bon Mature Lk	2007	TN			64701
NS	Queens	Bon Mature Lk	2007	TN			64699
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Burnaby Lk SE	2018	SH			
NS	Queens	Crane Lk SE	2018	SH			
NS	Queens	E of Solnow Lk	2017	CP			
NS	Queens	Little Bon Mature Lk	2017	CP			
NS	Queens	Little Bon Mature Lk	2017	CP			
NS	Queens	Little Bon Mature Lk C	2018	SH			
NS	Queens	Little Bon Mature Lk N	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk S	2018	SH			
NS	Queens	Little Bon Mature Lk W	2014	RC			425808
NS	Queens	Little Bon Mature Lk W	2014	RC			425810
NS	Queens	Little Bon Mature Lk W	2014	RC			425811
NS	Queens	Little Bon Mature Lk W	2014	RC			425812
NS	Queens	Little Bon Mature Lk W	2014	RC			425828

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Queens	Little Bon Mature Lk W	2014	RC			425831
NS	Queens	Little Bon Mature Lk W	2014	RC			425835
NS	Queens	McGowan Lk E	2018	JN			
NS	Queens	NE of Herring Cove Lk	2017	CP			
NS	Queens	S of First Lk	2017	CP			
NS	Queens	S of First Lk	2017	CP			
NS	Shelburne	Blue Hill Bog (N of 103)	2017	CP			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2005	TN			226905
NS	Shelburne	Canada Hill Area	2012	TN			
NS	Shelburne	Canada Hill Area	2011	TN			130577
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2013	CP			226343
NS	Shelburne	Canada Hill Area	2013	CP			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2007	TN			64702
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Shelburne	Canada Hill Area	2007	TN			64703
NS	Shelburne	Canada Hill Area	2007	TN			64704
NS	Shelburne	Canada Hill Area	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Clyde Rvr Rd	2017	FA,TN			
NS	Shelburne	Clyde Rvr Rd	2017	FA,TN			
NS	Shelburne	Clyde Rvr Road SW	2012	TN			226913
NS	Shelburne	Clyde Rvr Road W	2017	FA,TN			
NS	Shelburne	Clyde Rvr Road W	2007	TN			64706
NS	Shelburne	Clyde Rvr Road W	2017	FA,TN			
NS	Shelburne	Clyde Rvr Road W	2007	TN			64707
NS	Shelburne	Clyde Rvr Road W	2017	FA,TN			
NS	Shelburne	Clyde Rvr Road W	2007	TN			64705
NS	Shelburne	Duck Hole (HL1)	2017	FA,TN			
NS	Shelburne	Duck Hole (HL1)	2008	TN			64708
NS	Shelburne	E Sable Rvr Road	2017	FA,TN			
NS	Shelburne	E Sable Rvr Road	2012	TN			226916
NS	Shelburne	E Sable Rvr Road	2012	TN			
NS	Shelburne	Haley Lk	2005	TN			226906
NS	Shelburne	Haley Lk	2017	FA,TN			
NS	Shelburne	Haley Lk	2011	TN			130578
NS	Shelburne	Harpers Lk NE	1905	TN			
NS	Shelburne	Jordan Rvr S	2007	RC			64709
NS	Shelburne	Jordan Rvr W	2017	FA,TN			
NS	Shelburne	Jordan Rvr W	2012	TN			226909
NS	Shelburne	Jordan Rvr W	2012	TN			226908
NS	Shelburne	Lk John Road	2017	FA,TN			
NS	Shelburne	Lk John Road	2007	TN			64710
NS	Shelburne	Lk John Road	2007	TN			64711
NS	Shelburne	Lk John Rd (W of Veitchs Lk)	2017	CP			
NS	Shelburne	Lower Ohio E	2012	TN			226914
NS	Shelburne	Lower Ohio E	2012	TN			226915
NS	Shelburne	Misery Brook	2017	FA,TN			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Shelburne	Misery Brook	2007	TN			64713
NS	Shelburne	Misery Brook	2007	TN			64714
NS	Shelburne	Misery Brook	2017	CP			
NS	Shelburne	Misery Lk	2017	CP			
NS	Shelburne	Misery Lk	2017	FA,TN			
NS	Shelburne	Misery Lk	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Misery Lk	2011	TN			226907
NS	Shelburne	Misery Lk	2017	FA,TN			
NS	Shelburne	Misery Lk	2007	TN			64712
NS	Shelburne	Misery Lk North	2013	CP			226344
NS	Shelburne	Misery Lk North	2013	CP			
NS	Shelburne	Sable River	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Sable River	2008	TN			64715
NS	Shelburne	S of Colins Lk	2017	CP			
NS	Shelburne	S of Wilkins Lk	2017	CP			
NS	Shelburne	Upper Clyde Rvr E	2006	TN			FL-11751
NS	Shelburne	Upper Clyde Rvr NE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr NE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr NE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	FA,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	FA,TN			
NS	Shelburne	Upper Clyde Rvr SE	2012	TN			226910
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr SE	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2006	TN			FL-11769
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr S	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Upper Clyde Rvr W	2017	FA,TN			
NS	Shelburne	Upper Clyde Rvr W	2012	TN			226911
NS	Shelburne	Upper Ohio	2017	CP			
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Welshtown Lk N	2006	TN			FL-11752
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Welshtown Lk N	2017	SH,FA,SC,RC,TN			
NS	Shelburne	Wentworth Lk NW	2012	TN			226912
NS	Shelburne	Wentworth Lk SW	2013	RC			423939
NS	Shelburne	West Beech Hill Lk	2017	CP			

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
NS	Shelburne	Western Lk (1/2 way between Western & Harpers Lk)	2017	FA,TN			
NS	Shelburne	Western Lk (1/2 way between Western & Harpers Lk)	2012	TN			226918
NS	Shelburne	Western Lk (1/2 way between Western & Harpers Lk)	1905	TN			
NS	Shelburne	Western Lk (1/2 way between Western & Harpers Lk)	2012	TN			226917
ON	Algoma	Lk Superior Prov. Park (Nokomis Trail, Canada Highway 17, near Old Woman Bay)	1993	SS,SS			CANL 116130
ON	Nipissing	Gull Lk Portage Lk Temagami.	1935	Cain			CANL 62278
ON	Rainy River	Emo	1901	Fink			CANL 2912
ON	Rainy River	Quetico Provincial Park	2016	SB			13195
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13568
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13566
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13570
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13575
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13591
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13599
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13588
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13582
ON	Thunder Bay	2 km N of Pigeon Rvr	2017	SB			13580
ON	Thunder Bay	Albert Lk	2017	SB			13499
ON	Thunder Bay	Albert Lk	2017	SB			13487
ON	Thunder Bay	Albert Lk	2017	SB			13493
ON	Thunder Bay	Albert Lk	2017	SB			13485
ON	Thunder Bay	Albert Lk	2016	SB			12897
ON	Thunder Bay	Albert Lk	2017	SB			13488
ON	Thunder Bay	Albert Lk	2017	SB			13491
ON	Thunder Bay	Albert Lk	2017	SB			13520
ON	Thunder Bay	Albert Lk	2017	SB			13522

Prov.	County	Locality	Year	Obs.	Lat	Lon	Accession
ON	Thunder Bay	Albert Lk	2017	SB			13519
ON	Thunder Bay	Albert Lk	2017	SB			13514
ON	Thunder Bay	Albert Lk	2017	SB			13516
ON	Thunder Bay	Albert Lk	2017	SB			13518
ON	Thunder Bay	Albert Lk	2017	SB			13517
ON	Thunder Bay	Dorion Cutoff Cedar Swamp	2017	SB			13625
ON	Thunder Bay	Dorion Cutoff Cedar Swamp	2017	SB			13624
ON	Thunder Bay	Dorion Cutoff Cedar Swamp	2017	SB			13623
ON	Thunder Bay	Dorion Cutoff Cedar Swamp	2017	SB			13622
ON	Thunder Bay	Lankinen Cedar Swamp	2017	SB			13548
ON	Thunder Bay	Lankinen Cedar Swamp	2017	SB			13546
ON	Thunder Bay	Lankinen Cedar Swamp	2017	SB			13543
QC	Bas-Saint Laurent	Riv. Rimouski, Rapide du Bois Brûlé - taken from another specimen with the same collection number	1943	Lepage			C1005373F
QC	Lanaudière	Lac Clair	1905	Unk.			437227
QC		St-Félicien cté de Lac-St-Jean	1939	Marie-Anselme			C1005165F