COSEWIC
Assessment and Status Report

on the

Wrinkled Shingle Lichen
Pannaria lurida

in Canada

THREATENED
2016

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:

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Wrinkled Shingle Lichen (*Pannaria lurida*), courtesy of Frances Anderson.

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COSEWIC
Assessment Summary

Assessment Summary – May 2016

Common name
Wrinkled Shingle Lichen

Scientific name
Pannaria lurida

Status
Threatened

Reason for designation
This lichen colonizes mature deciduous trees, most often Red Maple, and is known from 56 occurrences in the Atlantic provinces. Surveys have failed to confirm the lichen is still present in Prince Edward Island, at one of two occurrences in Newfoundland, at two of four occurrences in New Brunswick, and at several of the 49 known occurrences in Nova Scotia. Threats to this species include continuing forest harvesting leading to the removal of host trees, and the impact of climate change, leading to a reduction in the amount of suitable moist climate.

Occurrence
New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Status history
Designated Threatened in April 2016.

COSEWIC
Executive Summary

Wrinkled Shingle Lichen
Pannaria lurida

Wildlife Species Description and Significance

The Wrinkled Shingle Lichen, *Pannaria lurida*, is a leafy lichen forming patches or rosettes that can be up to 10 cm across. It almost always grows on the trunks of deciduous trees. The upper surface is brownish grey and wrinkled. The photosynthetic partner is a cyanobacterium.

Distribution

The Wrinkled Shingle Lichen occurs in Asia, Australia, Pacific Islands, Africa, Asia and America. Three subspecies have been described. The subspecies that occurs in Canada and northeastern USA is reported to be subspecies *russellii*. There is a possibility that it could be a different subspecies, but no molecular work has been done to substantiate this.

In Canada, the Wrinkled Shingle Lichen is known from 56 occurrences: 49 are in Nova Scotia, four are in New Brunswick, two in Newfoundland and one in Prince Edward Island. There may be undiscovered occurrences, particularly in Nova Scotia and possibly in New Brunswick or even Newfoundland.

Habitat

The Wrinkled Shingle Lichen in Nova Scotia and New Brunswick colonizes mature deciduous trees, most often Red Maple that grow near, but not usually within, imperfectly drained habitats. Hence, this lichen is found on trees close to the edge of treed swamps or floodplains. The only occurrence on Prince Edward Island was on Cedar while the ones in Newfoundland are on White Spruce growing in an unusual habitat on cliffs close to the sea.

Biology

Fungal fruiting bodies are frequent on the Wrinkled Shingle Lichen and provide the only specialized means of reproduction. The spores ejected from the fruit bodies need to land on the trunk of a mature tree, germinate and encounter a compatible strain of the cyanobacterium *Nostoc*. Once enveloped by the fungus, the cyanobacterium, as a result of its ability to photosynthesize and fix atmospheric nitrogen, supplies the fungus with both carbohydrates and nitrogen. No specialized vegetative reproductive structures, which are common on many other lichens, are produced by the Wrinkled Shingle Lichen. However, fragmentation and reattachment of thalli may provide for very local dispersal on host tree trunks.

Population Sizes and Trends

The estimated population of Wrinkled Shingle Lichen in Canada is about 5,000 individuals but as not all known occurrences were revisited or enumerated and as the number of mature individuals varied greatly at sites, the population may exceed 10,000 individuals. The number of lichens per occurrence ranged from one individual to just over 2,400 at a given occurrence.

A total of 56 occurrences are known from Canada. Of the 24 pre-1986 occurrences discovered before 1986, 19 were revisited and the lichen was not found at 15. The lichen was also found to be absent at two more recently discovered occurrences in Nova Scotia and one in Prince Edward Island. Thus the lichen was absent from 18 of the 56 occurrences amounting to a *loss of 32%.* It is argued that this loss of occurrences has been accompanied by an equivalent decline in the number of mature individuals of the lichen.

Threats and Limiting Factors

Threats calculator analysis indicated that the overall threat impact to *P. lurida* was “high to very high” with the major current threat being forest harvest resulting in both loss of host trees and changes in microclimate. The impact of forest harvesting for lumber, firewood, woodchips and biomass is particularly serious because this lichen typically colonizes trees after they have developed rough bark, which takes some 50 years post-harvest. The annual hardwood harvest in Nova Scotia doubled between 1990 and 2000 and is expected to continue with continued harvesting of deciduous trees. The same pattern of decline in the amount of old deciduous forest has also occurred in New Brunswick although most forestry activities are on upland mesic sites.

Less serious threats to the Wrinkled Shingle Lichen are climate change, road construction, development, and pollution. A reduction in rain, longer periods of summer drought and less fog, all of which have been projected for Nova Scotia, could lead to reduced growth or death of the Wrinkled Shingle Lichen. Where road construction or development affects drainage leading to changes in humidity in surrounding or nearby woodland habitats, it may reduce growth or lead to death of the Wrinkled Shingle Lichen. Finally, this lichen is also sensitive to sulphur dioxide and acid rain. While the levels of both these have fallen in recent years, the continuing emissions may overcome the buffering capacity of the host tree bark, rendering it too acidic for this lichen to colonize.

Protection, Status and Ranks

The Global Status of the Wrinkled Shingle Lichen is G3 (Vulnerable) to G5 (Secure). The species is Unranked or Not Yet Assessed in the USA. In Canada, the Wrinkled Shingle Lichen is Unranked.

In Nova Scotia, five occurrences are protected: one in Kejimkujik National Park, one in the Five Islands Provincial Park, another in a municipally owned Common Land, and a fifth in a provincial Nature Reserve. In New Brunswick, one occurrence at Clark Point is in a Protected Natural Area.

TECHNICAL SUMMARY

Pannaria lurida

Wrinkled Shingle Lichen

Pannaire jaune pale

Range of occurrence in Canada (province/territory/ocean): New Brunswick, Prince Edward Island, Nova Scotia, Newfoundland and Labrador

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used) *Between 10-30 years with 17 being the best estimate.*	17 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? *Yes, inferred decline as a result of continued loss of host trees due to forestry activities, and climate change*	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations (34 years)]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. *A total of 56 pre-1986 and recently discovered occurrences are known from Canada. Of the 24 pre-1986 occurrences discovered before 1986, 19 were revisited and the lichen was not found at fifteen. The lichen was also found to be no longer present at two of the more recently discovered occurrences in Nova Scotia and one in Prince Edward Island, so known to be absent from 18 of the 56 occurrences.* *Thus, this amounts of a loss of 32% of the occurrences. It is argued that this loss of occurrences has been accompanied by an equivalent decline in the number of mature individuals.*	32%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations (50 Years)].	Unknown
[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.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No, not in the short term b. Partially understood c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	127,338 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	120 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. No b. Probably Yes
Number of "locations"* (use plausible range to reflect uncertainty if appropriate) *The Wrinkled Shingle Lichen is known from 56 occurrences in Canada: 49 in NS, 4 in NB, 2 in NL and one in PEI.* *As occurrences are scattered, a single threatening event is not likely to affect several occurrences at a time, so the number of locations is considered to be the same as the number of occurrences.*	56
Is there an [observed, inferred, or projected] decline in extent of occurrence? *The lichen is no longer present on PEI*	Yes
Is there an [observed, inferred, or projected] decline in index of area of occupancy? *Loss of 16 of 18 occurrences that were discovered before 1986.*	Yes
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"*? *Surveys failed to confirm the lichen's presence at 16 of nineteen revisited occurrences that were discovered prior to 1986, and at two recently discovered revisited occurrences NS and one in PEI.*	Yes
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat? *Observed and inferred habitat decline as a result of forestry activities and climate change in NS and NB*	Yes
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 occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	N Mature Individuals
Newfoundland	103
New Brunswick	70
Nova Scotia **Note that this number was extrapolated based on the median number of thalli per occurrence (see section on Abundance)*	4,410
Total: As the lichen was enumerated at only a small number of the recently discovered occurrences and as a large number of individuals can occasionally occur on a single tree, the total number of mature individuals may exceed 10,000	5,000 to >10,000

Quantitative Analysis

Probability of extinction in the wild is 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 (Appendix 1)

Major threats include:

i. Logging and wood harvesting
ii. Air pollution
iii. Road construction and developments
iv. Climate change

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Declining in northern part of USA. Two occurrences in Maine, neither found on recent re-surveys.
Is immigration known or possible?	Possible, but unlikely
Would immigrants be adapted to survive in Canada?	Yes, provided that suitable habitat remains
Is there sufficient habitat for immigrants in Canada?	Yes, at the moment
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source population deteriorating?[+]	Yes
Is the Canadian population considered to be a sink?[+]	Unknown
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Status History

COSEWIC: Designated Threatened in April 2016.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** A2b
Reasons for designation: This lichen colonizes mature deciduous trees, most often Red Maple, and is known from 56 occurrences in the Atlantic provinces. Surveys have failed to confirm the lichen is still present in Prince Edward Island, at one of two occurrences in Newfoundland, at two of four occurrences in New Brunswick, and at several of the 49 known occurrences in Nova Scotia. Threats to this species include continuing forest harvesting leading to the removal of host trees, and the impact of climate change, leading to a reduction in the amount of suitable moist climate.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Meets Endangered A2b. This lichen species appears to be absent at 18 of 56 known occurrences (therefore 32% loss). The lost occurrences include one in Newfoundland, one in PEI, two in New Brunswick and 14 in Nova Scotia and, in some cases, the habitat has been destroyed. This loss of occurrences has resulted in a significant loss of mature individuals.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Although the IAO (120 km²) is very small, the number of locations exceeds the threshold and there are no extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Population): Not applicable.
Criterion E (Quantitative Analysis): Not performed.

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 (2016)

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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Wrinkled Shingle Lichen

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2016

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Name: *Pannaria lurida* (Mont.) Nyl. (Mém. Soc. Sci. Nat. Cherbourg 5:109,1857).

Classification: The genus *Pannaria* contains some 80 species of which eight occur in North America (Brodo *et al.* 2001; Ekman *et al.* 2014). This genus is in the family Pannariaceae with 300 known species which after recent phylogenetic analysis have been assigned to 30 genera (Ekman *et al.* 2014). The family is part of the order Peltigerales and class Leconoromyctes in the division Ascomycota.

Pannaria lurida s.l. currently comprises three subspecies: ssp*. lurida,* ssp*. russellii*, and ssp*. quercicola* (Jørgensen 2000*)*. Recent studies on the first two showed that they could be distinguished phylogenetically (Ekman *et al.* 2014). However, *Pannaria lurida* ssp*. russellii* is difficult to distinguish with certainty from ssp*. quercicola* which is reported to occur in southern New England and the Appalachian mountains. Black and white illustrations of all three subspecies are provided by Jørgensen (2000).

Pannaria lurida ssp*. russellii* (Tuck.) P.M. Jørg. is understood to be the subspecies that occurs in Canada and in the more northern parts of the USA (Jørgensen 2000). The type specimen of this subspecies is from Hingham, Massachusetts, USA (J.L. Russell, 1844. Proc. Acad. Arts & Sci. 1848:1; 227). This subspecies was reported by Jørgensen (2000, p. 691) to have “mostly negative” reactions to the application of paraphenylenediamine (Pd) to the medulla. A positive reaction occurs in the presence of pannarin which reacts by turning red when Pd is applied. Over 30 fresh and herbarium specimens of *P. lurida* s.l., including those from the New York Botanical Garden from the southern US, the Appalachians and further north, were examined recently. It was found that *P. lurida* ssp*. russellii* specimens only reacted to Pd immediately under the growing lobe tips (Anderson pers. comm. 2014). This reaction pattern was also found in collections of *P. lurida* from eastern Canada lodged at the National Herbarium in Ottawa (McMullin pers. comm. 2014). Although most specimens from Canada and Maine appear similar, they vary somewhat from the original subspecies description by Jørgensen (2000) in thallus colour, spore shape and size, texture of upper surface and colour of rhizohyphae (see Morphological Description). Because of this variation, there is the possibility that yet another subspecies could exist in Canada and Maine. Unfortunately no molecular work has been done to substantiate this and so this status report refers to the Canadian material as *P. lurida*, omitting any mention of the subspecies.

Pannaria lurida ssp*. lurida* (Mont.) Nyl. contains pannarin throughout the thallus (reacts Pd+) and has narrow lobes, a prominent prothallus and narrowly ellipsoid spores. It is subtropical, being found in Florida and the Gulf States.

Pannaria lurida ssp*. quercicola* (P.M. Jørg.) also contains pannarin throughout the thallus but has ellipsoid spores with pointed ends and is found in warm-temperate hardwood forests in eastern North America and Mexico (Jørgensen, 2000, Nash *et al.* 2002) and around the world (see Global Distribution below).

Common Name: “Wrinkled Shingle Lichen” (NatureServe 2014). The name refers to the wrinkles that are commonly seen on the upper surface of the thallus. This lichen has also been called the “Veined Shingle Lichen” (Brodo *et al.* 2001) and in Australia is known as the “Matted Lichen” (ALA 2014).

Morphological Description

Pannaria lurida, is a foliose lichen forming patches or rosettes that are 4-9 cm across with individual lobes being 1-4 mm wide. The upper surface is brownish grey, wrinkled across the whole thallus, and is often pruinose, especially near the outer tips. The red-brown apothecia have a thalline margin and often have bristle-like hairs around their bases. The asci contain eight colourless simple, broadly ellipsoid to ovoid spores about 10 -17 x 8-11 µm. The lower surface is tan coloured and attached to the substratum by pale tan to blue-black rhizohyphae (Anderson pers. comm. 2014). The photosynthetic partner is the cyanobacterium *Nostoc* and its arrangement among the fungal hyphae in the medulla results in the thallus becoming quite gelatinous when wet compared with other members of the genus (see Physiology and Adaptability). Isidia and soredia are absent.

Chemistry: Thalli contain more or less of a depsidone called pannarin, the structure of which involves a central seven-membered heterocycle fused on either side to highly substituted phenyl rings (Blaser and Stoeckli-Evans 1991; Huneck & Yoshimura 1996). It is often in higher concentration at the lobe margins (Brodo *et al.* 2001). This lichen compound reacts orange-red using the spot test with paraphenylenediamine. There is no reaction with either K or C in spot tests.

Pannaria lurida may be confused with *Pannaria rubiginosa*, but that species does not have a wrinkled thallus nor develop a gelatinous texture when wet (Jørgensen, 2000). It has a more prominent blue-black hypothallus and frequently has round lobules on the margin (Brodo *et al.* 2001). *P. lurida* has a distinct brown-grey cast to the thallus.

Designatable Units

One designatable unit (DU) is considered to be present in Canada as no genetic work has been done on material from North America, and no morphological or other differences have been observed to support more than one DU.

Special Significance

Pannaria is considered one of the ancient genera of cyanolichens. The genus evolved during the Cretaceous when the protopacific margin had temperate conditions and was linked to South America, and the South Pacific land areas, one of which became Australia (Galloway 2008). This ancient origin is also supported by phylogenetic studies of the *Nostoc* symbiont of *Pannaria* (Elvebakk *et al.* 2008).

DISTRIBUTION

Global Range

In addition to Canada, *Pannaria lurida* s.l. is reported to occur in the following countries and French Overseas Territories (the number of records in parentheses follows the country name): Australia (75), Taiwan (3), Ecuador (1),Fiji (4), Honduras (1), Indonesia (3), Japan (88), Kenya (6), Korea (7), Malawi (1), Mexico (2), New Caledonia (1), New Zealand (1), Papua New Guinea (4), Reunion (1), South Africa (1), Sri Lanka (2), Tanzania (10), United States (102) (Global Biogeographic Information Facility 2014), as well as Chile, Madagascar, Philippines, Samoa, and Saint-Pierre et Miquelon (Jørgensen 2003; Andreas Beck pers. comm. 2014; GBIF 2015).

United States Range

Pannaria lurida s.l. occurs from the eastern states southward to Florida and Texas (Flenniken 1999) and west to the Sonoran Desert (Nash *et al.* 2002) (Figure 1). There are two relatively recent US collections of *P. lurida* ssp*. russellii* from Maine. One was collected in 1997 from near the Maine border at Jordan Pond on Mt. Desert Island (J. Hinds pers. comm. 2014) and one from near Eagle Hill in Steuben (A. Dibble pers. comm.). Wolfgang Maass recorded two Maine occurrences quite close to the New Brunswick border in 1981, one at Princeton and the other at Wesley. *P. lurida* was not found at these sites when searched in 2014. The lichen flora of the northeastern part of the USA has been surveyed by a very active group (>30) of professional and amateur lichenologists (the Tuckerman Workshop) who have worked in this region over the past 20 years. They have documented very few records of *P. lurida* from this area of the USA.

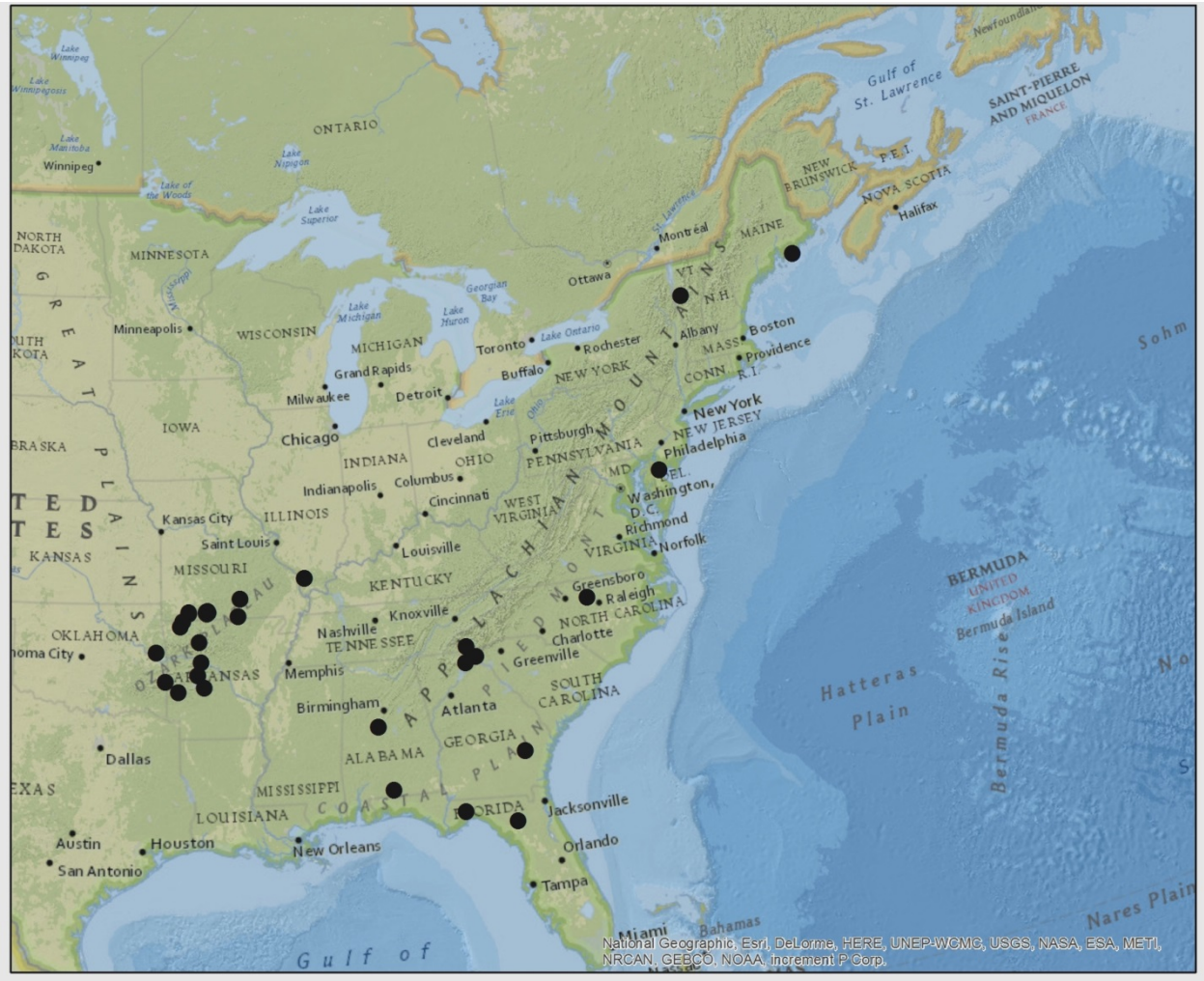

Figure 1. The distribution of *Pannaria lurida* s.l. in the USA based on records held by the Consortium of North American Lichen Herbaria.

Canadian Range

Pannaria lurida was first reported in 1956 from Newfoundland, in 1981 from Nova Scotia, in 1986 from New Brunswick and in 2009 from Prince Edward Island (Table 1A, 1B). Reports by Lepage (1947, 1958) that the species occurred in Quebec have been discounted (Maass *et al.* 1986). Finally, there is a 19th century record from the islands of Saint-Pierre et Miquelon but *P. lurida* was not be found in a recent search of this area (Cameron, pers. comm. 2015).

Table 1. Known *Pannaria lurida* occurrences in Nova Scotia, Prince Edward Island, New Brunswick, and Newfoundland.

Part A. Occurrences for *Pannaria lurida* which were discovered before 1986. In the absence of a revisit, it is uncertain whether the lichen is still present at a particular occurrence.

	Province	Location	County	Collector	Date Found	Revisited Y/N	Lichen still judged to be present
1	NL 1	Woodville Codroy Valley		Teuvo Ahti	1956	y	Y
2	NL 2	Eels Brook Gros Morne NP		Teuvo Ahti	1978	y	N
1	NB 1	Rexton	Northumberland	Wolfgang Maass	1986	y	N
2	NB 2	Sackville	Westmorland	Wolfgang Maass	1986	y	N
1	NS 1	Five Islands PP	Colchester	H. Harries	1998	y	Y
2	NS 2	St. Andrews River	Colchester	Wolfgang Maass	1981	n	?
3	NS 3	Lake Midway	Digby	Wolfgang Maass	1982	y	N
4	NS 4	Sissiboo River	Digby	Wolfgang Maass	1981	n	?
5	NS 5	Gaetz Brook	Halifax	Wolfgang Maass	1982	y	N
6	NS 6	Murchyville	Halifax	Wolfgang Maass	1982	y	N
7	NS 7	Porter's Lake	Halifax	Wolfgang Maass	1982	y	N
8	NS 8	Upper New Cornwall	Lunenburg	Wolfgang Maass	1981	y	N
9	NS 9	West Northfield	Lunenburg	Brodo & Angus	19??	y	N
10	NS 10	Greenfield	Queens	Wolfgang Maass	1982	y	N
11	NS 11	Kejimkujik National Park	Queens	Wolfgang Maass	1981	y	Y
12	NS 12	Kejimkujik National Park	Queens	Wolfgang Maass	1982	y	Y
13	NS 13	Kempt	Queens	Wolfgang Maass	1982	y	N
14	NS 14	Lake Rossignol	Queens	Wolfgang Maass	1982	y	N
15	NS 15	Meagher	Queens	Wolfgang Maass	1981	y	N
16	NS 16	Medway River	Queens	Wolfgang Maass	1982	y	N
17	NS 17	Ponhook	Queens	Wolfgang Maass	1981	n	?
18	NS 18	Summerville	Queens	Wolfgang Maass	1981	y	N
19	NS 19	Ohio Rd.	Shelburne	Wolfgang Maass	1983	n	?
20	NS 20	N. Kemptville	Yarmouth	Wolfgang Maass	1981	n	?

Part B. Recently discovered occurrences of *Pannaria lurida.* The lichen is judged still to be present unless the occurrence was revisited and the lichen found to be absent.

Province	Location	County	Collector	Date Found	Revisited Y/N	Lichen still judged to be present
PEI 1	Pleasant View	Prince	Troy McMullin	2009	Y	N

Province	Location	County	Collector	Date Found	Revisited Y/N	Lichen still judged to be present
NB 1	Clark Point	Charlotte	Stephen Clayden	2006/7	N	Y
NB 2	Pomeroy Ridge	Charlotte	Stephen Clayden	2008	Y	Y
NS 1	Ruggles Lake	Annapolis	Tom Neily	2007	N	Y
NS 2	Hardwoodlands	Hants	Chris Pepper	2014	N	Y
NS 3	Ash Brook	Lunenburg	Frances Anderson	2008	N	Y
NS 4	Beech Hill	Lunenburg	Frances Anderson	2009	N	Y
NS 5	Chelsea	Lunenburg	Frances Anderson	2014	N	Y
NS 6	Grimm Road	Lunenburg	Frances Anderson	2008	Y	N
NS 7	Indian Falls	Lunenburg	Frances Anderson	2008	Y	N
NS 8	Indian Path	Lunenburg	Frances Anderson	2004	N	Y
NS 9	Lapland	Lunenburg	Frances Anderson	2014	N	Y
NS 10	Rhodes Lake	Lunenburg	Frances Anderson	2009	N	Y
NS 11	Shingle Lake	Lunenburg	Tom Neily	2007	N	Y
NS 12	West Clifford	Lunenburg	Troy McMullin	2014	N	Y
NS 13	Beech Hill	Queens	Tom Neily	2007	N	Y
NS 14	Bon Mature Lake	Queens	Tom Neily	2007	N	Y
NS 15	McGowan Lake	Queens	Tom Neily	2007	Y	Y
NS 16	Medway	Queens	Frances Anderson	2014	N	Y
NS 17	Grand River	Richmond	Chris Pepper	2014	N	Y
NS 18	Canada Hill	Shelburne	Tom Neily	2005 - 2011	N	Y
NS 19	Eight Mile Brook?	Shelburne	Chris Pepper	2014	N	Y
NS 20	Granite Village	Shelburne	Tom Neily	2012	N	Y
NS 21	Jordan Falls	Shelburne	Chris Pepper	2014	N	Y
NS 22	Sable River	Shelburne	Tom Neily	2010	N	Y
NS 23	Six Mile Brook	Shelburne	Frances Anderson	2007	N	Y
NS 24	South of Misery Lake	Shelburne	Tom Neily		N	Y
NS 25	Tidney Meadows	Shelburne	Frances Anderson	2008	N	Y
NS 26	Tidney River	Shelburne	Tom Neily	2005-2011	N	Y
NS 27	Veitch's Lake	Shelburne	Chris Pepper	2014	N	Y
NS 28	W of Canada Hill Lake	Shelburne	Tom Neily	2007	N	Y
NS 29	Rushy Lake	Yarmouth	Tom Neily	2008	N	Y

Most known occurrences of *Pannaria lurida* occur near the Atlantic Coast of Nova Scotia, south of Halifax, and through the centre of the province into Cape Breton (Figure 2). In New Brunswick, the occurrences are near the Northumberland Strait, opposite Prince Edward Island and in the southern boundary with the state of Maine. The Newfoundland and Prince Edward Island occurrences are known exclusively from the west coasts.

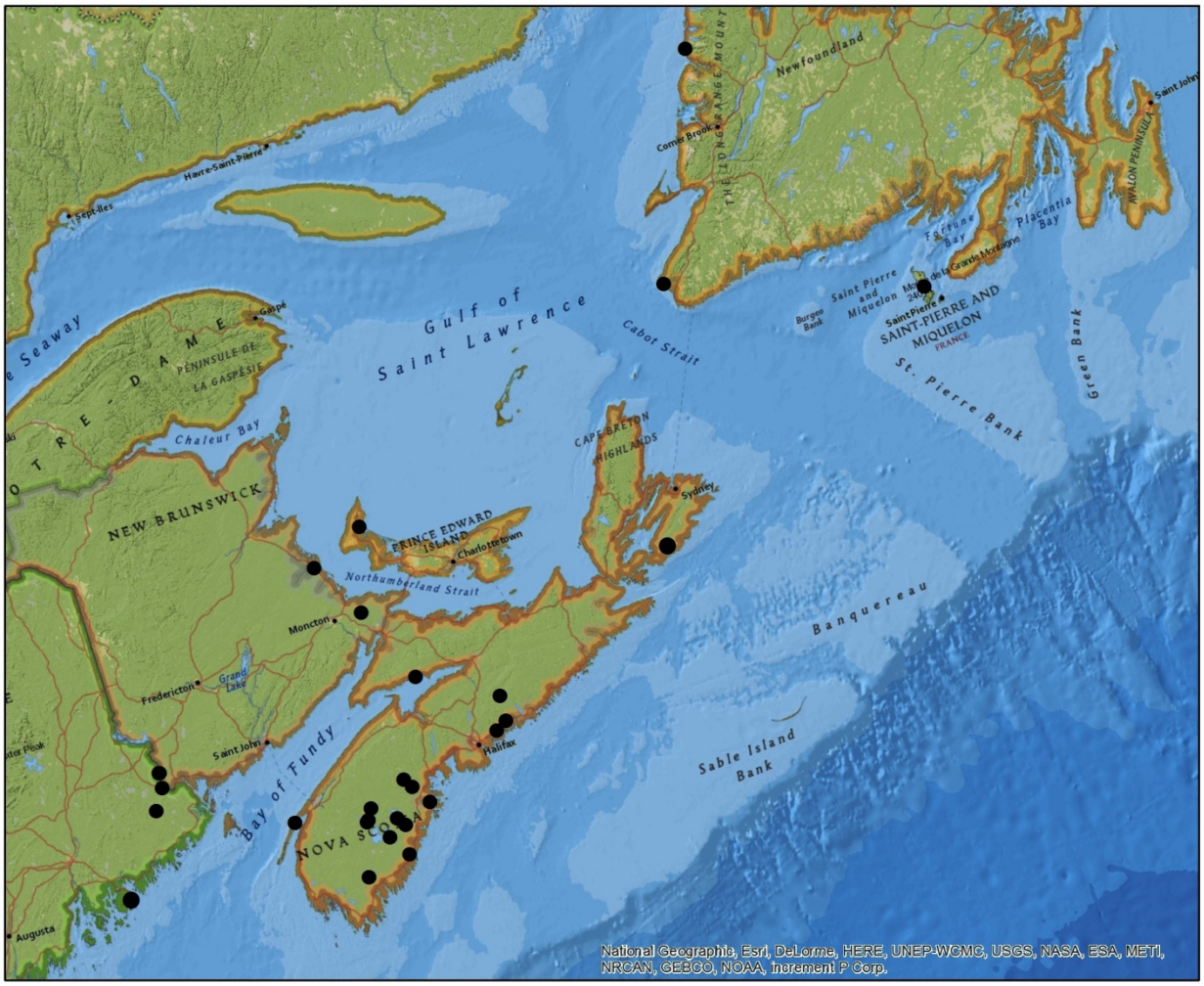

Figure 2. All known occurrences in Canada, those in Maine, USA, and the one on Saint-Pierre et Miquelon, where *Pannaria lurida* has been collected or recorded.

Extent of Occurrence and Area of Occupancy

Search Effort

There is a long history of lichen collecting in eastern Canada documented by sources including Goward *et al.* (1998) and Clayden (2010). Searches prior to the start of fieldwork for this report did not focus on *Pannaria lurida* although it was well known to those undertaking general surveys (Figure 3).

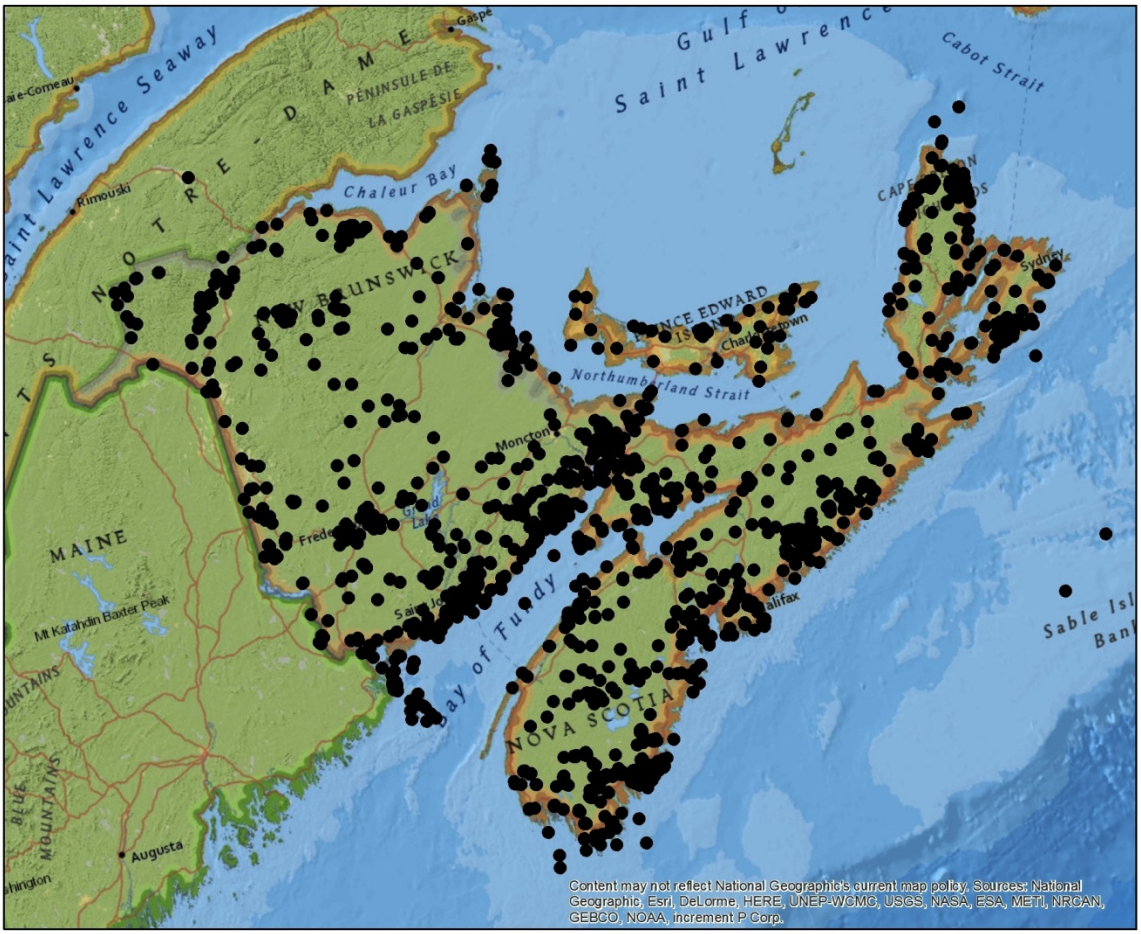

Figure 3. Lichen collections from New Brunswick and Nova Scotia (based on data from the Consortium of North American Lichen Herbaria MNRF 2016). This includes data from the 19th century to present. The black dots in the sea represent collections from islands.

A total of 56 occurrences of *Pannaria lurida* are known from Canada. Twenty four *P. lurida* occurrences were discovered before 1986 (Table 1A) which marked the year that Maass *et al.* (1986) completed and published their account of this lichen. Interest in *P. lurida* resumed in 2000 with the publication by Jørgensen (2000). Additional collections from the Maritimes began in 2005, so the estimated two generation interval (~34 yrs) between 1986 and the more recent collections provided a logical division between pre-1986 and recent discoveries.

Nineteen of the occurrences found in 1986 or earlier were revisited for this report. They comprised 15 in Nova Scotia, 2 in New Brunswick and 2 in Newfoundland. Thirty-two *P. lurida* occurrences were discovered recently (post-1986). Of these, five were revisited. The visits were made to confirm whether or not the lichen was still present and to enumerate, where possible, the number of individuals. The results of these revisits are included in Table 1A and 1B and Figure 4.

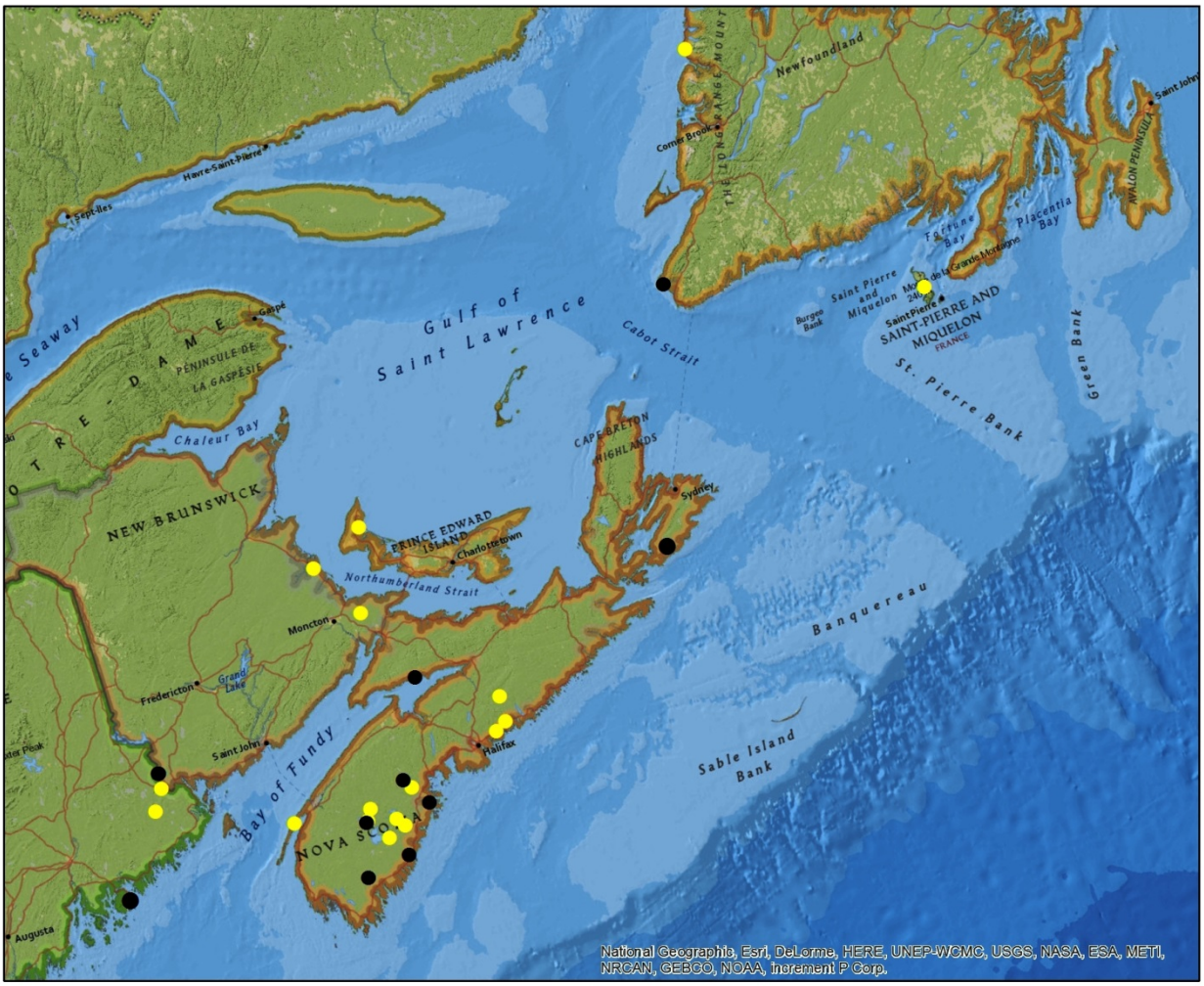

Figure 4. Known occurrences for *Pannaria lurida* that were revisited mostly in 2014 (see Text). Black dots are occurrences where *P. lurida* is still extant in Canada; yellow dots are occurrences where *P. lurida* was not re-found.

Prince Edward Island

Only one occurrence is known for *P. lurida* in this Prince Edward Island. *Pannaria lurida* was found in 2009 by T. McMullin at the Pleasant View Cedars Natural Area (McMullin *et al.* 2012). In 2014, he revisited the occurrence three times to find *P. lurida* without any success. Two other areas were examined on the island with potentially suitable habitat: the North Enmore Nature Reserve and the Townshend Woodlot Natural Area. Both areas have relatively large forested areas with old deciduous trees and high humidity. The North Enmore Nature Reserve was the only place on the island, other than the Pleasant View Cedars Natural Area, to contain *P. rubiginosa,* but *P. lurida* was not located. The Townshend Woodlot Nature Area has been visited by many lichenologists (Selva in 1995 and 1997, McMullin in 2006 and 2014, Clayden in 2009, and Richardson in 2011), but *P. lurida* was not found.

Newfoundland

Two occurrences are known for *Pannaria lurida* on the Island of Newfoundland.

Pannaria lurida was first found by T. Ahti in southwestern Newfoundland at Halls Farm, Codroy Valley, on July 7 1956. In 2007 M. Pitcher initiated efforts to relocate *P. lurida*. With J. Brazil, they searched the scrub conifer forest south from Halls Farm and the shoreline forest of the cove north of Woody Cape, without success. Pitcher returned in 2008 with J. McCarthy and searched north from Hall's Farm. They relocated the population on mature but stunted *Picea glauca* at the very edge of the high sandstone sea-cliffs west of Millville, Codroy Valley, in western Newfoundland. The occurrence was revisited in 2010 by Emilie Kissler*. P. lurida* was found on both the branches and boles of 14 trees, predominantly White Spruce. A total of 103 thalli were counted.

Ahti also found *P*. *lurida* at a site near at Eel's Brook at the mouth of Western Brook in western Newfoundland. It was a coastal wind-exposed *Abies balsamea* wood behind sand dunes with an elevation of 6 m. The lichen grew on *Picea glauca*. In 2014, Ahti and M. Piercey-Normore visited the area, but failed to relocate *P. lurida.* They also looked for *P. lurida* near Sally's Cove, but again they failed to find *P. lurida*.

The Species Status Advisory Committee (SSAC) in Newfoundland identified the need for further fieldwork. The heuristic model developed by R. Cameron for *Erioderma pedicellatum* was applied by E. Kissler to Newfoundland using the "hot zones" that Cameron had previously suggested would be potential habitat for *P. lurida*. The areas predicted by the model include the Avalon Peninsula, Bay de l'Eau, Bay d'Espoir, Codroy Valley, Port au Port Bay, and the Bay of Islands (Kissler 2010). Subsequent fieldwork in the Codroy Valley, Port au Port/Stephenville Crossing, Three Mile Rock on the Northern Peninsula and Cow Head to Port au Choix, failed to discover further populations of *P. lurida* (Kissler, 2010). In addition, M. Pitcher surveyed the area in the northeastern Avalon Peninsula, north of St. John's for the East Coast Trail Corporation. He also searched in the Cow Head area looking for *P. lurida* in an old forest near a small coastal cemetery but the species was not found*.* In 2014*,* C.Hanel looked at a site on the western coast of the Port au Port Peninsula along a coastal hiking trail where conditions were very similar to the Halls Farm occurrence but did not find *P. lurida*.

There is also a nineteenth century record of *P. lurida* from the nearby islands of Saint-Pierre et Miquelon (Delamare *et al.* 1888; Le Gallo 1952). The area was revisited in 2015 but the lichen was not found (Cameron, pers. comm. 2015).

New Brunswick

Four occurrences are known for *P. lurida* in New Brunswick: Clarke Point, Pomeroy Ridge, Rexton, and North of Sackville. The lichen was absent at the last two occurrences when they were revisited in 2014 (see Table 1B). In addition, the Tuckerman Workshop collected along the lower Bay of Fundy coast and did not find the lichen.

Nova Scotia

General surveys for lichens in Nova Scotia have included fieldwork by the Tuckerman Workshop (see United States Range section), who visited the province twice (White Point and Parrsboro) and Newfoundland once (Avalon Peninsula) in recent years and whose members are able to identify *P. lurida*.

As part of the fieldwork for this report, known occurrences of *P. lurida* were revisited in 2014. *P. lurida* was first found in Nova Scotia in 1981 by W. Maass (Maass *et al.* 1986). The notes on Maass' collection packets provide directions to the sites, but coordinates are lacking, producing some uncertainty about the exact position of occurrences so searches were extended to areas all around the presumed site. Of the 24 pre-1986 occurrences, 19 were revisited along with five of the more recently discovered occurrences (Table 1A).

HABITAT

Habitat Requirements

Pannaria lurida s.l. worldwide has been found to occupy a wide range of habitats and climates, which range from temperate forests as far north as the western tip of Newfoundland (Ahti, pers comm. 2014) to tropical coastal mangrove communities in Australia (Stephens 1979).

In Nova Scotia, *P. lurida* most frequently inhabits sites near imperfectly drained, humid habitats dominated by deciduous trees. Such sites are close to the edge of treed swamps or riparian floodplains, or are at the base of moderate to steep slopes. A few occurrences are known from upland hardwood stands at the tops of slopes that are less than 100m in elevation. Only two occurrences are within a few kilometres of the coast; the rest occur more than five kilometres inland. Canopy density is moderately open (in 13 of the 15 occurrences where the canopy was assessed). The lichen grows on the rough bark of mature trees, mainly on the more sun-exposed sides. Red maple (*Acer rubrum*) is the main host species, with poplar (*Populus tremuloides, Populus balsamifera*) the second most frequent species. It is also known from Black and White Ash (*Fraxinus nigra, Fraxinus americana*), Sugar Maple (*Acer saccharum*), Red Oak (*Quercus rubra*) and American Beech (*Fagus grandifolia*) (Maass *et al.* 1986). There is a single record of *P. lurida* on a conifer (White Spruce) at Five Islands Provincial Park in Nova Scotia where the lichen was recently observed. The habitat was very similar to that of the Codroy Valley Occurrence in Newfoundland (See Search Effort above). Furthermore, this site is very unusual because the spruces (when last examined by H. Harries in the 1990s) were also colonized by other cyanolichens, including *Collema subflaccidum*, *Lobaria pulmonaria*, *Pseudocyphellaria perpetua*, and *Sticta fuliginosa.*

In New Brunswick, at one occurrence, the wet mixed forest was dominated by *Thuja occidentalis*, *Acer rubrum* and *Fraxinus nigra*, with scattered *Abies balsamea* and *Picea mariana.* However, in neither this province nor Nova Scotia is *P. lurida* known to colonize *Thuja*, the only tree species on which it has been found on Prince Edward Island. About fifteen cedar swamp-forests have been intensively surveyed for lichens throughout New Brunswick (S. R. Clayden, unpubl. data). Although cyanolichens, including *Pannaria conoplea* and *P. rubiginosa* are frequently present on the trunks and (or) branches of *Thuja* in these stands, *P. lurida* is not among them. The stand age in New Brunswick and Nova Scotia is generally mature. At a few occurrences *P. lurida* are found in stands that range from pole to mature, and even a few that are over-mature. Sometimes large numbers of thalli are found on a single tree (Figure 5).The host tree stem size ranges from 8-50 cm dbh. The majority of the stems are between 12-23 cm dbh in the treed swamps, but larger (22-36 cm dbh) in the slightly better drained sites. The understory includes standing water, *Sphagnum* and moss cushions as well as shrubs such as *Ilex verticillata and Alnus incana* in the treed swamps. *P. lurida* can be found as the only cyanolichen on a host tree trunk or it may occur among a range of other species, most frequently *Lobaria pulmonaria, Lobaria quercizans, Collema subflaccidum/furfuraceum, Leptogium cyanescens, Pannaria conoplea, Pannaria rubiginosa and Pseudocyphellaria perpetua.*

In Prince Edward Island, the single known collection was from a mature cedar (*Thuja occidentalis*) stand (McMullin *et al.*, 2012). There is standing water throughout this stand and it is sheltered by a dense canopy and surrounding forest resulting in high humidity. The stand is contained within a mature mixed-wood forest that is drier and is composed of coniferous and deciduous trees. The cedar stand is located approximately 500 m from the coast. It is inhabited by many lichen species that are rare and sensitive on Prince Edward Island including: *Heterodermia speciosa, Leptogium saturninum, Menegazzia terebrata, Nephroma helveticum* ssp*. helveticum, N. laevigatum, Pannaria rubiginosa, Parmeliella triptophylla, Physconia grumosa, Protopannaria pezizoides*, and *Scytinium subtile. Pannaria lurida* was also in close proximity to *Lobaria pulmonaria, L. quercizans, Collema subflaccidum,* and *Leptogium cyanescens.*

In Newfoundland, *P. lurida* occurs on coastal headlands within 10 m from the cliff edge on the trunks or branches of White Spruce (*Picea glauca*) in conifer woods (Figure 6). Presumably, the exposure to salt neutralizes the pH of the conifer bark. The lichen grows mainly on the north side of the bole, with occasional thalli facing the ocean. The trees colonized by *P. lurida* had a dbh ranging from 4 to 21 cm. *P. lurida* was found on both the branches and boles of 14 trees. The stand was within 10 m of a sandstone cliff at an elevation of 39 m. The main stand has a wet seep and the forest floor is covered by feather mosses, especially *Rhytidiadelphus triquetrus*, as well as grasses but little in the way of ferns or other plants (Kissler, 2010; Ahti in Jørgensen 2000; Hanel pers. comm. 2014).

There are no details of the habitat of the Saint-Pierre et Miquelon specimen except that it was collected on Miquelon at Langlade on tree bark at Belle River, with *Ulota drummondii* and *Lobaria scrobiculata* (Delamare 1888).

Figure 5. Photo of *Pannaria lurida* growing luxuriantly on Red Maple near Chelsea, Nova Scotia. Other lichens associated with this lichen include *Lobaria pulmonaria* and *Pseudocyphellaria perpetua* (photo Troy McMullin).

Figure 6. *Pannaria lurida* and *Lobaria pulmonaria* growing on the trunks and branches of twisted wind-swept White Spruce (*Picea glauca)* at Hall's Farm in the Codroy Valley in Western Newfoundland (Photo Claudia Hanel).

Habitat Trends

In Nova Scotia over the last 10 years, suitable habitat for *P. lurida* has declined due to the harvesting of deciduous forest. In 1996, hardwood harvest was only about 6% of total wood harvest in Nova Scotia but by 2010, it was 15%. In terms of amount harvested, between 1990 and 2000 the annual hardwood harvest in Nova Scotia increased from 400,000 cubic metres to over 800,000 cubic metres (see Threats section). This resulted in a significant decrease in the amount of forest area with trees greater than 60 years of age (NSDNR 2008) which are the trees preferred by *P. lurida* as they are the ones with rough bark. Projections are that in future harvests, hardwoods will amount to 30% of the total, amounting to about 1,900,000 m^3 (Woodbridge Associates 2011).

It is important to assess if the amount of suitable habitat in Canada limits the occurrence of *P. lurida*. A logistic regression was developed to provide a predictive habitat model for *P. lurida*. Explanatory variables included thirty-year climate normals for annual precipitation and July temperature (from Environment Canada); elevation and distance from the coast (extracted from Atlas) GIS data, mean forest stand height, percentage hardwood, maturity class, cover type (deciduous, coniferous, mixed) and percent crown closure (extracted from NS and NB Department of Natural Resources GIS Forest Cover Data) and distance from the nearest wetland (derived from Department of Natural Resources GIS wetland database). Response variables were known locations of *P. lurida* for positive locations (n=26) and cyanolichen search locations that did not have *P. lurida* as negative locations (n=77).

The predictive habitat model was created using a backward stepwise procedure and then Moran's I test was performed to test for spatial autocorrelation of residuals. The residuals were not spatially autocorrelated and no adjustment was made. The area under the Receiver Operating Curve was 0.848 (AUC is a common metric of model performance with 0.5 being no better than random and 1.0 being a perfect fit). The model had Nagelkerke R^2 of 0.426 and a McFadden R^2 of 0.301. (P = 0.001). Elevation, annual precipitation, stand tree height and distance from a wetland were significant factors in predicting presence of *P. lurida*. Factors that were not significant in the model were July temperature, crown closure, % hardwood in the stand, stand maturity and cover type (hwd, swd, mwd). These are coded as binary data in the model whereas % hardwood is a continuous variable. The lack of significance with respect to the percentage hardwood may reflect limitations in the photo-interpretation. For example, if *P. lurida* occurs at sites where there is a low % hardwood, the photo-interpreter may not include hardwood as a stand component and sometimes confusion or misinterpretation can occur between tree species e.g., hemlock can be confused with hardwoods. There is no doubt that hardwoods are important when describing *P. lurida* habitat because this lichen lives on the bark of deciduous trees. However, it does seem that % hardwood, as assessed by the current available data, is not a good predictor of where *P. lurida* occurs. A confusion matrix indicated that the model correctly predicted presence of *P. lurida* when it actually occurred 58% of the time and correctly predicted absence 91% of time. The model showed that the ideal habitat (>90% probability of occurrence) occurs at elevations < 100 m, annual precipitation of 1400-1600 mm in stands with tree heights >14 m and within 1200 m of a wetland. There is about 4589 ha of predicted ideal habitat (> 90% probability of occurrence) in NS, which is about 0.0834% of province (Figure 7). There is about 391 ha of predicted ideal habitat in New Brunswick but none for PEI.

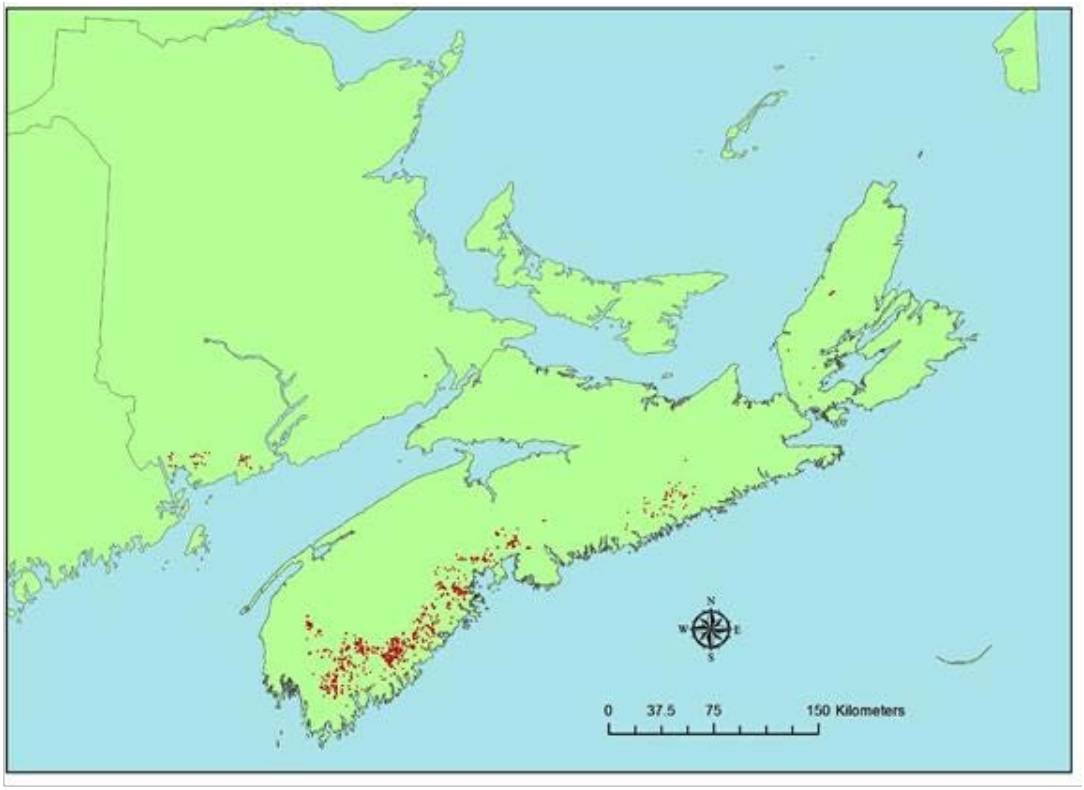

Figure 7. A map of the predicted *P. lurida* habitat in Maritime Canada. Red polygons indicate ideal habitat (>90% probability of occurrence). Note that the habitat is less abundant than appears on the map because the polygons have been enlarged so that they can be seen more clearly.

BIOLOGY

Life Cycle and Reproduction

Pannaria lurida reproduces by means of ascospores (Figure 8) which are ejected from apothecia that are common on thalli of this species (see Dispersal below). Once the apothecia are mature, spores are ejected and carried by wind and rain to new substrata, developing into new lichen only when they encounter a compatible *Nostoc* cyanobacterium.

The generation time for lichens varies from ten years in rapidly colonizing lichens such as *Xanthoria parietina* to more 17 years for old growth forest lichens such as *Lobaria pulmonaria* (Scheidegger & Goward 2002, Larsson & Gauslaa 2010). Since *Pannaria lurida* grows mainly in older forests, 17 yrs is a good estimate of generation time for this lichen.

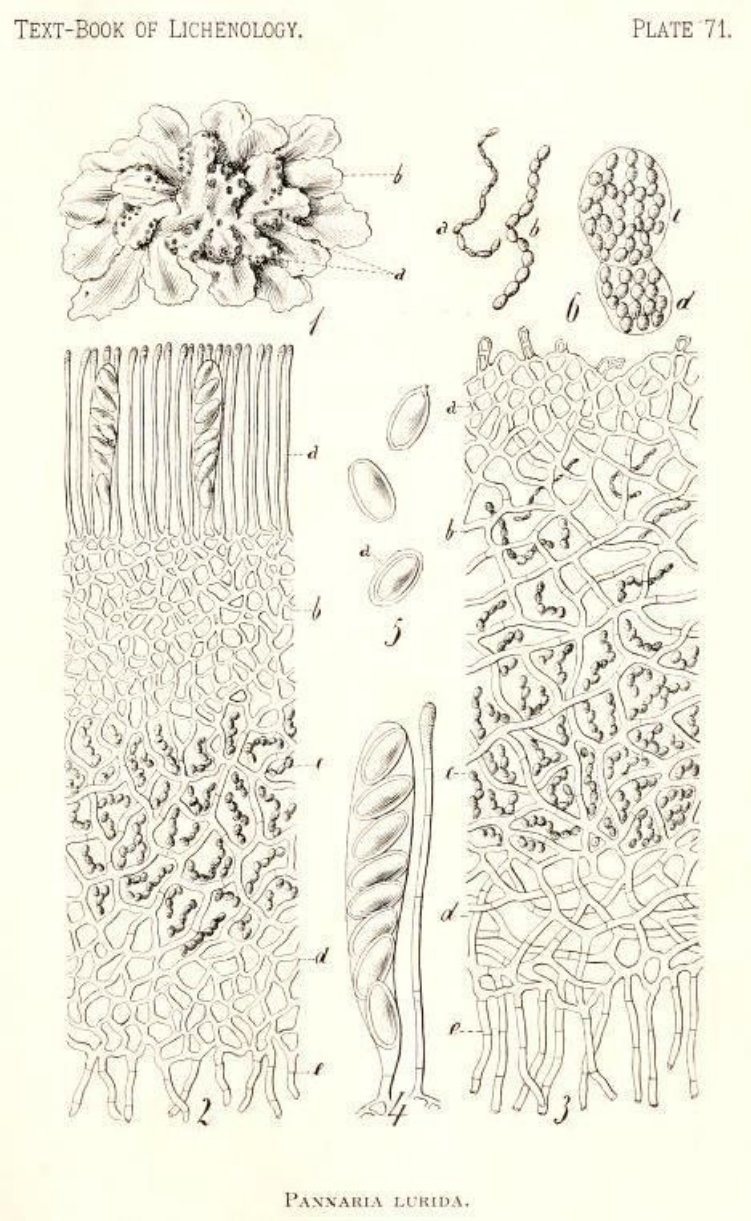

Figure 8. The structure and life cycle of *Pannaria lurida*. Note the simple ascospores, (in the centre) and the cyanobacteria in the thallus section (on the right) in which the chains are increasingly compressed towards the base of the photosynthetic layer of the thallus (Schneider 1897).

The *Nostoc* chains in *P. lurida* swell conspicuously when wet, so that under these conditions the thallus becomes quite gelatinous (Jørgensen 2000). The resultant increased water storage provides for an extended period of photosynthesis. The underside of *P. lurida* is connected to the substratum by dense and tangled rhizohyphae. Studies suggest that these enhance the rapid absorption of water (Rundel 1988).

Physiology and Adaptability

Pannaria lurida's cyanobacterial symbiont, *Nostoc,* provides the host with amino acids as a result of fixation of atmospheric nitrogen through a phosphate-dependent process. The diversity and abundance of cyanolichens can be enhanced by elevated levels of phosphate as was found after fertilizing a montane forest in Hawaii (Benner & Vitousek 2007). However, increased phosphate did not increase the rate of nitrogen fixation in individual species. *Nephroma helveticum* had the lowest nitrogen fixation rate, *Pseudocyphellaria crocata* the highest, and *Pannaria lurida* was in the middle (Benner & Vitousek 2012).

Factors like acid rain and sulphur dioxide pollution, which interfere with phosphate uptake, have the opposite effect, inhibiting nitrogen fixation (Nash, 2008) (See Threats below).

The lack of serious grazing by slugs and other gastropods (slight grazing damage was observed at 4 of 15 occurrences) may reflect the production of pannarin by this lichen. This is one of the secondary products found in lichens which have a broad range of functions (Rankovic, 2015).

The adaptability of individual subspecies *P. lurida* has not been studied.

Dispersal and Migration

Pannaria lurida has no specialized vegetative reproductive structures such as isidia or soredia. Fragmentation of thalli may provide very local dispersal on a tree although the rather thick thallus (generally 106 to 200µm thick) is probably not easily detached and blown off due to the mat of rhizohyphae. The main means of dispersal is via the ascospores (Figure 8), which are ejected a few cm into the air and can be carried by the wind a considerable distance. Production of apothecia at known occurrences appears to be common. At the occurrences where data were collected, six or more apothecia were recorded per thallus (22 trees) more frequently than thalli with less than six (8 trees). Spore production should thus be adequate for dispersal. However to form a new thallus, spores must encounter a viable, compatible cyanobacterium upon landing, and this must normally be on a tree trunk with suitable roughness and pH.

Interspecific Interactions

Lichens are subject to being colonized by lichenicolous fungi and although several are known from the genus *Pannaria*, none so far have been discovered on *P. lurida (*Hawksworth 1983; Ihlen & Wedin 2008; Lawrey and Diederich 2015).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Prior to the fieldwork in 2014, herbaria at the Nova Scotia Museum, the New Brunswick Museum, and Canadian Museum of Nature were consulted for specimens. In addition, the Consortium of North American Lichen Herbaria (online) together with members of the Tuckerman Workshop, and members of the lichen listserve were consulted to obtain records for the species, especially in North America.

Extensive fieldwork was carried out in the summer and autumn of 2014 by the writers of this report. The aim was to visit sites where the lichen *P. lurida* was known to occur and to look for potential habitat in areas where it might be expected, to examine the habitats and take photos to illustrate the habitats and document any threats. The abundance of the lichen at each visited site was assessed by counting thalli and recording the abundance of reproductive bodies using a standardized field form. Photographs of *P. lurida* thalli and specimens were collected. Some specimens have been lodged in CANL in Ottawa and others at NBM in Saint John.

Abundance

In Canada, the Wrinkled Shingle Lichen is known from 56 occurrences: 49 in Nova Scotia, four in New Brunswick, two in Newfoundland and one in Prince Edward Island. Surveys have failed to confirm that the lichen is still present on Prince Edward Island, at one occurrence in Newfoundland, and at two occurrences in New Brunswick.

Data on thallus numbers were collected from 11 occurrences (Table 2). An estimate of the total population of *P. lurida* in Canada is 4,583 mature individuals and was based on extrapolation of the enumerated occurrences (see below). This was done using the median number per tree. This is statistically more appropriate than using the average where the data are highly skewed (Baldi and Moore 2014). In the present case, there is one occurrence out of ten that is skewed by the estimated population of 2,446 thalli the other occurrence have 2, 7, 20, 40, 50, 73, 103,191, 248 thalli (see Table 2 and details below).

There was wide variation in the number of colonized trees and number of thalli at the various occurrences. *P. lurida* was found on one tree at four occurrences; the other occurrences had from two to more than 10 colonized trees. The numbers of thalli per tree range from a tree with a single thallus to two trees with a very large number. Generally there was a countable number of thalli on each tree but under very favourable conditions the thalli covered large areas of the tree trunk. The abundant lichens on these trees suggest either thallus fragmentation and re-attachment or the widespread colonization of trees that have compatible strains of *Nostoc* on the trunk surface.

Table 2. Estimated numbers of mature individuals at each of the enumerated occurrences of *Pannaria lurida*.

Province	Occurrence	County	Host	No of thalli	Revisited	Present
NB	*Clarke Point*	*Charlotte*	*Ash Poplar*	*50***	*N*	*Y*
NB	*Pomeroy Ridge*	*Charlotte*	*Ash*	*20*	*Y*	*Y*
NS	*Hardwoodlands*	*Lunenburg*	*Poplar*	*40*	*N*	*Y*
NS	*Chelsea*	*Lunenburg*	*Red Maple*	*3 trees covered by large patches (*1122 + 1290 + 34)*	*N*	*Y*
NS	*Grimm Road*	*Lunenburg*	*Red Maple*	*7*	*Y*	*Y*
NS	*Indian Falls*	*Lunenburg*	*Poplar*	*145 + three trees covered by large patches (34+15+54)*	*Y*	*Y*
NS	*West Clifford*	*Lunenburg*	*Red Maple*	*11 + 1 tree covered by a large patch (*180)*	*N*	*Y*
NS	*Medway*	*Queens*		*2*	*N*	*Y*
NL	*Codroy Valley Woodville*		*White Spruce*	*103*	*Y*	*Y*
NS	*Five Islands Prov Park*	*Colchester*	*White Spruce*	*2*	*Y*	*Y*
NS	Kejimkujik Ntl Park	Queens	Ash, Oak, Poplar	73	Y	Y

*Estimated number of thalli based an average thallus size of 5cm, an inter-thallus distance of one cm and the known DBH and height of coverage (see section on Abundance for details)

**Estimated number based on observations but not detailed enumeration

At three occurrences (on seven trees) in Nova Scotia, the thalli were so abundant that individual colonies could not be counted easily (Table 2, Figure 5). At Chelsea Road, there were three trees covered with lichen thalli. Two trees had DBHs of 20 and 23 cm and the lichen cover extended from ground to 5 m up the tree while a third tree with a DBH of 12 cm, was covered by a band of lichen that extended for 25 cm on the trunk. At Indian Falls, there were three trees with large lichen patches on them. At West Clifford the lichen was found on a tree with a DBH of 16 cm and *P. lurida* covered the bark from the ground up to one metre up.

Using an average thallus diameter of 5cm and an inter-thallus distance of 1 cm, the number of thalli on these trunks was estimated by dividing the area of tree bark covered (respectively 5,027; 31,420; 36,133; 94 and 2,894 cm^2) by 28 cm^2. This gave an estimated population of *P. lurida* at these three occurrences (Chelsea, Indian Falls and West Clifford) of 2,446,191 and 248 respectively (Table 2). When added to the other data the total *P. lurida* population at all enumerated occurrences is 3,180 thalli and the median number of thalli per occurrence is 61. If this figure is used to estimate the population at the 23 recent occurrences which were not revisited, then the population at these would amount to an additional 1,403 *P. lurida* thalli, for a total Canadian population of 4,583 mature individuals. Of this population about 100 thalli are from New Brunswick, 103 thalli from Newfoundland and the remainder from Nova Scotia. .As the lichen can be very abundant at some occurrences, and since the lichen was only enumerated at a small number of the more

recently discovered occurrences, the total population of *P. lurida* could be in excess of 10,000 mature individuals. For this reason changes in abundance were assessed from the decline in number of occurrences. Thus, this lichen species was found to be no longer present at 18 of 56 pre-1986 and more recent known occurrences. This amounts to a loss of 32%. The lost occurrences include one of two in Newfoundland and the one in PEI, two of the four occurrences known from New Brunswick, and the remainder in Nova Scotia. It is argued that this loss of occurrences has been accompanied by an equivalent % decline in the number of mature individuals.

Fluctuations and Trends

While 32 of the 56 known occurrences in Canada were found in the last decade as a result of increased lichen survey activity (Table 2) at least 18 occurrences are known to have been extirpated since the lichen was first discovered in Canada. Of the 24 older occurrences discovered in Nova Scotia before 1986, fifteen were revisited and the lichen was not found at 12. The lichen was also found to be absent at more recently discovered occurrences that were resurveyed: two in Nova Scotia, two in New Brunswick and one in Prince Edward Island.

Pannaria lurida was not re-found at two occurrences in Maine near the New Brunswick border which suggest that the loss of the two occurrences in New Brunswick may be part of a trend (Figure 4). *P. lurida* is a cyanolichen that was found historically in VT, MA, RI and CT but has not been seen since 1950, and is considered in danger of extirpation (Hinds & Hinds, 2007).

There are no known extreme fluctuations in the populations of *P. lurida*.

Rescue Effect

Unlikely because the nearest extant location is on Mount Desert Island, Maine, 200 km southwest of the closest suitable habitat at Pomeroy Ridge, New Brunswick, where there is currently an occurrence of *P. lurida*.

THREATS AND LIMITING FACTORS

Threats

Threats Calculator analysis indicated that the overall threat impact to *P. lurida* was “high to very high” (Appendix 1). The major current threat is logging and wood harvesting, resulting in both loss of host trees and disappearance of the imperfectly drained humid conditions that this lichen requires. Less serious threats are climate change, residential development, road construction, and air-borne pollutants. Further details of the threats faced by *P. lurida* are provided below and in Table 3.

Table 3. The habitat, threats and presence of *Pannaria lurida* at occurrences which were revisited. Most were discovered before 1986.

Occurrence & Name of finder & date of original discovery	Habitat	Presence of *Pannaria. lurida*	Threats: Observed or inferred	Ownership	Other cyanolichens found	*P. lurida* Host	Most recent Searcher and date
Prince Edward Island							
Pleasant View Cedars area, Troy McMullin, 2009	Cedar dominated woodland, Only found on a single cedar tree	Not Re-found	No clear threats		Various other rare lichens seen	NA	Troy McMullin
Newfoundland							
Codroy Valley, Teuvo Ahti, 1956	on mature but stunted *Picea glauca* at the very edge of the high sandstone sea-cliffs West of Millville, Codroy Valley, in western Newfoundland.	Healthy thalli		Private	*L. scrobiculata*, *L. pulmonaria*, *Leptogium cyanescens*, *Collema subflaccidum* and *Parmeliella triptophylla*	White Spruce	Emilie Kissler, 2010
Eel's Brook near Gros Morne National Park, Teuvo Ahti, 1978	a coastal in wind-exposed *Abies balsamea* wood behind sand dunes, elevation 6m.	Not re-found		National Park			Teuvo Ahti and Michele Piercey-Normore, 2014
New Brunswick							
Clark Point, St. Croix River, Charlotte County, Stephen Clayden, 2006 and 2007	Wet mixed forest dominated by *Thuja occidentalis*, *Acer rubrum and Fraxinus nigra*, with scattered *Abies balsamea* and *Picea mariana.*	Not Revisited		Within the Clark Point Protected Natural Area, Province of NB		Black Ash	Stephen Clayden, 2007
Pomeroy Ridge Stephen Clayden, 2008	Wet, open, hummocky forest of *Thuja occidentalis, Abies balsamea, Acer rubrum, Fraxinus nigra, Alnus incana* and *Ilex verticillata*, and a nearby wet area with these species and *Populus balsamifera*.	Healthy thalli		Private		Black Ash, Red Maple, Balsam Poplar	Stephen Clayden & Kendra Driscoll, 2014
North Chockpish River, south of Rexton, Wolfgang Maass, 1983	Very wet mixed *Thuja* forest, with *Abies*, *Acer*, *Fraxinus* (from specimen label)	Not re-found	The area has been heavily harvested. . Several areas were examined	Private	*Collema leptaleum, C. furfuraceum, L. cyanescens, L. pulmonaria* and *L. quercizans* NA	NA	Frances Anderson, 2014
Aboujagane Road, north of Sackville, Hinrich Harries & Wolfgang Maass, 1979	Moist *Abies*, *Picea*, *Acer rubrum* moss-herb forest near the edge of an *Alnus incana* swamp (from specimen label)	Not Re-found	In 2014, a long strip of mature wet woods flanked the road. Beyond this it had been harvested. Active forestry was occurring in the area.	Private	NA	NA	Frances Anderson, 2014
Nova Scotia							
Upper New Cornwall, Lunenburg Co, Wolfgang Maass, 1981	One site was the edge of a floodplain, facing south, along a brook running out of Caribou Lake. The cyanolichen flora was minimal. A second site further south had larger trees, and a wider range of cyanolichens,	Not Re-found	Despite the presence of mature maples and birches among conifers no sign of *P. lurida*.	Private	*(L. cyanescens, L. pulmonaria, L. scrobiculata.* Second site including *P. rubiginosa*, *Pannaria conoplea, Fuscopannaria ahlneri*	NA	Frances Anderson, 2014

Occurrence & Name of finder & date of original discovery	Habitat	Presence of *Pannaria. lurida*	Threats: Observed or inferred	Ownership	Other cyanolichens found	*P. lurida* Host	Most recent Searcher and date
Summerville, Queens Co Wolfgang Maass, 1981	A narrow swath of older trees fringed the road, indicating the kind of forest that had been there.	Not Re-found	Occurrence logged c.10 years ago and is now young growth.	Private	Cyanolichens present included *P. conoplea* and the *Lobaria* sp	NA	Frances Anderson, 2014
Kejimkujik National Park, Queens Co (2 occurrences) Wolfgang Maass 1981, 1982	A woodland with Oak, Ash and Poplar in hardwood-dominated wet flat areas along the dirt road to Georges Lake	Healthy thalli		National Park		Oak, ash and poplar	Troy McMullin & Frances Anderson, 2014
Greenfield, Queens, Co, Wolfgang Maass 1982	One side of road logged, the other mostly conifers in a wet area. *Lobaria* occurred on the few red maples in the wet area	Not Re-found	One side of the road to Greenfield logged c.5 years ago	Private	*Lobaria sp*	NA	Frances Anderson, 2014
Kempt, Queens Co Wolfgang Maass 1982	The woods did not look promising	Not Re-found	The woods did not look promising	Private		NA	Frances Anderson, 2014
Midway, Digby Co. Wolfgang Maass 1982	Lake Midway is 1.9 km long. Mature trees including maple and ash. A few cyanolichens were present in the road side stand at the swampy end of the lake	Not Re-found	The east end woods have been partially though there was still a substantial stand of trees	Private		NA	Frances Anderson, 2014
Lake Rossignol, Queens Co., N.S. Wolfgang Maass 1982	There were a few mature red maples on the cut side of the area in a small gully; the rest had been harvested.	Not Re-found	One side of the road was cut around 2005. The other side of the road is higher and drier, and White Pine dominated.	Former Bowater Mersey lands		NA	Frances Anderson, 2014
Medway River, Queens Co. Wolfgang Maass 1982	Varying amounts of woodland. Some is mature and some regenerating woodland.	Not Re-found	Little indication of forestry activity, but cottages and dwellings flank the road for 10+ kilometres	Private		NA	Frances Anderson, 2014
Gaetz Brook, near Scotts Lake Wolfgang Maass, 1982	The area was largely disturbed. While there are some older trees left, a subdivision was built some years ago	Not Re-found	A large portion of the former woodland has been completely cleared for what looks like a subdivision	Private		NA	Christopher Pepper, 2014
Porters Lake, Grande Lake off the #107 highway east of Halifax, Wolfgang Maass, 1982	Some intact older woodland but it was mostly coniferous. Many of the older deciduous trees had fallen over, probably during Hurricane Juan.	Not Re-found	The surrounding area was mostly burnt during a large wildfire in 2008 and a large clear-cut was observed	Private	A few common cyanolichens		Christopher Pepper, 2014
Murchyville northeast of Halifax, Wolfgang Maass, 1982	A small clump of deciduous trees were carefully examined. The site was likely good habitat at one time as there is a small brook and spring *pulmonaria* and *L. quercizans*.	Not Re-found	The area was mostly clear-cut and it appeared the lichens were suffering from desiccation	Private	A number of cyanolichens were present including *Collema subflaccidum, Leptogium cyanescens* as well as *Lobaria*		Robert Cameron, 2014
West Northfield, Lunenburg County Irwin Brodo 19??	The damp woodland was primarily conifers	Not Re-found	Much harvesting has occurred in the last ten years	Private		NA	Frances Anderson, 2014

Occurrence & Name of finder & date of original discovery	Habitat	Presence of *Pannaria. lurida*	Threats: Observed or inferred	Ownership	Other cyanolichens found	*P. lurida* Host	Most recent Searcher and date
Indian Falls, Lunenburg County Frances Anderson 2008	An open mostly flat wet area flanking a gravel road that leads to a municipal park called Indian Falls on the LaHave River	Healthy thalli on nine trees				Red Maple	Frances Anderson, 2014
South of Grimm Rd., Middle LaHave, Lunenburg County. 2008	Maple trees were nestled against a south-facing slope at the edge of a Black Spruce bog	Healthy thalli present	No sign of disturbance at the site or nearby.			Red Maple	Frances Anderson, 2014
McGowan Lake, Queens County Tom Neily, 2007		Not Re-found	Reconfiguring of roads and buildings in the area	McGowan Lake Fish Hatchery		NA	Frances Anderson & Troy McMullin, 2014

Logging and Wood Harvesting

Past forest harvesting has led to the disappearance of documented occurrences of *Pannaria lurida* in Nova Scotia and New Brunswick. Current forest harvesting has expanded to include harvesting for biomass production and woodchips, which has increased the amount of deciduous tree harvesting. Furthermore leases for future tree harvesting have recently been approved, covering extensive areas of southern and eastern Nova Scotia.

In Nova Scotia, *P. lurida* frequently inhabits habitats close to (but not necessarily in) imperfectly drained sites. Such sites are close to the edges of treed swamps and riparian floodplains, or at the base of moderate to steep slopes. As a result, these trees generally grow on drier ground and are more liable to be exploited for forestry than maple trees that grow within swamps (see Habitat section above). Removal of trees on which *P. lurida* grows reduces thallus numbers and affect the overall population. This is especially of concern for *P. lurida*, where individual trees are known to host >2400 thalli, or more that 50% of the thalli known in Canada. Cameron *et al.* (2013) concluded that forest harvesting adjacent to and within the landscape results in lower humidity. Clear felling can deleteriously affect *P. lurida* populations but if harvest activities are localized, and in a suitable orientation, they can be tolerated by the lichen (see Transportation and Service Corridors).

Forest harvesting for pulp, lumber, firewood and biomass is currently ongoing in Nova Scotia. Total timber harvest between the early 1980s and the mid-2000s has steadily increased, peaking in 2005 at 6.9 million m^3. It then decreased to 4.1 million m^3 by 2009 (Woodbridge Associates 2011) and to 3.6 million by 2014 (Province of NS 2015). This trend is reflected in both the softwood and hardwood harvest levels individually. Hardwood harvest peaked in 2004 at about 890,000 m^2 and declined to a ten-year low of 474,000 m^2 in 2011 (NSDNR 2012). However, hardwood harvest was predicted to increase (Woodbridge Associates 2011). Since 2011, there has indeed been a steady increase in the annual harvest of hardwood to 705,000 m^2 in 2014 (Province of Nova Scotia 2015).

The Annual Allowable Cut (AAC) for hardwood in Nova Scotia in 2005 was assessed as just under 2,000,000 m^3 (NSDNR 2008). Although hardwood harvest has been well below the AAC, past harvesting and the current rate of hardwood harvesting has the potential to have a serious impact on the habitat of *P. lurida* in the province (see also Habitat Trends section). In particular, there has been a decline in forest age classes greater than 61 years (Figure 4 NSDNR 2008), which is of concern because at least 50 years is likely required before regenerating trees offer the mature bark substrate that is required by *P. lurida*. In addition, Northern Pulp has recently requested access to an additional 500,000 green metric tonnes of fibre from Crown land in southern Nova Scotia, where *P. lurida* is frequent. To date, the government limited them to a previously agreed additional 125,000 green metric tonnes (Gorman & Zaccagna 2014). The remainder will likely come from private woodlots. Many of the sites on which *P. lurida* occurs or has the potential to colonize are in private woodlots in this area, so there is the potential for a serious impact on the populations of this lichen.

In New Brunswick, there has been a decline in the amount of old hardwood forests of about 20% between the 1980s and the present. This is based on an analysis of forest inventory data on Crown land and small private freehold forests which together make up more than 80% of forested lands in the province (NB DNR unpubl. data). Strip-cutting of late-successional, uneven-aged, shade-tolerant hardwood forests has been occurring and second-entry selection cuts are starting to take place, so negative effects are likely to increase (Clayden 2014). Although harvesting of old hardwood forests in New Brunswick is occurring mainly in mesic, upland sites, known or potential occurrences of *P. lurida* on wet sites are also being affected. Three of the four known occurrences are (or were) on hardwoods in openings or along the margins of white cedar (*Thuja occidentalis*) swamp-forests. This community type has been surveyed extensively for lichens in the Maritime provinces and Gaspésie (Clayden *et al.* 2011 and unpubl.). The other NB occurrence of *P. lurida* was in a mixed wet forest, lacking *Thuja*; this locality and one of the cedar swamp localities, both in eastern New Brunswick, were logged or disturbed by nearby logging in the years following their discovery. Attempts to relocate *P. lurida* at these localities in 2014 were unsuccessful (F. Anderson, pers. comm. 2014)

Climate Change

Climate change and its expected increase in summer temperature, coupled with periods of heavy rain interspersed with drought, could affect all populations of this lichen in Nova Scotia. A reduction in fog frequency may particularly affect occurrences in Shelburne County. These changes in the moisture regime are a likely threat *to P. lurida*. This lichen seems to be restricted to habitats that are generally moist (See Habitat section above). These occurrences are mostly above the fog lines, with the exception of many of the Shelburne County occurrences on the Atlantic coast of Nova Scotia, south of Halifax.

Bioclimatic models are commonly used for assessing species' responses to climate change. BIOCLIM is a well published bioclimatic model that was used to characterize current suitable and potential future climate for *P. lurida*. BIOCLIM summarizes up to 35 climatic parameters within a species' known range and assesses the climatic suitability of current and future climate (Beaumonta *et al.* 2005). Five degree world climate data were used from Hijmans *et al.* (2005) in DIVA-GIS software for the modelling. The future climate scenario for Eastern North America was a 2^{o}C increase in mean annual temperature and a 10% increase in annual precipitation (Govindamsay *et al.* 2003).

BIOCLIM modelling suggests the greatest current suitable climate is in the USA. In eastern Canada, Nova Scotia has the greatest area of suitable climate with marginal climate in Prince Edward Island and only little suitable climate in New Brunswick and Newfoundland. Future climate scenarios (100 year projection) suggest the area of suitable climate in the USA, Nova Scotia and PEI will greatly diminish. Some increase in low- and medium-suitability climate is predicted for northern Nova Scotia and Newfoundland (Figure 9).

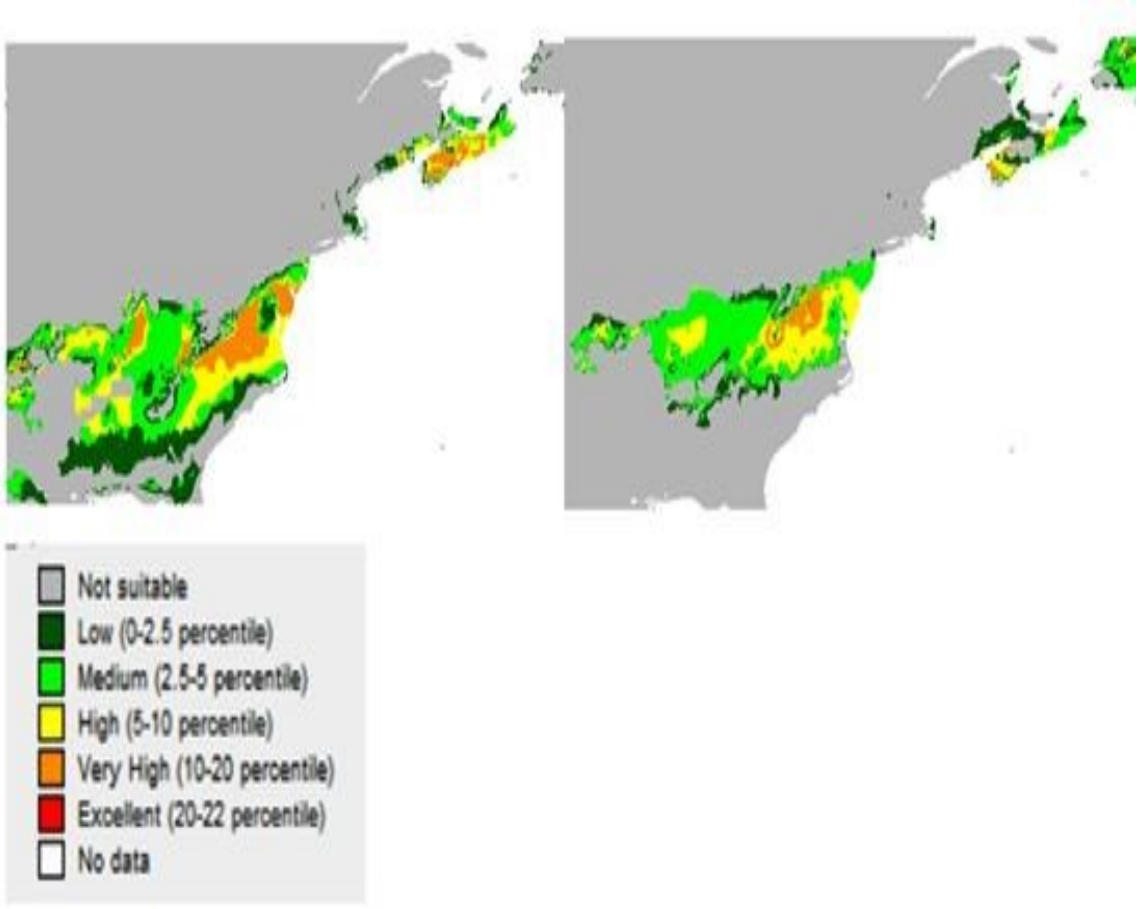

Figure 9. Current (left) and future (100 years ahead) (right) climate suitability for *Pannaria lurida* in Eastern North America using BIOCLIM modelling.

Air-borne Pollutants

Cyanolichens are extremely sensitive to sulphur dioxide air pollution and acid rain (Richardson & Cameron 2004; Cameron & Richardson 2006). Trans-boundary air pollution is still affecting Atlantic Canada. The 2004 Canadian Acid Deposition Science Assessment results indicate that even though total acid deposition has declined in eastern Canada (CCME 2013), large areas in southern New Brunswick and southern Nova Scotia will continue to receive levels of acid deposition (CCME 2008). This applies particularly to southern Nova Scotia and the eastern shores of Nova Scotia and New Brunswick, where *P. lurida* occurs. Ongoing acid precipitation in these areas could overcome the buffering capacity of the tree bark, making it unsuitable for colonization or growth of this lichen, or for the growth of its obligate cyanobacterium partner. Tree bark has an inherent buffering capacity, with maple having a greater buffering capacity than coniferous trees. Continued exposure to acid rain eventually results in the buffering capacity being exceeded and the substratum can quickly become too acid for sensitive cyanolichens. Juvenile thalli are particularly vulnerable to this chemical threat (Nieboer *et al.*1984)

Residential and Commercial Developments

A number of the *P. lurida* occurrences, especially in Lunenburg Co., are in areas that are suitable for cottage and housing development, as they are attractive and close to roads. The disappearance of *P. lurida* from Gaetz Brook in Halifax Co. is thought to have resulted from both new road construction and housing. A further larger proportion of the woodland has been cleared for an apparent subdivision expansion. Another occurrence in the Medway River area, Queens Co., is in an active area for cottage construction.

Transportation and Service Corridors

The construction of roads for wind farms, mining and residential developments results in tree removal and changes in moisture regimes that threaten *P. lurida.* This is especially true when it involves drainage and changing humidity in nearby woodlands that support or could support *P. lurida*. Road construction related to fracking and related activities are another threat, but fracking is currently on hold in both Nova Scotia and New Brunswick. Once a road has been constructed and provided that changes in the moisture regime have not led to the loss of the lichen, road traffic itself does not seem to be a threat to *P. lurida*. Sometimes edge effects can lead to the loss of lichens. The impact of road construction on the moisture regime of nearby trees depends on several factors such as the orientation of the road with respect to the sun and prevailing winds. For example, the disappearance of the Gaetz Brook occurrence seems to be the result of extensive construction of roads and opening up the area for a subdivision extension. On the other hand, the Chelsea occurrence, which has abundant thalli of *P. lurida,* is 20 m from a paved, two-lane road that has been in use by lumber trucks and regular traffic for at least fifty years. Similarly, the West Clifford occurrence also has abundant thalli and is less than 20 m from Highway 325, a regular route into and out of Bridgewater.

Number of Locations

The key threats leading to the disappearance of this lichen are loss of mature forest due to forest harvest activities, climate change and air pollution. No single threatening event is likely to concurrently affect more than one occurrence at a time. Thus, the number of locations is best assessed as the total number of known occurrences, which is 56. Although some occurrences documented in the past may have disappeared, there are probably undiscovered occurrences, particularly in Nova Scotia. The number of occurrences yet to be documented is unlikely to be more than the current number, so the best estimate of the maximum number of locations is <100.

PROTECTION, STATUS AND RANKS

Non-Legal Status and Ranks

Global

Global Status: G3 (Vulnerable) to G5 (Secure)
Global Status Last Reviewed: 11 Dec 2000
Global Status Last Changed: 21 Jan 2001
Rounded Global Status: G4 (Apparently Secure) (NatureServe 2014)

USA

National Status: NNR (Unranked)
North Carolina: SNR, Pennsylvania: SNR (Not Yet Assessed)

Canada

National Status: NNR (Unranked)
Quebec: SNR (Not Yet Assessed)

Habitat Protection and Ownership

In Nova Scotia, two occurrences are protected in Kejimkujik National Park, another in Five Island Provincial Park, a fourth in a municipal Common, and a fifth in a provincial Nature Reserve. In New Brunswick, one occurrence at Clark Point is in a Protected Natural Area. All other occurrences in Canada are on Crown or private land. With the exception of those in New Brunswick, none have formal protection. In New Brunswick, buffers of at least 30 m are required on all wetlands and watercourses (*NB Clean Water Act, NB Crown Lands* and *Forest Act*). In addition, the maintenance of habitat for wildlife species is a requirement of Crown forest management (*NB Crown Lands and Forest Act*). Area targets and stand/landscape descriptions have been developed for Old Tolerant Hardwood Habitat, and Old Mixedwood Habitat. Forest management plans since 1992 include the spatial

identification of area to meet habitat targets in appropriate stand and landscape configurations.

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David Richardson is Dean Emeritus at Saint Mary's University. He has studied lichens since 1963 and as sole author written two books on lichens: The Vanishing Lichens and Pollution Monitoring with Lichens. He has also completed over twenty book chapters and 100 research papers on various aspects of lichenology. He has studied lichens in Australia, Canada, Ireland and the United Kingdom.

Frances Anderson is a Research Associate at the Nova Scotia Museum of Natural History, Halifax. She has been carrying out fieldwork on lichens in Nova Scotia for more than eight years and has extensive experience in doing field inventories. She has produced a macrolichen checklist for the province, which is available on the NS Museum website under Curatorial Reports.

Robert Cameron has been studying lichens for over ten years beginning with a Master's degree in Biology at Acadia University studying the effects of forestry practices on lichens. More recently, Mr. Cameron has been studying the effects of air pollution on lichens, coastal forest cyanolichens and more specifically boreal felt lichen. He is currently the ecologist with Protected Areas Branch of Nova Scotia Environment and Labour, responsible for the protected areas research program.

Stephen Clayden is Curator of the Botany and Mycology Section at the New Brunswick Museum. He became interested in lichens as a student at Mount Allison University, and investigated the dynamics of lichen-rich communities in northwestern Quebec for his M.Sc. at the Université de Montréal. His Ph.D. research at Kings College, London, U.K, was on the life histories of *Rhizocarpon* species. He has studied lichens widely in Atlantic Canada and Quebec and co-authored *The Rare Lichens of Canada: A Review and Provisional Listing* with Trevor Goward and Irwin Brodo

Christopher Pepper is a naturalist who has been working with the Mersey Tobeatic Research institute for more than two years assisting with the Boreal Felt Lichen project.

Troy McMullin is a postdoctoral fellow at the University of Guelph. He began studying lichens in 2004 during his Master's at Dalhousie University, where he examined lichens in old-growth Acadian forests. During his PhD and currently he has been examining the conservation and management of lichens in Ontario's boreal forest. As a consultant, Troy regularly works with a variety of organizations doing lichen inventories and ecological monitoring with lichens. His lichen studies have ranged from California and Haida Gwaii to the Maritimes and the Everglades. Troy is also the lichen collections manager at Biodiversity Institute of Ontario Herbarium.

COLLECTIONS EXAMINED

Canadian Museum of Nature, Ottawa

The Consortium of North American Lichen Herbaria CNALH

(http://lichenportal.org/portal)

Herbier Louis-Marie, Université Laval, Québec City

The Nova Scotia Museum, Halifax

The New Brunswick Museum, Saint John

Appendix 1. Threats calculator for *Pannaria lurida.*

Species	*Pannaria Lurida*
Date:	27/07/2015
Assessor(s):	Members: Dwayne Lepitzki (moderator), Rene Belland (M&L SSC Co-chair), David Richardson (M&L SSC Co-chair & report writer), Mary Sabine (NB) External Experts: Frances Anderson (report writer), Troy McMullin (report writer), Robert Cameron (Lichen SSC member & report writer)

Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	1	0
B	High	0	1
C	Medium	3	0
D	Low	2	5
Calculated Overall Threat Impact:		Very High	High

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	A number of occurrences are close roads and in areas suitable for building lots and residential developments, especially in Lunenburg. The disappearance from Gaetz Brook in Halifax is thought to have resulted from both new road construction and housing. A further larger proportion of woodland at this occurrence has been cleared for an apparent subdivision expansion. Another occurrence in the Medway River area, Queens Co, is in an active area for cottage construction.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
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%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Most of the fracking would probably occur in Northern NS and probably be negligible. Fracking is included in roads and railways.
3.2	Mining & quarrying						
3.3	Renewable energy						
4	Transportation & service corridors	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	The construction of roads for wind farms, mining and developments with the consequent tree removal and changes in moisture regimes would affect the lichen. Fracking related activities and road construction could also have an impact but is currently under an embargo.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	AB	Very High - High	Pervasive - Large (31-100%)	Extreme - Serious (31-100%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting	AB	Very High - High	Pervasive - Large (31-100%)	Extreme - Serious (31-100%)	High (Continuing)	Past forest harvesting has led to the disappearance of documented occurrences of *Pannaria lurida* in Nova Scotia and New Brunswick. Current forest harvesting has expanded to include harvesting for biomass production and woodchips which has increased the amount of deciduous tree harvesting. Furthermore leases for future tree harvesting have recently been approved which cover extensive areas southern and eastern Nova Scotia. Scope: range denoted for uncertainty * Information from NB suggests that severity is closer to 30% for that province and there may be more sites to be discovered. However most occurrences for this lichen are in on NS which resulted in the assigned wide range. The impact in NS will be much higher especially since the gov't just approved additional leases for harvesting. This lichen is more sensitive to changes in microclimate than the Black Foam Lichen.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.3	Work & other activities		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Lichen collection for scientific study
7	Natural system modifications						
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes						Very little slug damage has been reported for this species by either alien slugs or native slugs
8.1	Invasive non-native/alien species						
8.2	Problematic native species						
8.3	Introduced genetic material						
9	Pollution	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Acid rain may overcome the buffering capacity of the deciduous host tree bark making it unsuitable for the growth of cyanolichens, or for the growth of the cyanobacterium which has to be present for the fungal spores to associate with in each generation to form a new lichen. Severity: range denoted for uncertainty * closer to the 30% * acid rain is important for this lichen as the population is greatest in the southern portions of Nova Scotia, closer to the sources of this pollutant. There is less precipitation inland but the acid rain is still a factor.
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11	Climate change & severe weather	CD	Medium - Low	Restricted (11-30%)	Moderate - Slight (1-30%)	Moderate - Low	The expected increase in summer temperature coupled with periods of heavy rain interspersed with drought could affect all populations of this lichen in Nova Scotia while a reduction in fog frequency may particularly affect occurrence in Shelburne county. Models suggest area of suitable climate may increase slightly in New Brunswick, Cape Breton and Newfoundland. Combination of 11.1 - 11.4 * On a world-wide basis, the species appears to be quite adaptable and occurring in a number of different habitat * models show that climate change is probably bad for the lichen, but in the long term, climate change model suggest that suitable habitat may increase
11.1	Habitat shifting & alteration						
11.2	Droughts						
11.3	Temperature extremes						
11.4	Storms & flooding						