COSEWIC
Assessment and Status Report

on the

Scaly Fringe Lichen
Heterodermia squamulosa

in Canada

THREATENED
2022

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. 2022. COSEWIC assessment and status report on the Scaly Fringe Lichen *Heterodermia squamulosa* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 54 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Production note:
COSEWIC would like to acknowledge Alain Belliveau for writing the status report on the Scaly Fringe Lichen *Heterodermia squamulosa* in Canada, prepared under contract with Environment and Climate Change Canada. This report was overseen and edited by David Richardson, Co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment and Climate Change Canada
Ottawa, ON
K1A 0H3

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: ec.cosepac-cosewic.ec@canada.ca
www.cosewic.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur l'Hétérodermie squamuleuse (*Heterodermia squamulosa*) au Canada.

Cover illustration/photo:
Scaly Fringe Lichen — Photograph by Alain Belliveau.

Catalogue No. CW69-14/826-2023E-PDF
ISBN 978-0-660-48475-4

COSEWIC
Assessment Summary

Assessment Summary – December 2022

Common name
Scaly Fringe Lichen

Scientific name
Heterodermia squamulosa

Status
Threatened

Reason for designation
Within Canada, this lichen only occurs only in Nova Scotia and New Brunswick on old undisturbed hardwood or mixedwood forests without signs of past forest harvesting. The small Canadian population (less than 550 thalli on 145 known host trees) is projected to decline as a result of threats. These include forest harvesting, road construction, and residential development that lead to the loss of host trees or open the forest canopy that makes the habitat unsuitable for the lichen. In addition, air pollution, and the Emerald Ash Borer are other factors that are likely to contribute to the projected decline.

Occurrence
New Brunswick, Nova Scotia

Status history
Designated Threatened in December 2022.

COSEWIC
Executive Summary

Scaly Fringe Lichen
Heterodermia squamulosa

Wildlife Species Description and Significance

Scaly Fringe Lichen (*Heterodermia squamulosa*) is a rare lichen that grows on the bark of hardwood trees in old forests, which are now rare in Atlantic Canada. This leafy lichen usually has small pale grey lobes and numerous upright lobules. The disc-shaped fruiting bodies (apothecia) have only been found once in Canada and once in the USA, being extremely rare in North America.

Aboriginal (Indigenous) Knowledge

All species are significant and are interconnected and interrelated. There is no species-specific ATK in this report.

Distribution

Scaly Fringe Lichen has a disjunct global distribution across North, Central and South America, and also occurs in Africa and Asia. The global population is primarily concentrated in the southern and central Appalachians of the USA. In Canada, this lichen is at the northern, colder limit of its range. It is found mainly in Nova Scotia but is also known in New Brunswick.

Habitat

In Canada, Scaly Fringe Lichen is only found within 50 km of the coast and lives almost exclusively in old hardwood or mixedwood forest with no obvious signs of past forest harvesting. It is found on living Yellow Birch, Sugar Maple, Red Maple, and White Ash trees that grow on reasonably nutrient-enriched soils in both wetland and upland habitats.

Biology

Lichens are symbiotic organisms, formed by the association of a fungus and a photosynthetic green alga or cyanobacterium. Scaly Fringe Lichen is a symbiosis between the *Heterodermia squamulosa* fungus and *Trebouxia*, a green alga. The generation time for Scaly Fringe Lichen individuals is thought to be 19 years. The lichen's primary means of reproduction is by vegetative lobules, which are relatively heavy, or thallus fragments, which means that dispersal is mostly limited to short distances (i.e., within a forest stand). The species very rarely forms fruit bodies in North America.

Population Sizes and Trends

Scaly Fringe Lichen occurs in Nova Scotia and New Brunswick, where 31 occurrences have been found. These occurrences form 14 subpopulations. The enumerated population is 515 thalli growing on 145 trees. The occurrence at Cape Split (Scots Bay subpopulation) comprises approximately 50% of all the known thalli on about 50% of the colonized host trees. While more than 73 previously-undocumented thalli and 31 previously-unknown host trees were discovered in the extensive 2019-2020 surveys that were done in association with this report, the total known number of thalli is still small. The total population in Canada is estimated to be fewer than 1000 thalli. Overall, as a result of the threats described below, the population appears to be in decline at sites where re-measurements exist.

Threats and Limiting Factors

The main threats to Scaly Fringe Lichen are the harvesting of host trees and the construction of roads leading to habitat disruption. Other threats that affect the Scaly Fringe Lichen or its host trees include climate change, air pollution (particularly acid rain), the invasive Emerald Ash Borer, and land development. The limiting factors for this lichen include short dispersal distance, a limited amount of suitable habitat and being, in Canada, at the northern edge of its climatic and geographic range.

Protection, Status and Ranks

Scaly Fringe Lichen has a global rank of G3G5 (Vulnerable to Secure), a national rank of N3 (Vulnerable), a New Brunswick rank of S1 (Critically Imperiled), and a Nova Scotia rank of S3 (Vulnerable). It has a status of SNR (unranked) in Quebec, where the lichen was reported in the past, based on an incorrectly identified specimen that was a different species. Approximately 32% of Scaly Fringe Lichen host trees in Canada currently occur within protected areas.

TECHNICAL SUMMARY

Heterodermia squamulosa

Scaly Fringe Lichen

Hétérodermie squamuleuse

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

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)	19 years (see **Biology – Life Cycle and Reproduction**)
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, inferred and projected; on the basis of declines in host trees mainly as a result of forest harvesting (see **Fluctuations & Trends; Threats**).
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years]	Data are not available to estimate, with confidence, the percentage decline in the number of mature individuals. However, the decline is estimated to be about 18% over 5 years (see **Fluctuations and Trends**).
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Uncertain, but the decline based on the reduction in colonized trees over the last 10 years is estimated to be 36% (see **Fluctuations and Trends**).
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	A projected decline over three generations is > 50% based on the projected reduction in number of colonized host trees over next 57 years (see **Fluctuations and Trends**).
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any period [10 years, or 3 generations, whichever is longer up to a maximum of 100 years], including both the past and the future.	Observed and inferred reduction over the past 10 years and projected for a further two generations is > 50% (see **Fluctuations and Trends**).
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. b. Yes, most causes are understood. c. No, not all causes have ceased.
Are there extreme fluctuations in number of mature individuals?	No.

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	33,848 km² (~8,000 of this is ocean)
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. Unknown. b. Yes, very likely.
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	29 based on stand related threats. (31 known occurrences, but two are no longer extant; see **Number of Locations**.)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, observed and projected decline based on loss of occurrences in NB has made the EOO smaller.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, observed and projected decline in index of area of occupancy based on loss of occurrences in NB, and projected declines in colonized host trees.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, projected, as four of 14 subpopulations have < 10 mature individuals and face forestry and other threats and there has been a loss of the Grand Bay-Westfield occurrence.
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Projected, based on threats and observed losses.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, there is an observed and projected reduction in area, extent and quality of habitat. (See **Habitat**.)
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 for more information on this term.

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	No. Host Trees	No. Mature Individuals (No. Thalli)
NB-01 Grand Bay-Westfield	1	1
NB-02 Fundy NP	6	24–28
NS-01 Cape Chignecto PP	3	5–13
NS-02 Scots Bay	81	253–255
NS-03 Lily Lake	2	5
NS-04 Digby	11	11–33
NS-05 Saint Joseph	1	2
NS-06 Hectanooga	9	17–25
NS-07 Tusket River	8	19–21
NS-08 Four Mile Stillwater	1	12
NS-09 Kempt	1	3
NS-10 Shingle Lake	14	83–102
NS-11 Upper LaHave	3	5
NS-12 Spider Lake	4	10
Total estimated population of thalli and colonized host trees at the known subpopulations in NS and NB.	145	450–515
The total population of mature individuals of *H. squamulosa* at known occurrences and those that could occur in the remaining small amount of suitable undisturbed habitat is estimated as < 1000 mature individuals (see **Abundance**).		<1000

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, 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.

Overall threat impact was high

- 4. Transportation & Service: Road Building: **medium impact** (4.1 Roads & railroads)
- 5. Biological Resources: Logging and Wood Harvesting: **medium impact** (5.3 Logging and wood harvesting)
- 9. Pollution: Acid Rain: **medium-low impact** (9.5 Air-borne pollutants)
- 1. Residential & Commercial Development: **low impact** (1.1 Housing & urban area)
- 7. Natural System Modifications: fires and deer: **low impact** (7.1 Fire & fire suppression)
- 8. Invasive & Problematic Species: **low impact** (8.1 Invasive non-native/alien species/diseases)
- 11. Climate Change and severe weather: **unknown impact**

What additional limiting factors are relevant?

- Limited dispersal via thallus lobules
- Northern edge of the range of this lichen

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The Canadian population is ~100 km from the nearest next occurrence in Maine, where it is reported to be rare.
Is immigration known or possible?	Highly unlikely; short-distance dispersal is the norm for this lichen.
Would immigrants be adapted to survive in Canada?	Probably.
Is there sufficient habitat for immigrants in Canada?	Probably, but only if forestry activity is reduced.
Are conditions deteriorating in Canada?+	Yes (see **Habitat**).
Are conditions for the source (i.e., outside) population deteriorating?+	Likely, as few occurrences have been found recently in Maine or nearby US states where there have been declines in old forest (see **Population Spatial Structure and Variability**).
Is the Canadian population considered to be a sink?+	No.
Is rescue from outside populations likely?	Highly unlikely.

Data Sensitive Species

Is this a data sensitive species?	No.

Status History

COSEWIC Status History: Designated Threatened in December 2022.

Status and Reasons for Designation

Status Threatened	**Alpha-numeric codes:** C2a(i); D1
Reasons for designation: Within Canada, this lichen only occurs only in Nova Scotia and New Brunswick on old undisturbed hardwood or mixedwood forests without signs of past forest harvesting. The small Canadian population (less than 550 thalli on 145 known host trees) is projected to decline as a result of threats. These include forest harvesting, road construction, and residential development that lead to the loss of host trees or open the forest canopy that makes the habitat unsuitable for the lichen. In addition, air pollution, and the Emerald Ash Borer are other factors that are likely to contribute to the projected decline.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): May be close to meeting the threshold for Endangered, A3acde, as there is a suspected reduction in the total population over the next three generations, but there is current uncertainty as to the magnitude of the projected decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. The IAO is 120 km², but EOO exceeds 20,000 km², and there are > 10 locations. Although there is a projected decline in the population, the species is not severely fragmented and does not experience extreme fluctuations in IAO, EOO, locations, subpopulations or number of individuals.

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

Criterion C (Small and Declining Number of Mature Individuals): Meets Threatened, C2a(i), as there are < 10,000 mature individuals and no subpopulation has > 1000 individuals. In addition, there is an inferred and projected decline in the number of mature individuals.
Criterion D (Very Small or Restricted Population): Meets Threatened, D1, as the population is estimated to be < 1000 mature individuals.
Criterion E (Quantitative Analysis): Not applicable. Analysis not conducted.

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
(2022)

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.

COSEWIC Status Report

on the

Scaly Fringe Lichen
Heterodermia squamulosa

in Canada

2022

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Heterodermia squamulosa* (Degel.) W.L. Culb.

Original Description: *Anaptychia squamulosa* Degel.

Synonyms (GBIF 2020, Mongkolsuk *et al.* 2015):
Polyblastidium squamulosum (Degel.) Kalb
Anaptychia squamulosa Degel.

English vernacular name: Scaly Fringe Lichen

French vernacular name (Fournier 2006): Hétérodermie squamuleuse

Aboriginal names: [unknown in Canada]

Genus: *Heterodermia*

Family: Physciaceae

Order: Caliciales

Class: Lecanoromycetes

Phylum: Ascomycota

Kingdom: Fungi

Morphological Description

Heterodermia squamulosa (Scaly Fringe Lichen) is a pale-grey to blue-grey foliose lichen (Hinds and Hinds 2007; Lendemer 2009). Thalli typically reach 5 to 12 cm in diameter, while lobes are 0.2 to 1.2 mm wide. Fine, often upright lobules (phyllidia/squamules) usually populate the lobes, especially near the thallus center. Tips or entire lobules can break down or develop into tiny squamules. The medulla is white, and the underside is purple pigmented centrally and lacks a cortex, while the rhizines are dark, squarrose or tufted and located along lobe margins (Brodo *et al.* 2001).

Apothecia on *H. squamulosa* have not been found in North America (Brodo *et al*. 2001; Moberg 2011), except for one specimen from Giles County, Virginia, USA, (Culberson 223954 Duke) and one recent find in Digby County, Nova Scotia, Canada, by Alain Belliveau (see left centre of cover photo). However, in South Korea, apothecia are more common, occurring on the surface of the lamina and being sessile, dark reddish brown, and 1–4 mm in diameter (Wang *et al.* 2008). This description matches that of the apothecia recently found in Nova Scotia.

Heterodermia squamulosa is the only member of the genus in eastern North America that disperses almost exclusively via lobules or thallus fragments (see **Life Cycle and Reproduction**). Fruit bodies (apothecia) have only been found once in Canada (see above). Their absence makes this species more easily identified in the field. Immature or damaged specimens can lack lobules, but in such cases the ecorticate and purple-pigmented undersurface, as well as chemistry, can be used for identification.

The photobiont partner of *H. squamulosa* is a species of *Trebouxia* (Trebouxiophyceae) green alga (Brodo *et al.* 2001; Nash *et al.* 2002; Hinds and Hinds 2007).

Chemistry

Secondary metabolites of *H. squamulosa* include atranorin, zeorin, leucolytin, and norstictic acid (Lendemer 2009). Atranorin in its cortex results in a yellow reaction with a spot test of K (potassium hydroxide) and with PD (para-phenylenediamine). The zeorin and other terpenoids found in the medulla can be detected with thin layer chromatography (TLC). All other standard diagnostic spot tests and UV reactions are negative.

Population Spatial Structure and Variability

Heterodermia squamulosa is known in Canada from southern New Brunswick and mainland Nova Scotia. To date, 31 occurrences (see **Canadian Range**) are known (Table 1). Approximately 95 km is the largest gap between two adjacent occurrences in Canada, with all other occurrences being within 60 km of another (AC CDC 2020).

Outside of Canada, the nearest occurrences are in Maine, USA, (Figure 1) where only five occurrences are known (Hinds and Hinds 2007; Seaward *et al.* 2017; Hinds 2020). The nearest of these Maine occurrences, on Roque Island, is about 100 km from the occurrence in Welsford, New Brunswick. There is also one occurrence in New Hampshire, USA, (Clyne 246-16 CUP; Cleavitt pers. comm. 2020), with the next closest site being in Pennsylvania, USA, (Lendemer 37763 NY), approximately 500 km away from the New Hampshire site and 950 km away from Canadian occurrences.

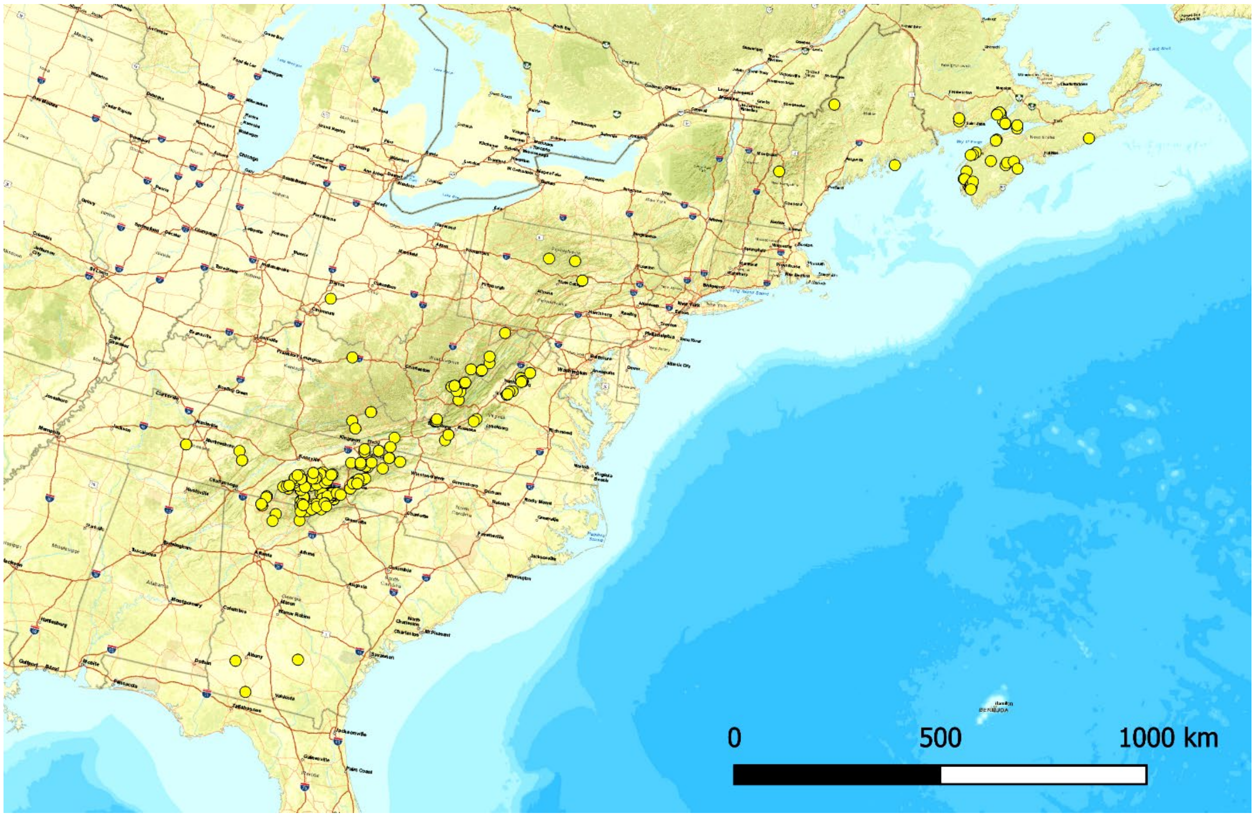

Figure 1. The distribution of *Heterodermia squamulosa* in eastern North America based on records at CNALH (2020) and the AC CDC (2020) (Map: Alain Belliveau). (See **Distribution** for the USA states where the lichen occurs.)

Designatable Units

The Canadian population is considered a single designatable unit because there are no known biological or other differences between occurrences that might reflect historical or genetic distinctions (see **Population Spatial Structure and Variability**).

Special Significance

Heterodermia squamulosa is part of a group of lichen species with a strong Appalachian distribution or a strictly Appalachian biogeographical affinity (Hinds and Hinds 2007; Clayden 2010). They include *Anaptychia palmulata* (S3S4 / Vulnerable in both NB and NS), *Heterodermia neglecta* (S4 / Apparently Secure in NB, S3S4 / Vulnerable in NS), *Punctelia appalachensis* (S1 / Critically Imperilled in NB, S3 / Vulnerable in NS), and *Rinodina ascociscana* (not ranked in NB, S4 / Apparently Secure in NS; AC CDC 2020; CNALH 2020). Several members of this group reach eastern Canada (see **Distribution – Global Range**) and co-occur with *H. squamulosa* in New Brunswick and Nova Scotia, often on the same tree or on neighbouring trees. Compared with these lichens, *H. squamulosa* has the fewest known occurrences, being restricted to New Brunswick and Nova Scotia. It is an indicator of undisturbed habitat within cool, temperate, hardwood or mixedwood, and mature to old forests (see **Habitat – Habitat Requirements**).

In New Brunswick and Nova Scotia, *H. squamulosa* occurs in, and indicates, old undisturbed forest, an increasingly rare forest type in Atlantic Canada (Loo and Ives 2003). Its preferred habitat of mature to old hardwood or mixedwood forest is home for other at-risk species, such as *Pectenia plumbea* (formerly *Degelia plumbea*: Special Concern; COSEWIC 2010) and Eastern Wood-pewee (*Contopus virens*, Special Concern (COSEWIC 2012).

ABORIGINAL (INDIGENOUS) KNOWLEDGE

Aboriginal Traditional Knowledge (ATK) is relationship-based. It involves information on ecological relationships between humans and their environment, including characteristics of species, habitats, and locations. Laws and protocols for human relationships with the environment are passed on through teachings and stories and Indigenous languages, and can be based on long-term observations. Place names provide information about harvesting areas, ecological processes, spiritual significance, or the products of harvest. ATK can identify life history characteristics of a species or distinct differences between similar species.

Cultural Significance to Indigenous Peoples

There is no species-specific ATK in the report. However, *H. squamulosa* is important to Indigenous Peoples who recognize the interrelationships of all species within the ecosystem.

DISTRIBUTION

Global Range

Heterodermia squamulosa has been reported from North, Central, and South America, western Africa, and eastern Asia (CNALH 2020). In North America (Figure 1), it has been reported from eastern Canada and eastern United States (Georgia, Kentucky, Maine, Maryland, New Hampshire, North Carolina, Ohio, South Carolina, Tennessee, Virginia, and West Virginia) and in western United States (Arizona and Utah) (CNALH 2020). In South and Central America, *H. squamulosa* has been reported from Argentina, Brazil, Costa Rica, Dominican Republic, Ecuador, Haiti, Mexico, Peru, Uruguay, Venezuela, and French Guiana. It is also known from South Korea, Japan, and Guinea (Wang *et al.* 2008; Moberg 2011; Sarlej 2018; CNALH 2020).

Canadian Range

Heterodermia squamulosa is found in coastal forests of the Atlantic Maritime Ecozone, disjunct from its core North American Appalachian mountain range (Clayden 2010). In Canada, it is known only from New Brunswick and Nova Scotia (Figure 2). All 31 known occurrences are within 50 km of the coast and are most frequent along or near the Bay of Fundy, becoming increasingly sparse going eastward along Nova Scotia's south and eastern shores. There is a correlation between the occurrence of *H. squamulosa* and the areas of the province that support an exceptionally high diversity of lichens (Cameron and Bayne 2020). The one collection from Quebec (Lutzoni 840718-L138 QFA) was examined for this report and proved to be a different species, likely *H. neglecta* or *H. galactophylla* (Anderson pers. comm. 2020).

An occurrence is defined as a site where the lichen is growing on one or more trees and is separated by more than 1 km from a second group of colonized trees (see NatureServe 2020). Seven occurrences have been documented in New Brunswick, but two were not confirmed in the recent field verifications. One other occurrence was likely confirmed in a recent survey, although there was uncertainty about the original coordinates. Another could not be confirmed, mostly due to geographic uncertainty, and a final occurrence with some uncertainty was found and has been added to this report (Table 1).

The occurrences are grouped into 14 subpopulations,12 in Nova Scotia and two in New Brunswick (Figure 2), of which one (NB 01) may no longer be extant (Figure 2). Subpopulations are defined as geographically or otherwise distinct groups, between which there is little demographic or genetic exchange, typically one successful migrant individual or gamete per year or less (IUCN 2019). The subpopulations are separated from one another by a distance that is greater than 15 km, a distance that likely exceeds the dispersal of its heavy propagules. In Canada, this lichen has only once been found fertile (see **Dispersal and Migration**).

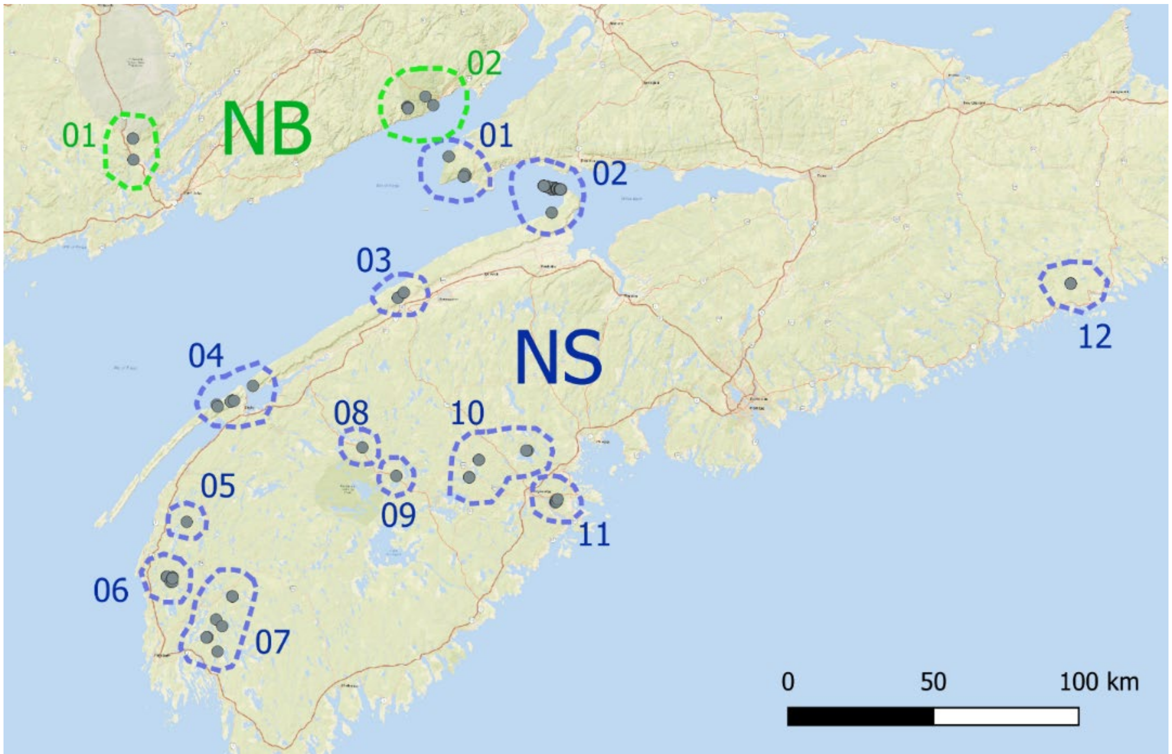

Figure 2. Subpopulations of *Heterodermia squamulosa* in Canada. Green dashed polygons and blue dashed polygons group together occurrences within each subpopulation in New Brunswick and Nova Scotia, respectively (Map: Alain Belliveau).

No genetic analyses have been done to assess the degree of relatedness among occurrences or subpopulations. The occurrences were grouped into subpopulations that are separated by relatively small distances. This was justified by the fact that *Heterodermia squamulosa* reproduces almost exclusively, in Canada, by means of lobules (see **Dispersal**).

The recent discovery of apothecia (sexual reproduction) on a specimen in Digby County, Nova Scotia, suggests that the capacity for genetic diversity among sites may be higher than previously thought. In the past, apothecia may have been formed more often on thalli when habitats and environmental conditions were more favourable.

Extent of Occurrence and Area of Occupancy

The calculated extent of occurrence (EOO) is 33,848 km^2, and the index of area of occupancy (IAO) is 120 km^2 (see Figure 3). The oceanic part of the EOO represents c. 8000 km^2. There has been an observed decline in IAO based on loss of occurrences in New Brunswick and Nova Scotia between 2006 and 2007, when the species was first observed there, and 2019, when the most recent surveys occurred.

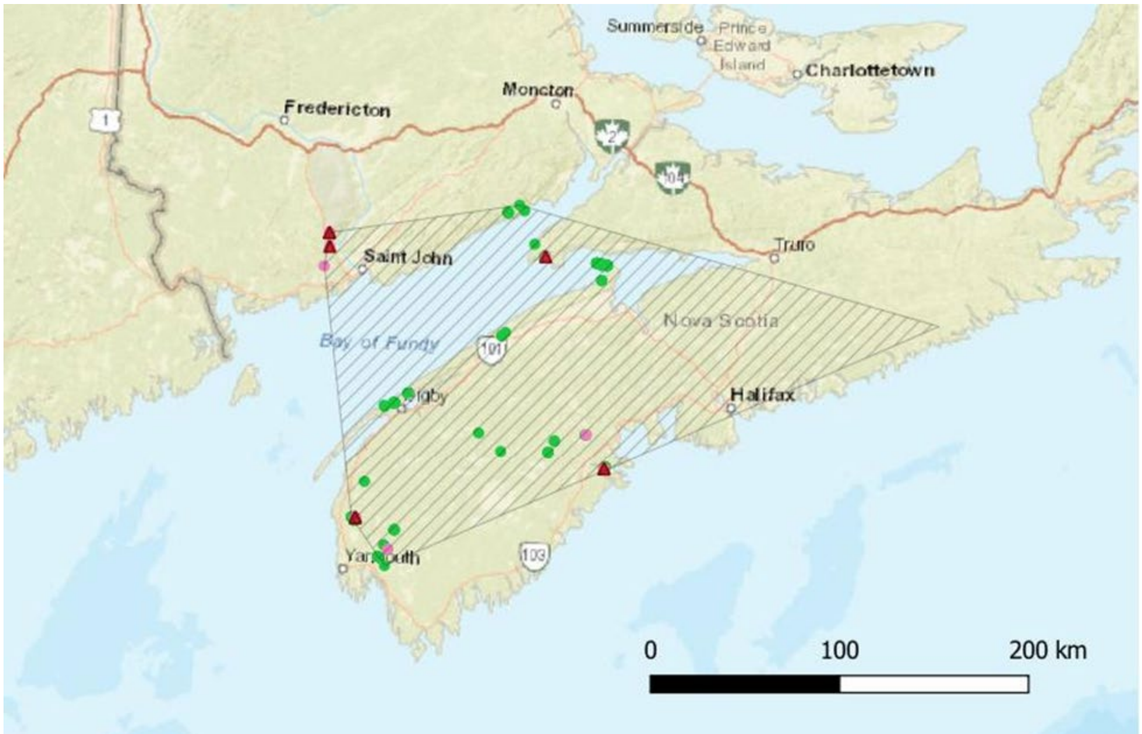

Figure 3. The extent of occurrence (EOO) for *Heterodermia squamulosa* in Canada. Green circles represent occurrences that have been confirmed or are very likely extant. The three pink circles denote occurrences that are uncertain but may be extant. The five red triangles denote occurrences that are no longer extant (map: Alain Belliveau).

Search Effort

Since 2007, targeted lichen surveys extending over 2,000 km of track distance (average of 20–50 m wide band captured, for a total area surveyed of 4,000–10,000 ha) have been carried out. As a pre-condition for forestry activity on public land in Nova Scotia, a survey is carried out to detect and monitor the occurrence of Boreal Felt Lichen (*Erioderma pedicellatum*) as a result of a provincial management policy (COSEWIC 2014; Belliveau and McMullin 2017; Brad Toms pers. comm. 2020). Although surveys target habitat suitable for *E. pedicellatum*, surveyors actively record lichens outside of those areas, including habitat suitable for *H. squamulosa* (AC CDC 2020). Some of the surveys occurred in close proximity (<10 km) to known *H. squamulosa* occurrences. The lichens recorded by surveyors included *H. squamulosa* and associated species such as *Anaptychia palmulata*, *H. neglecta*, and *Pectenia plumbea* (see **Habitat – Habitat Requirements**), indicating that surveyor proficiency was sufficient to detect *H. squamulosa*. Despite the extensive searches, only one occurrence (Spider Lake) of *H. squamulosa* was found.

Another method for assessing search effort is to map occurrences of species that are visually or ecologically similar to the focal species (Ponder *et al.* 2001; Phillips *et al.* 2009). In the Atlantic Region, the target group for *H. squamulosa* includes other members of the genus *Heterodermia*, as well as *Punctelia appalachensis* and *A. palmulata*, which are visually similar and occur in the same habitat. There are over 500 records of this target group (Figure 4) available from the Consortium of North American Lichen Herbaria and the Atlantic Canada Conservation Data Centre databases, and even more records from a local personal herbarium with unpublished collections (F. Anderson pers. comm. 2021). Despite this widespread search effort, *H. squamulosa* has been found infrequently, and only in certain regions. The historical and more recent herbarium records of known lichen associates of *H. squamulosa* provide a good indication of the likely limits of its distribution.

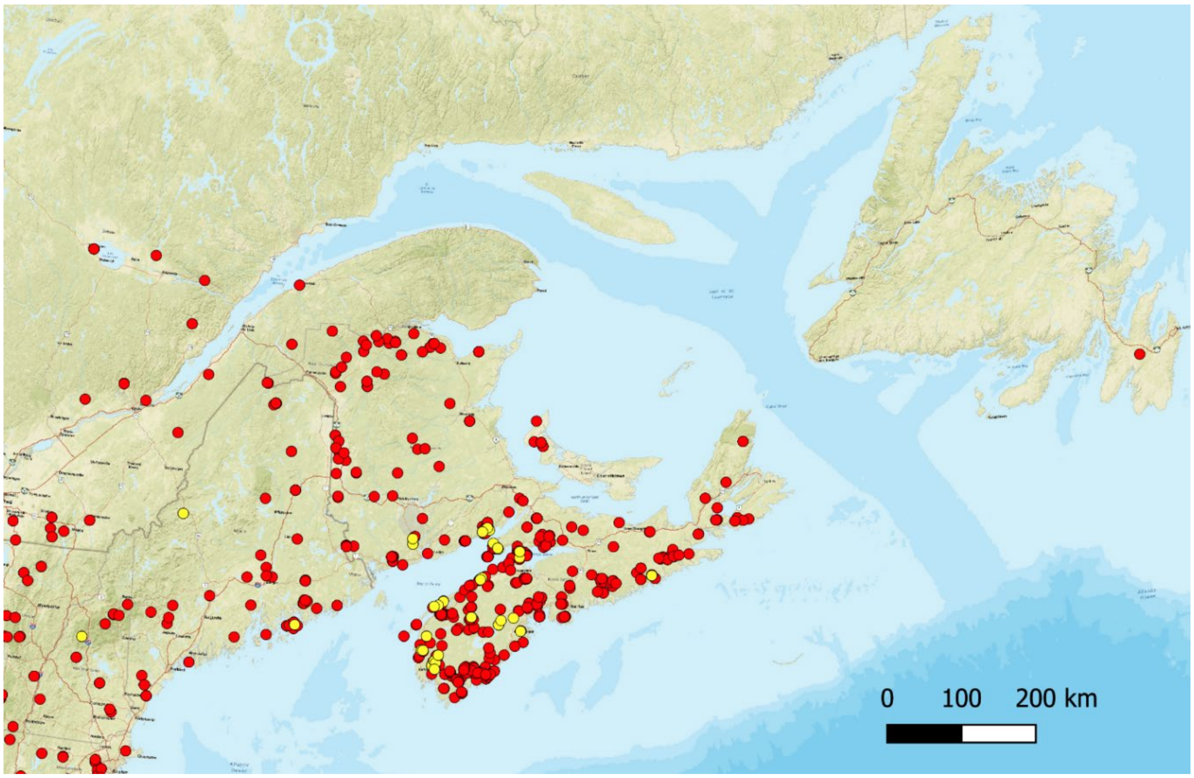

Figure 4. Northeastern North American occurrences (red circles) of *Heterodermia* species, *Punctelia appalachensis*, and *Anaptychia palmulata* from the Consortium of North American Lichen Herbaria (2020) and the Atlantic Canada Conservation Data Centre (2020). Yellow circles represent occurrences of *H. squamulosa* within northeastern North America (map: Alain Belliveau).

Recent Searches

Sites were searched in 2019 and 2020 specifically for *H. squamulosa*, and the finds have been grouped into a total of 16 occurrences (Table 1). The Lac de l'École occurrence was not surveyed because of the high geographic uncertainty of the original record. This also applied to the Maple Grove occurrence, and so only a partial survey was done there. The Goose River occurrence was not surveyed because of its remoteness, but an area adjacent to it was searched opportunistically. In 2020, several lichen surveyors in both provinces surveyed areas that had potentially suitable habitats, or paid particular attention to areas with potential habitats while conducting other fieldwork. Several occurrences were more extensively surveyed in 2020 to provide further data for this report. These included surveys of areas immediately adjacent to or nearby known occurrences that appeared to have potential for suitable habitat, based mostly on forest cover as observed in various satellite imagery. The Loch Alva occurrence was added in 2022 after a recent survey.

Table 1. Results of 2019–2021 surveys for *Heterodermia squamulosa* in Canada. The occurrences are grouped into subpopulations (see Figure 1).

Subpopulation.	Occurrence Code	Occurrence Place Name	2019-2020 Surveys	Status	Surveyor(s)*
NB01	NB-01	Welsford	Yes	Likely not extant	SC
	NB-02	Grand Bay-Westfield	No	Likely not extant (logged)	Remote sensing survey in 2020 (initial survey by DS)
	NB-07	Loch Alva	No	Unknown	n/a (initial survey by SC)
NB02	NB-03	Goose River	Adjacent area surveyed	Likely not extant	SC, AGB, NV
	NB-04	Maple Grove	Partial survey	Likely not extant	AGB, NV
	NB-05	Marven Lake	Found in 2020	Extant	NV
	NB-06	Herring Cove	Found in 2020	Extant	NV
NS01	NS-01	McGahey Brook	Yes	Extant	CC, NV
	NS-02	Eatonville	Found in 2020	Extant	NV
NS02	NS-03	Cape Split	Yes	Extant	AGB, JLC
	NS-04	Ross Creek	Found in 2020	Extant	JLC
NS03	NS-05	Lily Lake	Yes	Extant	AGB, JLC
	NS-06	Victoria Vale	Found in 2020	Extant	TN, HC
NS04	NS-07	Victoria Beach	Found in 2020	Extant	TN, HC
	NS-08	Van Tassel Lake	Yes	Extant	JR
	NS-09	Awkward Cove	Yes	Extant	JR
NS05	NS-10	Saint Joseph	Found in 2020	Extant	AGB
NS06	NS-11	Churchills Lake	Yes	Extant	AGB
	NS-12	Hectanooga	Yes	Extant	AGB, JLC, TN, HC
NS07	NS-13	Bennetts Lake	Yes	Extant	AGB

Subpopulation.	Occurrence Code	Occurrence Place Name	2019-2020 Surveys	Status	Surveyor(s)*
	NS-14	Canaan	Found in 2020	Extant	AGB
	NS-15	Lac de l'École	No	Unknown	n/a (initial survey by TN)
	NS-16	Pearl Lake	Yes	Extant	AGB
	NS-17	Moses Lake	Yes	Extant	AGB, CC
NS08	NS-18	Four Mile Stillwater	Found in 2020	Extant	AGB
NS09	NS-19	Kempt	Found in 2020	Extant	AGB
NS10	NS-20	Shingle Lake	Yes	Extant	AGB, ICB
	NS-21	Hirtle Lake	Yes	Extant	FA
	NS-22	Caribou Brook	Yes	Unknown	FA
NS11	NS-23	Upper LaHave	Yes	Extant	FA
NS12	NS-24	Spider Lake	Yes	Extant	AGB, JLC

*SC = Stephen Clayden, DS = Dwayne Sabine, AGB = Alain G. Belliveau, NV = Neil Vinson, CC = Colin Chapman-Lam, JLC = James L. Churchill, TN = Tom Neily, HC = Harold Clapp, JR = Jonathan Riley, ICB = Ian C. Bryson, FA = Frances Anderson.

A Maxent species distribution model (Phillips *et al.* 2019) was developed for *H. squamulosa* in Nova Scotia to help guide field survey efforts for this Status Report (Haughian *et al.* 2019). The initial model included known, spatially-precise occurrences and a suite of environmental variables known to be important to the species, which described climate, forest stand structure, disturbance, soils, topography, and hydrology. A backwards-stepwise selection process was used to find the most parsimonious model of the distribution of suitable conditions for the species in Nova Scotia. The final model had an AUC of 0.913 (suggesting the model fit the data well) and included five variables: estimated acid critical threshold exceedance (from Moran *et al.* 2008), mean annual daily standard deviation in temperature, distance to nearest waterbody, forest structure (minimum forest height of 10 m and crown closure > 30%), and mean number of days with rainfall > 0.2 mm.

Despite the model being limited by the quality of available geographic information systems (GIS) data, four medium-to-high probability sites in Digby and Kings counties in Nova Scotia were identified and visited in 2019. However, no new occurrences of *H. squamulosa* were found, and no strongly associated indicator lichen species (see **Habitat – Habitat Requirements**) were discovered (see **Population Sizes and Trends – Abundance)**.

In addition to the lichen surveys mentioned above, other unpublished searches have been conducted specifically within the distribution range of *H. squamulosa* in New Brunswick and Nova Scotia by the surveyors listed in the legend of Table 1. They surveyed an estimated minimum of 100 km of track distance (average of 20–50 m wide band captured, for a very conservative total area surveyed of 200–500 ha). These surveys occurred through work-related or personal volunteer efforts, and approximately eight of 11 surveyors live in and/or work in areas known to have occurrences or areas with especially high potential for suitable *H. squamulosa* habitat. Survey efforts for lichens in New Brunswick are generally lower than in Nova Scotia and in New England. Therefore, information from those adjacent jurisdictions was used to help with New Brunswick assessments including lichen abundance estimates using the species distribution model.

HABITAT

Habitat Requirements

Heterodermia squamulosa requires mature to old hardwood or mixedwood forest dominated by long-lived, shade-tolerant tree species. Sites typically include nutrient-enriched soils and are within 50 km of the coast. The majority of occurrences are in hardwood-dominated forests, while mixedwood and softwood-dominated forests account for five and only one occurrence, respectively. The most frequent dominant and co-dominant tree species observed in at least six occurrences of an *H. squamulosa* habitat are: Yellow Birch (*Betula alleghaniensis*), Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), and White Ash (*Fraxinus americana*).

The climate in southern New Brunswick and Nova Scotia is temperate, with a blending of continental and maritime influences. The proximity of all known occurrences to the ocean (<50 km) suggests that habitat requirements include fog, cooler warm season temperatures, and greater annual precipitation. In New England, higher-elevation forests appear to provide some of these same habitat characteristics at sites that are further inland. This biogeographical pattern is seen in several lichens that occur in coastal forests of the Maritimes and Maine and also in the northern and southern Appalachian Mountains (see Clayden 2010 and Allen and Lendemer 2015 for examples).

Elsewhere in the world, *H. squamulosa* consistently occurs in areas with a pronounced geographic relief or in relatively close proximity to the ocean, or frequently both (CNALH 2020). Data from weather stations from New Brunswick and Nova Scotia, and from many occurrences around the world spanning four continents, suggest a minimum annual precipitation of 1,000 mm is required (Anderson *et al.* 2011; PRISM Climate Group 2013; IPCC 2014; Climate-data.org 2021).

The New Brunswick and Nova Scotia occurrences, along with those in Maine and New England, survive in the coldest climate for *H. squamulosa* in the world (see **Global Distribution**). Mean annual temperatures range from 4°C to 8°C in this region, compared to above 8°C in other temperate regions where *H. squamulosa* occurs and well above 10°C elsewhere (Government of Canada 2021a,b; NOAA 2021a,b; Tutiempo.net 2021; WorldClimate.com 2021). This suggests that colder temperatures in suitable habitats further north may inhibit a broader distribution range for this lichen in Canada. Cold air temperatures and intense ultra-violet radiation levels are harmful to some lichen species.

The more moderate temperature, the relatively high number of days with cloud cover, and the high relative humidity enable *H. squamulosa* to thrive in Nova Scotia and coastal parts of New Brunswick but not in continental New Brunswick and much of eastern Canada.

For about three quarters of occurrences, soils are well-drained, while the rest of the occurrences are influenced by poorly drained soils. All are in areas of lower-acidity bedrock or glacial till, or both. In both soil drainage types, based on soil profiles under uprooted trees, and on indicator vascular plant species at several occurrences, there is significant nutrient enrichment. A tree bark's physical and chemical properties, and in turn a host tree's suitability for *H. squamulosa* colonization, are affected by soil properties (Gustafsson and Eriksson 1995). Predictive soil type GIS data in Nova Scotia suggest that *H. squamulosa* occurrences in the province occur on moderate to rich, fresh to moist (occasionally wet) soils (NSDNR 2010; NSDLF 2020). Soil richness appears to be particularly important. In the southern half of Nova Scotia, where most Canadian occurrences of *H. squamulosa* are found, there is an abundance of poor, acidic soils. Correspondingly, the availability of habitats with a combination of old undisturbed forest and richer soils is limited.

When observed growing in wet or lowland sites, occurrences are often close to a slope and near running water, suggesting that inputs of minerotrophic flows produce soil conditions more akin to upland *H. squamulosa* occurrences. Nearly 72% of observations with aspect data (n = 89) were on slopes, with a strong association with northern aspects. However, the dozens of north-facing occurrences in the Cape Split area produce a strong bias in this analysis. Outside of Cape Split, there is no clear preference for slope position or aspect.

All available data indicates that *H. squamulosa* has a preference for mature to old hardwoods or for old mixedwood forests. In other words, these are forests with high temporal continuity (McMullin and Wiersma 2019). No occurrences of *H. squamulosa* were found in habitats with obvious signs of past forest harvesting. All 82 observations with forest maturity information describe *H. squamulosa* forest habitat as mature climax, old, or old-growth forest (*sensu* NSDNR 2012). This suggests a minimum dominant or co-dominant tree age of at least 80 years, as well as long-term forest type and cover continuity. *Heterodermia squamulosa* appears to be relatively sensitive to open sunlit conditions; no occurrences have been found in places with < 50% crown closure.

Yellow Birch, Sugar Maple, Red Maple, White Ash, and Eastern White Cedar (*Thuja occidentalis*) are the only known host tree species in Canada. Sugar Maple and Yellow Birch are the predominant host tree species in upland sites, while Red Maple, Yellow Birch, and White Ash provide host tree microhabitats for *H. squamulosa* in wetland and wetland-edge sites. The lone occurrence on Eastern White Cedar was clear-cut in 2006; however, cedar trees have been recorded as hosts in New England (CNALH 2020) and remain as potential *H. squamulosa* hosts in New Brunswick or Nova Scotia. However, recent searches of this host tree in these provinces have so far been unsuccessful. Several thalli in Nova Scotia were noted as growing on bryophytes on bark, instead of directly on bark. Only three of nine occurrences with aspect data were found on the southeast, south, southwest, or west sides of host trees, possibly suggesting an aversion to high light or heat loading leading to desiccation stress. Most thalli are located between 1 and 2 m above ground, with the lowest and highest thalli at 0.1 and 3.5 m above ground, respectively. Only three host trees were visibly leaning, suggesting that this characteristic is not as important to *H. squamulosa* as it is for other rare lichens in eastern Canada (COSEWIC 2019).

Heterodermia squamulosa is strongly associated with several other lichen species with an Appalachian biogeographical affinity (Hinds and Hinds 2007) and is a strong indicator of mature to old forest conditions (see **Interspecific Interactions**). Only two occurrences in the United States (both collected in West Virginia by J.C. Lendemer) of over 500 occurrences had associated lichen taxa that were similar to those found in Canada and are listed in Table 2 (CNALH 2020).

In the eastern United States, *H. squamulosa* is found in hardwood forests, especially on mossy tree bases (Brodo *et al.* 2001; Lendemer 2009). With respect to host species, data are available from the specimen labels of over 500 collections of *H. squamulosa* (CNALH 2020). These show that in the United States, the most common host trees are oak (*Quercus* spp.) and American Beech (*Fagus grandifolia*). Several occurrences were noted as growing on bryophytes, both on bark and on the ground. Rock is also an occasional substratum in eastern United States and in other countries (Moberg 2011; CNALH 2020), but *H. squamulosa* has not been found on rock in Canada.

Several habitat requirements are difficult to map because of a lack of high-precision geographic data. This limits the ability to accurately assess habitat trends and population abundance (NSDNR 2016; NBDNRED 2017). More accurate data are needed, over several time periods, to capture the requirement of this species for temporally continuous connected habitat. This need is a consequence of the very limited dispersal mechanism in *H. squamulosa* (see **Dispersal and Migration**). In this report, the use of coarse-scale data and a predictive GIS model likely resulted in an over-estimate of the amount of present-day suitable habitat, and in turn an over-estimate of the population abundance (see **Population Sizes and Trends**).

Based on habitat preferences and human alteration of habitat, the amount of remaining habitat for *H. squamulosa* in New Brunswick and Nova Scotia is very small. An analysis between 2008 and 2012 of permanent sample plots indicates that forests over 80 years old represent approximately 16% of forests in Nova Scotia (NSDNR 2017). In addition, approximately 38% of forest cover in Nova Scotia is represented by hardwoods or mixedwoods (<25% softwood composition, representing approximately 1.6 out of 4.2 million ha). Overall, only 6% (16% of 38%) of the province’s forests are of a suitable age and composition for colonization by *H. squamulosa* (NSDLF 2019). A reasonable estimate of maximum potential suitable habitat is that just 4% has enough temporal and geographic continuity to sustain *H. squamulosa* (see **Threats – Logging and Wood Harvesting**).

Habitat Trends

Historically, old hardwood and mixedwood forests were much more frequent in New Brunswick and Nova Scotia; prior to European contact with Indigenous peoples, they may have covered about 50% of the Maritime Provinces (see Loo and Ives 2003; Mosseler *et al.* 2003; Stewart *et al.* 2003). In this region, the amount of mature to old forests has significantly declined since the late 18th century. The loss of old forests was the result of clearing for agriculture, land development, forest fires, and tree harvesting. Agricultural clearing peaked in the 1890s, when approximately 15% of the Nova Scotian land base was used for farming (MacKinnon 1991). This figure should be treated as a minimum for total area cleared for agriculture in the province, because other previously cleared areas had already been abandoned and regrown into shrubby or forested lands. The amount of land clearing in New Brunswick is likely similar, based on the two provinces' comparable socio-economic history and currently active farmland. Land development, including residential, commercial, transportation, and other permanent or semi-permanent forest clearing activities, currently accounts for over 3% of the landscape in both provinces (Gorelick *et al.* 2017; NSDNR 2017). Forest fires, mostly anthropogenic (naturally-occurring fires are exceedingly rare), historically burned large swaths of both provinces; however, this disturbance was poorly defined spatially, and specific impacts to *H. squamulosa* habitat are largely unknown (Wein and Moore 1979). If not burned, the forests have been harvested, often through clear-cutting, which continues to be the most common forestry practice in both provinces. About 15% of Nova Scotia's forests were clear-cut between 1990 and 2007 (Cheng *et al.* 2009), an annual rate of 0.88%, a trend that appears to have continued since 2007, based on annual satellite imagery (Gorelick *et al.* 2017). A slight decline in overall annual harvesting occurred late in the 2000s and into the 2010s due to the economic recession and to the associated idling or shutdown of forestry mills (Lahey 2018a). Clearcutting was the method of forest harvesting for approximately 65% and 89% of harvests on public land and private land, respectively, in Nova Scotia in 2016. In New Brunswick, clearcutting has represented 80% or more of the total provincial harvest from the late 1990s to the early 2010s. The harvest levels were, and continue to be, similar to those in Nova Scotia (Auditor General of New Brunswick 2015; Gorelick *et al.* 2017). Harvesting of shade-tolerant hardwood forests in New Brunswick has increased sharply over the past few decades (Clayden 2014).

In New Brunswick, there are swaths of public lands in central and southern parts of the province (including lands immediately adjacent to known *H. squamulosa* occurrences) (J.D. Irving Limited 2014). Mature forests comprise 37% of the forested land base, with approximately 35% of that being mixedwood and hardwood; this represents approximately 13% of suitable habitat availability, although only a small amount is climatically suitable. The New Brunswick threshold for "mature" status is 65 years old for Red Maple and 75 years old for shade-tolerant hardwoods, including Sugar Maple and Yellow Birch (J.D. Irving Limited 2014). Given this, and the fact that only the southern fifth of New Brunswick seems to be climatically suitable (i.e., within approximately 50 km of the ocean), a reasonable estimate of the maximum potential suitable habitat in that province is approximately 3%. Compared with pre-colonization times, mature to old forests have declined significantly (Loo and Ives 2003; Stewart *et al.* 2003).

In summary, the majority of old forests in Nova Scotia and New Brunswick were lost during initial colonial activities by land clearing and forestry. Even though the amount of old forest loss is smaller today, it is still significant and limits the amount of available suitable host trees for *H. squamulosa.*

Acid rain has resulted in widespread soil acidification in New Brunswick and Nova Scotia, which can lead to a change in forest vigour and composition. For example, a reduced growth rate of Sugar Maple on acid or non-calcareous soils has been reported from Quebec and New England since 1960. This can be attributed, at least partially, to soil acidification and acid deposition levels (Ouimet *et al.* 2001; Schaberg *et al.* 2001; Duchesne *et al.* 2002; Schaberg *et al.* 2006). Reversal of the negative impacts of acid rain on soils has only recently begun in some parts of northeastern North America (Lawrence *et al.* 2015). Although *H. squamulosa* is usually found in nutrient-rich sites (*sensu* NSDNR 2010), the southern New Brunswick and southern Nova Scotia occurrences predominantly involve trees growing on non-calcareous soils that would buffer impacts of acid rain less well compared with occurrences in Vermont (see **Threats**: Air pollution). In Atlantic Canada, acid rain has likely caused and will continue to cause reduced growth and potential mortality in Sugar Maple trees, a regionally important host tree for *H. squamulosa*, thereby reducing the amount of available substrate for colonization.

In Atlantic Canada, there have been significant declines in mature American Beech trees due to Beech Bark Disease. While this is not currently a significant threat, and no Canadian occurrences of *H. squamulosa* are known from this host tree, it is a common host in the USA. Hence, this disease may well have reduced the amount of suitable habitat for *H. squamulosa* in New Brunswick and Nova Scotia in the past. Recently, the number of healthy American Beech trees has increased owing to the spread of disease-resistant individuals (Houston 1983; Stephanson and Coe 2017; AC CDC 2020). However, healthy trees are relatively rare in the Atlantic Provinces of Canada, and there is a lack of forest harvesting practices aimed at preserving them.

BIOLOGY

Life Cycle and Reproduction

Heterodermia squamulosa's primary means of reproduction is by vegetative lobules (phyllidia). Apothecia are known from South Korea (Wang *et al.* 2008) and from two specimens in North America (one in Digby County, Nova Scotia) (CNALH 2020), but there is no information on the presence, viability, and dispersal of spores from the apothecia in this species (CNALH 2020). With only one fertile specimen (see photo front page) out of hundreds of known thalli in Canada, the apothecia do not represent a common or effective method for dispersal of *H. squamulosa* in this region.

Lobules contain both the green alga *Trebouxia* as the photobiont and the mycobiont species. Lobules can be anchored (established) within a year of reaching suitable habitat. The pattern of growth changes as the new thallus expands (Seminara *et al.* 2018); growth zones differentiate, and lobes become evident (Armstrong and Bradwell 2011). In the Canadian population, several thalli measuring just over 1 cm^2 were observed to be starting to form lobules. The largest thallus was approximately 300 cm^2 (with a radius of 100 mm). The largest group of thalli on one tree measured roughly 3,500 cm^2 and was found at Shingle Lake, Lunenburg County (Table 3).

Determining the average age of lobule-dispersing individuals is imprecise because of the lack of long-term monitoring and the challenge of delineating individual thalli. However, lichenometric methods, such as extrapolating thallus age by dividing mean thallus diameter by mean growth rate, have been used to make age estimates for other at-risk lichens. Published data on other members of the Physciaceae from temperate regions helps to provide estimates of growth rates and age ranges for *H. squamulosa*. The annual growth range for eight Physciaceae species (including *H. speciosa*) across 10 studies in temperate regions was 1.38 to 1.89 mm/yr (Hayward and Grace 1999; Armstrong and Bradwell 2011). The estimated average width of 20 lobule-bearing individual thalli from photographs taken at nine sites from the 2019 surveys in Nova Scotia was 26 mm, ranging from 10 to 100 mm. Only photographs of thalli that were clearly a single entity were used, because thalli in this species can split and/or merge, which makes age estimation more difficult. Using single thalli, the minimum and maximum estimated ages for *H. squamulosa* thalli in Nova Scotia that are old enough to produce reproductive lobules was between 5 years for a young thallus and 72 years for a large, very old thallus. The estimated mean age of lobule-bearing *H. squamulosa* thalli in Nova Scotia was estimated to range from 14 to 19 years. Generation times for old forest lichens based in juvenile development have given results ranging from 9 to 22 years (Larsson and Gauslaa 2011).

The climate for the Canadian population of *H. squamulosa* is the coldest in the world. Both lower temperatures and lower light levels tend to result in lower growth rates in lichens (Palmqvist and Sundberg 2001). As a result of the expected slower growth rate, the age of 19 years, rather than 14, is used as the generation time for *H. squamulosa* in this report, giving a three-generation time of 57 years.

In Nova Scotia, the thallus that has been re-located after the longest interval is one at the Lily Lake occurrence. This was documented again 14 years after it was first recorded. The lichen was located again based on a description of the host tree, its position, and the habitat described by the original observer who documented the discovery in 2005 (T. Neily pers. comm. 2019). However, it is not known if the original thallus has changed (e.g., split into several thalli) or if a new thallus has grown on the tree from vegetative propagules released by the original thallus.

Physiology and Adaptability

Some thalli in the Canadian population of *H. squamulosa* exhibit a very high tolerance of deep shade. For example, many thalli in the Cape Split occurrence were found on the north side of trees on steep, north-facing slopes. The north side of the host trees, under a dense forest canopy from June to October, seldom receives direct sunlight. This apparent ability to metabolize in cool, dark conditions may be attributable to the presence of atranorin in its chemistry (C. Deduke pers. comm. 2022). This, combined with the fact that its global distribution does not reach further north than New Brunswick and Nova Scotia, suggests that *H. squamulosa* needs a moderate maritime climate in order to persist in a region. The symbiont of *H. squamulosa* is the alga *Trebouxia,* which is unable to fix atmospheric nitrogen, which may partially explain the preference of this lichen for colonizing trees that grow on nutrient-rich soils that provide throughfall that is richer in nutrients (*sensu* NSDNR 2010; see **Habitat – Habitat Requirements**). Some species of *Trebouxia* are non-lichenized and occur independently in the wild (Bubrick *et al.* 1984; Mukhtar and Galun 1994). It is not known which species of *Trebouxia* is required by the fungal component of *H. squamulose,* but recent research has shown that it likely belongs to the I, A, or C clade of Trebouxia (Kosecka *et al*. 2022). Many lichens have a basidiomycete fungus as a third partner in the symbiosis (Spribille *et al.* 2016), but Lendemer *et al.* (2019) found no cystobasidiomycete yeast in two *H. squamulosa* specimens.

Dispersal and Migration

Heterodermia squamulosa reproduces asexually by means of lobules (phyllidia) that are dispersed by wind, animals, or flowing water. Older thalli (generally > 5 cm^2) will often exhibit numerous lobules. Occasionally, thalli have a frayed appearance after many of the lobules have been dispersed, exposing the medulla. Dead sections of a large *H. squamulosa* thallus at Shingle Lake had almost no remaining lobules.

Heterodermia squamulosa lobules are larger and heavier than other asexual propagules, such as soredia and isidia, that are produced by many lichens. As a result, lobules are not easily dispersed by wind and are likely to travel shorter distances than isidia or soredia (Scheidegger and Werth 2009). However, they may have a higher success rate in terms of colonization at the forest stand level (Hedenås and Ericson 2008; Fedrowitz *et al.* 2012; see COSEWIC 2019). This notion appears to be supported at several occurrences in Nova Scotia (e.g., Cape Split, Churchills Lake, Van Tassel Lake) where many trees within one contiguous area of suitable habitat are colonized by *H. squamulosa*. In Canada, most occurrences are found 1–3 m above the ground. Assuming a height of 5 m, lobules falling off a thallus would spend about 1 second in freefall. Maximum wind speeds observed in this region are typically ~100 km/h, which could carry lobules up to 28 m. Sloping ground or a slower freefall speed as a result of the small lobule size and the relatively high surface-to-weight ratio could extend the maximum dispersal distance to an estimated 50 m. Although this is only a rough estimate, it provides a picture of the physical constraints placed on this species' with respect to its ability to disperse across the landscape.

Animals probably play an important role in both intra- and inter-stand dispersal (see COSEWIC 2020). Propagules carried by mammals, such as Northern Flying Squirrel (*Glaucomys sabrinus*), Southern Flying Squirrel (*G. Volans*) and Red Squirrel (*Tamiasciurus hudsonicus*), could be carried several hundred meters, while those carried by birds could travel longer distances. Bark-gleaning bird species, such as Brown Creeper (*Certhia americana*) and woodpeckers (Family Picidae), are more likely to be in contact with *H. squamulosa* (and therefore to pick up its lobules) than other bird species. Typically, resident species do not migrate large distances. A recent review of the literature on bark-gleaning bird species suggests that the home ranges of most Nova Scotia taxa are only a few ha in size, and the greatest travel distances range from 1 to 10 km (COSEWIC 2020). In conclusion, *H. squamulosa* probably undergoes regular intra-stand dispersal, but longer inter-stand dispersal events are likely rare. As a result, there is little chance of this species dispersing easily in the current patchwork landscape of Atlantic Canada. It is thus not surprising that in 25 of 30 occurrences, the lichen is found on fewer than five host trees, and most occurrences are currently surrounded by unsuitable habitat (see **Habitat**).

Interspecific Interactions

Grazing by gastropods may limit growth and early development in macrolichens (Asplund and Gauslaa 2008) and may be contributing to declines in Boreal Felt Lichen (*Erioderma pedicellatum*) and Vole Ears (*E. mollissimum*) (Cameron 2009). No evidence of grazing has been documented on *H. squamulosa*, but it may take place, as invertebrate grazing occurs on a broad range of lichens (Seyd and Seaward 1984; Baur *et al.* 1995; Pöykkö *et al.* 2005). *Heterodermia squamulosa* is found to be associated with a group of lichens that are also strong indicators of mature to old forest conditions (Table 2).

Table 2. Lichen species found in the same forests in Canada as *Heterodermia squamulose* and their indicator properties

Associated Lichen Taxon	NatureServe Status	Host Trees (n = 80)	Indicator Properties
Punctelia appalachensis	S1 / Critically Imperilled in NB, S3 / Vulnerable in NS	31	Predominantly in the Appalachian region on deciduous trees (Hinds and Hinds 2007)
Anaptychia palmulata	S3S4 / Vulnerable in both NB and NS	26	A species of old-growth hardwood forests in New England (Selva 1994)
Parmotrema crinitum	S4 / Apparently Secure in NB, S5 / Secure in NS	10	Although considered an old-growth indicator in Great Britain (Rose 1976), in Canada, it mostly occurs on mature trees and in humid habitats
Pyxine sorediata	S4 / Apparently Secure in NB, S5 / Secure in NS	10 (2 fertile)	Common in mature forest (Hinds and Hinds 2007); fertile occurrences indicate old forest conditions in Nova Scotia (Belliveau pers. obs. 2019)
Lobaria pulmonaria	S5 / Secure in both NB and NS	7	Oceanic and montane on deciduous trees; locally common in mature woods; considered an old-growth indicator in hardwood forests in Maine and Great Britain (Rose 1976; Selva 1994)

Associated Lichen Taxon	NatureServe Status	Host Trees (n = 80)	Indicator Properties
Ricasolia quercizans	S5 / Secure in both NB and NS	4	Considered an old-growth indicator in hardwood forests in Maine and Great Britain (Rose 1976; Selva 1994); indicator of relatively undisturbed forests in New England (Hinds and Hinds 2007)
Pectenia plumbea	S1 / Critically Imperilled / Special Concern in NB, S3 / Vulnerable in NS, Special Concern in Canada	4	Prefers mature to old deciduous trees in maritime climate (COSEWIC 2010)
Rinodina ascociscana	Not Ranked	3	Strong preference for mature hardwood forest in New Brunswick and Nova Scotia (CNALH 2020)

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

The fieldwork goals for this report were: (1) to visit as many known sites for *H. squamulosa* as possible to verify the current status (e.g., presence, number of thalli, number and species of host trees, site characteristics); (2) to document additional subpopulations by visiting as many high-probability sites as possible, within time constraints; and (3) to photograph and collect specimens where appropriate. For this report, each thallus found was counted as a “mature individual” according to IUCN (2019) guidelines, as fewer than 1% of thalli had no lobules. The capability of small, immature or poor specimens to reproduce successfully is likely very low. The IUCN’s definition mentions “individuals known […] to be capable of reproduction”, and this is open to further interpretation. In summary, the definition used in this report could result in an overestimation of reproductive capacity of *H. squamulosa* in Canada and should be considered when interpreting the following sections.

Most field surveys for known occurrences took place during the autumn of 2019. Surveys focused on the 16 occurrences that had not been visited since 2017. Eleven other occurrences with data from 2018 onward or having been found in 2020 were considered recent enough that no further visit was needed. Photos and voucher specimens were also collected, when appropriate. In New Brunswick, of the seven occurrences, one was presumed no longer extant due to clearcutting observed on satellite imagery, and a second was presumed no longer extant after searching by experts. Two others were not searched because of remoteness or geographic uncertainty, and another because the occurrence was only reported after field verification had been completed. In Nova Scotia, of the 24 occurrences, 13 were visited in 2019, and 10 had data from 2018 onward or were found in 2020 (Table 3). The Lac de L’École occurrence was not visited because the position of the original site was uncertain (~2300 m radius around the coordinates). Surveys of known occurrences in 2019 consisted of one to four surveyors meandering through a site until *H. squamulosa* was relocated, or not. Surveyors looked at all suitable tree hosts within approximately 50 m of the coordinates provided by the original record of the occurrence.

Abundance

The total number of current and historical occurrences in Canada is 31, with seven in New Brunswick and 24 in Nova Scotia (Table 3). This table includes data on the date of surveys, number of thalli and colonized trees and whether the lichen was missing from some previously known sites at an occurrence; listed in the table as “Extant but partial loss of occurrence”.

Table 3. Data from surveys of *Heterodermia squamulose* that include the date of surveys, number of thalli, number of colonized (host) trees, as well as whether the lichen was missing from previously known sites at an occurrence. The last category is listed in the table as “Extant but partial loss of occurrence”.

Subpopulation		Occurrences		Individuals*		Year Discovered	Year Last Surveyed	2019-2020 Status
Number	Name	Number	Name	Trees	Thalli			
NB-01	Grand Bay-Westfield	NB-01	Welsford	0	0	2007	2019	Not found – presumed extirpated
		NB-02	Grand Bay-Westfield	0	0	2006	2019	Not extant (loss due to logging)
		NB-07	Loch Alva	1	1	2001	2022	Extant
NB-02	Fundy NP	NB-03	Goose River	1	1+	1993	1993 (adjacent area surveyed in 2019)	Likely not extant
		NB-04	Maple Grove	1	5	1980	1980 (approximate area surveyed in 2019)	Likely not extant
		NB-05	Marven Lake	3	15+	2020	2020	Extant
		NB-06	Herring Cove	1	3	2020	2020	Extant
NS-01	Cape Chignecto PP	NS-01	McGahey Brook	2	2+	2004	2019	Extant (partial loss for unknown reasons)
		NS-02	Eatonville	1	3+	2020	2020	Extant
NS-02	Scots Bay	NS-03	Cape Split	79	247+	1987	2020	Extant (partial loss due to threats)
		NS-04	Ross Creek	2	6	2020	2020	Extant
NS-03	Lily Lake	NS-05	Lily Lake	1	4	2005	2019	Extant
		NS-06	Victoria Vale	1	1	2020	2020	Extant
NS-04	Digby	NS-07	Victoria Beach	1	1	2020	2020	Extant
		NS-08	Van Tassel Lake	8	8+	2019	2019	Extant
		NS-09	Awkward Cove	2	2+	2019	2019	Extant
NS-05	Saint Joseph	NS-10	Saint Joseph	1	2	2019	2019	Extant
NS-06	Hectanoo	NS-11	Churchills Lake	6	7	2019	2019	Extant

Subpopulation		Occurrences		Individuals*		Year Discovered	Year Last Surveyed	2019-2020 Status
Number	Name	Number	Name	Trees	Thalli			
	ga	NS-12	Hectanooga	3	10+	2009	2019	Extant (partial loss due to logging)
NS-07	Tusket River	NS-13	Bennetts Lake	2	4	2010	2019	Extant
		NS-14	Canaan	1	4	2020	2020	Extant
		NS-15	Lac de l'École	1	1+	2010	2010	Unknown
		NS-16	Pearl Lake	2	6	2010	2019	Extant
		NS-17	Moses Lake	2	4	2019	2019	Extant
NS-08	Four Mile Stillwater	NS-18	Four Mile Stillwater	1	12	2020	2020	Extant
NS-09	Kempt	NS-19	Kempt	1	3	2020	2020	Extant
NS-10	Shingle Lake	NS-20	Shingle Lake	5	74	2007	2019	Extant
		NS-21	Hirtle Lake	8	8+	2014	2019	Extant
		NS-22	Caribou Brook	1	1+	2014	2019	Unknown
NS-11	Upper LaHave	NS-23	Upper LaHave	3	5	2007	2019	Extant
NS-12	Spider Lake	NS-24	Spider Lake	4	10	20??	2019	Extant (partial loss due to logging)
		TOTAL		**145**	**450+**	**1980–2020**		

*Data reflects most numbers available the time of writing this report (2020).

The numbers of host trees and thalli were estimated using surveys. Most included thallus counts on one or a cluster of host trees separated by a minimum of 10 m. Host tree data were consistently recorded by the lichen surveyors, and the total number of trees was 145. Seven host trees were in New Brunswick, while 138 were in Nova Scotia. The average number of host trees per occurrence was 4.8 across the entire population or 2.2 if the Cape Split occurrence is not included. The occurrence at Cape Split (Scots Bay subpopulation) comprises approximately 50% of all the known thalli on about 50% of the colonized host trees. While more than 73 new thalli and 31 new host trees were discovered in extensive surveys done in 2019 and 2020, the total known population is only about 500.

Estimating the total possible number of thalli present in the past is difficult, because thallus numbers were not recorded in a consistent way from the time that the species was first found in the Maritimes in 1980. The number of thalli that have been recorded is 421, but the number of host trees for which thallus counts were not made is 31. Dividing the number of total thalli (450, see Table 3) by the number of host trees (145) produces an average 3.1 thalli per tree. The 31 host trees without thallus records can thus be estimated to host 65 additional thalli. The one host tree with 74 thalli in Shingle Lake skews the thalli-per-tree average overall, as do the occurrences in the Scots Bay subpopulation at Cape Split in Nova Scotia. The latter has the largest recorded number of thalli (247 thalli on 79 host trees, out of a total of 450 thalli). The maximum number of thalli at known occurrences is estimated at 450 to 515, with 25 to 29 thalli located in New Brunswick and 425 to 486 thalli located in Nova Scotia. Even taking into account the >73 new thalli and 31 new host trees discovered in recent surveys (2019/2020), and the estimates of the small amount of suitable undisturbed habitat (c. 4%) (see **Habitat Trends**) for *H. squamulosa,* it is estimated that the total population of mature individuals of this lichen in Canada is < 1,000.

A species distribution model was also used to help estimate the total number of host trees for *H. squamulose*, following methods employed for White-rimmed Shingle Lichen (*Fuscopannaria leucosticta*) (**Appendix 1**). First, Predicted Abundance (PA) was calculated by multiplying the Probability of Occurrence (PO) of *H. squamulosa* (from the Species Distribution Model predictive surface) by the Known mean Abundance (KA; the number of known host trees within each 50 m^2 area or the number of occupied 50 m cells) within areas of the province with sufficient survey effort for *H. squamulosa*. Correction factors, based on observed versus predicted occupancy, were then applied to PA estimates using classification tree analysis (Setchell and Haughian 2021) to correct for the approximate proportion of searched sites that contained *H. squamulosa*. Based on this model, the calculated estimates for the number of thalli and the number of host trees were 756 and 937, respectively. This is likely an overestimate for Nova Scotia, because the habitat parameters used in the model are likely broader than what the species actually tolerates or needs. Nevertheless, because the estimates are within the same order of magnitude as the observed population size and because the model does not account for population contributions from New Brunswick (which includes 4.2% of known host trees for Canada), these numbers may serve as a conservative high-end estimate for the Atlantic Canadian population. Despite low survey rates, New Brunswick likely has fewer occurrences than Nova Scotia, given the rarity of this species in adjacent New England (where survey effort is similar or higher). The colder climate and more varied topography may provide Nova Scotia more opportunities for wetland occurrences. It should be noted that the model included all of Nova Scotia. More than half of Nova Scotia has no *H. squamulosa* occurrences. This also seems likely for the part of New Brunswick that was not included in the model and supports the overall abundance estimate provided by the model for Nova Scotia and New Brunswick combined.

Fluctuations and Trends

Population trends for *H. squamulosa* are difficult to assess in Canada, because only nine occurrences (Table 4) have been enumerated more than once. For trend assessment, only those occurrences with either reliable host tree or thallus counts or estimates from at least two observation years were used. Among nine occurrences that qualified for the analysis (two in New Brunswick, seven in Nova Scotia), seven showed declines in host trees in 2019, while two others showed no change (Table 4). Of the occurrences considered to be no longer extant, three (Grand Bay-Westfield, Hectanooga, and Spider Lake) have been subject to clear-cut harvesting (as defined in Natural Resources Canada 2020). Two other sites (Upper LaHave) may have been subjected to over-collection before the rarity of the species in the province became known. At two sites (Welsford and McGahey Brook), suitable habitat appeared to persist, and the reason for the disappearance of *H. squamulosa* was not clear. The Welsford site is on Canadian Forces Base (CFB) Gagetown lands (AMEC 2011), and the lichen could not be found, even though the trees are unlikely to have been cut. However, other species in this region, such as *Erioderma pedicellatum* and *E. mollissimum*, are known or suspected to be in decline as a result of air pollution and nearby forest alteration (COSEWIC 2009, 2014, 2015, 2020).

Table 4. Summary of host tree and thallus counts for observations of *Heterodermia squamulosa* with two comparable years of survey data

Occurrence Name	Initial Survey Year	Latest Survey Year	Initial Host Tree Count	Initial Thallus Count	Latest Host Tree Count	Latest Thallus Count	Threat
Welsford (NB-01)	2007	2019	1	1+	0	0	Uncertain
Grand Bay-Westfield (NB-02)	2006	2019 (remote sensing)	1	1+	0	0	Logging
McGahey Brook (NS-01)	2004	2019	2	2+	0	0	Uncertain
Lily Lake (NS-03)	2005	2019	1	1+	1	4	n/a
Hectanooga (NS-12)	2009	2019	1	1+	0	0	Logging
Upper LaHave (NS-23)	2007	2019	1	1+	0	0	Over-collection
Upper LaHave (NS-23)	2008	2019	1	1+	0	0	Over-collection
Upper LaHave (NS-23)	2008	2019	1	1+	1	1	Unknown
Spider Lake (NS-24)	20??	2019	1	1+	0	0	Logging

* 1+ indicates a minimum of 1 thallus (the data did not provide a finer resolution).

Using data from observation sites with two reference years, the annual decline rate for the number of host trees for *H. squamulosa* was 4.5%. Based on limited available data from the nine observation sites (summarized in Table 4 and Box 4 of the Technical Summary), a loss of 33% of host trees to logging and 22% of host trees to unknown causes can be inferred from the average 12.25-year span between first and second monitoring visits (excluding Spider Lake, for which the original survey year is unknown).

The predicted future yearly decline rate of *H. squamulosa* is 3.6% or 18% over 5 years and is based on past decline rate in host trees, with weighted average adjustments on protected land, i.e., where forest harvesting should not occur (see **Habitat Protection and Ownership**). This estimated annual decline rate of colonized host trees (See Appendix 1) is used to estimate a decline in population of *H. squamulosa* as exceeding 50% over a three-generation time period. This is reported in box 5 and 6 of the Technical Summary. Declines are largely caused by continuing threats (see **Habitat Trends**; see **Threats**), justifying their use in estimating future loss. Non-protected host trees (68.1%) are expected to decline by the full 4.5% rate each year, while protected host trees (31.9%) are expected to decline by 1.5% (see **Habitat Trends**).

Fourteen of the total 31 occurrences were documented as new for the Canadian population since 2017 (Table 3). The new occurrences have likely been in existence but not documented for at least a decade, judging from the size of thalli and the generation time. *H. squamulosa* was first found in New Brunswick in 1980 and in Nova Scotia in 1987. As a result of the decline in old forest habitat in both provinces (see **Population Sizes and Trends**; see **Threats**), an overall decline in the number of mature individuals is likely.

In New England, USA, where the nearest non-Canadian population of *H. squamulosa* occurs, there are insufficient data to assess fluctuations and trends. In 2007 there were four known occurrences in Maine (Hinds and Hinds 2007). A fifth record from this state is from Roque Island, a private island with a very rich lichen flora that includes three species of *Heterodermia*. The mature forest there has only been selectively cut on a very limited scale (Seaward *et al.* 2017), A sixth record for New England is from New Hampshire (*Clyne 246-16 CUP*; Cleavitt 2020; Hinds 2020).

Rescue Effect

The likelihood for mitigation of declines in the Canadian population of *H. squamulosa* or rescue from US populations of this lichen is very low. This is a result of the dispersal limitation of the lichen and the large distance between US subpopulations and suitable Canadian habitat. The nearest non-Canadian occurrence of *H. squamulosa* is over 100 km away, in Maine (see **Wildlife Species Description and Significance**; see **Population Spatial Structure and Variability**). A total of six occurrences are known in New England. Beyond this is a gap of approximately 500 km to Pennsylvania, where the species is also present. It becomes more abundant southwest along the Appalachian Mountains (Figure 1).

THREATS AND LIMITING FACTORS

Threats

The Threats Calculator was used in 2021 to assess the threats to *H. squamulosa* in Canada, and the overall impact was high (Appendix 2). The various threats to this lichen are discussed below. The *threats* are organized and evaluated according to the unified threats classification system (IUCN and CMP 2017) of the International Union for the Conservation of Nature - Conservation Measures Partnership (IUCN-CMP). The threats that directly and negatively affect the *H. squamulosa* population are listed below from highest to lowest calculated impact.

<u>Road Building (IUCN Threat 4.1 Roads & railroads) Impact: Medium</u>

Road building results in the clearing of forest habitat, opening up of the canopy, modification of local hydrology and alteration of moisture and air quality conditions in adjacent forest ecosystems. *Heterodermia squamulosa* is sensitive to open sunlit conditions, and no occurrences have been found in places with < 50% crown closure. Thus, road construction results in a loss of the species from the adjacent forest. The threat from road construction includes both those built for forestry, e.g., the Spider Lake occurrence, and those built for cottage development, such as that found near the Hirtle Lake occurrence. Future road building poses a threat to *H. squamulose*, as 68.1% of host trees are not currently within protected areas and roads could therefore be constructed next to the sites.

<u>Logging and Wood Harvesting (IUCN Threat 5.3 Logging and wood harvesting) Impact Medium</u>

As mentioned above, *H. squamulosa* is sensitive to open sunlit conditions, as no occurrences have been found in places with < 50% crown closure. Consequently, logging results in the definitive loss of trees with thalli, but also results in a decrease in habitat quality on trees with thalli in proximity to harvested areas. Logging resulted in the partial loss of the Spider Lake occurrence in 2016 or 2017 and the loss of the Grand Bay-Westfield occurrence in 2014 or 2015.

While some *H. squamulosa* occurrences are found in operationally challenging terrain, such as steep slopes or wetlands, most sites where the lichen was observed could be harvested in the future. As evidence, 12 occurrences were found within 100 m of clearcutting (as defined by Natural Resources Canada 2020) that has occurred between 1984 and 2018, when satellite imagery became available for GIS analysis (Gorelick *et al*. 2017). About 15% of Nova Scotia’s forests were clear-cut between 1990 and 2007 (Cheng *et al*. 2009), for an annual rate of 0.88%, a trend that appears to have continued since 2007 based on annual satellite imagery (Gorelick *et al*. 2017).

Heterodermia squamulosa relies on very old forests. No occurrence was found in habitats that had visible signs of past machine forest harvesting, such as tree stumps or skidder trails. All forests where it is found are described as mature climax, old, or old-growth forest (sensu NSDNR 2012). This suggests a minimum dominant or co-dominant tree age of at least 80 years as well as long-term forest type and cover continuity. The temporal continuity requirements of this species suggest that other occurrences were lost in the past, given the dominance of clearcutting as a forestry practice in the Maritimes (Johnson 1986; Gorelick *et al*. 2017; Lahey 2018a, b; Global Forest Watch 2020). Most forests of New Brunswick and Nova Scotia have been logged in the past and continue to be included as part of the timber landbase.

The threat from logging in Nova Scotia could be reduced by a commitment by the provincial government, as outlined in the Lahey Report (Lahey 2018a, b), to reduce clearcutting from the present-day level of 65% to between 20% and 25% on Crown land. However, this has not yet been implemented and only applies to Crown land. Only five host trees from one occurrence of *H. squamulosa* have been found on Crown land, and protection for them is currently pending (NSE 2020). Another 93 host trees from 17 occurrences are unprotected as they are on private land and may be subject to future logging. At least in the short term, the proposed ban on clearcutting on Crown land will probably result in an increase in clearcutting on private land. While the Nova Scotia Endangered Species Act fully applies on both private and Crown land, on private lands the onus is on the private landowner to ensure that prohibitions under the Act for threatened or endangered species are not breached.

<u>Acid Rain (IUCN Threat 9.5 Air-borne pollutants) Impact Medium-Low</u>

An adverse change in air quality and precipitation pH, and resulting changes of bark pH, soil pH and nutrient availability, can both directly affect lichen growth and impact habitat quantity and quality through their effects on forest composition and vigour, and on physical and chemical properties of trees, including the texture and moisture-retaining ability of bark (OMNR 2004; see COSEWIC 2020). *Heterodermia squamulosa* is known to occur in habitats with nutrient-enriched soils, which may have buffered these effects to some extent. However, nutrient-enriched sites are still being impacted by acid precipitation (Nieboer *et al.* 1984) through the stunting or killing of suitable host trees. Acid rain pollution diminished significantly in the late 1980s and 1990s. Some effects may persist, but sites may be slowly recovering.

<u>Land Development (IUCN Threat 1.1 Residential & commercial development) Impact Low</u>

Residential development results in the clearing of forest habitat and modification of local hydrology, humidity and air-quality conditions in adjacent forest ecosystems. The area within 200 and 500 m of the Hirtle Lake occurrence has experienced a significant increase in dwellings since 1978 (Gorelick *et al.* 2017), accompanied by road building and land clearing. Much of the development has occurred since 2016. The Hirtle Lake occurrence is found in an area with already-subdivided plots, and upwards of 30 dwellings are within 500 m of the occurrence. The Cape Split occurrence has also experienced ~0.1 hectares of forest clearing for dwellings and viewscapes for these dwellings. The latter clearing resulted in the removal of trees in habitat (steep slope-tolerant hardwood forest) in which *H. squamulosa* is prevalent, and *H. squamulosa* was found on both sides of the clearing. Although it is impossible to know with certainty that host trees were removed, based on occurrence data and presence of suitable habitat in adjacent uncut forests, host tree loss is likely. No other occurrence appears to be threatened by residential development at this time.

Fire (IUCN Threat 7.1 Fire & fire suppression) Impact Low

An increase in fires is expected as a result of the recent and predicted increase in the length and severity of summer droughts (see Climate Change). Forest fire ignitions are mostly anthropogenic in origin and are expected to continue to occur. The hardwood component of suitable *H. squamulosa* habitat does provide a protective buffer against extensive fire damage, which generally points to a low level of impact.

Invasive Species (IUCN Threat 8.1 Invasive non-native/alien species/diseases) Impact Low

Several invasive species are known to kill or stunt the growth of hardwood trees in the Maritimes (Belliveau and Mersey Tobeatic Research Institute 2012). The Emerald Ash Borer (*Agrilus planipennis*), confirmed in New Brunswick and Nova Scotia in 2018 (CFIA 2020), is known to kill most species of ash tree in infested areas (COSEWIC 2018). Of 144 total host trees for *H. squamulosa* in Canada, eight are White Ash trees (which support a total of 25+ thalli), and nine others are in forested ecosystems dominated or co-dominated by White Ash, all of which are in southwestern Nova Scotia. The shortest distance between a present Emerald Ash Borer infection and an occurrence of *H. squamulosa* in White Ash habitat is approximately 95 km. This insect appears to be capable of jumping hundreds of kilometers in range in just a few years (CFIA 2020), which suggests that White Ash trees and other host tree species within White Ash forests may be negatively affected within a single *H. squamulosa* generation. Some thalli of this lichen may survive on other trees upon the death of White Ash trees in an occupied forest; thus the severity of this threat is considered serious rather than extreme.

Climate Change (IUCN Threat 11 Climate change and severe weather) Impact: Unknown

A high level of uncertainty exists regarding climate change in Nova Scotia with respect to fog, precipitation and wind (Lemmen 2016; McClearn 2018). Higher temperatures, with more frequent extreme temperature events and high precipitation events as well as earlier spring thaws, may have already stressed *H. squamulosa*. Direct impacts may include physical stressors from changes in moisture availability or changes in freeze-thaw cycles, while indirect impacts may include metabolic and other chemical changes within the lichen.

The apparent coastal affinity of Canadian *H. squamulosa* occurrences suggests that this species requires a relatively moist climate influenced by frequent fog (See **Habitat Requirements**). Declines in fog frequency and duration could potentially negatively impact its ability to thrive in coastal forests. In Nova Scotia, multiple trends point to a reduction in fog frequency (Beauchamp *et al.* 1998; Mucara *et al.* 2001). New Brunswick trends are likely similar, although data are not available for the province.

Higher temperatures and drought events will significantly reduce moisture regimes in the region despite the increase in projected precipitation in Atlantic Canada (Vincent et al. 2018). For example, projections for the Annapolis Valley, a region of Nova Scotia roughly in the center of *H. squamulosa*'s Canadian EOO, expects mean annual temperatures in the 2050s to increase by 2.3°C compared to historical data from the 1980s (Climate Data for Nova Scotia 2021). Annual water deficit (potential actual evapotranspiration) is expected to increase (36 mm to 48.8 mm) in the same time period, despite an increase in precipitation (from 1,351.8 mm to 1,396 mm). In New Brunswick, projected climate change signals are similar to Nova Scotia. In Saint John, a city situated on the Fundy coast within *H. squamulosa*'s Canadian distribution, mean annual temperatures in the 2050s are projected to increase by between 2.2°C and 3.1°C compared to the historical reference period from 1981 to 2010 (Roy and Houard 2016). Annual precipitation is projected to increase from 6.8% to 7.9% in the same period, but no projections on water deficits have been made. Broadly, drier conditions are projected for all Maritime Canada, although coastal areas may be impacted less than inland regions (Vasseur and Catto 2008). Outside of Canada, *H. squamulosa* grows in areas where there are higher temperatures and more precipitation, both of which are expected to increase in Atlantic Canada with climate change (Vincent *et al.* 2018), suggesting that these changes may not affect this species.

An increased frequency and severity of extreme weather events is expected (Vasseur and Catto 2008, Vincent *et al.* 2018). The latter could result in more windthrow of host trees for *H. squamulosa*. Additionally, loss to windthrow may be more likely on the older, often taller old host trees required by *H. squamulosa* in comparison to the younger, shorter, and denser forests that frequently result from past forest harvesting activities. The host trees at the Cape Split occurrence, where the greatest population of the lichen is found, are not only in a very windy area but are also especially vulnerable to uprooting, given that Yellow Birch, the main host species at Cape Split, tends to grow leaning at an angle on the steep slopes. Windthrow losses are also likely to have a greater impact on lichen survival at the 23 occurrences where there are fewer than five host trees.

Changes to the winter freeze-thaw cycle, the timing of frosts, and the frequency of ice storms are possible threats (Vasseur and Catto 2008, Vincent *et al.* 2018). These could increase damage to host trees. For example, in eastern North America, winter freeze-thaw has been linked to historical dieback of Yellow Birch (Bourque *et al.* 2005), of which at least 62 are host trees for 92 thalli.

Trail Clearing (IUCN Threat 1.3 Tourism & recreation areas) Impact: Negligible (See Appendix 2 comments.)

Clearing trees for trail building or upgrading can result in the removal or harm of host trees for *H. squamulosa* and other lichens of conservation concern. Several cut trees were reported in 2020 from the Cape Split Trail (Cape Split Provincial Park), approximately 1 km into the trail from the parking area and within suitable *H. squamulosa* habitat. It is not known if the removed trees hosted any thalli, but the lichen is very common at this occurrence, with over 200 thalli being recorded.

Utility & Service Lines (IUCN Threat 4.2 Utility and service lines) Impact Negligible (See Appendix 2 comments.)

Utility and service lines may be constructed in order to service new residential developments or cottages. Such activities could destroy or alter habitat for *H. squamulosa*.

Non-lethal Harvesting (IUCN Threat 5.2 Gathering terrestrial plants) Impact Negligible

Some collecting for monitoring of lichen populations has gone on in the past (see **Fluctuations and Trends**). When necessary, only part of a thallus is now collected for identification or other purposes, so the impact is now negligible.

White-tailed Deer Herbivory (IUCN Threat 7.3 Other ecosystem modifications) Impact Uncertain (See Appendix 2 comments.)

White-tailed Deer (*Odocoileus virginianus*) are known to browse on hardwood seedlings, affecting the recruitment of hardwood trees, and may alter or inhibit the growth of suitable host trees for *H. squamulosa*. This ungulate is not native to the current Canadian distribution range of *H. squamulosa* (Nova Scotia and part of New Brunswick) and was introduced to this region just over 100 years ago. As a ruminant, it will consume plants including woody vegetation. Unpublished data from Kejimkujik National Park and National Historic Site, where White-tailed Deer numbers are relatively high, suggest that heavy browsing may result in a lack of recruitment of seedlings into the sapling stage and subsequently into the mature tree stage (Mersey Tobeatic Research Institute 2010). However, as the typical age of trees that host this lichen is > 80 years, lichen abundance will not be greatly affected within the next 57 years (three generations for *H. squamulosa)* by the increased deer abundance. With respect to lichens, White-tailed Deer can rub snout or hides against the lichen or scrape their antlers in the fall on tree trunks. However, these activities are unlikely to remove significant amounts or *H. squamulosa* from the trees or lead to an increase in dispersal of the lichen.

Human Intrusions and Disturbance (IUCN Threat 6.1 Recreational activities) Not scored

Several hardwood trees were cut down within 75 m of two occurrences at Bennetts Lake. The trees were cut down to increase visibility in a line of sight between a White-tail Deer hunting blind on the ground and a pile of bait apples. The area where trees were cut down was moderately suitable habitat for *H. squamulosa*. Several sites (at least Pearl Lake and Van Tassel Lake) are, or have recently been, impacted by All-Terrain Vehicle (ATV) use. ATV trails in suitable habitat, especially in occupied wetland habitat, can alter hydrology and tree health (root damage).

Limiting Factors

Habitat Specificity

Scaly Fringe Lichen requires mature to old hardwood or mixedwood forest dominated by long-lived, shade-tolerant tree species. Even within surveyed mature to old hardwood or mixedwood forest types, this lichen is limited in local and regional distribution. In short, suitable forest types now represent a very small proportion of forests in Nova Scotia and New Brunswick.

Dispersal

Heterodermia squamulosa is likely dispersal-limited. It can only disperse via its lobules or thallus fragments; longer-distance dispersal events are likely rare, limiting its ability to colonize the small remaining areas of suitable habitat in New Brunswick and Nova Scotia (see **Biology – Dispersal and Migration**).

Northern Edge of Range

The New Brunswick and Nova Scotia occurrences of *H. squamulosa* are the northernmost in the world and experience the coldest climate or any global population. The lack of known occurrences further north suggests that its current range in Canada represents its furthest biogeographic reach. It is possible that warming climates will lead to expanded climatic suitability, but the lack of large mature hardwood deciduous trees to the north of current occurrences and limited dispersal ability may impede the northward movement of this rare lichen in Canada.

Number of Locations

The number of locations for *H. squamulosa* in Canada is 29, which is the same number as the number of extant occurrences. This number represents the impact of threats that apply at the local stand scale, such as forestry activities and road construction. There are 31 known occurrences, but two are no longer extant (Table 5).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Heterodermia squamulosa is not legally protected in any jurisdiction in which it is known to occur.

Non-Legal Status and Ranks

Globally, NatureServe assigns *H. squamulosa* a status of G3G5 / Vulnerable to Secure (last reviewed 2000-12-08). In the USA, it is unranked in North Carolina and Pennsylvania. In Canada, *H. squamulosa* is ranked as N3 / Vulnerable (NatureServe 2021).

At the provincial level, it is ranked S1? / Critically Imperiled in New Brunswick and S3 / Vulnerable in Nova Scotia by the Atlantic Canada Conservation Data Centre (in collaboration with provincial government staff). The species still has an SNR ranking in Quebec, where it does not occur (the only collection was misidentified).

Habitat Protection and Ownership

Currently, 31.9% of *H. squamulosa* host trees in New Brunswick and Nova Scotia are in protected areas (as defined by the IUCN), with an additional 3% pending designation to protected status in Nova Scotia, and another 8% that may be protected from tree harvesting by riparian zone regulations (Table 5). In terms of the 29 extant occurrences, 11 (37%) are completely protected from development activities. Four of these protected occurrences, encompassing six host trees, are in Fundy National Park, New Brunswick. The former Welsford occurrence in New Brunswick is on CFB Gagetown lands (AMEC 2011), and so the trees are unlikely to be cut. Eighteen (60%) of the occurrences are not protected. One, Cape Split, is protected in part, as the land ownership is split between a provincial park and private ownership. Most of the land protection in New Brunswick and Nova Scotia has occurred in the last 25 years. This means for *H. squamulosa,* with its three-generation time frame, that most of the protected areas established to date have a disproportionately high amount of unsuitable habitat for this species and have poor soils. This is, in part, due to the fact that protection has been of lands that are mainly public. In many cases, these lands remained as public land because they were never claimed by settlers that sought areas with fertile soils for subsistence farming.

Table 5. Summary of protection and ownership types for locations and occurrences of *Heterodermia squamulosa* in Canada

		Percent of Host Trees								
		Protected					Not Protected			
Occurrence Name	No. Host Trees	Nat. Park	Prov. Nature Reserve	Prov. Wilderness Area	Land Trust	Prov. Park	Crown Land	Mun. Land	Small Private Land	Large Private Land
Welsford	0						100[1]			
Grand Bay-Westfield	0									100
Loch Alva	1			100						
Goose River	1	100								
Maple Grove	1	100								
Marven Lake	3	100								
Herring Cove	1	100								
McGahey Brook	2					100				
Eatonville	1					100				
Cape Split	79					38			62	
Ross Creek	2									100[2]
Lily Lake	1							100		
Victoria Vale	1								100[3]	
Victoria Beach	1								100	
Van Tassel Lake	8							87.5[2]	12.5[2]	
Awkward Cove	2									100[1]
Saint Joseph	1									100
Churchills Lake	6								100	
Hectanooga	3		33.3						66.7	
Bennetts Lake	2				100					
Canaan	1									100[1,2]
Lac de l'École	1				100					
Pearl Lake	2				100					
Moses Lake	2								100[2]	
Four Mile Stillwater	1			100						
Kempt	1								100[2]	
Shingle Lake	5						100[2,4]			
Hirtle Lake	8								100[5]	
Caribou Brook	1								100	
Upper LaHave	3								100	
Spider Lake	4								100[6]	
TOTAL	**145**	**32%**					**68%**			

[1] On Department of National Defense (CFB Gagetown) land.

[2] On land owned by a large, international property management firm.

[3] Within or likely within protected riparian zone as per the Wildlife Habitat and Watercourses Protection Regulations made under Section 40 of *Nova Scotia's Forests Act*.

[4] Within land that has Nova Scotia provincial nature reserve status pending official designation.

[5] Occurrence on subdivided private lands; other nearby parcels have already been developed.

[6] Occurrences likely managed by large forest company.

ACKNOWLEDGEMENTS

Much of the fieldwork and report writing was supported by Acadia University's E.C. Smith Herbarium and K.C. Irving Environmental Science Centre. The report writer thanks the following individuals for their assistance with this report: Frances Anderson (data sharing and volunteer fieldwork), Colin Chapman-Lam (fieldwork, report writing and reviewing), James Churchill (fieldwork, data sharing, habitat suitability modelling, and EOO/IAO mapping), Stephen Clayden (volunteer fieldwork), Sean Haughian (habitat suitability modelling and draft reviewing), Katie King (volunteer fieldwork), Tom Neily (data sharing), David Richardson (report), Charity Robicheau (fieldwork and habitat suitability modelling), Cole Vail (volunteer report research), and Neil Vinson (fieldwork).

AUTHORITIES CONTACTED

- Frances Anderson, Research Associate, Nova Scotia Museum, Halifax, Nova Scotia.
- Sean Blaney, Director, Atlantic Canada Conservation Data Centre, Sackville, Nova Scotia.
- Stephen Clayden, Curator and volunteer lichen expert, New Brunswick Museum, Saint John, New Brunswick.
- Sean Haughian, Plant ecologist, Nova Scotia Museum of Natural History, Halifax, Nova Scotia.
- David Richardson, Dean Emeritus, Saint Mary's University, Halifax, Nova Scotia.
- Mary Sabine, Biologist, Species at Risk and Protected Natural Areas Section, New Brunswick Department of Natural Resources and Energy Development, Fredericton, New Brunswick.
- Mark Seaward, Faculty of Life Sciences, University of Bradford, Bradford BD7 1DP, United Kingdom.

INFORMATION SOURCES

AC CDC (Atlantic Canada Conservation Data Centre). 2020. Lichen occurrence data. Digital database, Atlantic Canada Conservation Data Centre, Sackville NB [exported February 2020].

Allen, J.L. and J.C. Lendemer. 2015. *Japewiella dollypartoniana*, a New Widespread Lichen in the Appalachian Mountains of Eastern North America. Castanea 80(1): 59-65.

AMEC 2011. Final report: provision of consulting services SAR P*seudevernia cladonia* inventory and assessment CFB GAGETOWN, NB.DCC FILE NO.: GA162383. Submitted to Defence Construction Canada Oromocto, New Brunswick.March 28, TE101095.

ANBG (Australian National Botanic Gardens and Australian National Herbarium). 2020. Information about Australia's Flora – Australian Lichens: Form and structure. Website: https://www.anbg.gov.au/lichen/form-structure-reproduction.html [accessed March 2020].

Anderson, E., A. Limaye, A. Flores, and E.A. Cherrington. 2011. Climate Change Impacts on Surface Water in Central America and Hispaniola. CATHALAC (Centro del Agua del Trópico Húmedo para América Latina y el Caribe), USAID (United States Agency for International Development), NASA (National Aeronautics and Space Administration), SERVIR. 35 pp.

Armstrong, R. and A. Bradwell. 2011. Growth of foliose lichens: A review. Symbiosis 53(1):1-16.

Asplund, J., and Y. Gauslaa. 2008. Mollusc grazing limits growth and early development of the old forest lichen *Lobaria pulmonaria* in broadleaf deciduous forests. Oecologia 155:93-99.

Auditor General of New Brunswick. 2015. Auditor General Report – Volume II (June 2015): Chapter 3 – Department of Natural Resources – Silviculture. Website: https://www.agnb-vgnb.ca/content/dam/agnb-vgnb/pdf/Reports-Rapports/2015V2/Agrepe.pdf [accessed March 2020].

Beauchamp, S., R. Tordon, A. Pinette. 1998. Chemistry and deposition of acidifying substances by marine advection fog in Atlantic Canada. Pp. 171–174.In: R.S. Schemenauer and H. Bridgman (eds). First International Conference on Fog and Fog Collection, Vancouver, Canada, July 19-24, 1998 [Proceedings].

Baur, B., L. Fröberg, and A. Baur 1995. Species diversity and grazing damage in a calcicolous lichen community on top of stone walls in Oland, Sweden. Annales Botanici Fennici 32:239 -250.

Belliveau, A.G. and R.T. McMullin. 2017. *Parmotrema perforatum* new to Canada from Kejimkujik National Park and national historic site in Nova Scotia, Canada. Opuscula Philolichenum 16:322-328.

Belliveau, A.G. 2012. Invasive alien species in Nova Scotia: Identification & information guide. Kempt, N.S.: Mersey Tobeatic Research Institute.

Bourque, C.P.A., R.M. Cox, D.J. Allen, P.A. Arp, and F.R. Meng. 2005. Spatial extent of winter thaw events in eastern North America: historical weather records in relation to yellow birch decline. Global Change Biology 11(9):1477–1492.

Brodo, I. M., S.D. Sharnoff and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven, Connecticut. xxiii + 795 pp.

Brodo, I. M., S. Laurie-Bourque, S.D. Sharnoff and S. Sharnoff. 2016. Keys to Lichens of North America. Yale University Press, New Haven, Connecticut. xi + 427 pp.

Bubrick, P., M. Galun and A. Frensdorff. 1984. Observations on free-living *Trebouxia* De Puymalyand *Pseudotrebouxia* Archibald, and evidence that both symbionts from *Xanthoria parietina* (L.) Th. Fr. can be found free-living in nature. New Phytologist 97(3):455-462.

Cameron, R. 2009. Are non-native gastropods a threat to endangered lichens? Canadian Field-Naturalist 123(2):69-171.

Cameron, R. and D.M. Bayne, 2020. Identifying lichen-rich areas in Nova Scotia. Proceedings of the Nova Scotian Institute of Science 50(2):227-231.

CFIA (Canadian Food Inspection Agency). 2020. Emerald Ash Borer - Latest Information. Website: https://inspection.gc.ca/plant-health/plant-pests-invasive-species/insects/emerald-ash-borer/latest-information/eng/1337287614593/1337287715022 [accessed March 2020].

Cheng, R., P.G. Lee. 2009. Recent (1990-2007) anthropogenic change within the forest landscapes of Nova Scotia. Global Forest Watch Canada, Edmonton, Alberta.

Clayden, S.R. 2010. Lichens and allied fungi of the Atlantic Maritime Ecozone. In Assessment of Species Diversity in the Atlantic Maritime Ecozone. Edited by D.F. McAlpine and I.M. Smith. NRC Research Press, Ottawa, Canada. Pages 153–178.

Clayden, S.R. 2014. Old tolerant hardwood forests in New Brunswick: Going down fast. New Brunswick Naturalist 2014(4):61-66.

Clayden, S.R. 2010. Lichens and allied fungi of the Atlantic Maritime Ecozone. In Assessment of Species Diversity in the Atlantic Maritime Ecozone. Edited by D.F. McAlpine and I.M. Smith. NRC Research Press, Ottawa, Canada. Pages 153–178

Cleavitt, N.L., pers. comm. 2020. *Email correspondence to A.G. Belliveau*. March 20, 2020. Vegetation Scientist and Research Associate, Cornell University, Ithaca, New York.

Climate Data for Nova Scotia. 2021. Climate Data for Nova Scotia.Website: https://climatechange.novascotia.ca/climate-impacts. [accessed 2021 Jun 2]

Climate-Data.org. 2021. Wakkanai Climate.

CNALH (Consortium of North American Lichen Herbaria). 2020. Consortium of North American Lichen Herbaria. site: https://lichenportal.org/portal/[accessed March 2020].

COSEWIC. 2009. COSEWIC assessment and status report on the Vole Ears *Erioderma mollissimum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 51 pp.

COSEWIC. 2010. COSEWIC assessment and status report on the Blue Felt Lichen *Degelia plumbea* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 42 pp.

COSEWIC. 2012. COSEWIC assessment and status report on the Eastern Wood-pewee *Contopus virens* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 39 pp.

COSEWIC. 2014. COSEWIC assessment and status report on the Boreal Felt Lichen *Erioderma pedicellatum*, Boreal population and Atlantic population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 66 pp.

COSEWIC. 2015. COSEWIC assessment and status report on the Black-foam Lichen *Anzia colpodes* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 47 pp.

COSEWIC. 2018. COSEWIC assessment and status report on the Black Ash *Fraxinus nigra* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 95 pp.

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.

COSEWIC. 2020. Status report on Vole Ears Lichen *Erioderma mollissimum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiii + 69 pp.

Duchesne, L., R. Ouimet and D. Houle. 2002. Basal area growth of Sugar Maple in relation to acid deposition, stand health, and soil nutrients. Journal of Environmental Quality 31(5):1676-1683.

Fournier, R. 2006. Liste des Lichens de l'est du Canada. Université de Moncton Campus D'Edmundston, Faculté de foresterie.

GBIF. 2019. *Heterodermia squamulosa* (Degel.) W.L. Culb. in GBIF Secretariat. GBIF Backbone Taxonomy. Checklist dataset. Website: https://doi.org/10.15468/39omei [accessed March 2020

Global Forest Watch. 2020. Location of tree cover loss in Nova Scotia, Canada. Website: http://www.globalforestwatch.org. [accessed March 2020].

Gorelick, N., M. Hancher, M. Dixon, S. Ilyushchenko, D. Thau and R. Moore. 2017. Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment. Website: https://earthengine.google.com/timelapse/ [accessed March 2020].

Government of Canada. 2021a. Canadian Climate Normals 1981-2010 for Halifax Citadel. Environment Canada. Website: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=halifax&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=6357&dispBack=0. [accessed January 2021].

Government of Canada. 2021b. Canadian Climate Normals 1981-2010 for Moncton. Environment Canada. Website: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=Moncton&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=6206&dispBack=0. [accessed January 2021].

Gustafsson, L. and I. Eriksson. 1995. Factors of importance for the epiphytic vegetation of aspen *Populus tremula* with special emphasis on bark chemistry and soil chemistry. Journal of Applied Ecology 32:412-424.

Hallmann, C., M. Hoppert, O. Mudimu and T. Friedl. 2016. Biodiversity of green algae covering artificial hard substrate surfaces in a suburban environment: a case study using molecular approaches. Journal of Phycology 52(5):732-744.

Haughian, S., J. Churchill, C. Robicheau. 2019. *Heterodermia squamulosa* habitat suitability model developed for the COSEWIC *Heterodermia squamulosa* Status Report. Nova Scotia Museum of Natural History and Atlantic Canada Conservation Data Centre.

Hayward, B.W. and R.V. Grace. 1999. Transient and ancient lichens – twenty-one years of growth monitoring at Kawerua, Northland, New Zealand. Tane 37:27-41.

Heterodermia squamulosa (Degel.) W.L. Culb. in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset. Website https://doi.org/10.15468/39omei [accessed March 2020].

Hinds, J.W. and P.L. Hinds. 2007. The macrolichens of New England: Descriptions, color illustrations, identification keys, conservation status. Botanical Garden Press, Bronx, New York. xviii + 584 pp.

Hinds, J.W., pers. comm. 2020. *Email correspondence to A.G. Belliveau*. March 2020. Orono, Maine.

Houston, D.R. 1983. American Beech Resistance to *Cryptococcus fagisuga*; In: Proceedings, I.U.F.R.O. Beech Bark Disease Working Party Conference; 1982 September 26-October 8; Hamden, CT. Sponsored by the USDA Forest Service, Northeastern Forest Experiment Station. Gen. Tech. Rep. WO-37. U.S. Department of Agriculture, Washington, DC. Forest Service:38-42.

IPCC (Intergovernmental Panel on Climate Change). 2014. Mean annual rainfall 1981–2014, with number of months of 50 mm or more of rainfall: maps were reproduced for West Africa using IPCC 5th Assessment Report data (see https://www.ipcc.ch/assessment-report/ar5/). Website: https://eros.usgs.gov/westafrica/node/157 [accessed January 2021].

IUCN and Conservation Measures Partnership (CMP). 2017. IUCN-CMP Unified Classifications of Direct Threats and Conservation Actions. Website: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwju2fyxrf_9AhUrlGoFHbmFDaoQFnoECBEQAQ&url=https%3A%2F%2Fnc.iucnredlist.org%2Fredlist%2Fcontent%2Fattachment_files%2Fdec_2012_guidance_threats_classification_scheme.pdf&usg=AOvVaw1ZzeBZ6BW6hjwYERmpASeg. [accessed March 2020].

IUCN (International Union for the Conservation of Nature). 2019. IUCN-CMP Unified Classifications of Direct Threats and Conservation Actions. Website: http://cmp-openstandards.org/using-os/tools/threats-taxonomy [accessed March 2020]. https://www.iucnredlist.org/resources/redlistguidelines

J.D. Irving Limited. 2014. The 2012-21 Forest Management Plan for Crown License 7. Prepared and submitted by J. D. Irving, Limited on July 31st, 2014, to the New Brunswick Department of Natural Resources as required under the New Brunswick Crown Lands and Forest Act. Website: https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/ForestsCrownLands/ScheduleC.pdf [accessed March 2020].

Johnson, R. 1986. Forests of Nova Scotia: A history. Nova Scotia Department of Lands and Forests, Halifax. 407 pp.

Larsson, P. and Y. Gauslaa 2011, Rapid juvenile development in old forest lichens. Botany 89:65-72.

Lahey, W. 2018a. An Independent Review of Forest Practices in Nova Scotia: Addendum. 253 pp. Website: https://novascotia.ca/natr/forestry/Forest_Review/FP_Addendum.pdf [accessed March 2020].

Lahey, W. 2018b. An Independent Review of Forest Practices in Nova Scotia: Executive Summary Conclusions and Recommendations. 70 pp. Website: https://novascotia.ca/natr/forestry/forest_review/Lahey_FP_Review_Report_ExecSummary.pdf [accessed March 2020].

Lavers, A., K. Rowter and A.G. Belliveau, A.G. 2008. Unpublished tracking data on PIT-tagged flying squirrels in Queens County, Nova Scotia.

Lawrence, G. B., P.W. Hazlett, I.J. Fernandez, R. Ouimet, S.W. Bailey, W.C. Shortle, K.T. Smith and M.R. Antidormi. 2015. Declining acidic deposition begins reversal of forest-soil acidification in the Northeastern U.S. and Eastern Canada. Environmental Science & Technology 49(22):13103-13111.

Lemmen, D.S., F.J. Warren, T.S. James and C.S.L. Mercer-Clarke (ed.) 2016. Canada’s Marine Coasts in a Changing Climate; Government of Canada, Ottawa, Ontario. 274 pp.

Lendemer, J.C. 2009. A synopsis of the lichen genus *Heterodermia* (Physciaceae, lichenized Ascomycota) in eastern North America. Opuscula Philolichenum 6:1-36.

Lendemer, J.C., K.G. Keepers, E.A. Tripp, C.S. Pogoda, C.M. McCain and N.C. Kane. 2019. A taxonomically broad metagenomic survey of 339 species spanning 57 families suggests cystobasidiomycete yeasts are not ubiquitous across all lichens. American Journal of Botany 106(8):1090–1095.

Loo, J.A. and N. Ives. 2003. The Acadian forest: historical condition and human impacts. Forestry Chronical 79:462-474.

MacKinnon, R.A. 1991. The Historical Geography of Agriculture in Nova Scotia, 1851-1951. A Thesis Submitted In Partial Fulfilment of The Requirements For The Degree Of Doctor of Philosophy in The Faculty of Graduate Studies (Department of Geography, University of British Columbia. Website: https://open.library.ubc.ca/cIRcle/collections/ubctheses/831/items/1.0100608 [accessed March 2020].

McLearn, M. 2018. Rising seas and climate change. Globe and Mail. Website: https://www.theglobeandmail.com/canada/article-sea-change-primer/ [accessed March 2020].

McMullin, R.T. and Y.F. Wiersma. 2019. Out with OLD growth, in with ecological continNEWity: New perspectives on forest conservation. Frontiers in Ecology and the Environment 17(3):176-181.

McMullin, R.T. 2020. *Email Correspondence to A.G. Belliveau*. March 2020. Research Scientist, Lichens, Canadian Museum of Nature, Gatineau, Quebec.

Mersey Tobeatic Research Institute (MTRI). 2010. Unpublished data for vegetation surveys of five 300 m^2 transects in mixedwood forests of Kejimkujik National Park and National Historic Site. Kempt, Queens County, Nova Scotia.

Mikryukov, V.S., I.N. Mikhailova and C. Scheidegger. 2010. Reproductive parameters of *Lobaria pulmonaria* (L.) Hoffm. in the Urals. Russian Journal of Ecology 41(6):475-479.

Moberg, R. 2011. The lichen genus *Heterodermia* (Physciaceae) in South America - A contribution including five new species. Nordic Journal of Botany 29(2):129-147.

Mongkolsuk, P, V. Meesim, V., Poengsungnoen ,K. Buaruan, F. Schumm and K. Kalb 2015. The lichen family Physciaceae in Thailand—II. Contributions to the genus *Heterodermia* sensu lato. *Phytotaxa* 235 (1):1–66.

Moran, M., O. Zheng, R. Pavlovic, S. Cousineau, V. Bouchet, M. Sassi, P. Makar, W. Gong, and C. Stroud. 2008. Predicted acid deposition critical-load exceedances across Canada from a one-year simulation with a regional particulate-matter model.

Mosseler, A., Lynds, J.A. and J.E. Major. 2003. Old-growth forests of the Acadian Forest Region. Environmental Reviews 11: S47-S77.

Mucara, G., D.C. Maciver, N. Urquizo, and H. Auld. 2001. The climatology of fog in Canada. Pp. 513–516. In R.S. Schemenauer and H. Bridgman (eds.) Proceedings: First International Conference on Fog and Fog Collection, July 19-24, 1998, Vancouver, Canada.

Mukhtar, J.G. and M. Galun. 1994. Does the lichen alga *Trebouxia* occur free-living in nature: Further Immunological Evidence. Symbiosis 17:247-253.

Nash, T.H., B.D. Ryan, C. Gries and F. Bungartz (eds.). 2002. Lichen Flora of the Greater Sonoran Desert Region Volume 1. Arizona State University Lichen Herbarium, Tempe, Arizona. 532 pp.

Natural Resources Canada. 2020. Forestry glossary. Website: https://cfs.nrcan.gc.ca/terms/category/11 [accessed March 2020].

NatureServe. 2020. Definitions of NatureServe Conservation Status Ranks. Website: http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm [accessed March 2020].

NatureServe. 2021. *Heterodermia squamulosa* | NatureServe Explorer 2.0. Website: explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.125413/Heterodermia_squamulosa [accessed January 2021].

NBDNRED (New Brunswick Department of Natural Resources and Energy Development). 2017. Old Tolerant Hardwood Habitat - habitat supply analysis for forest-dependent vertebrate species in New Brunswick. Unpublished analysis.

NOAA (National Oceanic and Atmospheric Administration). 2021a. Salt Lake City Area monthly summarized data, 1981-2010, mean of monthly average temperatures. Website: https://w2.weather.gov/climate/xmacis.php?wfo=slc [accessed January 2021].

NOAA (National Oceanic and Atmospheric Administration). 2021b. Pittsburgh monthly summarized data, 1981-2010, mean of monthly average temperatures. Website: https://w2.weather.gov/climate/xmacis.php?wfo=slc [accessed January 2021].

NSE (Nova Scotia Department of Environment). 2020. Interactive Map – Parks and Protected Areas. Website: https://novascotia.ca/parksandprotectedareas/plan/interactive-map/ [accessed March 2020].

NSDNR (Nova Scotia Department of Natural Resources). 2010. Forest Ecosystem Classification for Nova Scotia Part II: Soil Types. Report FOR 2011-3. Keys. K., P. Neily, E. Quigley. Website: https://novascotia.ca/natr/library/forestry/reports/Soil-Types.pdf [accessed March 2020].

NSDNR. 2011. The Path We Share, A Natural Resources Strategy for Nova Scotia 2011-2020, Nova Scotia Department of Natural Resources. 79 pp.

NSDNR. 2012. Nova Scotia's Old Forest Policy. Report FOR 2012-4.

NSDNR. 2016. Forest Inventory – Current Forest Data. Shapefile. Website: https://novascotia.ca/natr/forestry/gis/pdf/Forest_metadata_web_attrib.pdf [accessed March 2020].

NSDNR. 2017. State of the Forest. ISBN: 978-1-55457-737-8. Website: https://novascotia.ca/natr/forestry/reports/State_of_the_Forest_2016.pdf [accessed March 2020].

NSDLF (Nova Scotia Department of Lands and Forestry). 2020. Forest Ecosystem Classification Soil Type Data. Shapefile. Website: https://novascotia.ca/natr/forestry/veg-types/[accessed March 2020].

OMNR (Ontario Ministry of Natural Resources). 2004. Ontario Tree Marking Guide, Version 1.1. Ontario Ministry of Natural Resources. Queen's Printer for Ontario, Toronto. 252 p. Website: https://dr6j45jk9xcmk.cloudfront.net/documents/2807/guide-treemarking.pdf [accessed June 2020].

Ouimet, R., L. Duchesne, D. Houle and P.A. Arp. 2001. Critical loads and exceedances of acid deposition and associated forest growth in the northern hardwood and boreal conifers forests in Quebec, Canada. Water, Air and Soil Pollution: Focus 1:119-134.

Palmqvist, K. and B. Sundberg. 2001. Light use efficiency of dry matter gain in five macro-lichens: Relative impact of microclimate conditions and species-specific traits. Plant, Cell and Environment 23(1):1-14.

Phillips, S.J., M. Dudík, J. Elith, C.H. Graham, G.A. Lehmann, J. Leathwick, and S. Ferrier. 2009. Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. Ecological Applications 19: 181–197.

Phillips, S.J., M. Dudík, and R.E. Schapire. 2019. Maxent software for modelling species niches and distributions (version 3.4.1). Website: http://biodiversityinformatics.amnh.org/open_source/maxent/. [accessed on 2019-10-01].

Ponder, W.F, G.A. Carter, P. Flemons, and R.R. Chapman. 2001. Evaluation of Museum Collection Data for Use in Biodiversity Assessment. Conservation biology 15 (3): 648-657.

Pöykkö , H., M. Hyvarinen and M. Backor 2005. Removal of lichen secondary metabolites affects food choice and survival of lichenivorous moth larvae. Ecology 86:2623–2632.

PRISM Climate Group. 2013. 30-yr Normal Precipitation: Annual (1981-2010). Oregon State University. Website: http://www.prism.oregonstate.edu/comparisons/ [accessed January 2021].

Rose, F. 1976. Lichenological indicators of age and environmental continuity in woodlands. Pp. 279-307, *in* D.H. Brown, D.L. Hawksworth and R.H. Bailey (eds.), Lichenology: Progress and Problems, Academic Press, London.

Roy, P. and Huard D. 2016. Future Climate Scenarios – Province of New Brunswick. Ouranos, Montreal, Quebec. 46 pp. + Appendices.

Sabine, Mary, pers. comm. 2020. *Email correspondence to A.G. Belliveau*. March 2020. New Brunswick.

Sarlej, M.I., A. Michlig and LI. Ferraro. 2018. El género *Heterodermia* (Physciaceae, Lecanorales) en la reserva de biosfera Yaboty (Misiones, Argentina). Boletín De La Sociedad Argentina De Botánica 53(1):1-10

Schaberg, P.G., D.H. DeHayes and G.J. Hawley. 2001. Anthropogenic calcium depletion: A unique threat to forest ecosystem health? Ecosystem Health 7:214-228.

Schaberg, J.W. Tilley, G.J. Hawley, D.H. DeHayes and S.W. Baily. 2006. Associations of calcium and aluminum nutrition with the growth and health of sugar maple trees in Vermont. Forest Ecology and Management 223:159-169.

Scheidegger, C. 1995. Early development of transplanted isidiate soredia of *Lobaria pulmonaria* in an endangered population. Lichenologist 27:361-371.

Scheidegger C and S. Werth 2009.Conservation strategies for lichens: insights from population biology. Fungal Biology Reviews 2 3:55–66.

Seaward, M.R.D., D.H.S. Richardson, I.M. Brodo, R.C. Harris and D.L. Hawksworth. 2017. Checklist of lichen-forming, lichenicolous and allied fungi of Eagle Hill and its vicinity, Maine. *North Eastern Naturalist* 24(3):349-379.

Selva, S. 1994. Lichen diversity and stand continuity in the northern hardwoods and spruce-fir forests of northern New England and western New Brunswick. Bryologist 97: 424-429.

Seminara, A., J. Fritz, M.P. Brenner and A. Pringle. 2018. A universal growth limit for circular lichens. Journal of the Royal Society Interface15: 20180063:8pp. https://doi.org/10.1098/rsif.2018.0063

Setchell, A., and S.R. Haughian. 2021. Translating a species distribution model into management recommendations for an at-risk lichen, Ecoscience 29(12):1-7:

Seyd, E.L., and M.R.D. Seaward, 1984. The association of oribatid mites with lichens. Zoological Journal of the Linnean Society 80:369-420.

Spribille, T., V. Tuovinen, P. Resl, D. Vanderpool, H. Wolinski, M.C. Aime, K. Schneider, E. Stabentheiner, M. Toome-Heller, G. Thor, H. Mayrhofer, H. Johannesson and J.P. McCutcheon. 2016. Basidiomycete yeasts in the cortex of ascomycete macrolichens. Science 353(6298): 488-92.

Stephanson, C.A. and N.R. Coe. 2017. Impacts of Beech Bark Disease and Climate Change on American Beech. Forests 8(5):155.

Stewart, B.J., P.D. Neily, E.J. Quigley, A.P. Duke and L.K. Benjamin. 2003. Selected Nova Scotia old-growth forests: age, ecology, structure, scoring. The Forestry Chronicle 79(3)(2003): 632.

Tutiempo.net. 2021. Data reported by the weather station: 472025 (RJER). https://en.tutiempo.net/climate/ws-472025.html [accessed January 2021].

Vasseur, L. and N. Catto. 2008. Chapter 4: Atlantic Canada. Pp. 119-170. In: D.S. Lemmen, F.J. Warren, J. Lacroix, and E. Bush (eds.) From impacts to adaptation: Canada in a changing climate 2007. Government of Canada, Ottawa, ON.

Vincent, L.A., X. Zhang, É. Mekis, H. Wan, and E.J. Bush. 2018. Changes in Canada's Climate: Trends in Indices Based on Daily Temperature and Precipitation Data. Atmosphere - Ocean 56:332–349. 10.1080/07055900.2018.1514579.

Wang, X.Y., Hur, H., Lee, Y.M., Koh, Y.J. and Hur, J.S. 2008. First report of *Heterodermia squamulosa* (Lichenized Ascomycota, Physciaceae) in South Korea. Mycobiology 36(3):190-192.

Wein, R.W. and J.M. Moore. 1979. Fire history and recent fire rotation periods in the Nova Scotia Acadian Forest. Canadian Journal of Forest Research 9(2): 166-178.

WorldClimate.com. 2021. Data from US Climate Normals for Jackman, ME. Website: http://www.worldclimate.com/climate/us/maine/jackman [accessed January 2021].

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Alain Belliveau is the Irving Biodiversity Collections Manager for the E.C. Smith Herbarium, K.C. Irving Environmental Science Centre for Biodiversity at Acadia University in Wolfville, Nova Scotia. He is responsible for the E.C. Smith Herbarium, the largest collection of vascular plant specimens in Atlantic Canada. He has collected and contributed records for tens of thousands of vascular plant and lichen occurrences in Atlantic Canada. He is a member of several Species Recovery Teams, including the Plants Recovery Team, Black Ash Recovery Team, and the Atlantic Coastal Plain Flora Recovery Team for Nova Scotia. He has written or co-written or is currently in the process of writing or co-writing several COSEWIC and provincial status reports. Prior to employment at Acadia University, Alain received a Master of Resource and Environmental Management and worked for several years as a botanist for both the Atlantic Canada Conservation Data Centre and the Mersey Tobeatic Research Institute.

COLLECTIONS EXAMINED

Lutzoni 840718-L138 QFA: Specimen reviewed and determined to not be *Heterodermia squamulosa*, thereby removing it as a species known to occur in Quebec. (CNALH 2020).

Appendix 1 Estimation of decline rates for trees and thalli.

A Species Distribution Model was used to help estimate the maximum number of occurrences and maximum number of host trees for *H. squamulosa* following the methods employed by S. Haughian for the White-rimmed Shingle Lichen (COSEWIC 2019). First, the Predicted Abundance (PA) was calculated by multiplying the Probability of Occurrence (PO) of *H. squamulosa* (from the Species Distribution Model: predictive surface) by the Known Mean Abundance (in this raster model, the cell-size is equal to 50 m;KA; the number of known host trees within each 50 m area or the number of occupied 50 m cells) within areas of the province with sufficient survey effort for *H. squamulosa*. Correction factors were then applied to PA using classification tree analysis (as in Setchell and Haughian 2021) to correct for the approximate proportion of searched sites that contained *H. squamulose*. The model did not account for any distribution in New Brunswick (which includes 4.2% of host trees for Canada), but it is thought to be a reasonable estimate for both provinces combined, because it modeled all of Nova Scotia (much of which is not within *H. squamulosa* EOO).

1. <u>In GIS Software:</u>
    a. Use a 'habitat suitability' criterion (using a mix of stand, soils, or other data) to produce probability of occurrence (PO) data across the province.
    b. Interpolate the occurrence point data to create a raster of *Heterodermia squamulosa* known abundance (KA – probably the number of trees) at the same resolution.
    c. Determine the Predicted Abundance, or PA = PO × KA.
    d. Overlay lichen track / survey data.
    e. Convert lichen tracks into points for which spacing corresponds with the cell size of the PO/PA/KA rasters.
    f. Use "extract values to points" to add the PO (0-1), PA (0-??), and KA values (0-??) to the entire set of lichen survey points.
    g. Export as a CSV for use in another program.

2. <u>In R Software:</u>
    a. Isolate data columns with PA and KA values; upload into R.
    b. Install and load rpart package.
    c. Run classification tree analysis with PA as the predictor and KA as the responding variable.
    d. Select 3-10 classes with +/- equal replication of survey points. Record your correction factors for each class. (The number of correctly classified KA values gives the correction factor for that class.)

3. <u>In GIS Software:</u>
    a. Create a new raster from the PA layer using the “reclassify” function, with conditional statements such that PA values corresponding to the classes you identified are multiplied by the corresponding correction factors within that class.
    b. Add up the corrected KA values across all cells for the newly derived raster layer. This represents the population size for the province (/proxy of parts of NS and NB combined).

Based on the above model, calculated estimates for maximum occurrences and maximum host trees are 756 and 937, respectively. This may be a high estimate, because the habitat parameters used in the modelling are likely broader than what the species actually needs.

Appendix 2. Threats calculator assessment for Scaly Fringe Lichen

Species or Ecosystem Scientific Name	*Heterodermia squamulosa*			
Date:	2021-02-17			
Assessor(s):	Dwayne Lepitzki (Moderator), David Richardson (Co-chair), Alain Belliveau (SR writer) SSC members: Jennifer Doubt, Karen Golinski, André Arsenault, Chris Deduke, Sean Haughian, Marion Barbé Jurisdictions: Mary Sabine (NB) External experts: Frances Anderson, Julie McKnight.			
	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	3	2
	D	Low	3	4
	Calculated Overall Threat Impact:		High	High
	Assigned Overall Threat Impact:		**B = High**	
	Impact Adjustment Reasons:			
	Overall Threat Comments		The generation time = 19 years. Therefore, timeframe for severity and timing is 57 years into the future; 31 occurrences comprising 14 subpopulations, 145 trees, total 450–515 mature individuals (~53% of the population is at Cape Split [Scots Bay]; 19.2% Shingle Lake; 5.4% Fundy NP; 4.4% Digby & Hectanooga, 4.2% Tusket River) This lichen is found in wetland and upland habitats on mature hardwood forests on Yellow Birch, Sugar and Red Maple, and White Ash. Overall, a continuing decline very probable. The Cape Split occurrence partially protected (Provincial Park), but adjacent private land not protected.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1% to 10%)	Extreme (71% to 100%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1% to 10%)	Extreme (71% to 100%)	High (Continuing)	There is an increasing amount of cottage development in southern Nova Scotia, particularly in areas where mixed mature forests are close to lakes, rivers or the coast. Tree removal for access and around these developments means the loss of host trees or suitable trees for colonization and also opens up the canopy or changes water flow, which can make the habitat less suitable for Scaly Fringe Lichen.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Serious (31% to 70%)	High (Continuing)	The Cape Split occurrence is a popular tourist site. Trails are modified to provide access, and there has been some cutting of trees there.
2	Agriculture & aquaculture						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						As part of the forestry plans, wood and pulp plantations on unproductive agricultural land may be proposed. These are not likely to have an impact, but their construction and management may have an impact on adjacent sites (see 9).
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						There is currently a moratorium on fracking, but if it were lifted such activities could have an impact on lichens including Scaly Fringe Lichen.
3.2	Mining & quarrying						The number of mining permit applications has increased in Nova Scotia in recent years, but none are known that include occurrences of Scaly Fringe Lichen.
3.3	Renewable energy						No wind farms are known that are close to known occurrences of Scaly Fringe Lichen, although the Cape Split area is certainly a windy area where wind farms could be built.
4	Transportation & service corridors	C	Medium	Restricted (11% to 30%)	Extreme (71% to 100%)	High (Continuing)	
4.1	Roads & railroads	C	Medium	Restricted (11% to 30%)	Extreme (71% to 100%)	High (Continuing)	Improved road networks are key for servicing new cottage developments and for access to logging, which is occurring on a wide scale in southern Nova Scotia. Road construction not only has the potential to remove trees that are colonized by this lichen or available for colonization, but can also change water flow and water levels in adjacent habitat or increase light levels, which appear to be detrimental to Scaly Fringe Lichen.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Serious (31% to 70%)	High (Continuing)	New power lines are needed for cottages and new developments and these go via the shortest route, often through old forested wetlands that are one of the habitats for this lichen.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	C	Medium	Restricted (11% to 30%)	Extreme (71% to 100%)	High (Continuing)	-

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants		Negligible	Negligible (<1%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Some collecting for monitoring of lichen populations has gone on the past but is now lower. Whenever necessary, only part of a thallus in now collected for identification or other purposes, so the impact now negligible.
5.3	Logging & wood harvesting	C	Medium	Restricted (11% to 30%)	Extreme (71% to 100%)	High (Continuing)	Logging resulted in the loss of the Spider Lake occurrence in 2016 or 2017 and the loss of the Grand Bay-Westfield occurrence in 2014 or 2015. It was also the likely cause of the loss of a Hectanooga occurrence in 2010 or 2011 and of other occurrences in the past, given the dominance of clearcutting as a forestry practice in the Maritimes. Ninety-three host trees (65% of total number of host trees) from 17 occurrences are unprotected and may be subject to future logging. Clearcutting accounts on average for approximately 80% of harvesting in NS and NB (see **Habitat Trends** and **Threats**). Harvesting is likely to continue into the future. Old mature woodlands on private land are a preferred source, as the volume of timber is large, especially if new management on Crown land limits the amount of mature forest that can be harvested.
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						Over-collection may have been responsible for loss of two sites in the past.
7	Natural system modifications	D	Low	Small (1% to 10%)	Serious - Slight (1% to 70%)	High (Continuing)	
7.1	Fire & fire suppression	D	Low	Small (1% to 10%)	Serious - Slight (1% to 70%)	High (Continuing)	An increase in fires is expected as a result of the predicted increase in the length and severity of summer droughts and the increase in numbers of people who use the woodlands (cottage residents, hunters). People are responsible for starting almost all forest fires in summer.
7.2	Dams & water management/use						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications						The increasing White-tailed Deer population in Nova Scotia may result in increased browsing of young host trees; however, this is not currently a threat, as the typical host age is >80 years.
8	Invasive & other problematic species & genes	D	Low	Small (1% to 10%)	Serious (31% to 70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
8.1	Invasive non-native/alien species/diseases	D	Low	Small (1% to 10%)	Serious (31% to 70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	The very invasive Emerald Ash Borer (EAB) will probably infect the eight known White Ash host trees and affect nine sites that are dominated or co-dominated by White Ash. EAB can jump hundreds of kilometers via anthropogenic spread and also spread locally. However, local spread in Nova Scotia may be slower, because ash trees are less common in the province compared with Quebec, Ontario, and the USA, where the spread rate has been measured.
8.2	Problematic native species/diseases						Native and alien slugs are responsible for damage to several species of lichens in Nova Scotia, often being spread by vehicles involved in forestry activities, but Scaly Fringe Lichen appears not to be susceptible to such damage, perhaps because of the combination of secondary metabolites produced by this species.
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% to 100%)	Moderate - Slight (1% to 30%)	High (Continuing)	-
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents		Unknown	Small (1% to 10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	After clearcuts or other forestry, the regenerating forest is often sprayed with herbicides to deter regeneration of hardwoods, and if plantation forestry is implemented on abandoned agricultural land, it will need to be fertilized and sprayed following planting. Such spraying, especially if done from the air, can drift to nearby mature forests that could be colonized by Scaly Fringe Lichen, leading to harmful effects on the lichen or host trees.
9.4	Garbage & solid waste						
9.5	Air-borne pollutants	CD	Medium - Low	Pervasive (71% to 100%)	Moderate - Slight (1% to 30%)	High (Continuing)	Transboundary air pollution in the form of acid rain, although reduced in amount, can eventually overcome the buffering capacity of tree bark, making it unsuitable for colonization by the Scaly Fringe Lichen, or have an impact on the growth of the host trees. The lichen prefers low light conditions, and if the canopy is affected, the lichen growth may also be reduced
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather		Unknown	Pervasive (71% to 100%)	Unknown	High (Continuing)	
11.1	Habitat shifting & alteration						Scaly Fringe Lichen is at the northern edge of its range in Canada, where colder temperatures currently limit its expansion northward. There could be a northwards shift of host trees with a warming climate, but suitable mature host trees would not be available within three generations.
11.2	Droughts						Increased summer droughts are likely to result in more forest fires, but severity and frequency is difficult to predict.
11.3	Temperature extremes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding						The host trees of Scaly Fringe Lichen are susceptible for windthrow, especially at the Cape Split occurrence, where the largest subpopulation is found, because this area is not only very windy but the main host species there, Yellow Birch, tends to grow leaning at an angle on the steep slopes and can be unrooted by high winds. The occurrence of severe storms in this and other areas is difficult to predict but could have a great impact on the population of Scaly Fringe Lichen if predicted severe weather events occur.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008).							