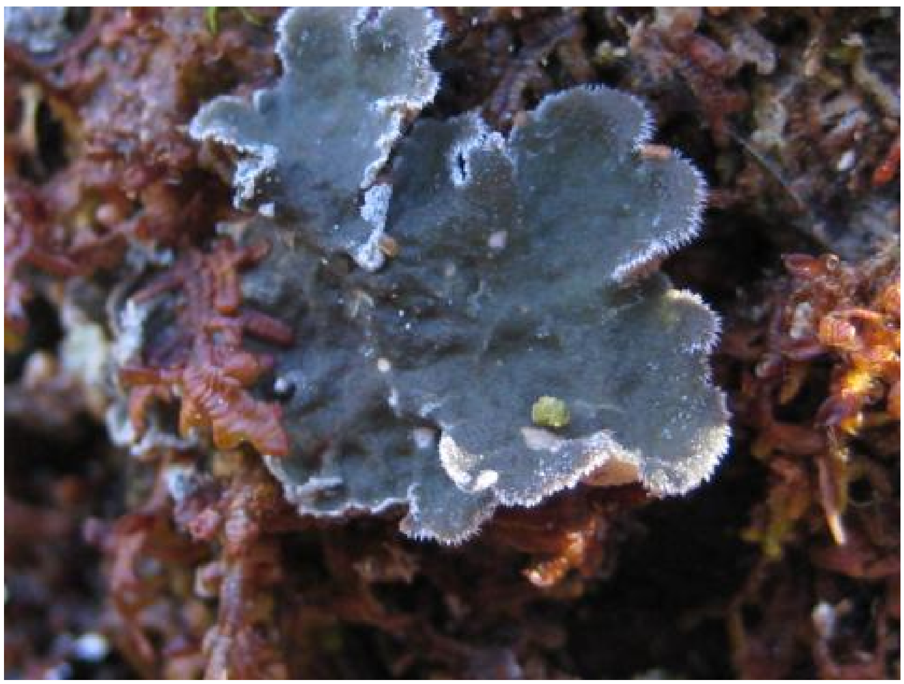
COSEWIC
Assessment and Status Report

on the

Vole Ears Lichen
Erioderma mollissimum

in Canada



ENDANGERED
2021

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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Previous report(s):

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. (www.sararegistry.gc.ca/status/status_e.cfm).

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COSEWIC
Assessment Summary

Assessment Summary – April 2021

Common name
Vole Ears Lichen

Scientific name
Erioderma mollissimum

Status
Endangered

Reason for designation
In Canada, this large foliose lichen currently occurs only in Nova Scotia, and on Newfoundland and Labrador's Avalon Peninsula. It previously occurred in New Brunswick and in the United States, in Tennessee and North Carolina. The lichen can be found on Red Maple, Yellow Birch and Balsam Fir trees in forests that are humid and within 30 km of the ocean. The number of mature individuals in Canada is estimated to be < 2500 thalli based on data from observations of mature thalli in the field and the remaining amount of suitable habitat. A continuing decline in the population is likely as a result of the threats faced by this lichen which include climate change, air pollution, and habitat destruction from forest clearance and wood harvesting.

Occurrence
Nova Scotia, Newfoundland and Labrador, New Brunswick.

Status history
Designated Endangered in November 2009. Status re-examined and confirmed in May 2021.

COSEWIC
Executive Summary

Vole Ears Lichen
Erioderma mollissimum

Wildlife Species Description and Significance

Vole Ears Lichen, *Erioderma mollissimum*, is a leafy lichen up to 12 cm across, with a felty upper surface that is grey-brown when dry and grey-green when wet. It is part of a group of rare cyanolichens found in the coastal forests of eastern North America. Vole Ears Lichen is rare and the Canadian population is the only remaining one in North America following its disappearance from the Great Smoky Mountains of Tennessee. The nearest extant populations are in Central America.

Distribution

Vole Ears Lichen has a disjunct global distribution. It occurs mainly in montane tropical and sub-tropical cloud forests. Most of its known occurrences are in Central and South America. It also is found in eastern North America, coastal southwestern Europe, and east Africa. In North America, the only extant population is now found in Canada. It was known from the Great Smoky Mountains in North Carolina in the United States but after extensive targeted lichen surveys appears to be no longer extant there. In Canada, Vole Ears Lichen occurs in forested areas along the coast of Nova Scotia and on the Avalon Peninsula of Newfoundland. It was previously found in New Brunswick but has not been recorded there since the 1980s and is likely no longer present in the province.

Habitat

In Atlantic Canada, Vole Ears Lichen occurs in coastal forests dominated by Balsam Fir and Red Maple that are characterized by relatively cool maritime climates, mild winters, frequent fog, and high annual precipitation that often exceeds 1400 mm. Vole Ears Lichen in Atlantic Canada is typically found within 30 km of the coast and at low elevations, rarely exceeding 150 m above sea level. It is found in stands with long-term ecological continuity, without recent large-scale disturbances. In Nova Scotia, it occurs most often on trunks of Red Maple, less frequently on Yellow Birch and occasionally on Balsam Fir. In Newfoundland, it has only been found to date on Balsam Fir. Host trees are found in poorly drained areas with *Sphagnum* and Cinnamon Fern ground cover, particularly in Nova Scotia. Vole Ears Lichen colonizes mature trees, which tend to be older in Newfoundland than in Nova Scotia.

Biology

Vole Ears Lichen is part of a group of lichens known as the cyanolichens that are composed of a fungal partner and a cyanobacterium. The cyanobacterium, which photosynthesizes and fixes atmospheric nitrogen, belongs to the genus *Rhizonema.* Sexual reproductive structures (apothecia) are rare and Vole Ears Lichen in Atlantic Canada propagates asexually through specialized structures called soredia or by fragmentation. Dispersal is limited as soredia generally disperse no more than a few hundred metres by wind or animals in forested environments and fragmentation only leads to dispersal on the same host tree as the parent thalli. Distribution over larger distances is probably by the inadvertent transport of soredia on bird feathers and subsequent deposition on a suitable host tree growing in a suitable environment for the growth of Vole Ears Lichen. This is almost certainly a rare event.

Population Sizes and Trends

Within the known range, Nova Scotia has the largest known number, 280, of mature thalli which were enumerated on 194 trees in surveys from 2016-2018. In Newfoundland 32 mature thalli are known. There are 55 extant occurrences, 40 of which have been discovered since 2009 as a result of increased search effort. Of these occurrences, 49% have only a single occupied tree (an occurrence is defined as a site where the lichen is growing on one or more trees and this site is more than 1 km from a second group of colonized trees). The great majority of known thalli (83%) are found in western Queens County and eastern Shelburne County in Nova Scotia. The population in the province appears to be declining as the lichen is no longer found at 11 of 12 occurrences (92%) first discovered in the 1980s and 1990s, and no longer found in four of the 17 occurrences monitored between 2007/08 and 2016/18 (a loss of 23.5% occurrences in 8.5 years). There is uncertainty about the rate of new colonization, but likely to be very low. In Newfoundland, 30 juvenile thalli have been discovered, but in Nova Scotia only 11 juveniles have been recorded. The total population of mature individuals of Vole Ears Lichen in Nova Scotia is estimated to be 1,774 with 250 in Newfoundland, where the lichen was discovered in 2006. None of the known occurrences in Newfoundland have been lost.

Threats and Limiting Factors

A combination of climate change and transboundary air pollution is likely to be a threat to Vole Ears Lichen over the next three generations. This is because it is a cyanolichen and hence very sensitive to acid rain which is thought to have been responsible for the loss of this lichen from the Great Smoky Mountains in the USA. Climate change is also expected to have a serious impact on Vole Ears Lichen in both Nova Scotia and Newfoundland, particularly if the pattern of precipitation changes or fog decreases as predicted. Furthermore, seasonal droughts are predicted to reduce humidity affecting Vole Ears Lichen and elevate the risk of forest fires. Vole Ears Lichen, as a cyanolichen, requires liquid water to initiate photosynthesis and moisture to sustain it unlike other lichens that only need humid air. Increases in the frequency and severity of storms are also likely to result in more windthrown trees.

Forest harvesting is the most direct threat to Vole Ears Lichen, particularly in Nova Scotia as tree removal means the loss of host trees. On provincial Crown Land in Nova Scotia, the threat may be partially mitigated by a required 200 m protected zone around known host trees. However, this does not remove threats to undiscovered occurrences, or those on private lands.

Mining in areas that overlap Vole Ears Lichen range is anticipated to increase in Nova Scotia, exacerbating the threat of habitat loss and air pollution. To a lesser extent, cottage and residential development may be a threat. Road development associated with forest harvesting, mining, and development can threaten Vole Ears Lichen directly by removal of host trees as well as indirectly via edge effects and by altering microclimate in adjacent habitat. In Newfoundland, browsing of young Balsam Fir trees by Moose (and possibly Snowshoe Hare) is a concern as it prevents host tree regeneration. Over the long term, this alters forest composition and reduces the number of available mature trees for lichen colonization.

Protection, Status and Ranks

Vole Ears Lichen was listed as Endangered under Schedule 1 of the federal *Species at Risk Act* in 2012 and was listed as *Endangered in 2013* under provincial legislation in Nova Scotia, Newfoundland and Labrador, and New Brunswick. Vole Ears Lichen was assigned a global NatureServe rank of G4G5*, Apparently Secure*, and a national rank of N1N2 *Imperiled* to *Critically Imperiled* in Canada. It is unranked in the United States. Provincially, it is ranked S1S2*, Imperiled* to *Critically Imperiled*, in Nova Scotia and Newfoundland and Labrador and SH, *Possibly Extirpated*, in New Brunswick. A SARA compliant recovery strategy was finalized in 2014 and a proposed action plan was posted for consultation in fall 2018. Vole Ears Lichen is also included in a multi-species action plan for Kejimkujik National Park and National Historic Site of Canada, finalized in 2017.

TECHNICAL SUMMARY

Erioderma mollissimum

Vole Ears Lichen

Érioderme mou

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

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)	Estimated at 20 yrs based on similar species *E. pedicellatum*
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes, observed & projected
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Decline of mature individuals at sites in NS. Estimated to be >57% over two generation on the basis of the decline in host trees (proxy). The rate of establishment of new occurrences is unknown but low. See **Dispersal and Migration and Fluctuations and Trends,** Table 5 and Appendix 2 for methods and caveats.
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Observed decline of c.12 % in host trees (as a proxy for mature individuals) over an average 8.5 year period from 2007-2009 to 2016-2018. See Table 6 and **Fluctuations and Trends** for methods and caveats.
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	A decline in excess of 50% is projected for the number of occurrences and the number of host trees over the next 3 generations (60 yrs.) (Table 5). This is a proxy for the decline in mature individuals. There is uncertainty on the rate of establishment. See **Dispersal and Migration** and **Fluctuations and Trends**, Table 5 and Appendix 2 for methods and caveats.

[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Not calculated
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Some, others unknown b. Partly understood c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	39,700 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	244 km² (61 grid cells) based on currently known sites
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. Possibly; though dispersal is poorly understood
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	Less than five related to a combination of climate change and air pollution in NS, and logging and moose browsing in NL. These combinations are expected to have a serious impact on the four extant subpopulations of the lichen (see **Locations**) 55 for local threats that act at the stand (occurrence) level.
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Observed – current EOO is approximately 35% of total historical EOO (including NB and Fundy coast of NS). See Figure 2 and **Extent of Occurrence and Area of Occupancy**
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Observed NS – Loss of occupancy amounts to 60 km² (15 2x2 km grid cells NB – Loss of occupancy at ~8 km² (2 2x2 km grid cells, 2 occurrences lost). See **Extent of Occurrence and Area of Occupancy**

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

Is there an [observed, inferred, or projected] decline in number of subpopulations?	Observed decline as there were six subpopulations but two are considered no longer to be extant. All are separated by distances greater than the likely dispersal capability of the species. The six subpopulations are: Avalon Peninsula NL, South Shore NS, Central Shore NS, Eastern Shore NS, East Bay of Fundy NS/NB, West Bay of Fundy NB).
Is there an [observed, inferred, or projected] decline in number of "locations"?	Yes, there are less than five locations related to a combination of climate change and air pollution in NS, and logging and moose browsing in NL. One location (subpopulation) in NS has just a single living thallus on a tree and likely to be lost as a result of nearby forestry. With respect to stand level threats, a decline from 55 is inferred due to forestry activity and other threats. The magnitude of the future declines is unknown but five stand level locations have been lost since 2008 (including 1 discovered in 2012). See **Fluctuations and Trends**.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Observed and inferred. Loss of habitat from logging, development, roads and from mining in NS. Also, inferred declines in habitat quality from climate change, acid rain and pollution. Projected decline in habitat quality in NL by logging and moose browsing.
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

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
South Shore NS – 40 occurrences	262 known
Eastern Shore NS – 12 occurrences	17 known
Lunenburg County NS – 1 occurrence	1 known
Avalon Peninsula NL – 4 occurrences	32 known
Total	312 known

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

The estimated total population of mature individuals that have not been enumerated within the known range in NS is 1,774 and 250 in Newfoundland so that the total likely population in Canada is fewer than 2,500 mature individuals (Table 5). (see Table 4, Appendix 3 and **Abundance**). **Note:** two other subpopulations, the East Bay of Fundy, and West Bay of Fundy are considered no longer extant (see **Canadian Range**).

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

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

Was a threats calculator completed for this species? Yes see Appendix 4 i. Logging and wood harvesting ii. Airborne pollutants iii. Climate change and severe weather iv. Mining and quarrying v. Recreational and commercial development vi. Roads and railroads What additional limiting factors are relevant? Limited dispersal, relatively long generation time, reliance on stable habitat conditions over time. Suite of environmental conditions that make trees suitable hosts is complex and not well understood.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Status unknown for the next closest extant population, which is likely >2500 km away in Central America. The population in the Great Smoky Mountains of the United States is no longer extant.
Is immigration known or possible?	Unlikely given the large distance to the next nearest extant population in Central America.
Would immigrants be adapted to survive in Canada?	possibly
Is there sufficient habitat for immigrants in Canada?	unknown
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source (i.e., outside) population deteriorating?[+]	N/A
Is the Canadian population considered to be a sink?[+]	N/A
Is rescue from outside populations likely?	No

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

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Endangered in November 2009. Status re-examined and confirmed in May 2021.

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric** B2ab(i,ii,iii,iv,v)
Reasons for designation: In Canada, this large foliose lichen currently occurs only in Nova Scotia, and on Newfoundland and Labrador's Avalon Peninsula. It previously occurred in New Brunswick and in the United States, in Tennessee and North Carolina. The lichen can be found on Red Maple, Yellow Birch and Balsam Fir trees in forests that are humid and within 30 km of the ocean. The number of mature individuals in Canada is estimated to be < 2500 thalli based on data from observations of mature thalli in the field and the remaining amount of suitable habitat. A continuing decline in the population is likely as a result of the threats faced by this lichen which include climate change, air pollution, and habitat destruction from forest clearance and wood harvesting.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): May meet Endangered, A3c, if the projected declines are accepted that indicate that the decline in the number of mature individuals may exceed 50% and may be as high as 75%.This is based on a projected decline in the number of occurrences over the next three generations (60 years). There is a projected decline in the quality of the habitat due to forestry activities, exacerbated by air pollution and climate change. The projected reduction in number of occurrences is a proxy for a decline in number of mature individuals (see Fluctuations and Trends for justification).
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B2ab(i,ii,iii,iv,v), with IAO (244 km^2) <500 km^2 and inferred future declines in EOO, IAO, extent and quality of habitat, number of locations, and number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): May meet Endangered, C1, as the estimated number of mature individuals is below the threshold of 2,500, if the estimated continuing decline in number of mature individuals of c. 50% (Table 5) within the next two generations (40 years) is accepted. Meets Threatened, C2a(i), as the number of mature individuals is less than the threshold of 10,000 and no subpopulation exceeds 1000 mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. Estimated number of mature individuals exceeds thresholds for criterion D1 and IAO (244 km^2) exceed thresholds for D2.
Criterion E (Quantitative Analysis): Not applicable. Insufficient data, analysis not conducted.

PREFACE

This is an updated status report. Since the original status report (COSWIC 2009) on Vole Ears Lichen, *Erioderma mollissimum,* there has been significant research. The effort has been directed towards increasing knowledge about the distribution, abundance, population trends, habitat requirements and basic biology of the species. The approach, effort, and focus of the studies have differed among the jurisdictions. At the time of the previous status assessment (COSEWIC 2009), not much was known about the species in Newfoundland as it was only discovered there in 2006. In the last nine years, the small Newfoundland population has been more intensively investigated and monitored than the Nova Scotia population. The latter is larger and more dispersed. In Nova Scotia, the number of known occurrences has increased as a result of surveys, while some previously identified occurrences have been lost. In spite of extensive searches, the lichen has not been re-found in New Brunswick and is considered extirpated in this province.

The federal and provincial listing of the species in Canada, Nova Scotia and Newfoundland and Labrador has changed the threat picture somewhat, as some of the immediate local scale threats have been partially mitigated by protections and recovery actions directed towards listed species. However, other threats are less certain, less controllable, more widespread, and more long-term.

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
(2021)

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

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Erioderma mollissimum

in Canada

2021

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Kingdom: Fungi

Phylum: Ascomycota

Class: Lecanoromycetes (Lücking *et al.* 2016)

Order: Peltigerales (formally Lecanorales) (Lücking *et al.* 2016)

Family: Pannariaceae

Scientific name: *Erioderma mollissimum* (Sampaio) Du Rietz

English common names: Vole Ears Lichen (COSEWIC 2009)
Graceful Felt Lichen (Species Status Advisory Committee 2008)
Most Gracious Felt Lichen (Fournier 2006)

French common names: érioderme mou (COSEWIC 2009) érioderme très gracieux (Fournier 2006)

Synonyms: *Erioderma limbatum* (Nyl.) Vain. (Jørgensen 2001) *Lobaria mollissima* Samp. (Jørgensen 2001) *Erioderma wrightii* var. limbatum Nyl. (Jørgensen 2001)

Type: Portugal, Minho, Sierra do Gerês, Castello Lanhoso, G. Sampaio s.n. (Lich. Exs. 226, UPS, lectotype designated by Jørgensen 2000).

Lichen names apply only to their fungal components, but by convention serve as a short-hand for the symbiosis involving both the fungal and photosynthetic components (Brodo *et al.* 2001).

The genus *Erioderma* includes 40 species (Lücking *et al.* 2016). *Erioderma mollissimum* is one of eight vegetatively reproducing (sorediate) species currently recognized in the genus (Jørgensen and Arvidsson 2001). The only other sorediate species occurring in North America, *E. sorediatum* (Mouse Ears), is known only from the west coast of the continent (Maass 1983; Goward 1995; Glavich *et al.* 2005) and is unlikely to be confused with *E. mollissimum*. Jørgensen (2000) suggested that the eastern North American sorediate *Erioderma* collections might not belong to *E. mollissimum* as the specimens available at the time were in poor condition. However, examination of more recently collected thalli from Nova Scotia and Newfoundland have confirmed that specimens from Atlantic Canada are *E. mollissimum* (COSEWIC 2009).

While no work has been published specifically on the photobiont component of *E. mollissimum*, cyanobacteria of the genus *Rhizonema* have been confirmed as the photobionts of two related species, *E. pedicellatum* (Boreal Felt Lichen) and *E. sorediatum* (Cornejo *et al.* 2016).

Morphological Description

Erioderma mollissimum is a foliose macrolichen growing up to 12 cm in diameter, with ascending lobes up to 1 cm broad (COSEWIC 2009). Lobe margins tend to be revolute when wet but when dry they can curl up exposing the whitish edge of the underside. This curling of the lobes can confound size measurements.

The upper surface of the thallus is grey to grey-brown when dry and dark grey-green when wet. The tomentum (covering of fine hairs) on the upper surface is especially prominent at the lobe margins (Jørgensen and Arvidsson, 2002) The usual lack of apothecia and the especially prominent tomentum normally serve to distinguish *E. mollissimum* from *E. pedicellatum*, but some juvenile thalli that could be confused with immature apothecia have occasionally been found on lobe margins of *E. mollisimum* in Newfoundland (Figure 1). The lower surface which is white-fibrous has a dense light brown tomentum except for a narrow band at the margin (Jørgensen and Arvidsson 2002).

Figure 1. A thallus of *Erioderma mollissimum* in Newfoundland with primordial apothecia, shown by the red arrows (photo used with permission from the NL Department of Fisheries and Land Resources).

Bluish-grey granular soredia are produced along the lobe margins and sometimes occur at breaks or in round patches on the upper surface (see **Dispersal and Migration** and **Life Cycle and Reproduction**).

Population Spatial Structure and Variability

The genetic differentiation within and among the Canadian subpopulations has not been examined for either the fungal or cyanobacterial partner. Molecular studies of the photobiont *Rhizonema* in *E. pedicellatum* and other lichen species showed that *Rhizonema* strains are widely distributed in boreal forests, have high genetic diversity and are associated with many different lichen species (Cornejo *et al.* 2016). However, no samples of *E. mollissimum* from Atlantic Canada were included in these studies.

Designatable Units

One designatable unit is recognized for the purpose of this assessment. Although the lichen occurs in two ecozones, there is no evidence of morphological, genetic, or other differences to support more than one designatable unit apart from the very rare occurrence of immature apothecia in Newfoundland. However, there are differences in habitat between the two provinces, particularly in the host tree species. In Newfoundland and Labrador, *E. mollissimum* has so far only been found on Balsam Fir (*Abies balsamea*) while in Nova Scotia, while it can occur on Balsam Fir, but is more commonly found on Red Maple (*Acer rubrum*) and Yellow Birch (*Betula alleghaniensis*).

Special Significance

Erioderma mollissimum is part of a group of rare cyanolichens found in the humid coastal forests of eastern North America (Cameron and Richardson 2006; Cameron and Neily 2008). The Canadian population of *E. mollissimum* is disjunct from other populations in the world and is the only remaining population in North America. Furthermore, the group of cyanolichens to which *E. mollissimum* belongs is highly sensitive to acid precipitation and air pollution, potentially making them useful indicators (Cameron *et al.* 2007).

DISTRIBUTION

Global Range

Erioderma mollissimum has a highly disjunct global range (see COSEWIC 2009). It occurs mainly in montane tropical and subtropical cloud forests. Most of its known occurrences are in Central and South America, where it has been recorded at elevations ranging from 1600 to 3400 m in the Dominican Republic, Costa Rica, Venezuela, Colombia, Ecuador, and Brazil (Maass 1983; Jørgensen and Arvidsson 2002). It occurs more rarely on the eastern side of the Atlantic Ocean, where it is confined to oceanic, montane sites, with records in Portugal, Spain, the Azores, and the Canary Islands (Maass 1983). Another population has been documented in the mountains of Kenya in east Africa (Jørgensen and Arvidsson 2001). Reports of *E. mollissimum* from Southeast Thailand were based on an incorrect identification (Jørgensen and Wolseley 2009).

In North America, *E. mollissimum* was known from two separate areas: the Great Smoky Mountains of Tennessee and North Carolina at elevations of around 800 to1800 m, and the hemiboreal to boreal coastal region of Atlantic Canada at less than 100 m in elevation (Maass 1983). However, it has not been re-discovered in the Great Smoky Mountains and is now considered extirpated from the region and the USA (Lendemer *et al.* 2013), probably as a result of air pollution (Anon 2018). *Erioderma mollissimum* was reportedly found in southeast Alaska (Geiser *et al.* 1998) but this is now believed to be a misidentification (Jørgensen and Wolseley 2009). Consequently, the population in Atlantic Canada is the only extant one in North America.

Canadian Range

In Canada, *Erioderma mollissimum* occurrences are known from New Brunswick, Nova Scotia, and Newfoundland and Labrador (Figure 2). An occurrence is defined as a site where the lichen is growing on one or more trees and this site is more than 1 km from a second group of colonized trees. The occurrences are grouped into six subpopulations, two of which, in New Brusnwick, are considered to be extirpated, and four of which are extant (Figure 3).

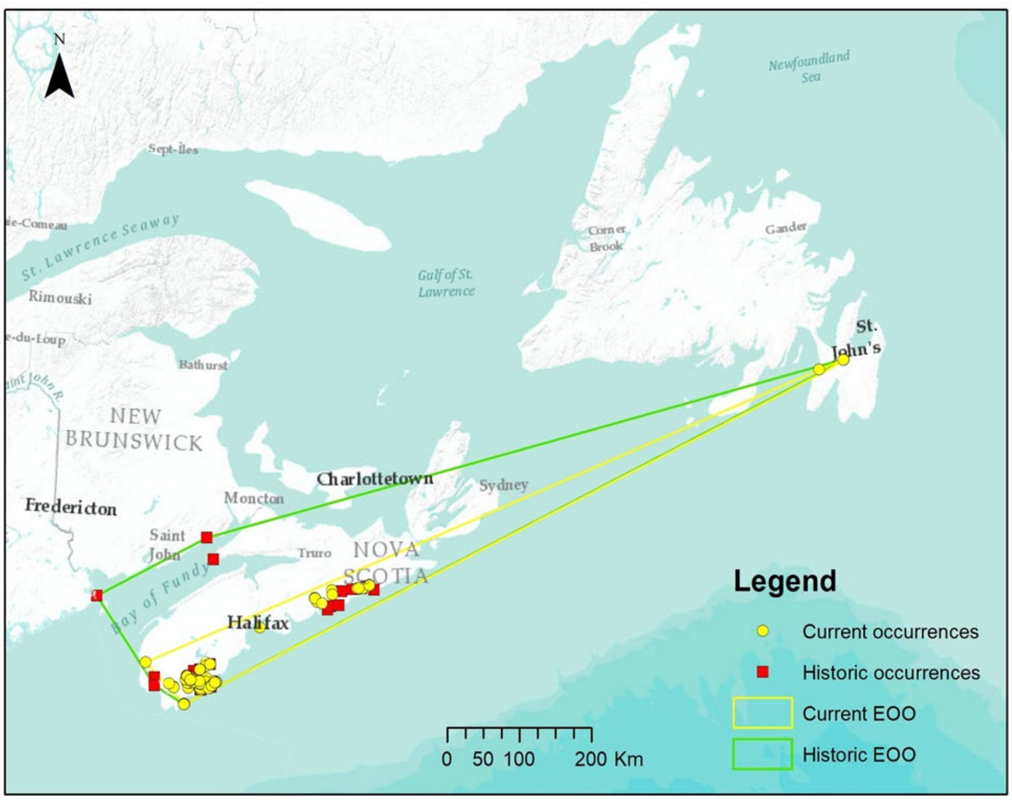

Figure 2. The Canadian range of *Erioderma mollissimum*. Yellow circles are current occurrences, while red squares are occurrences that are no longer extant.

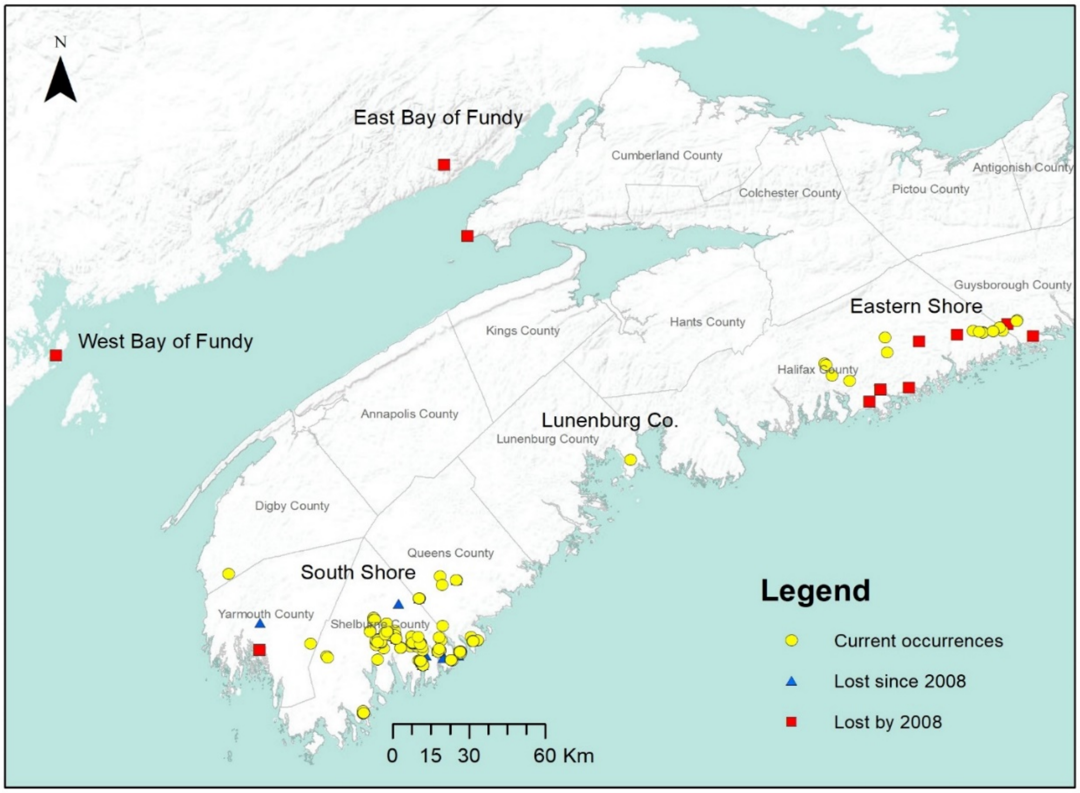

Figure 3. The three clusters of extant occurrences (yellow circles) in Nova Scotia of *Erioderma mollissimum.* These comprise the three subpopulations (see labels on the figure): South Shore, Lunenburg Co and Eastern Shore. These are geographically separated. Occurrences in New Brunswick and Nova Scotia that were lost before 2008 are shown by red squares. The blue triangles are occurrences that have been lost since 2008.

The justification for these subpopulations is based on IUCN (2014) criteria *B and C,* Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less). Subpopulation size is measured as numbers of mature individuals only. No genetic tests have been done to assess the degree of relatedness of different clusters of occurrences for *E. mollissimum* or any other lichen species. Moreover, it is essentially impossible to track 'migrants', or movement among occurrences or locations, because the propagules are neither visible to the naked eye, nor likely abundant and frequent enough to detect with such methods as spore trapping. Considering the number of occurrences to be equal to the number of subpopulations, as has been suggested, is not defensible from a methodological standpoint. This is because not all suitable habitats between such occurrences have necessarily been surveyed. Consequently, we argue that there are likely three extant subpopulations for *E. mollissimum* in Nova Scotia and one in Newfoundland. Two lines of evidence support these subpopulation designations: the likely distances travelled by the lichen's hypothetical primary inter-stand dispersal vector (birds), and the distances between bioclimatically suitable areas (Haughian pers. comm. 2020a).

Firstly, the primary vector for among-stand dispersal of soredia is likely birds that spend much of their time on tree boles. Both lichen spores and moss spores that are similar in size to lichen soredia have been shown to be carried on the feet and feathers of forest birds (Chmielewski and Eppley 2019). In Nova Scotia's forested wetlands, the likely avian vectors include primarily woodpeckers and bark-gleaning birds such as: Yellow-bellied Sapsucker (*Sphyrapicus varius*), Downy Woodpecker (*Picoides pubescens*), Hairy Woodpecker (*Picoides villosus*), Black-capped Chickadee (*Parus atricapillus*), Boreal Chickadee (*Parus hudsonicus*), Brown Creeper (*Certhia familaris*), Red-breasted Nuthatch (*Sitta canadensis*) and Black and White Warbler (*Mniotilta varia*). These species usually have defined territories of a few hectares during the breeding season (Kilham 1974; Hill and Lein 1989; Walters *et al.* 2002; Foote *et al*. 2010; Kricher 2014), but have been observed travelling a kilometre or more during foraging trips (Walters 1996; Jackson and Ouellet 2018). The most likely distances for inter-patch dispersal of lichens are therefore less than 2 km, but dispersal distances of up to 10 km may be possible.

Secondly, a recently developed habitat model for *E. mollissimum*, based on both climate and stand features, predicted three main clusters of more or less continuous (i.e., patches separated by less than 2 km) suitable habitat in Nova Scotia (Haughian pers. comm. 2020b). Regions between clusters of observations have a much lower likelihood of undetected occurrences existing. Given the distribution of these envelopes in Nova Scotia travel distances of 50-100 km would be required to reach another climatically suitable area in the province. Such dispersal events are not likely to happen very often.

The four extant and two extirpated subpopulations are made up of one or more occurrences separated by a distance of greater than 50 km. As mentioned above, this distance greatly exceeds the estimated dispersal capability of the species (See **Dispersal and Migration)**. The first two subpopulations, East Bay of Fundy NS/NB, West Bay of Fundy NB, are believed to be no longer extant (Figure 3, Appendix 1). The third subpopulation occupies the Eastern Shore of Nova Scotia in Halifax and Guysborough counties and appears to be declining. The fourth subpopulation occupies the South Shore of Nova Scotia in Queens, Shelburne, and Yarmouth counties, where the lichen is most abundant and where over 80% of the known thalli occur (Table 4). The fifth subpopulation comprises a single occurrence in Lunenburg county, Nova Scotia, equidistant from the Eastern Shore and South Shore subpopulations. The sixth subpopulation is on the Avalon Peninsula in Newfoundland (Figure 4).

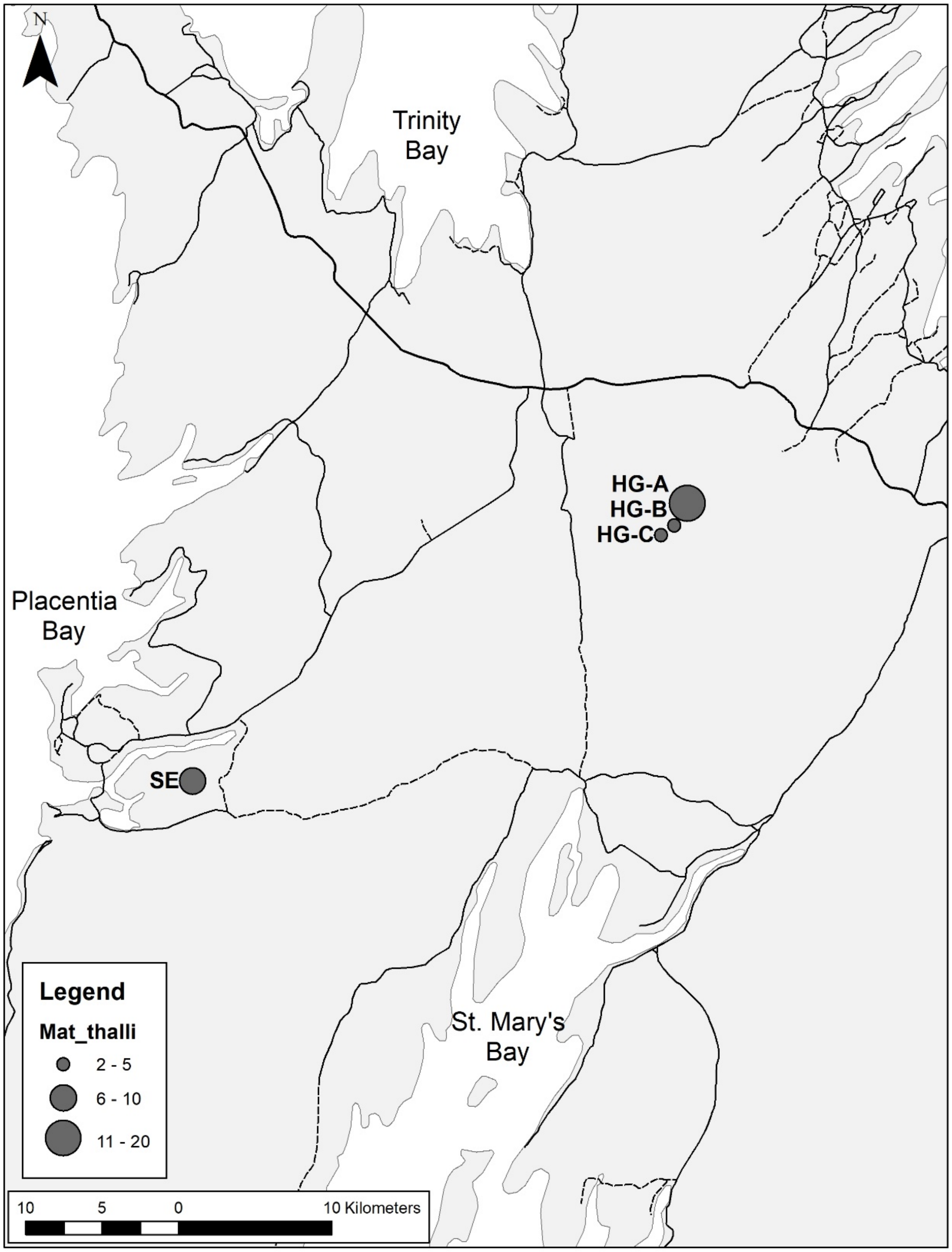

Figure 4. The occurrences of *Erioderma mollissimum* at Halls Gullies (HG) and Southeast Placentia (SE) in Newfoundland in 2018. The diameter of the black circles shows the size of the population (Map provided by NL Department of Fisheries and Land Resources).

Erioderma mollissimum was first identified as a Canadian lichen by Jørgensen (1972) from a fragment mixed with a specimen of *E. pedicellatum*, collected in 1902 by W. G. Farlow on Campobello Island, New Brunswick. It was later reported from a second site in New Brunswick in Fundy National Park, though the authors describe it as a tiny specimen that "probably belongs to this species" (Gowan and Brodo 1988). There are no additional records of *E. mollissimum* from New Brunswick, despite searches in areas near the original sightings and elsewhere (see **Search Effort**) and the species is almost certainly lost from the province (Nature Serve 2018).

In Nova Scotia, *E. mollissimum* was first found in the early 1980s. It was originally reported from a few sites in Halifax County and on the South Shore (Maass 1983) and by 2009 was known from ~20 occurrences (COSEWIC 2009). Survey efforts from 2010-2018 resulted in the discovery of an additional 40 occurrences and increased the known range, particularly in the South Shore subpopulation (see **Search Effort**). All sightings occur within 30 km of the Atlantic coast in Digby, Yarmouth, Shelburne, Queens, Lunenburg, Halifax and Guysborough counties (Figure 3).

Erioderma mollissimum was first discovered in Newfoundland in 2006 on the Avalon Peninsula (Jørgensen *et al.* 2009). In the following year, research and field surveys (see **Search Effort**) led to the discovery of four new occurrences on the Avalon Peninsula (COSEWIC 2009). It is still present at the same four occurrences (Figure 4). In the ten years since the previous assessment, no new occurrences have been discovered in Newfoundland.

Extent of Occurrence and Area of Occupancy

The extent of occurrence (IAO) in Canada was measured using all current sites from Nova Scotia and Newfoundland, and is 39,700 km^2. This is approximately 35% of the historical extent of occurrence (113 000 km^2) calculated using all documented current and historic documented occurrences, including those from the northern shore of Nova Scotia and southern New Brunswick. However, both calculations include large areas of unsuitable habitat (Figure 2).

The index of area of occupancy (AOO) was calculated using point coordinates of currently occupied host trees, and is 12 km^2 in Newfoundland (three 2×2 km grid cells) and 232 km^2 in Nova Scotia (58 2×2 km grid cells) for a total of 244 km^2 (61 2×2 km grid cells). There has been a documented loss of occupancy at 60 km^2 (15 2 x 2 km grid cells) in Nova Scotia and 8 km^2 (2 2x2 km grid cells) in New Brunswick calculated using coordinates of historically occupied host trees and excluding any grids that also have currently occupied trees.

Search Effort

Since *E. mollissimum* was observed in three separate jurisdictions, there has been no coordination of search effort throughout the species' range in Canada.

New Brunswick

Prior to 2009, many areas of potential occurrence along the Fundy coast of New Brunswick were searched for lichens, resulting in at least 7,000 lichen specimen vouchers (COSEWIC 2009). Since publication of the previous status report, there has been little search effort specifically for *E. mollissimum* in the province. However, there have been several lichen surveys in the province that would have recorded this lichen, if present. These included surveys at or near the two previously recorded occurrences in the province. In September 2016, several lichen specialists surveyed near Fox Hill on Campobello Island in what is believed to be the area from which the original specimen of *E. mollissimum* was collected in 1902. They concluded from the limited range of rare chloro and cyanolichens present that it was unlikely that *E. mollissimum* remained in the area (Clayden pers. comm. 2018). Surveys were also conducted in Fundy National Park in 2013, where the second documented occurrence was located, though it is not known if the specific site of the previous record was surveyed.

Other surveys that would likely have detected *E. mollissimum* include bio-blitz surveys in protected areas led by the New Brunswick Museum (as part of the BiotaNB program). In addition, there have been targeted surveys for *E. pedicellatum,* also no longer found in New Brunswick, by experienced lichenologists (Stephen Clayden, David Richardson, Mark Seaward and Wolfgang Maass) who all failed to find either *Erioderma* species. Furthermore, systematic surveys for *Fuscopannaria leucosticta* (White-rimmed Shingle Lichen), which has similar habitat requirements to *E. mollisimum*, were conducted at 17 previously known and 22 new sites in New Brunswick in 2017 (Haughian *et al.* 2018). Several rare lichens were recorded, but not *Erioderma* spp.

Erioderma mollissimum has not been detected in the province since 1980. Remaining areas in New Brunswick that appear to be most similar to colonized habitats in Nova Scotia, may be too far inland and thus with a microclimate unsuitable for *E. mollissimum* (Clayden pers. comm. 2018).

Nova Scotia

Much of the survey effort for *E. mollissimum* in Nova Scotia has been driven by the search for a related species, *E. pedicellatum,* which occurs in a similar, though more restricted, habitat than *E. mollissimum*. A predictive model for *E. pedicellatum* developed by Cameron and Neily (2008) identified 13,852 potential habitat polygons, which are Balsam Fir forest stands that occur less than 30 km from the coast and within 80 m of *Sphagnum* dominated wetlands. Pre-harvest lichen surveys have been required in blocks identified by the model on provincial Crown Lands since 2011, despite its relatively poor predictive power for *E. pedicellatum* (NS Department of Natural Resources 2018). The model proved useful for finding rare lichen species, including *E. mollissimum.* A total of 183 blocks were identified by the model and, of those that were surveyed, the lichen was found in three (Cameron and Neily 2008).

During pre-harvest lichen surveys, search tracks were recorded using GPS units (Figure 5). Since 2007, a total of 8124 km has been surveyed for lichens, primarily within and around the *E. pedicellatum* habitat polygons (Table 1). Most of this effort has occurred since 2011. Although 60% of Nova Scotia's landmass is privately owned (Nova Scotia Department of Natural Resources 2016), survey effort in Nova Scotia has been focused on provincial crown lands. Sixty-seven percent of recorded survey kilometres were on crown lands (5395 km), 3% in provincial protected areas (260 km), 1% on federal lands (80 km), 1% on land belonging to land trusts, and 28% on other land holdings, which include private, industrial and municipal lands (2238 km).

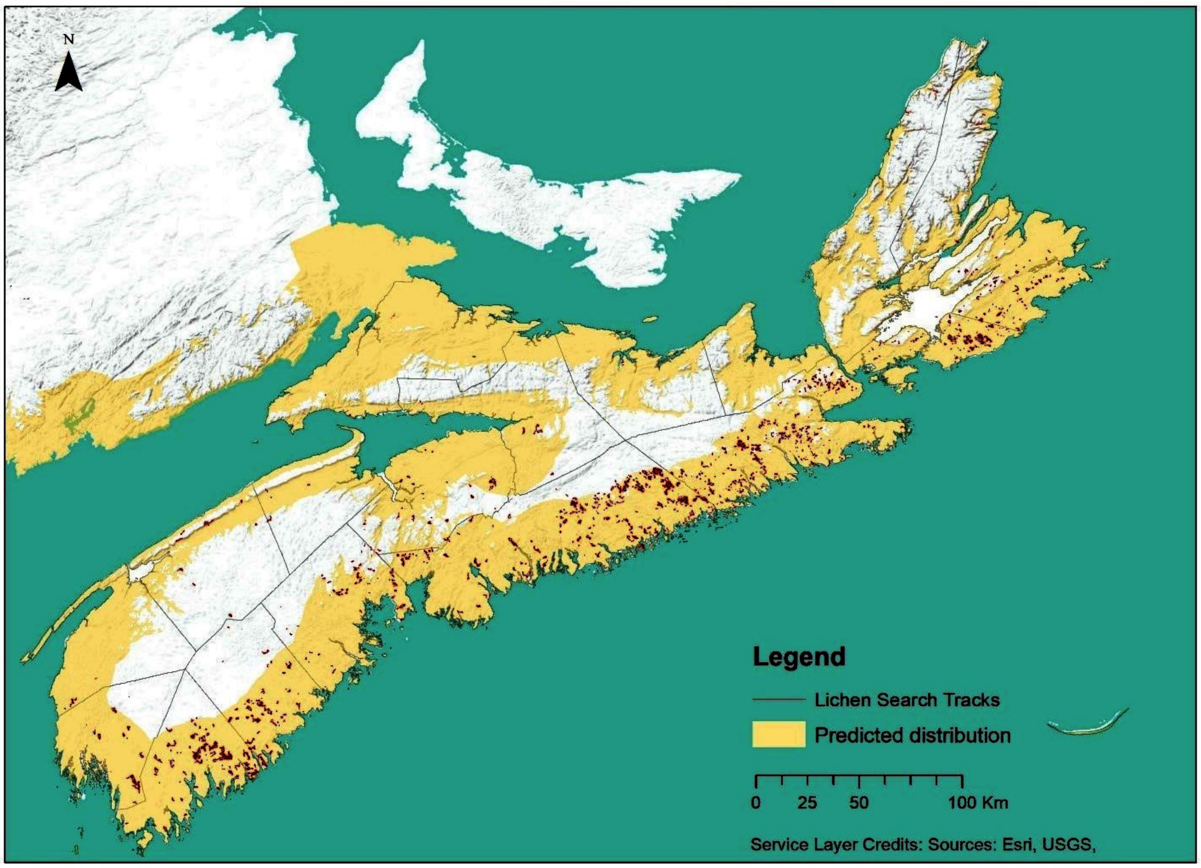

Figure 5. Survey effort in Nova Scotia for lichens, including *Erioderma mollissimum* shown by the survey tracks (red spots). The yellow area represents the predicted climactic distribution identified in Cameron *et al.* (2011) that could contain suitable habitat for the lichen which is unlikely to be found in the white areas.

Table 1. Nova Scotia survey effort. Number of kilometres searched for lichens in each county of Nova Scotia from 2007 to November 2018. Most surveys were conducted in or near *E. pedicellatum* predicted habitat polygons.

County	Kilometres	% total	*E. mollissimum* occurrences	
			Extant	Historical
Annapolis	78.52	0.97	0	0
Antigonish	0.88	0.01	0	0
Cape Breton	344.51	4.24	0	0
Colchester	175.73	2.16	0	0
Cumberland	39.59	0.49	0	1
Digby	27	0.33	1	0
Guysborough	1481.45	18.24	1	0
Halifax	2593.46	31.92	11	7
Hants	448.45	5.52	0	0
Inverness	20.69	0.25	0	0
Kings	18.9	0.23	0	0
Lunenburg	282.05	3.47	1	0
Pictou	9.42	0.12	0	0
Queens	468.68	5.77	9	1
Richmond	688.41	8.47	0	0
Shelburne	1246.89	15.35	28	3
Victoria	18.28	0.23	0	0
Yarmouth	181.17	2.23	1	2
Total	**8124.08**	**100**	**52**	**14**

Other studies in Nova Scotia have also contributed to the search effort for *E. mollissimum* since its discovery in 1980. Maass (Maass 1983; Maass and Yetman 2002) surveyed many areas for *E. pedicellatum* and other cyanolichens; their search effort was not recorded but was considerable (COSEWIC 2009). Cameron and Richardson (2006) surveyed 14 protected areas in Nova Scotia for cyanolichens. Other lichen richness surveys in Nova Scotia include Casselman and Hill (1995), Seaward *et al.* (1997), Sneddon (1998), Selva (1999), Cameron *et al.* (2007), McMullin *et al.* (2008), Tuckerman lichen workshops in 1999 and 2004 (Buck 2016) and several Bio-Blitzes. In December 2018, a one-day survey blitz at the Kejimkujik National Park, Seaside Adjunct (not included in Table 1 survey tracks) resulted in the discovery of a new occurrence in the park (McMullin, pers. comm. 2018).

Newfoundland

Erioderma mollissimum was first discovered in Newfoundland in 2006 (Jørgensen *et al.* 2009). Most of the extensive surveys for rare lichens prior to 2006 were conducted by persons that only received training to recognize *E. pedicellatum*, and likely would not have recognized *E. mollissimum*. However, Maass and Yetman (2002), who reported 84 occurrences for *E. pedicellatum* and numerous other cyanolichens on the island of Newfoundland, were familiar with *E. mollissimum* and would have recorded it if present in their survey areas. Ahti (1974, 1983) also studied lichens during several trips to the island of Newfoundland. A review of his collections and those by earlier researchers included no records of *E. mollissimum*.

Following the initial discovery of *E. mollissimum* in 2006, digital photographs of over 2000 supposed *E. pedicellatum* thalli were re-examined. Several thalli that appeared to be *E. mollissimum* were detected in these photographs and in 2007-2008 follow-up surveys confirmed E*. mollissimum* on nine additional host trees (NL Department of Fisheries and Land Resources 2018).

Surveys for *E. mollissimum* have focused on Halls Gullies and Southeast Placentia, near the known occurrences, but have also occurred elsewhere. In 2007, the Newfoundland and Labrador Department of Natural Resources conducted 22 hours of surveys for *E. pedicellatum* and *E. mollissimum* on the Avalon Peninsula, including 10 hours in the Halls Gullies area, but did not find any *E. mollissimum*. The 35 participants of the Tuckerman lichen workshop in 2007 also spent several hours in Halls Gullies and did not locate any additional *E. mollissimum*, underlining its rarity in Newfoundland.

Since the last status report, some surveys have been conducted specifically for *Erioderma* species, while others targeted arboreal cyanolichens, or arboreal lichens in general. Crown Land surveys have been completed by various government employees and contractors, local and visiting academic researchers (e.g., McMullin and Wiersma 2017) and consultants (e.g., Eagleridge International Limited 2015), though not all search effort was documented. In addition to Crown Land, protected areas have also been targeted (McCarthy *et al.* 2015; McMullin and Wiersma 2017). Survey effort has exceeded 1700 person-hours but only nine new thalli have been found on four new host trees, all within existing occurrences (Table 2).

Table 2. Newfoundland survey effort. Survey efforts from 2008-2018 for *Erioderma* species or general lichen surveys in habitats that could potentially be colonized by *Erioderma mollissimum*.

Organization	Estimated No. of Person-Hours	Survey Area	*E. mollissimum* found
Forestry and Wildlife Research Division, NL Dept. of Fisheries and Land Resources	120	Avalon Peninsula, Bay D'Espoir, (also surveys on Northern Peninsula, Codroy, central west coast, hours not included)	0
Canadian Forest Service, Natural Resources Canada	500	Avalon Peninsula, Burgeo Highway, Bay D'Espoir, (also central west coast, hours not included)	7 thalli on 2 trees
Memorial University of Newfoundland/ Canadian Museum of Nature	240	Avalon Peninsula	1 thallus on 1 tree

Organization	Estimated No. of Person-Hours	Survey Area	*E. mollissimum* found
AMEC Foster Wheeler	170	Avalon Peninsula (near Whitbourne), south coast (Bay du Nord), transmission corridor	0
LGL	50	south coast (Bay du Nord), transmission corridor	0
Forest Management District Offices, NL Dept. of Fisheries and Land Resources	180 (up to 2012)	Avalon Peninsula, and the Bay D'Espoir area and the Bay du Nord Wilderness Reserve	0
Parks Canada and Miawpukek First Nation	192	Terra Nova National Park	0
Eugene Conway, Independent consultant	4	Avalon Peninsula, Salmonier Line	0
Salmonier Nature Park, Wildlife Division, Department of Environment and Conservation	300 (up to 2012)	Avalon Peninsula, with emphasis on central Avalon	1 thallus on 1 tree
John McCarthy, Independent Consultant	10	Bay D'Espoir, Avalon Peninsula	0
Total	**1766**		**9 thalli on 4 trees**

It is difficult to estimate what proportion of suitable habitat has been searched in Newfoundland. On the Avalon Peninsula, it is likely that only 20 to 50% of the suitable habitat for *E. pedicellatum* has been thoroughly searched. While all known *E. mollissimum* on the Avalon Peninsula has been found within *E. pedicellatum* sites, *E. mollissimum* has only been found in a very small subset of this area and at a much lower frequency than *E. pedicellatum*. No *E. mollissimum* has been found in areas outside of the Avalon Peninsula where *E. pedicellatum* and other cyanolichens occur. This includes the Bay D'Espoir area, where *E. pedicellatum* occurs at high frequency and search effort has been considerable, Terra Nova National Park, and the Great North Peninsula. The climate may not be suitable for *E.mollissium* in some of these areas, particularly the latter two (Cameron *et al.* 2011). Limited surveys also have occurred in southwestern Newfoundland, where no *E. pedicellatum* has been found, but where other cyanolichen associates have been observed on Yellow Birch and Red Maple.

HABITAT

Habitat Requirements

Erioderma mollissimum occurs in humid forests throughout its range, including tropical rain forests, wet montane habitats, and in Atlantic Canada, humid coastal forests (Maass 1983; Jørgensen 2000; Cameron *et al.* 2011). In Nova Scotia, this lichen is most often found as an epiphyte on Red Maple (*Acer rubrum*), less frequently on Yellow Birch (*Betula alleghaniensis*) and occasionally on Balsam Fir (*Abies balsamea*), but in Newfoundland, it only occurs on Balsam Fir (see **Host Trees**).

Its Canadian distribution is in areas described as perhumid boreal, and hemi-boreal, forests of Atlantic Canada, These are characterized by cool to mild maritime climates, mild winters and relatively high annual precipitation (Clayden *et al.* 2011). These forests are considered to be temperate rain forests by DellaSala (2018), although they lack the specialized rainforest tree species and abundant epiphytic bryophytes found in other temperate rainforest regions, such as British Columbia (Clayden *et al.* 2011). *E. mollissimum* in Atlantic Canada is found within 30 km of the coast in areas with precipitation often exceeding 1400 mm annually, and at elevations rarely exceeding 150 m above sea level (Maass 1983; Cameron *et al.* 2011). Fog is frequent in these areas (COSEWIC 2010). *E. mollissimum* often occurs in or near wetlands (Environment Canada 2014). Like other cynanolichens, *E. mollissimum* is susceptible to airborne pollutants and requires a relatively pollutant-free environment (Richardson and Cameron 2004; Environment Canada 2014).

Climate

Climate, particularly humidity, is an important component of *E. mollissimum* habitat. In all areas of the species' former and current range in Canada, the climate is moderated by the proximity of the Atlantic Ocean, with coastal regions experiencing cooler summers and milder winters than interior regions. The *E. mollissimum* areas in Newfoundland and Nova Scotia have a generally similar climate, though the summers tend to be warmer in Nova Scotia, with more days above 20°C (Table 3).

Table 3. Climate normals for *Erioderma mollissimum* areas on the Avalon Peninsula of Newfoundland and the Atlantic Coast of Nova Scotia 1971–2000* (Environment and Climate Change Canada 2018b).

Weather Station (1971–2000)	Total Precipitation (mm)	Number of days with rainfall (≥2mm)	Number of days entirely below freezing	Number of days entirely above freezing	Number of days above 20°C	Number of days above 30°C
Newfoundland						
Long Harbour	1366	160	53	215	25	0
St. Mary's	1510	147	50	217	19	0
Colinet	1392	108	55	194	23	0
Nova Scotia						
Ecum Secum	1541	163	51	205	35	0
St Margaret's Bay	1364	122	47	193	79	1
Yarmouth	1274	165	39	235	53	0

*The data from two stations, Holyrood in NL and Liverpool Big Falls in NS, were excluded even though they were in close proximity to the *E. mollissimum* occurrences because they represent slightly warmer and drier climatic regions.

Table 4. Known abundance of mature individuals of *Erioderma mollissimum* in Canada. (Immature thalli that were not yet producing soredia are not included in these data.) Note there are no data reported in this table for the two Bay of Fundy subpopulations that are no longer extant.

Sub-population	County	Occurrences			Trees Current	Mature Thalli
		Current	Lost since 2008	Lost pre-2008		
Nova Scotia						
South Shore	Digby	1	0	0	2	2
	Yarmouth	1	1	1	1	1
	Shelburne	29	3	1	142	217
	Queens	10	1	0	32	42
Lunenburg Co.	Lunenburg	1	0	0	1	1
Eastern Shore	Halifax	11	0	5	14	15
	Guysborough	1	0	1	2	2
Bay of Fundy	Cumberland	0	0	1	0	0
	Totals	53	5	9	194	280
Newfoundland						
Avalon Peninsula		4	0	0	11	32

The coastal areas of the Maritimes and the Avalon Peninsula are known for their high fog frequency. According to the Nav Canada Local Area Weather Manual for Atlantic Canada and Eastern Quebec (Robichaud and Mullock 2001) the frequency of low ceilings and visibility (due to fog, low cloud and/or precipitation) is very high in the summer at the Saint John, Halifax, Yarmouth, and St. John's airports, which are located within the climatic envelope (Cameron *et al.* 2009) of *E. mollissimum*. These areas frequently (>45% of days) experience low visibility on summer mornings, which is mostly caused by advective fog, which is fog that forms during the night and is burned off during the day. This pattern was not observed at airports in areas where no *E. mollissimum* have ever been found, which all had a maximum frequency of low visibility in the summer below 20%.

In Nova Scotia, fog decreases rapidly with increasing distance from the coast, but this is not true for all areas of Newfoundland. In south-central Newfoundland areas that appear to be wet enough for *E. pedicellatum* occur 50 km from the coast, but it is unknown whether these areas are climatically suitable for *E. mollissimum*. The hyper-oceanic barrens along the southern part of the Avalon Peninsula are characterized by frequent and persistent fog, but forest growth is restricted, and where present, stunted to krummholz by low summer temperatures and wind exposure (Meades 1990), which likely makes them unsuitable for *E. mollissimum*.

The microclimate required by *E. mollissimum* has not been investigated in Nova Scotia but limited data are available for Newfoundland where temperature and relative humidity have been recorded with data loggers within occurrence HG-A, at Halls Gullies in the Avalon Peninsula (Wiersma and McMullin 2018). The results from seven data logger stations along one transect, located 1m off the ground, have been analyzed (Wiersma and McMullin 2018). The mean relative humidity from readings taken at six-hour intervals over two years ranged from 92.9% to 96.9%, with nearly two thirds of all the data points over 95%. Mean temperatures were between 3°C and 5°C. This underlines the importance of high humidity for *E. mollissimum* to thrive.

A predictive climate model specifically for *E. mollissimum* in Atlantic Canada was developed by Cameron *et al.* (2011). The model was based on 35 current and historical occurrences of *E. mollissimum* and data from 10 climate stations. The model identified elevation, distance from the coast and annual precipitation as the most important variables predicting distribution, but only a limited number of climate stations and small sample sizes were used to develop the model, which limited its predictive power. However, all occurrences of *E. mollissimum* in Atlantic Canada fall within the predicted distribution.

Landscape and Stand Characteristics

Erioderma mollissimum is part of a rich Atlantic coastal forest lichen community that is predominately found in mature stands that have not been subject to large-scale disturbances, resulting in long term ecological continuity (Cameron and Bondrup-Nielsen, 2012; Haughian *et al.* 2018, McMullin and Wiersma, 2019). The geology and landforms that host *E. mollissimum* vary across Atlantic Canada, but they have in common a relatively gentle topography and low elevation. The occurrences in Nova Scotia are generally located on sites with a high *Sphagnum* cover and a consistent presence of Cinnamon Fern (*Osmundastrum cinnamomeum)*, indicating greater soil moisture than in the occurrences in Newfoundland and Labrador, where feathermosses dominate with some admixture of *Sphagnum* and Cinnamon Fern is rare. The greater soil moisture in Nova Scotia likely compensates for warmer summer temperatures to produce comparable evapotranspiration demands.

<u>Nova Scotia</u>

In Nova Scotia, Balsam Fir occurs in all *E.mollissimum* habitats, making up at least one third of the tree species composition. Red Maple is most commonly the host species and a frequent associate (COSEWIC 2009). Habitat data collected in 2007-2008 found that dead trees were present at all occurrences examined. Tree age varied among sites (average 45 to 99 years) and within sites (e.g., range of 60 to 156 years), though young regenerating trees were absent. Average tree height for all sites was only 8 m, reflecting poor growing conditions. The shrub layer typically included Mountain Holly (*Ilex mucronata*), *Winterberry (Ilex verticillate), Speckled Alder (Alnus incana*), and Black Huckleberry *(Gaylussacia baccata*). Generally, shrubs were not dominant, covering between 3% and 25% of the ground (COSEWIC 2009). At all sites examined, Cinnamon Fern dominated the herb layer and *Sphagnum sp.* covered more than 70% of the ground layer.

All occurrences are in mature stands such as climax Red Maple floodplains or Balsam Fir forests. The number of occupied trees per occurrence ranges from 1 to 29 (mean 3.6, SD 5.7), with the most densely occupied sites in Shelburne and Queens Counties (Appendix 1, Figure 3). Unoccupied areas between occurrences often superficially appear to be suitable habitat, particularly in Shelburne County where treed bogs are abundant (Brad Toms 2019, pers. comm.). However, dispersal potential to these areas is unknown.

Maass (1983) described *E. mollissimum* as occurring in *E. pedicellatum* habitat in Nova Scotia. However, *E. mollissimum* appears to have a somewhat wider habitat tolerance than *E. pedicellatum,* which may be related to its wider substratum preference.

Newfoundland

The forests containing *E. mollisimum* in Newfoundland are old, poorly drained forests with frequent snags and open to patchy canopies. Many of the open patches are wind throw that originated during the particularly severe storms in 1994 and have been enlarged annually by additional blow downs. The canopy is usually dominated by Balsam Fir but can have significant Black Spruce (*Picea mariana*) components and occasional White Birch (*Betula papyrifera*).

The proportion of snags can be as high as 70% of total stems, though live stems more commonly outnumber dead ones. As in Nova Scotia, woody shrub cover, which was dominated by young trees, was relatively low, ranging from 11 to 31%, with a mean of 19%. Shrub species most consistently represented were Lowbush Blueberry (*Vaccinium angustifolium*), Sheep Laurel (*Kalmia angustifolia*), Labrador Tea (*Rhododendron groenlandicum*) and Wild Raisin (*Viburnum cassinoides*), indicating a relatively nutrient-poor environment.

Some habitats appear to be transitional between treed wetlands and adjacent uplands. The understory vegetation was dominated by feathermosses in all plots, and while the cover of *Sphagnum mosses* was sometimes as low as 1%, it could be as high as 40%.

Newfoundland *E. mollissimum* stands were generally older than those in Nova Scotia. The age of the oldest sampled tree in each stand varied from 92 years to 210 years. At all sampled *E. mollissimum* stands combined, the age of the Balsam Fir of a mean DBH (diameter at breast height) >7 cm (representing the population of potential host trees) averaged 87.8 years old at Halls Gullies and 111 years at Southeast Placentia. Smaller subcanopy trees of unknown age were also present. Advanced regeneration in canopy gaps appears to be limited to the height of winter snowpack by browsing pressure from Moose (*Alces alces*) and Snowshoe Hare (*Lepus americanus*).

Host Trees

Nova Scotia

In Nova Scotia, *E. mollissimum* most frequently grows on Red Maple (68% of thalli at 10 NS occurrences in 2007-08), Yellow Birch (25%) and Balsam Fir (7%) (COSEWIC 2009). Occurrences on Yellow Birch are limited to the Eastern Shore region while Red Maple is the most common substrate in the South Shore region. *E. mollissimum* occasionally occurs on Balsam Fir in both regions. All trees on which *E. mollissimum* has been found in Nova Scotia are mature to old (COSEWIC 2009). The height of thalli above the ground ranges from 0.3 m to 3 m, with an average height of 1.5 m (COSWIC 2009). As most host trees are not flagged, the duration of colonization on individual trees is not known.

Newfoundland

In Newfoundland, *E. mollissimum* has only been found on Balsam Fir that are either dead or old in appearance with a ragged crown and dead branches. The mean DBH (diameter at breast height) of host trees (10.7 cm) tends to be larger than the average Balsam Fir tree in surveyed plots (9.1 cm). Three of the host trees occupied in 2018 were standing dead and an additional one had blown down.

Due to the relatively recent discovery of this species in Newfoundland, the maximum (and average) length of time that the trees are colonized is not yet known. On at least one tree, *E. mollissimum* thalli have persisted for at least 13 years, from 2005 to 2018 (NL Department of Fisheries and Land Resources 2018). It is plausible that several generations of *E. mollissimum* can occur on a single tree.

The height of the thalli above the ground ranges from 0.45 m to almost 2.5 m (NL Department of Fisheries and Land Resources 2018). The examination of the upper boles of windthrown trees has not yielded discoveries of *E. mollissimum* individuals. *E. pedicellatum* is also rare higher on trees. Bole aspect was only recorded for 31% of the thalli, and of these, 62% were found in the northerly quadrant (NL Department of Fisheries and Land Resources 2018).

Habitat Trends

Nova Scotia

In Nova Scotia, the *E. mollissimum* sites have been revisited infrequently. On a landscape level, the quality and quantity of potential habitat for *Erioderma* species in Nova Scotia has been decreasing as a result of forestry, pollution and climate change (see **Threats**). Nova Scotia's Acadian forests have undergone great changes since European settlement (Loo and Ives 2003). Most have been extensively and repeatedly logged, resulting in simplified forest structure and composition (Loo and Ives 2003; Farrow and Nussey 2013). Recent forest practices, dominated by clearcutting (Lahey 2018), have increased the proportion of even-aged, early-successional forest types and decreased the proportion and age of shade-tolerant, late-successional forests (Farrow and Nussey 2013). Mature forests in Nova Scotia have declined continually since 1987 (Cameron and Toms 2016) and the loss is predicted to continue over the next 50 years (Cameron *et al.* 2013). This loss of habitat is believed to be a factor in declines of other rare cyanolichens with similar habitat requirements, such as *E. pedicellatum* (Cameron and Toms 2016), *Pectenia plumbea* (Blue Felt Lichen) (COSEWIC 2010), and *Fuscopannaria leucosticta* (COSEWIC 2019).

<u>Newfoundland</u>

Field observations since 2006 and preliminary monitoring data collected since 2010 suggest a future reduction in habitat quality in Newfoundland (NL Department of Fisheries and Land Resources 2018).

Trees appear to be suitable habitat for *E. mollissimum* for only parts of their lifespan. The trees currently hosting *E. mollissimum* are old, dying, or already dead and not likely to survive the next few decades. Dead trees are subject to bark loss and therefore are a less stable habitat for bark-dwelling lichens like *E. mollissimum*. Even if bark remains attached for several years, the suitability as an *E. mollissimum* substratum declines over time because of changes in bark and throughfall chemistry, as well as increased light and precipitation as the crown decays. Resurveys of *E. pedicellatum* sites have shown that the death rate of *E. pedicellatum* was higher on dead trees than on live trees (Arsenault pers. comm. 2018; NL Department of Fisheries and Land Resources 2018) and it is likely that *E. mollissimum* death rates would be accelerated on dead trees as well.

A comprehensive analysis of stand development has not yet been done for the Avalon Peninsula, but is believed to be similar to the dynamics described by McCarthy and Weetman (2007) from an insect-disturbed landscape in western Newfoundland. The majority of the stands on the landscape examined by McCarthy and Wheetman (2007) followed a fairly typical even-aged stand development pattern. Some stands were uneven-aged or bi-staged with younger trees present under an open canopy of older veterans. These stands had a greater structural complexity and longer history of continued forest cover and were more likely to be located in unproductive habitats similar to those preferred by *E. mollissimum*. The extent to which the age-structure of forests has been altered by human activities, such as logging and the introduction of Moose to Newfoundland is not known (See **Threats and Limiting Factors**).

BIOLOGY

Life Cycle and Reproduction

Erioderma mollissimum belongs to a group known as cyanolichens, so named because one partner of the symbiosis is a cyanobacterium. The cyanobacteria provide carbohydrates through photosynthesis to the fungal partner and also fix atmospheric nitrogen. Both require liquid water to initiate the process (Lange *et al*., 1986; Rikkinen 2015). Most epiphytic cyanolichens require relatively nutrient-rich substrata and a pH between about 5.0 and 6.0 (Rikkinen 2015).

In Canada, *E. mollissimum* reproduces asexually via soredia. These are specialized vegetative propagules composed of fungal hyphae wrapped around cyanobacteria that can be dispersed by wind, rain or animals (Rai 1990) and are the primary means of reproduction and dispersal in *Erioderma mollisimum*.

In old, large thalli central areas may decline in vigor and eventually die and detach. However, the outer lobes may remain heathy, and in this way an established thallus can, in time, give rise to several smaller, independent thalli by fragmentation (Species Status Advisory Committee 2008). This process does not contribute to long-distance dispersal but can locally help populate a tree. Not all large thalli fragment (COSEWIC 2009). Fragmented thalli were found at two of nine occurrences during the 2007-2008 surveys in Nova Scotia (COSEWIC 2009). Of the 32 mature thalli documented in Newfoundland in 2018, six (~19%) were fragmented.

Sexual reproductive structures (apothecia) have only been seen once in Nova Scotia at Jones Harbour in the South Shore sub-population (COSEWIC 2009) but may have been overlooked elsewhere (Neily pers. comm. 2018). Structures that appear to be immature apothecia have been seen on several thalli in Newfoundland (Figure 1). However, it is not known whether they can produce ascospores (Neily pers. comm. 2018).

Necrosis (yellowing of the thallus surface) indicates poor health of the photosynthetic tissue (Department of Fisheries and Land Resources 2018). Necrosis may be caused by a sudden change in microhabitat conditions, including opening of the adjacent canopy due to wind throw, or death of the host tree itself (NL Department of Fisheries and Land Resources 2018). although sometimes a high level of necrosis occurs suddenly from one year to the next and without an obvious explanation.

Generation time for *E. mollissimum* has not been studied but is estimated at 20 years, which is the value used for *E. pedicellatum* based on juvenile and adult growth rates and demographic modelling (COSEWIC 2014).

Physiology and Adaptability

Ability to persist for long periods in favourable habitats is indicated by the long-term presence (two decades) of *E. mollissimum* at two occurrences in Nova Scotia. The species has only been known in Newfoundland for 12 years. This is not long enough for observations on adaptability. As with other species that rely on exceptionally wet, mature forests, *E. mollissimum* is thought to be poorly adapted to stand-replacing disturbance. For example, mortality of the related *E. pedicellatum* in Nova Scotia is correlated with adjacent clearcutting (Cameron *et al.* 2013).

Dispersal and Migration

Dispersal of *E. mollissimum* is primarily via asexual propagules called soredia. These propagules are dispersed by wind and rain but the density of airborne soredia drops quickly with increasing distance from a point-source, leading to low likelihoods of dispersal and establishment at distances of more than 50 m and this drops to very low above 150 m (Werth *et al.* 2006a; Scheidegger and Werth, 2009). Thallus fragments are dispersed only to about one metre but up to 10 metres with the help of animals. This allows the lichen to spread over the bole of a single tree (Sheidegger and Werth, 2009). The vectors for fragments and soredia are rain and wind (Armstrong 1987, 1990) as well as insects (Heinken, 2006), gastropods (McCarthy and Healy 1978; Boch *et al.* 2011), other invertebrates and forest dwelling birds (see below). Dispersal distance for soredia and thallus fragments is more limited than that of ascospores (Heinken 1999). It is probably why *E. mollissimum* tends to occur in clusters on a tree, rather than as single individuals in comparison with *E. pedicellatum*, which produces apothecia that discharge ascospores into the air and can disperse more effectively over greater distances. Thus, once a tree has been colonized by *E. mollissimum,* there is a relatively effective movement and establishment of propagules on the trunk. Soredia go through the following phases: colonization/establishment, juvenile, pre-adult and adult (COSEWIC 2009, NL Department of Fisheries and Land Resources 2018). These stages are somewhat arbitrary and difficult to identify (Goudie *et al.* 2011). Some thalli become sorediate (i.e. reproductively mature) at diameters between 1 cm and 2 cm, a size that is usually considered “pre-adult” but most small thalli (68%) die without developing soredia (NL Department of Fisheries and Land Resources 2018), and so are not effective in dispersal.

The Canadian population of *E. mollissimum* is divided into four extant subpopulations and two historical subpopulations that are considered to be extirpated (see **Canadian Range**). These four subpopulations are separated by more than 50 km. One question is how the subpopulations have become established when this lichen has such a limited means of dispersal by wind. The most likely explanation is that soredia become attached to the feathers of migrating birds seeking insects on or around lichen thalli (Gerson and Seaward 1977). Such birds may land on trees on their migration path and if the host and microclimate are suitable, the soredia may develop into a soredia-bearing thallus. This can give rise to a cluster of occurrences, if soredia are then formed and dispersed. Soredia can then be spread locally by wind, water and rodents such as squirrels (Kimmerer and Young, 1996; Rosentreter *et al.* 1997) or by resident birds *et al.* (Coppins and James, 1979; Osorio-Zuñiga *et al.* 2014; Chmielewski and Eppley, 2019). The four extant subpopulations, where clusters of *E. mollissimum* occur, are also in four different biogeographic zones. Further expansions of the clusters may be limited by the poor dispersal of the lichen and the various threats to its survival (see **Threats and Limiting Factors**).

Interspecific Interactions

Erioderma mollissimum and many of its associates belong to the Lobarion Alliance (Maass and Yetman 2002), a species rich and sensitive epiphyte community which is also found in Europe (Gauslaa 1985). Recent research suggests that the establishment of *E.*

pedicellatum from spores is facilitated by the presence of "cyanobacterial gardens", or mats of bryophytes and other lichens which associate with the same cyanobacterial strains (Cornejo and Scheidegger 2016; Cornejo *et al.* 2016). As *E. mollisimum* is not known to reproduce sexually in Canada, it does not benefit from these assemblages.

Interspecific competition has been recognized as a potential factor implicated in the death of thalli of *E. pedicellatum* in Newfoundland and involves other lichens or bryophytes overgrowing thalli (NL Department of Fisheries and Land Resources 2018; Figure 6). Since 2013, the portion of thalli overgrown by other species has been monitored. In 2018, most *E. mollissimum* individuals (43 of 61) were partially overgrown, but only 12 of these had over 33% of their thallus surface covered by competing cryptogams. Of the 22 thalli that died in Newfoundland between 2010 and 2018, two had overgrowth exceeding 33% of the thallus surface and it was considered a potential contributing factor in their death. No experiments have been done to determine whether such overgrowth is a competitive interaction that causes *E. mollisimum* decline, or simply an opportunistic response by associated species to the declining health of *E. mollisimum* thalli from other causes. Species that have been observed to overgrow *E. mollissimum* tissue include *Frullania asagrayana*, *Platismatia glauca* (Varied Rag Lichen), *Hypogymnia* spp., *Sphaerophorus globosus* (Globe Ball Lichen), *Ochrolechia frigida* (Arctic Saucer Lichen), *Bryoria* spp., *Alectoria sarmentosa.* and *Lopadium disciforme* (Disc Granular Lichen) (McMullin and Arsenault 2019; NL Department of Fisheries and Land Resources 2018).

Figure 6. *Erioderma mollissimum* on a fallen host tree in Halls Gullies, Newfoundland. The thallus is in a cryptogam mat and likely experiencing competition from *Sphaerophorus globosus* and a moss in the genus *Dicranum*. Beige to brown colour indicates partial necrosis. Note the detaching bark flake below the lowest red pin; detachment of the substrate is a major mode of death in this species. The green pin marks the thallus, the two red pins stabilize the substrate on the tree and the screws form a frame for photo monitoring (photo used with permission from the NL Department of Fisheries and Land Resources).

Herbivory / Predation

Many groups of invertebrates are known to graze lichens including Thysanurans, Collembolans, Psocopterans, Lepidopteran larvae and orbatid mites (Seyd and Seaward 1984; Hesbacher *et al.* 1995; Brodo *et al.* 2001). Extensive grazing by slugs, particularly the non-native Dusky Arion (*Arion subfuscus*) has been identified as a concern for other at-risk cyanolichens in Atlantic Canada (Cameron 2009, COSEWIC 2014, 2019). Grazing on *E. mollisimum* has been reported in both Nova Scotia and Newfoundland, though it does not appear to be as significant a concern as with *E. pedicellatum* in either province (MTRI 2019, NL Department of Fisheries and Land Resources 2018).

In Nova Scotia, approximately 9% of thalli monitored in 2016 and 12% of thalli monitored in 2008 showed evidence of grazing (COSEWIC 2009, MTRI 2018). In most cases, less than 20% of the thallus was grazed. Most grazing observed in 2007-2008 had patterns typical of small invertebrates such as Oribatid mites or Collembola, with only three thalli showing grazing patterns typical of gastropods (Cameron 2009). Of 183 thalli inspected in 2016, only five were more than 20% grazed (MTRI 2018).

In Newfoundland, snails, slugs and mites have all been implicated in causing grazing damage because they occur in *E. mollissimum* habitat and have been observed on skeletonized thalli of *Lobaria pulmonaria* and *L. scrobiculata* (Textured Lungwort) (NL Department of Fisheries and Land Resources 2018). Grazing damage was monitored in 2018 using a 4-point ordinal scale. Twenty-five percent of thalli showed evidence of grazing (15 of 61); thirteen had only minor grazing damage, one had moderate grazing damage, and one had severe grazing damage (NL Department of Fisheries and Land Resources 2018).

Other Stressors and Mortality Factors

In Newfoundland, annual monitoring of both *E. pedicellatum* and *E. mollissimum* has also documented other factors related to the decline and death of thalli of both species. These “death factors” include fallen or damaged host trees, broken branches, poor attachment and loose substrate (NL Department of Fisheries and Land Resources 2018).

Detachment of the tree bark or cryptogamic mat (to which the lichen was attached) was the main suspected cause of 21 of the 22 *E. mollissimum* thallus deaths between 2010 and 2018 (NL Department of Fisheries and Land Resources 2018). Detachment of thalli from the substrata has also been noted for thalli in Nova Scotia (MTRI lichen database 2018).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Sampling effort with respect to the Nova Scotia and Newfoundland subpopulations has been different. In Newfoundland, the small size and geographic scope of the subpopulation has allowed for annual monitoring of all known thalli, which are identified individually via pins on the host tree (Figure 6). In Nova Scotia, where the subpopulations are much more widespread and larger, the focus has been on searching for new occurrences, and on presence-absence monitoring of known occurrences. These differences in methodology make it difficult to compare trends among the populations in these two provinces. The difference in the proportion of recorded juveniles, between the provinces, reflects the difference in sampling methods.

<u>Nova Scotia</u>

Monitoring was undertaken in 2007-2008 to verify suspected and past occurrences as well as search for new occurrences as part of field verification for the 2009 status report (COSEWIC 2009). Further monitoring was undertaken in 2016 to revisit *E. mollissimum* sites that were identified as extant in the 2009 report as well as those discovered in the intervening years. Fifty-three occurrences were surveyed during these efforts (Appendix 1). Two sites were not monitored in 2016 due to incorrect geographic coordinates. One of these (Bennett Lake) was revisited in 2018 as part of the field verification and was found to no longer contain *E. mollissimum*. The correct coordinates for the other site (Martin Brook) was only discovered after field verification had been completed and the site has not been re-surveyed.

Monitoring involved re-visiting sites of known host trees based on the recorded geographic coordinates. Some of the host trees were previously flagged but most were not. Researchers surveyed all trees in the surrounding area, which typically encompassed a 25-50 m zone, though occasionally extended further, depending on the extent of suitable-looking habitat (Pepper pers. comm. 2018). Researchers recorded presence/absence, geographic coordinates of each host tree, and, usually, number of thalli. Thallus health was estimated on a scale of 1 to 5 with 1 being the most healthy and vigorous and 5 being the least healthy. Percent grazing and percent necrosis of thalli was also visually estimated (MTRI lichen database 2018).

In an attempt to relocate *E. mollissimum* at a historical site in Thomas Raddall Park, five lichenologists spent a day surveying the park in 2016 but were unable to find the lichen (Cameron pers. comm. 2018). In 2018, an intensive lichen survey Bioblitz was undertaken at the Kejimkujik National Park Seaside Adjunct. During this, the original occurrence identified as *E. mollissimum* in the park (discovered in 2011) was monitored and photo-documented, New occurrences for *E. mollissimum* were also found (McMullin pers. comm. 2018).

Searches for new occurrences involved 8124 km of survey tracks since 2007 (Table 1, Figure 5). Many were undertaken during surveys for *E. pedicellatum* and occurred within or near the *E. pedicellatum* predicted habitat polygons (see **Distribution - Search Effort**).

Newfoundland

While there is an ongoing general lichen search effort that has led to the discovery of new thalli, the areas with known thalli have also been periodically intensively searched. These intensive searches involve looking at a large proportion of the suitable-looking trees surrounding the marked host trees and have been carried out in a portion of the Halls Gullies HG-A occurrence in 2010, 2012 and 2018, and in the remainder of HG-A and at HG-B and HG-C in 2016. The SE Placentia occurrence was intensively searched in 2014 and 2016. These intensive searches are included within the total search effort (Table 2) and have led to the discovery of two of the new host trees discovered since 2007.

Known thalli have been monitored on individual trees annually since 2010 by the NL Department of Fisheries and Land Resources with newly discovered colonized trees being added to the monitoring program. One single tree bearing almost half of the thalli was first included in the monitoring program in 2011. Another tree bearing seven thalli was included in 2012. Variables monitored include thallus size, necrosis, presence of soredia, attachment features, competition by other cryptogams and invertebrate grazing. Thalli have been photo-monitored annually. The photographs are standardized by four stainless steel screws placed around each cluster of thalli, allowing comparison of repeated photographs over time (Figure 6).

Abundance

Currently there are 312 enumerated mature thalli on 205 host trees in Canada. It is no longer extant in New Brunswick.

Nova Scotia

As of December 2018, *E. mollissimum* was known from 53 occurrences in Nova Scotia, with 280 mature thalli and 11 juvenile thalli occupying 194 trees (Figure 3). The majority of thalli (83%) are located in a 740 km^2 area in the South Shore subpopulation in western Queens County and eastern Shelburne County, one of the relatively few lichen rich areas in the province (Cameron, R. and D.M. Bayne, 2020).

Table 5. Projected declines in *Erioderma mollissimum* occurrences in Nova Scotia and Newfoundland, assuming a constant annual percent rate of decline ($[1-(N_{T2}/N_{T1})^{1/(T2-T1)}]\times100$). See Appendix 2 for more details on decline calculations.

Description of dataset	**Occurrences extant in 2008 or discovered since that were re-surveyed at least once**	**All occurrences (including historic sites) that were re-surveyed at least once**	**Occurrences sampled in 2007–2008 and re-surveyed in 2016–2018**
Province	**NS and NL**	**NS and NL**	**NS only**
Number of occurrences	50	60	17
Occurrences lost	5	14	4
Average sampling interval (yrs)	5.02	8.28	8.5
Annual percent rate of decline	0.02077	0.03158	0.03107
Projected decline - 1 generation (20 yrs)	34%	47%	47%
Projected decline - 2 generations (40 yrs)	57%	72%	72%
Projected decline - 3 generations (60 yrs)	72%	85%	85%

Although the number of known thalli and occurrences is higher than reported in the previous status report (COSEWIC 2009: 133 thalli, 20 occurrences), this primarily reflects an increase in search effort rather than an increase of abundance of the species. It is noteworthy that *E. mollissimum* is no longer found at 14 of the 53 occurrences that have been discovered to date in Nova Scotia (Appendix 1).

An attempt was made to estimate maximum likely number of thalli within the currently known range of *E. mollissimum* by extrapolation of success rates per unit effort, as described in Appendix 3. The occupied zone was estimated by applying a 1000 m buffer around the coordinates of each host tree, merging the resulting polygons, and clipping them to exclude large waterbodies. Within this zone, the area surveyed was estimated by applying a standardized 15 m detection distance to the linear survey tracks. The amount of forest cover was calculated using the provincial forest resource inventory layer and was adjusted to remove recent clear-cuts identified through aerial photographs. Maximum likely abundance was calculated as the success rate (lichens detected per m^2 surveyed) multiplied by the total forested area within the occupied zone. This is likely an over-estimate as the assessed forest cover was not limited to specific features and the estimate assumed that all thalli were mature. The life stage (mature/juvenile) was not considered because the proportion of juvenile thalli was not well recorded at most sites during monitoring from 2016-2018 and detection of larger more visible adults is easier. However, monitoring from 2006-2008 revealed 73% mature thalli (n=133) and 27% juvenile thalli (n=50) (COSEWIC 2009). Similarly, a detailed examination at the Kejimkujik Seaside in 2018 identified 67% mature thalli (n=10) and 33% juveniles (n=5) (McMullin, pers. comm. 2018). Using these rates, an estimate of 2532 total thalli was calculated that would be composed of 1,774 mature thalli in Nova Scotia and 250 in Newfoundland, while the number of juveniles is estimated as 760 and 234 in the two provinces respectively.

Estimating potential abundance beyond the known range is not feasible as no predictive habitat model exists for *E. mollissimum*. The *E. mollissimum* climate model included and identified areas east of the known range on the mainland and Cape Breton Island, where no *E. mollissimum* has ever been found despite considerable search effort (Figure 5). It also identified a wide swath of the northern shores where there are no sightings but where there has been relatively little search effort. Based on the success rate of recent years, it is likely there are more occurrences to be found, particularly in Shelburne County. However, over 7585 km have been searched outside of the known range, with no *E. mollissimum*, indicating that it remains a relatively rare lichen in the province.

Based on survey effort it is likely that the numbers of *E. mollissimum* do not greatly exceed that of *E. pedicellatum* in Nova Scotia. A comparison of survey effort, of suitable habitat, from 2008-2016 in the four counties where the distribution of the two species overlaps, shows that, on average, a new site containing *E. pedicellatum* is found for every 21.7 km of survey effort. It takes an average of 31.2 km of effort to find a new site of *E. mollissimum* (MTRI lichen database 2018).

<u>Newfoundland</u>

In 2018, 32 mature and 30 juvenile thalli were counted on 11 trees in the Avalon Peninsula (Appendix 1). There may yet be undiscovered thalli in Newfoundland because much of the potentially suitable habitat has not yet been surveyed. However, despite considerable survey effort in the last 10 years (Table 2) no new occurrences have been found. Thus, the total likely population of mature individuals in Newfoundland is likely fewer than 250. It is clear that the majority of *E. pedicellatum* habitat is not occupied by *E. mollissimum*. Even in areas of overlap, *E. mollissimum* is a much rarer species than *E. pedicellatum;* the latter species is approximately 40x more abundant in Halls Gullies and 5x more abundant in Southeast Placentia (NL Department of Fisheries and Land Resources 2018).

The number of known colonized trees in Newfoundland has never exceeded eleven in any one year. Approximately half of the known extant thalli in 2018 were on one single host tree, and the loss of this tree could have a severe impact on the subpopulation size.

Fluctuations and Trends

There are problems in using the number of lichen individuals counted during successive surveys as an indicator of a population fluctuation or trends. Weather conditions sometimes preclude optimal detection of thalli. On several occasions during *E. pedicellatum* monitoring in Newfoundland up to 25% of thalli reported as missing at an occurrence were found during a following visit. In Newfoundland, the disappearance of individual thalli could only be reliably demonstrated after both the trees and the individual thalli were permanently marked. In Nova Scotia, the exact position of thalli on the host tree has not been marked and most host trees have not been flagged. Most monitoring in Nova Scotia has been based on recording the presence/absence on a host tree and the number of thalli has not always been recorded. Nova Scotia data could also by complicated by inconsistent site naming, grouping into occurrences, and the lack of precise coordinates for some of the older sites.

The number of colonized trees is an important factor in population trends because the collapse or removal of a single host tree with many thalli could have a significant negative impact on population size. In addition, the loss of one or a few colonized trees may lead to the loss of an occurrence as almost half of the occurrences in Nova Scotia are on a single tree.

Due to uncertainty in counts of *E. mollissimum* thalli, losses of, and predicted declines in the number of occurrences, are a more reliable measure than the numbers of mature individuals. In addition, there is suitable habitat that has not been searched. Small numbers of new thalli have been detected on resurveys of sites. Losses of occurrences are hence more meaningful and can be reported with more confidence. For these reasons, losses and predicted losses of occurrences are used in this report as the primary proxy for declines in the number of mature individuals of *E. mollissimum.* The IUCN decline calculation document (IUCN 2019, p. 34) supports this approach, because it meets the criterion of a constant amount of habitat destruction on an annual basis, with an almost negligible recruitment.

With these comments, the following conclusions may be made.

<u>New Brunswick</u>

Erioderma mollissimum appears not to be present in the province or at the nearby occurrence on the Nova Scotia side of the Bay of Fundy that comprise the East Bay of Fundy NS/NB, and the West Bay of Fundy NB subpopulations (see **Canadian Range and Search Effort)**.

<u>Nova Scotia</u>

Erioderma mollissimum appears to be declining in Nova Scotia. A proxy for this decline is the change in number of occurrences described above, as it is the most reliable measure of trends given the dataset available. Overall, 21% of documented occurrences since the species' discovery in 1979 have been lost. The lichen is no longer found at 92% (11 of 12) of occurrences documented between 1979 and 1991. One of these historical occurrences was from Cape Chignecto in Cumberland County, the only documented record from that area of the province. More recently discovered occurrences have also been lost. For example, *E. mollissimum* was not found on re-surveys at 9% (5 of 58) of occurrences that were known to be present in 2005 or later. Twenty-six of the 53 extant occurrences have only one known host tree (Appendix 1).

Declines in occurrences were projected for three generations (60 years), by applying an exponential decline function, which assumes a constant annual proportional rate of decline (IUCN Standards and Petitions Subcommittee 2017). Details on the calculations are provided in Appendix 2. Three data sets were used, encompassing different time periods and geographic positions (see Table 5). The three generation decline in occurrences ranged from 72% to 85% (Table 5). There is uncertainty around these estimates, which do not consider any new occurrences that may arise during the projected timeframe. However, the number of these is expected to be low due to the biology of this lichen and limited amount of suitable habitat (see **Dispersal and Migration).**

There was a net loss of 14% in the recorded number of mature thalli (16 of 117) in the 17 occurrences that were surveyed in 2007-2008 and re-surveyed in 2016. Projected over three generations, using the same methods as described above, would result in a 65% reduction in the number of mature thalli (Table 6). However, as described above, some of this apparent decline in abundance may be attributable to differences in survey methods between the two time periods. At some sites in 2016, surveyors only recorded the presence or absence of the lichen on a tree, rather than a count of thalli (Toms, 2018 pers. comm.). In some cases, thalli documented in 2016 included some on newly discovered trees further impeding direct comparison between the 2008 and 2016 data.

Table 6. Projected declines in *Erioderma mollissimum* thalli and host trees in Nova Scotia and Newfoundland, assuming a constant annual percent rate of decline ($[1-(N_{T2}/N_{T1})^{1/(T2-T1)}]\times 100$). See Appendix 2 for more details on decline calculations.

Description of dataset	**Thalli counted during surveys at 17 occurrences in 2007-2008 and 2016-2018**	**Host trees re-surveyed in 2016-2018**	**Host trees identified in 2007 and re-surveyed in 2018**	**Host trees in both provinces that were re-surveyed in 2016-2018**
Province	**Nova Scotia**	**Nova Scotia**	**Newfoundland**	**Both**
Number of thalli or trees	117	133	10	143
Thalli or trees lost	16	15	2*	17
Average sampling interval (yrs)	8.5	4.2	11	8.5
Annual percent rate of decline	0.01715	0.02809	0.02008	0.01570
Projected decline - 1 generation (20 yrs)	29%	43%	33%	27%
Projected decline - 2 generations (40 yrs)	50%	68%	56%	47%
Projected decline - 3 generations (60 yrs)	65%	82%	70%	61%

* includes loss of 3 trees and a gain of 1 tree, a net loss of 2. The decline in mature thalli = 16/117=14%

As with the mature thalli count, differences in methodology complicate interpretation of trends in host trees. Approximately 15 of the 133 host trees resurveyed were no longer present or no longer contained thalli in 2016. Projected over three-generations this would result in an 82% reduction in number of host trees (Table 6). However, because individual trees were not flagged, it was not clear if the thalli recorded were on the same tree as in previous surveys. When a new tree is found, it is not known if it is a newly colonized tree or an existing host that had been previously undetected. There was an apparent increase in the number of host trees at three of the 2008 sites (Wolfgang Maas Conservation Lands, Canada Hill and East Sable River 1) but in all three cases, most of the new finds appeared to be located >100 m away from the previously recorded trees and may have been present but overlooked on the original surveys.

Newfoundland

In the eight years since the start of intensive monitoring, 22 of the 84 documented mature and juvenile thalli have died (26%). However, new thalli have been found so that the number of extant thalli has increased slightly from 53 in 2012 to 62 in 2018. Of the ten host trees identified in 2007, two have lost their single thallus. A third tree lost its necrotic thallus in 2011, but in 2014 a small juvenile thallus was discovered in the tree. This net loss of two trees over 11 years would result in an 82% reduction in number of host trees when projected over 3 generations (Table 6). All of the occurrences are in over-mature stands, and four of the eleven host trees have already died. For these reasons, a decline in the population of *E. mollissimum* is projected over the next few decades unless new host trees become available to be colonized.

At present there is still an abundance of seemingly suitable habitat, but the number of mature and over-mature trees in stands with *E. mollissimum* is declining due to decay and wind throw. These trees are not being replaced due to browsing of young trees by Moose and other herbivores (see **Threats**). This trend in declining populations of *E. mollissimum* could be accelerated by renewed insect outbreaks. Therefore, the persistence of *E. mollissimum* on the landscape over several generations is in doubt unless the lichen can colonize new areas with younger stands of Balsam Fir outside of the currently known occurrences. However, the young stands of Balsam Fir closest to an *E. mollissimum* occurrence are over 500 m from Halls Gullies (HG3-A) and originated from forest harvesting. This means that they are mostly on the drier, more productive sites which are less suitable for *E. mollissimum*. The wetter sites in the area surrounding Halls Gullies have generally not been harvested and have become more isolated from each other.

Summary

Though there are a number of issues with data used for the interpretation of trend projections, it is likely that the species is declining. However, the rate may not be as steep as the projections suggest. In particular the rate of colonization of new trees has not been well documented, which makes it challenging to determine if newly discovered occurrences represent colonization of new areas or simply the discovery of older thalli. Continued monitoring of marked thalli in Newfoundland may yield sufficient data to estimate colonization rates in the future, but such monitoring is not currently done in Nova Scotia.

Rescue Effect

Rescue from outside of Canada is extremely unlikely. The nearest extant population of *E. mollissimum* outside of Canada is likely in Central America, over 2500 km from the nearest Canadian occurrence.

THREATS AND LIMITING FACTORS

The Threats Calculator was used to assess the threats to *E. mollissimum* in Canada and the overall impact was “Very High” (Appendix 4). The various threats to this lichen are discussed below. At the stand level, logging and wood harvesting are the most immediate threats to the occurrences of *E*. *mollissimum* as loss of the host tree, or disturbance due to edge effects, can lead to death of the lichen. However, in the longer term, the impact of the combination of climate changes and air pollution is expected to threaten the survival of the three subpopulations of this lichen in Nova Scotia (one of which is currently represented by a single mature individual). The small subpopulation, 22 mature thalli, in Newfoundland may be less affected as it is further from the main transboundary air pollution sources, but post-tropical storms causing windthrow could have an impact there. These threats are discussed in more detail below.

Logging and Wood Harvesting

It is clear that forestry activities are a significant threat to *E. mollissimum* (Environment Canada 2014). Forestry practices such as clear cutting or harvesting on a large scale often cause habitat fragmentation. Forests that regenerate following clear-cut harvesting often have simplified structure and different species composition than intact natural forests. Ruderal and cosmopolitan species develop instead of old-growth associates (Loo and Ives 2003). Forest harvesting effects on lichens such as *E. mollissimum* can be direct through removal of host trees and indirect through alteration of microclimate and reduction in dispersal opportunity.

Activities such as road building and clearcutting can create edges that alter microclimates of nearby forests and *E. mollissimum*'s dependence on high levels of moisture likely make it particularly susceptible to such disturbances. For example, roads can affect hydrology by intercepting, concentrating, or diverting rainfall and overland flow (Cameron 2006). This, in turn, can affect the wetlands on which *E. mollissimum* depends. High levels of harvesting in a landscape can increase wind and drying effects in adjacent forests (Hunter 1990). Increased forest edges can also reduce dispersal ability in epiphytic lichens (Rheault *et al.* 2003). Edges can also alter light levels, resulting in higher temperatures, increasing tree blowdowns and providing a conduit for invasive species (Harper *et al.* 2005; Cameron 2006; Aragón *et al.* 2010). Relatively little is known about the spatial extent of edge effects on cyanolichens (Cameron and Neily 2008). However, Rheault *et al.* (2003) found that abundance was reduced up to 50 m from the forest edge for epiphytic chlorolichens (*Evernia mesomorpha* and *Usnea* spp.) in a Black Spruce forest in Quebec. More recent work suggests that cyanolichen growth and abundance may be suppressed by adjacent clearcuts at distances of 80-120 m (Haughian and Harper, 2018; Gauslaa *et al.*, 2019); deeper edge influences are difficult to detect, due to the pre-existing mosaic structure of the landscape in many lichen-rich forests (cf. Sjöberg *et al.* 1997).

In Nova Scotia, wood harvesting levels have met or exceeded sustainable harvest in recent years (NS Department of Natural Resources 2016). Clearcutting is widespread in the province. In 2016, clearcutting comprised 80% of the overall wood harvest in the province including 64% of harvest on Crown Lands and 89% of harvest on private lands (Lahey 2018). As a result, less and less area of mature and old forest remains available for *E. mollissimum*. In 1958, 25% of Nova Scotia's forests were over 80 years of age but this percentage had declined to just 1% by 2003 (Pannozzo and Colman 2008). The province of Nova Scotia has committed to implementing ecological forestry, following recommendations outlined in "An Independent Review of Forest Practices in Nova Scotia" (Lahey 2018) but the effect on harvest rates remains to be seen.

An analysis of aerial imagery showed evidence of tree harvesting within 200 m of *E. mollissimum* at 23 of 183 occupied trees prior to the implementation of protection measures (MTRI 2018). A Special Management Practice (SMP) was put in place in 2018 (NS Department of Natural Resources 2018) for harvesting on provincial Crown Land to protect *E. mollissimum* and other rare lichens within a 200 m zone of an occupied tree (see **Habitat Protection and Ownership**).

In Newfoundland, forest harvesting on the Avalon Peninsula has varied over time, with the amount of commercial harvesting pressure depending on the economic climate, and pressure for firewood harvesting depending at least partially on the cost of alternative domestic heat sources. Because the area is over 600 km (by road) from the closest paper mill (Corner Brook), any harvested wood would be used locally as saw logs or firewood. While most of the commercial forest harvesting is concentrated in the upland forests, it is highly likely that some stands suitable for *E. mollissimum* have also been lost to either cutting or to road building. It is possible that in the adjacent Fox Marsh area, which was harvested in the 1980s and early 1990s, some trees bearing *E. mollissimum*, as well as stands of potential habitat were lost, but this was before pre-harvest surveys of commercial harvest blocks were initiated. In 2007, the Halls Gullies area was being considered as a commercial harvest area and a road was constructed. In 2018, the pressure to harvest this area was reduced and the area remains intact (Glode, pers. comm. 2018). The Southeast Placentia occurrence is also within a commercial harvesting zone but due to the wet soil, poor stand quality, and difficulty of access, it is unlikely to be harvested in the future (Glode pers. comm. 2018).

Domestic forest harvesting for firewood and building timber could also impact potential and future *E. mollissimum* habitat in Newfoundland because the domestic cutting areas are large and could include at least some suitable habitat. It may never be known if any *E. mollissimum* host trees have been lost or are currently being cut by domestic harvesters because these areas have not been surveyed. Domestic cutting generally results in small patch cuts, which are concentrated near good access routes (both roads and snowmobile access) and in stands of higher timber quality. The patch cuts are not being replanted and could result in a higher landscape heterogeneity; the potential effect on *E. mollissimum* habitat is unclear, but loss of host trees is unequivocally detrimental.

Airborne Pollutants

Airborne pollutants are considered another major threat to *E. mollissimum* in Canada (Environment Canada 2014). It is thought that air pollution from the industrial city of Saint John in New Brunswick is a factor in the disappearance of *E. mollissimum* and the related *E. pedicellatum* from nearby Campobello Island, but logging, forest fires and Spruce Budworm, (*Choristoneura fumiferana*), infestations also played a role (Maass 1980). These threats may also have been implicated in the loss of *E. mollissimum* in the Bay of Fundy subpopulations in Fundy National Park, New Brunswick and Cape Chignecto, Nova Scotia. Air pollution is considered to be the reason for the disappearance of this lichen from the Great Smoky Mountains National Park in North Carolina and Tennessee, which experiences some of the highest measured air pollution of any national park in the USA (Anon 2019).

The sensitivity of lichens to air quality reflects their reliance on airborne nutrients and water, as well as lack of protective structures such as cuticles found in vascular plants (Richardson and Cameron 2004). Cyanolichens are particularly sensitive to acid rain, sulphur dioxide and nitrogen oxides (Hawksworth and Rose 1970; Gilbert 1986; Sigal and Johnston 1986; Hallingback 1989). Cyanolichens are especially affected because nitrogen fixation essential for their survival is sensitive to acid rain (Gries 1996, Cameron *et al.* 2007). Acid rain is produced when emissions of sulphur dioxide and nitrogen oxides, often a result of the high temperature combustion of coal or oil, react in the upper atmosphere to form sulfuric and nitric acid (Richardson and Cameron 2004; Environment Canada 2014). Acid fog may pose a greater problem than acid rain because droplets have an even lower pH and the lichens remain enveloped for extended periods (Cameron and Toms 2016). Airborne pollutants may originate locally from factories, vehicular traffic and other sources or they may be transported long distances in the atmosphere (McMullin *et al.* 2017).

In both Nova Scotia and Newfoundland, acid deposition decreased between 1990 and 2014, as it has on a national basis over the last twenty years (Environment and Climate Change Canada 2019). The annual wet sulfate deposition and annual wet nitrate deposition were lower in eastern Newfoundland than in southern Nova Scotia (International Joint Commission 2017). However, cyanolichens are very sensitive to air pollutants and acid deposition may eventually exceed the buffering capacity of host tree bark, making it unsuitable for colonization by cyanolichens (Nieboer *et al.* 1984). Lower levels of acid pollution will still have an effect although the time to exceedance of the buffering capacity will be greater.

In Nova Scotia, air pollution has been implicated in the decline of *E. pedicellatum* (Cameron and Toms 2016). Much of the acid rain in the province originates in the eastern and midwest United States (Richardson and Cameron 2004), where emission levels have been reduced in recent years. A ten-year study to monitor air quality using lichen indicators in Kejimkujik National Park and National Historic Site in southwest Nova Scotia found that air quality improved slightly from 2006-2016 (McMullin *et al.* 2017). However, local sources of pollutants may rise or fall with changes in industry. A gold mine opened on the eastern shore in 2017 and several additional mines are planned; long term effects of these mines on surrounding lichen habitat is not presently known (see **Mining and Quarrying**).

An analysis of sulphur isotopes in lichens showed that Newfoundland was relatively unaffected by long-range transport of pollutants but some areas were affected by local point sources (Wadleigh and Blake 1999). On the Avalon Peninsula, there are several large industrial developments that are point-emitters of sulphur dioxide and nitrogen oxides, but there is at present no evidence that habitat suitability for cyanolichens has been affected in areas occupied by *E. mollissimum*. Both Halls Gullies and Southeast Placentia are rich in cyanolichen species, suggesting that neither *E. mollissimum* location has been impacted. The major emitters are the Holyrood Generating Station (27 km from Halls Gullies, 64 km from SE Placentia) and the Come by Chance oil refinery (63 km from Halls Gullies, 63 km from SE Placentia). The prevailing winds are southwesterly to westerly, away from the known *E. mollissimum* areas.

Ecosystem Modifications

In Newfoundland, browsing of young Balsam Fir by Moose (and possibly Snowshoe Hare) is a concern as it reduces Balsam Fir regeneration, which over time alters forest composition. Moose and Snowshoe Hare are not native to Newfoundland and all Moose currently on the island originated from an introduction in 1904 and possibly an earlier introduction in 1878 (McLaren *et al.* 2004). In the absence of their main predator elsewhere, the Grey Wolf (*Canis lupus*), they have increased to approximately 125,000 - 150,000 animals island-wide (Coward, pers. comm. 2018) and occur in some of the highest densities on the continent (McLaren *et al.* 2004). The estimated Moose population in Moose Management Area 33, which includes the Halls Gullies *E. mollissimum* occurrence, increased from 683 to 1363 between 2005 and 2011 (Coward, pers. comm. 2018). It is likely that Moose are responsible for the lack of regeneration along ridgetops in the Halls Gullies area following extensive blowdowns in the mid-1990s. It is believed that Moose numbers may have slightly decreased in the last five years and tree planting trials by the NL Department and Fisheries and Land Resources have shown some promise; however, planting cannot quickly erase the effects of almost 25 years of local regeneration failure (Glode pers. comm. 2018).

Grazing of *E. mollissimum* thalli by native and non-native gastropods is also a potential threat but not a major problem at present (see **Interspecific Interactions)**.

Climate Change and Severe Weather

Erioderma mollissimum is vulnerable to the projected impacts of climate change within the next three generations (~60 yrs). Atlantic Canada is projected to become both warmer and wetter overall. In addition, the intensity of storms and duration of dry periods are expected to increase. This is likely to lead to increased drought and increased damage related to storms (Vasseur and Catto 2008, Vincent *et al.* 2018). In addition, cyanolichens are particularly sensitive to increased drought and a reduction in the duration of fog because the symbiotic cyanobacteria cannot initiate photosynthesis unless the lichen is wetted by liquid water or water in fog droplets (Lange *et al.* 1986, 1993). This contrasts with chlorolichens, those that contain green algae, that are able to absorb moisture from humid air and photosynthesize sufficiently to provide carbohydrates to the fungal partner in the symbiosis for a much longer period (Phinney *et al*. 2018)

Erioderma mollissimum depends on a moist, relatively oceanic climate. In Nova Scotia, both higher temperatures and increased drought events are projected. For example, at Liverpool, a coastal community within *E. mollissium'*s range in Queens County, the mean annual temperature is expected to increase 2.3 °C by the 2050s (~2 generations) with an average of 9.7 days above 30°C (Climate Data for Nova Scotia 2018). Annual precipitation is projected to increase slightly (from 1352 mm to 1396 mm). However, annual water deficit (actual – potential evapotranspiration), is expected to increase (36 mm to 48.8 mm) and extreme weather events are more likely to occur. In 2016, southwest Nova Scotia experienced the driest summer on record and 2020 was also another extremely dry year (Kennedy and Drage 2017, Surette 2020). Monitoring at Hayden Lake, Shelburne County, also showed that groundwater levels were below historic lows during this drought (Kennedy and Drage 2017). Such prolonged summer droughts if they continue, as predicted, could affect water levels in forested wetlands and lead to increased frequency and severity of forest fires. These climate changes are likely to have a major impact on *E. mollissimum* because it is a cyanolichen that requires liquid water to initiate photosynthesis and humidity to maintain it (see **Biology**). Thalli and occurrences have already been lost, especially from the Eastern Shore subpopulation that may reflect recent climate changes and a reduction in fog (Figure 3).

Reduction of fog frequency and duration could result in loss of vigor and reduced growth rates for *E. mollissimum*, if not death, by prolonged desiccation. Reported trends show declines in fog frequency in Nova Scotia (Beauchamp *et al.* 1998; Mucara *et al.* 2001). For Newfoundland, the trends are less clear; a decline was observed at St. Lawrence on the Burin Peninsula (Mucara *et al.* 2001) but at Cape Race on the Avalon Peninsula fog frequency increased (Beauchamp *et al.* 1998).

Natural disturbances could also threaten *E. mollissimum* across its range, and most natural disturbance regimes are likely to be altered by climate change. Wildfire is unlikely to be a disturbance agent in these habitats at present, due to the high water- table and high precipitation levels (Wien and Moore, 1979), but could become a more significant threat in the future, as recent drying trends seem to indicate (Kennedy and Drage 2017).

Severe weather events including hurricanes would likely be more of a threat to Balsam Fir host trees than Red Maple or Yellow Birch, due to differences in the lifespans and windfirmness of the species (Saad *et al.* 2017). A changing climate could also affect the winter freeze-thaw cycle, the timing of early and late frosts, and the frequency of ice storms (Vasseur and Catto 2008, Vincent *et al.* 2018), all of which could increase damage to host trees. Winter-freeze thaw has been linked to historical dieback of Yellow Birch in eastern North America (Bourque *et al.* 2005).

In the Avalon Peninsula post-tropical storms and the associated severe wind events have resulted in widespread wind throw of trees. The Halls Gullies location appears to be most affected, whereas there is no evidence of extensive wind damage in the Southeast Placentia area. However, most of the trees that are blown down are on ridgetops, while the trees colonized by *E. mollissimum* are relatively sheltered. Nevertheless, at least one host tree (with four thalli) has blown down and another host tree is within 20 m of an existing blowdown, putting it at an increased risk.

Mining and Quarrying

Mining was not identified as a threat in the *E. mollissimum* recovery strategy (Environment Canada 2014) but is expected to become a more significant threat to species at risk in Nova Scotia in the future. In recent years, mining exploration and interest has increased considerably in Nova Scotia due in part to high commodity prices and government incentive programs (Moss 2018; O'Neill 2018). In 2017, mineral exploration in Nova Scotia increased by 264% over the previous year (Moss 2018). Much of the mineral exploration overlaps with *E. mollissimum* distribution. As of November 2018, there were 529 exploration licences issued within the predicted distribution of *E. mollissimum* in Nova Scotia in 2018 (Figure 7). Twenty-two of the licences overlap *E. mollissimum* records, affecting nine occurrences on the south shore subpopulation and six occurrences on the eastern shore subpopulation in the province (Fisher *et al.* 2018). On provincial Crown Land, the SMP for at-risk-lichens provides some level of protection (see **Habitat Protection and Ownership**).

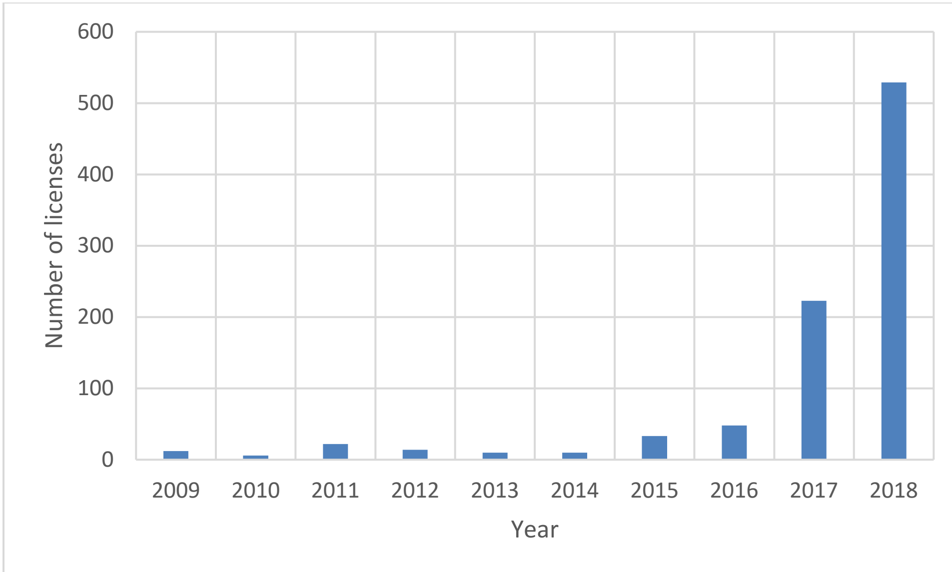

Figure 7. Number of mining exploration licences by year within the predicted climatic distribution of *Erioderma mollissimum* in Nova Scotia (Fisher *et al.* 2018).

If exploration leads to the development of active mines, risks to lichens could include direct loss of habitat for the mine site and road access as well as reduction in habitat quality due to airborne pollutants (see **Airborne Pollutants**) and changes to local microclimate. There is currently at least one active gold mine and smelting operation on the eastern shore of Nova Scotia and three related mines are in development in the region. While no *E. mollissimum* thalli were recorded at the sites of the proposed mines (Atlantic Mining NS 2017; Atlantic Mining NS 2018a, 2018b), they are within the range of *E. mollissimum*. The distance to which airborne pollution from a gold mine affects *E. mollissimum* habitat is not known.

In Newfoundland, mining appears to be less of a threat but some exploration is planned in an area where *E. pedicellatum* thalli were found (Eagleridge International Limited 2015). It is not close to any of the *E. mollissimum* sites but could result in a reduction of available habitat.

Recreational, Residential and Commercial Development

In Nova Scotia, cottage and residential development is on the rise, particularly along coastal areas and around lakes (Environment Canada and Parks Canada Agency 2010; Farrow and Nussey 2013). However, there are few data to indicate this is a particular concern in areas near known *E. mollissimum* occurrences. Two of the occurrences (Canada Hill and East Sable River) are found in areas with several small individual property lots that may be more at risk of future developments.

In Newfoundland, the amount of potential habitat is being reduced by abundant cottage development, especially along the shores of ponds. Since 2007, at least two large cottage developments with over one hundred lots have been developed in areas where *E. pedicellatum* was found. It is likely that the habitat would also be suitable for *E. mollissimum*. Unlike forest harvesting, which can reduce habitat suitability for a period, areas in cottage lots and roads are not reforested, and the habitat destruction can be permanent. In this context, the demand for cottage properties has not abated, especially in areas within an hour's drive of St. John's.

Because the Avalon Peninsula contains the greatest concentration of Newfoundland's human population and the coast is mainly ice free in the winter, industry, agriculture, infrastructure and other large developments either already exist there, are under construction, or are planned. If an Environmental Assessment is required and the area of the planned development is considered potential habitat, surveys for *Erioderma* species are carried out.

Roads and Railroads, and Utility Corridors

Road development can threaten *E. mollissimum* directly by removal of host trees as well as indirectly via edge effects and by altering microclimate in adjacent habitat as described under **Logging and Wood Harvesting**. Road development in *E. mollissimum* habitat is most likely to be associated with other threat categories such as Logging and Wood Harvesting, Mining and Quarrying and Recreational and Commercial Development.

In Nova Scotia, 15 of the 53 occurrences (28%) have a road within 200 m of at least one *E. mollissimum* host tree (MTRI lichen database 2018). Recent analyses of *E. mollissimum*'s relationship with landscape-scale habitat features showed that distance from major roads is not as strongly correlated with the presence of *E. mollisimum* as is that of *E. pedicellatum*, which most commonly occurs ≥ 3.2 km from addressed roads (S. Haughian, unpublished data). Nevertheless, the impacts of even small roads on the levels of dust are known to be detrimental to many plant and lichen species (Farmer 1993, Paoli *et al.* 2013).

Since 2008, *E. pedicellatum* has been found in several areas targeted for transmission line expansions in Newfoundland but no *E. mollissimum* have been found during these surveys.

Limiting Factors

Potential for recovery is limited by the relatively long generation time and apparent limited dispersal potential (see **Dispersal and Migration**). The species may rely on forests with no evidence of recent stand-replacing disturbance (see **Habitat**).

Number of Locations

COSEWIC defines a location as "a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present".

With respect to *E. mollissimum,* the number of locations was assessed as less than five as a result of a combination of climate change and air pollution in Nova Scotia, and logging and moose browsing in Newfoundland. In the former province, climate change and air pollution have an impact over large geographic areas and the potential to affect several occurrences of the cyanolichen, *E. mollissimum,* simultaneously. Cyanolichens are particularly vulnerable because they are unable to initiate photosynthesis without liquid water in the form of rain or water droplets provided by fog (see **Biology**). Thus, coupled with transboundary air pollution in the form of acid rain, the predicted dryer summers and reduction in fog are likely to lead to a decline and death of *E. mollissimum* over areas affected by these changes (see **Climate Change**). Already losses of occurrences of this lichen have been recorded (Figure 3, Table 7). Thus, climate change and air pollution is inferred to affect all three subpopulations of *E. mollissimum* in Nova Scotia (Figure 3): South Shore, Lunenburg Co and Eastern Shore.

Table 7.The number of locations of *Erioderma mollissimum* at the threat scale of climate change: one location per subpopulation (fewer than five in total) and at the stand scale for more local threats where the number of locations is the same as the number of occurrences (see Locations).

Province	Large scale threats		Local scale threats	
	Sub-population	**Locations**	**Ownership type**	**Locations**
Newfoundland	Avalon	1-2	Provincial crown	2
Nova Scotia	South Shore	1-41	Provincial crown	29
			Private	6
			Protected areas	5
	Eastern Shore	1-12	Provincial crown	8
			Private	2
			Protected areas	2
	Lunenburg Co.	1	Protected areas	1
			Total	55

In Newfoundland a combination of logging and moose browsing (Figure 4; Table 4) are the main threat to the subpopulation which is very small. The total known population of the lichen in the province is fewer than fifty mature thalli. The number of mature and over-mature Balsam Fir trees in stands with *E. mollissimum* is declining due to decay and wind throw. These trees are not being replaced due to browsing of young trees by Moose and other herbivores (see **Threats**) so that the number of trees suitable for recolonization by the lichen is expected to decline.

For more local threats affecting *E. mollissimum* at the forest stand level, the number of locations is assessed as 55, which is the number of extant occurrences. These are threatened by logging, development, and mining which have an impact at the forest stand level. These threats have the potential to harm or eliminate all individuals at a single occurrence, which is defined as a single tree or cluster of occupied trees separated by less than 1 km. The exception is the Halls Gullies occurrences which are close enough together to be considered a single location with respect to such threats.

Land ownership plays a key role in the likelihood of a threat event occurring, with risks likely higher on private lands than on provincial Crown Lands. However, even with Special Management Practices in place on Crown Lands in Nova Scotia, mistakes in surveys or practices associated with harvesting may threaten an occurrence.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Erioderma mollissimum was listed as *Endangered* under Schedule 1 of the federal *Species at Risk Act* (SARA; S.C. 2002, c. 29) in 2012, which makes it an offence to kill or harm this species or to destroy its residences on federal lands. A SARA compliant recovery strategy was completed and posted in 2014 (Environment Canada 2014). A multi-species action plan for Kejimkujik National Park and National Historic Site of Canada, finalized in 2017, includes *E. mollissimum* (Parks Canada Agency 2017). A proposed action plan for *E. mollissimum* and *E. pedicellatum* (Atlantic population) was posted to the SARA registry for consultation from 16-August-2018 to 15-October-2018 (Environment and Climate Change Canada 2018).

Erioderma mollissimum is listed as *Endangered* under the *Nova Scotia Endangered Species Act* (Nova Scotia Department of Natural Resources 2017), the *Newfoundland and Labrador Endangered Species Act* (001 cE-10.1 s1) and the New Brunswick *Species at Risk Act* (Bill 28, NB Reg 2013-38). The Nova Scotia *Endangered Species Act* prohibits killing or disturbing species at risk, destroying or disturbing its residence. It enables the Minister to identify core habitat and prohibits destruction of core habitat.

The *Newfoundland and Labrador Endangered Species Act* states that it is unlawful to disturb, harass, or destroy any individuals of this species. Any surveys or developments in *E. mollissimum* habitat that could result in inadvertent destruction of individuals of this species require a permit from the NL Department of Fisheries and Land Resources.

Non-Legal Status and Ranks

Erioderma mollissimum has a global NatureServe rank of G5G4, *Secure to Apparently Secure* (5-Dec-2002) and a national status rank in Canada of N1N2, *Imperiled to Critically Imperiled* (21-Mar-2017). It is unranked in the United States. Provincially, it is ranked as S1S2, *Imperiled to Critically Imperiled*, in Nova Scotia and Newfoundland and as SH, *Possibly Extirpated*, in New Brunswick (Nature Serve 2018).

Habitat Protection and Ownership

Under the *Species at Risk Act,* critical habitat is identified as “the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species’ critical habitat in the recovery strategy or in an action plan for the species” (SARA; S.C. 2002, c. 29). The Act prohibits the destruction of critical habitat on federal lands. Critical habitat for *E. mollissimum* is partially identified in the federal recovery strategy (Environment Canada 2014) and its associated action plans (Parks Canada 2017, Environment and Climate Change Canada 2018). The recovery strategy describes the methods for identifying critical habitat and outlines a schedule of studies required to complete the identification of critical habitat. It identified 106 ha of critical habitat in Newfoundland and Labrador and 1000 ha of critical habitat in Nova Scotia (Environment Canada 2014). The Kejimkujik multi-species action plan identified critical habitat at one new site within the national park in Nova Scotia (Parks Canada Agency 2017). An additional 1420 ha of critical habitat in Nova Scotia are identified in the proposed action plan (Environment and Climate Change Canada 2018).

<u>Nova Scotia</u>

In Nova Scotia, 70% of known occurrences are on provincial Crown Land, 15% on private lands and 15% in protected areas (Table 7). Protected areas include land protected by the Nature Conservancy of Canada (Deep Cove Conservation Lands, Wolfgang Maass Conservation Lands, and Johnson’s Pond Conservation Lands), provincial wilderness areas (Ship Harbour-Long Lake Wilderness Area, Tidney River Wilderness Area) and a national park (Kejimkujik Seaside).

A Special Management Practice (SMP) was put in place for at-risk lichen species in Nova Scotia in 2018 by the Nova Scotia Department of Lands and Forestry (DLF, formerly Nova Scotia Department of Natural Resources). The SMP outlines procedures that must be followed for activities occurring on provincial Crown Lands, including forest harvesting and mineral exploration and extraction. The SMP requires the establishment of a protected zone around known occurrences of very rare and highly sensitive lichens, including *E. mollissimum*. The protected zones encompass the area within a 200 m radius of the occurrence, which is managed for minimal disturbance. Within the zone, there is to be no active clearing, removal or disturbance of trees, soil or wetlands. Mineral samples may only be collected using non-mechanical methods and can be no greater than 2 kg per sample. Mineral exploration drill sites, trenching and test pitting, and the creation of new roads and trails are only permitted in exceptional situations and require approval under DLF’s

Variance process. Existing roads that are essential for access can only be maintained to the standard of the original road if maintenance or upgrades may affect local climate or air quality. The SMP also describes standards for lichen surveys, reporting and data management and prescribes site inspections by DLF staff or their appointed agents to monitor for compliance and effectiveness (NS Department of Natural Resources 2018).

Newfoundland

All the known occurrences of *E. mollissimum* are on Crown Land. They are not protected in a Provincial Park, Ecological Reserve or Wilderness Reserve. However, both occupied areas are within a Sensitive Wildlife Area, in the Newfoundland and Labrador Land Use Atlas, which means that any developments, including forest harvesting, would require review by the Wildlife Division and Forestry and Wildlife Research Division. The Sensitive Wildlife Area extends for at least 300 m around trees occupied by *E. mollissimum*, except in one area where the Sensitive Wildlife area boundary follows the shore of a pond, and the buffer is slightly less. The provincial government is currently investigating avenues of conservation for the Halls Gullies area, which hosts the majority of the thalli, has greater timber resources, is more accessible and faces more human pressures.

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Jeffie McNeil is the Species at Risk Biologist at the Mersey Tobeatic Research Institute. She has been involved in species at risk recovery in Nova Scotia since 1996. She has written or co-authored several provincial and federal status reports, recovery strategies and action plans for a variety of species at risk.

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Claudia Hanel conducted rare plant surveys in Newfoundland and completed several Provincial status reports between 1999 and 2006. Since 2006 she has been the Provincial Endangered Species Botanist with the Wildlife Division, now Forestry and Wildlife Research Division. Ms. Hanel has surveyed and monitored rare lichens, including *Erioderma mollissimum*, since 2006. She also has S-ranked species, participated in the planning and implementation of species recovery, reviewed development applications and proposed mitigations. She is a member of the Newfoundland and Labrador Lichen Recovery Team.

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Brad Toms has coordinated the lichen recovery project at Mersey Tobeatic Institute since 2010. He manages the databases of sites, site parameters and monitoring data for both *Erioderma* species as well as the field lichenologists that collect the data. He is a co-chair of the Nova Scotia Lichen Recovery Team.

Appendix 1. Canadian occurrences of *Erioderma mollissimum* (MTRI lichen database 2018, NL Department of Fisheries and Land Resources plant and lichen database 2018). An occurrence is a place where trees occupied by *E. mollissimum* are separated by no more than 1 km. Adults are thalli with reproductive structures, juveniles lack reproductive structures. In Nova Scotia, numbers of juveniles were not always documented, which is indicated by blanks. The total number of adults was not documented at all sites and is considered a minimum. Sites marked with an asterisk were included in the occurrence decline calculations outlined in Appendix 2. Sites marked "new" were found after the 2009 Status Report.

Sub-population	Occurrence	Status	Year discover-ed	Most recent survey	Number of occupied trees	Number of juveniles	Number of adults
Avalon NL	SE Placentia	Current*	2005	2018	3	3	7
Avalon NL	Halls Gullies HG-A	Current*	2006	2018	6	22	20
Avalon NL	Halls Gullies HG-B	Current*	2007	2018	1	3	3
Avalon NL	Halls Gullies HG-C	Current*	2007	2018	1	2	2
Avalon NL Totals					**11**	**30**	**32**
South Shore NS	Thomas Raddall	Historical*	1980	2016	0		0
South Shore NS	East Sable River 1	Current*	1981	2016	10		11
South Shore NS	Glenwood	Historical	1981	2008	0		0
South Shore NS	Haley Lake	Historical*	1981	2016	0		0
South Shore NS	Mud Lake Creek	Historical	1981	1999	0		0
South Shore NS	Lake John Road 1	Current*	2007	2016	1		1
South Shore NS	Lake John Road 2	Current*	2007	2016	2		11
South Shore NS	Bon Mature Lake	Current*	2008	2018	2		2
South Shore NS	Canada Hill	Current*	2008	2016	12		26
South Shore NS	Clyde River Road	Current*	2008	2016	2		2
South Shore NS	Jones Harbour	Historical*	2008	2016	0		0
South Shore NS	Martin Brook	Not known	2008	2008			
South Shore NS	Robarts Pond	Historical*	2008	2016	0		0
South Shore NS	Wolfgang Maass Cons. Lands	Current*	2008	2016	17		21
South Shore NS	Haley Lake Brook 1	Current (new)	2010	2016	1		1
South Shore NS	Haley Lake Brook 2	Current (new)	2010	2016	1		1
South Shore NS	Hectanooga	Current (new)	2010	2016	2		2
South Shore NS	Misery Lake Brook 7	Current (new)	2010	2016	1		1
South Shore NS	Johnstons Pond	Current (new)	2011	2016	3		3
South Shore NS	Kejimkujik Seaside	Current (new)	2011	2018	1		1
South Shore NS	Misery Lake Brook 4	Current (new)	2011	2016	3		10
South Shore NS	Oakhill Road	Current (new)	2011	2016	3		5
South Shore NS	Wentworth Lake 3	Current (new)	2011	2016	2		2

Sub-population	Occurrence	Status	Year discover-ed	Most recent survey	Number of occupied trees	Number of juveniles	Number of adults
South Shore NS	Bennetts Lake	Historical (new)	2012	2018	0		0
South Shore NS	Lake George 1	Current (new)	2012	2016	29		29
South Shore NS	Wentworth Lake 1	Current (new)	2012	2016	2		2
South Shore NS	Lake John Road 3	Current*	2013	2016	4		19
South Shore NS	Misery Lake Brook 5	Current (new)	2013	2016	8	1	11
South Shore NS	Misery Lake Brook 1	Current (new)	2014	2016	2		2
South Shore NS	Misery Lake Brook 2	Current (new)	2014	2016	22	1	39
South Shore NS	Misery Lake Brook 3	Current (new)	2014	2016	1		1
South Shore NS	Misery Lake Brook 6	Current (new)	2014	2016	1		1
South Shore NS	Ogdens Creek	Current (new)	2014	2016	4		4
South Shore NS	Blue Hill Mud Lake	Current (new)	2015	2016	6		10
South Shore NS	First Lake	Current (new)	2015	2016	1		1
South Shore NS	Port Joli	Current (new)	2015	2016	1		1
South Shore NS	Sable River	Current (new)	2015	2016	1		1
South Shore NS	Toney Lake Road	Current (new)	2015	2016	1		1
South Shore NS	Wentworth Lake 4	Current (new)	2015	2016	1		1
South Shore NS	Wilkins Lake	Current (new)	2015	2016	1		1
South Shore NS	Annapolis Road	Current (new)	2016	2016	1		1
South Shore NS	Lake George 2	Current (new)	2016	2016	1		1
South Shore NS	Quinan Lake	Current (new)	2016	2016	1		1
South Shore NS	Sucker Brook	Current (new)	2016	2016	7		7
South Shore NS	Wentworth Lake 2	Current (new)	2016	2018	4		4
South Shore NS	Round Bay	Current (new)	2017	2017	7		10
South Shore NS	Blue Hill Mud Lake 2	Current (new)	2018	2018	3	3	5
South Shore NS	Kejimkujik Seaside 2	Current (new)	2018	2018	5	5	9
Southshore NS Totals					**177**	**10**	**262**
Lunenburg Co. NS	Blandford	Current*	2006	2016	1		1
Lunenburg NS Totals					**1**	**0**	**1**
Eastern Shore NS	Clam Harbour	Historical	1979	1998	0	0	0
Eastern Shore NS	Eisan Lake Road	Historical	1981	1998	0	0	0
Eastern Shore NS	Lochaber Mines	Historical	1981	1984	0	0	0
Eastern Shore NS	New Chester	Historical	1982	1998	0	0	0
Eastern Shore NS	Tangier Ferry	Historical	1982	1999	0	0	0
Eastern Shore NS	Marinette	Historical	1983	1985	0	0	0
Eastern Shore NS	Dooks Pond	Current*	2005	2016	1		1
Eastern Shore NS	Bear Lake	Current*	2006	2016	1		1

Sub-population	Occurrence	Status	Year discover-ed	Most recent survey	Number of occupied trees	Number of juveniles	Number of adults
Eastern Shore NS	Otter Pond-Fuller Lake	Current*	2006	2015	2		2
Eastern Shore NS	Webber Lake	Current*	2007	2016	1		3+
Eastern Shore NS	Burnt Hill Lake Brook	Current (new)	2010	2016	2		2
Eastern Shore NS	Sandy Pond	Current (new)	2013	2016	1	1	0
Eastern Shore NS	Smith Brook	Current (new)	2014	2016	1		1
Eastern Shore NS	Square Lake East 1	Current (new)	2014	2016	1		1
Eastern Shore NS	Square Lake East 2	Current (new)	2018	2018	1		1
Eastern Shore NS	Square Lake East 3	Current (new)	2014	2016	3		3
Eastern Shore NS	West of Moser River	Current (new)	2014	2016	1		1
Eastern Shore NS	West of Smith Brook	Current (new)	2014	2016	1		1
Eastern Shore NS totals					**16**	**1**	**17**
Northern Shore NS	Cape Chignecto	Historical	1991	2003	0	0	0
Northern Shore NS totals					**0**	**2**	**0**
Total					**205**	**43**	**312**

Appendix 2. Method for calculating declines in occurrences.

The approach used to calculate the occurrence decline projections that are shown in Table 5 was recommended by the COSEWIC Mosses and Lichens Specialist Subcommittee, based on standards recommended by the International Union for Conservation of Nature (IUCN). The calculation applies an exponential decline, which assumes a constant annual proportional rate of decline (IUCN Standards and Petitions Subcommittee 2017). The annual decline was calculated as follows:

Annual percent rate of decline= $[\ 1-(N_{T2}/N_{T1})^{1/(T2-T1)}\ ] \times 100$

The reduction was then projected over the desired number of generations using the formula:

Percent projected decline = [1- (1-Annual percent decline)^ ^{years})] ×100

Years is the number of years the decline was projected, corresponding to the number of generations of interest. For *E. mollissimum*, the declines were projected at 20 years (1 generation), 40 years (2 generations) and 60 years (3 generations).

Three sets of data were examined, as summarized in Table 5. Below is an example of the 3 generation decline calculation for occurrences sampled in 2007-2008 and re-surveyed in 2016-2018 in Nova Scotia (the third column in Table 5). For these surveys, 17 occurrences were surveyed. Of these 13 remained extant and 4 were lost. The number of years between surveys ranged from 8 to 11 years with average interval of 8.5 years.

Annual decline rate
$= [1-(N_{T2}/N_{T1})^{1/(T2-T1)}\ ]$
$= [1-(13/17)^{1/(8.5)}\ ]$
= 0.03107

Percent projected decline
= [1- ((1-Percent annual decline)^ ^{years})] x 100
= [1- ((1-0.03107)^ ^{60})] x 100
= 84.94 %

Note that these equations are presented differently by the IUCN (2019)[1], but are effectively the same calculation, presented here with (a) more explicit terms, and (b) a conversion into a percentage.

[1] From page 34 of the IUCN (2019) Red List Guidelines:
Reduction=1–(Observed Change)$^{(3Generations\ /Observed\ Period)}$)

Appendix 3. Method for estimating abundance within the known occupied zone in Nova Scotia.

The following methods were used to estimate maximum likely abundance within the known occupied area:

- The occupied zone was estimated by applying a 1000m buffer around each occupied host tree, clipping the polygons to exclude lakes and oceans, and merging them into a single shape
- The forest cover within the occupied zone was estimated using the provincial forest resource inventory dataset. Stands identified as treed bogs and barrens were vetted individually by examining aerial photographs to determine if they were forested. The forest cover layer was further narrowed by removing stands that had been recently clear-cut, as identified by aerial photographs.
- The area surveyed was estimated by clipping the linear survey tracks to the occupied area and applying a 15m wide buffer to those tracks, with the assumption that surveyors would detect host trees within this range.
- The success rate was calculated by the number of lichens found from searches along these tracks divided by the m^2 searched.
- Lichen abundance was estimated by multiplying the success rate by the total forested area within the occupied area.

Total area within the occupied zone: 223,488,320 m^2

Area of occupied zone that is forested: 186,487,324 m^2
(Total forest area 192,797,466m^2 - recent clear-cuts 6,300,142 m^2)

Area surveyed within the occupied area: 16,543,345 m^2
(1104 km of tracks x 15m detection width)

Success rate within the occupied area: 0.00001358 lichens/m^2
(225 lichens / 16,543,345 m^2 surveyed)

Estimated number of lichens: 2532
(0.00001358 lichens/m^2 searched x 186,487,324 m^2 forested)

Appendix 4. Threats calculator assessment for *Erioderma mollissimum,* developed on Jun. 21, 2019.

Species	*Erioderma mollissimum* Vole Ears Lichen		
Date:	2019-06-21		
Assessor(s):	Teleconference at Mosses/Lichens SSC meeting: Dwayne Lepitzki (Facilitator), David Richardson (Co-chair), Rene Belland (Co-chair) M&L SSC: Diane Haughland, Chris Lewis, Troy McMullin, Richard Caners, Jennifer Doubt, Nicole Fenton, Karen Golinski, André Arsenault, Sean Haughian, (phoning in) Darwyn Coxson and Judith A. Harpel, Dan Benoit (ATK SC) COSEWIC: Jessica Humber (NL) SR writers: Jeffie McNeil, Claudia Hanel, Brad Toms External experts: Robert Cameron, Frances Anderson, Tom Neily		
References:	6-month draft COSEWIC report		
Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
	Threat Impact	**high range**	**low range**
	A Very High	0	0
	B High	2	1
	C Medium	1	2
	D Low	4	4
Calculated Overall Threat Impact:		Very High	Very High
Assigned Overall Threat Impact:		**A = Very High**	
Impact Adjustment Reasons:			
Overall Threat Comments		1 DU, generation time 20 years so timeline for severity and timing is 60 years; have known number of individuals within each of 4 extant subpopulations (Table 6): 250 NS south shore, 15 NS eastern shore, 32 NF Avalon peninsula. Total 297. 84.2%, 5.1%, and 10.8% respectively with 65.3% in Shelburne Co., NS. Extirpated from NB (around Bay of Fundy); 70% known occurrences in NS on provincial crown, 16% private, 14% protected areas. All 4 occurrences NF provincial Crown Land. Most often in poorly drained areas on mature Red Maple, > Yellow Birch, > Balsam Fir in NS; all on Balsma Fir NF. Within 30 km of coast, < 150 m elevation. Somewhat wider habitat tolerances than BFL. Range maps: Figures 4-6.	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Cottage development or cabin development less of a concern in NF because all occurrences are on provincial crown. Most known occurrences in NS also on provincial crown land, except for two occurrences near private properties.
1.2	Commercial & industrial areas						None known at this time
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	ATV activity can lead to disturbance or changes in water regimes or flow.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
3.1	Oil & gas drilling						Currently there is a moratorium on fracking in both NS and NF
3.2	Mining & quarrying	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Mining activity has increased and is anticipated to increase even more in NS. Exploration licenses overlap with 9 and 6 Vole Ears Lichen occurrences on Sough Shore and Eastern Shore, respectively
3.3	Renewable energy		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Wind Farm construction mainly on elevated areas and developments unlikely in areas where Vole Ears Lichen occurs
4	Transportation & service corridors	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	New road construction related to extensive logging activity on South Shore and mining activity, especially on Eastern Shore of NS
4.2	Utility & service lines						Most new utility lines for mining and other activities are placed along roads sides and therefore of no additional impact
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						With the increasing interest in lichens, especially rare species, easily identified species like Vole Ears Lichen could be more collected, but impact difficult to quantify

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	Forest harvesting which removes host trees and the lichens thereon is currently widespread on Southern Shore of NS where some 70% of the Vole Ears Lichen population occurs. Although there is a 200 m protection zone in NS around known host trees, this applies only to Crown Land. Occurrences on private land have no protection. Protection also depends of effectiveness of pre-harvest monitoring and follow-up adherence to Special Management Practices as well as Wildlife Habitat and Watercourses Protection Regulations. Furthermore edge effects leading to death of the lichen may exceed 200m as has been established for the related Boreal Felt Lichen
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Large (31-70%)	Negligible (<1%)	High (Continuing)	Regular monitoring of Vole Ears Lichen occurrences is going on in Newfoundland which has 10% of the total population. Preharvest surveys are being done on Crown Land in NS. These activities may dislodge thalli and have a serious impact at sites where fewer that ten thalli are found. However some naturally dislodged thalli may be re-attached by researchers and have a positive effect.
7	Natural system modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
7.1	Fire & fire suppression						There have been an increasing number of fires in recent years in NS, but to date not where Vole Ears Lichen is found. However, climate change which predicts warmer summers may lead to fires where this lichen occurs. In addition, the increasing number of roads for logging and mining activities, enables more public access via vehicles and ATCVs. People are known to a major cause for starting fires
7.2	Dams & water management/use						
7.3	Other ecosystem modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	Although moose numbers are declining in NF, their activity to date has prevented regeneration of host trees there (Balsam Fir) so there will be few suitable mature trees available for colonization in two or three generations (40 and 60 years).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8	Invasive & other problematic species & genes		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases		Negligible	Restricted (11-30%)	Negligible (<1%)	High (Continuing)	Grazing by non-native slugs has been found to affect about 12% of inspected thalli in NS, while 25% of thalli affected in NL but species not confirmed.
8.2	Problematic native species/diseases						Extensive overgrowth of thalli by aggressive bryophytes and lichen species found in about 5% of studied thalli in NL. Sawfly infestations there can also kill host trees and lichen then soon dies.
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	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	
9.1	Domestic & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						
9.5	Air-borne pollutants	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Vole Ears Lichen is a cyanolichen and very sensitive to air-borne pollutants (acid rain, sulphur dioxide, nitrogen oxides). Although pollution levels have fallen, most c. 70% of the lichen occur on the Southern Shore of NS and are susceptible to transboundary pollution. This can eventually make the host bark too acid for successful colonization and have direct effects on the lichen. The impact of Air pollution much less in NL due to greater distance from known sources.
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.1	Habitat shifting & alteration						Vole Ears Lichen global distribution shows it can thrive in warmer climates as long as moisture regimes suitable (Smokey Mountains) and no habitat disturbance or pollution. There could be a northwards shift of host trees with a warming climate, but suitably mature host trees would not be available within three generations,
11.2	Droughts	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Summer droughts predicted to increase as a result of global warming as well as a declining frequency of fog along the Southern and Eastern Shore of NS. Vole Ears Lichen like other cyanolichens requires liquid water or fog droplets to initiate photosynthesis and nitrogen fixation so will be negatively affected.
11.3	Temperature extremes						
11.4	Storms & flooding	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Windthrow from storm events can lead to blowdown of host trees. Although most blowdowns are on ridgetops, about 10% of the population of Vole Ears Lichen in NL has been lost due to blowdown. An excess of fog and rain in NL could also have a negative impact on this species
11.5	Other impacts						