COSEWIC
Assessment and Status Report

on the

Boreal Felt Lichen
Erioderma pedicellatum

Boreal population
Atlantic population

in Canada

Boreal population – SPECIAL CONCERN
Atlantic population – ENDANGERED
2014

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

COSEWIC. 2014. COSEWIC assessment and status report on the Boreal Felt Lichen *Erioderma pedicellatum*, Boreal population and Atlantic population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 66 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

Previous report(s):

COSEWIC. 2002. COSEWIC assessment and status report on the boreal felt lichen *Erioderma pedicellatum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 50 pp.

Maass, W. and D. Yetman. 2002. COSEWIC assessment and status report on the boreal felt lichen *Erioderma pedicellatum* in Canada, *in* COSEWIC assessment and status report on the boreal felt lichen *Erioderma pedicellatum* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1- 50 pp.

Production note:
COSEWIC would like to acknowledge Robert Ian Goudie and Robert Cameron for writing the status report on the Boreal Felt Lichen, *Erioderma pedicellatum,* in Canada, prepared under contract with Environment Canada. This report was overseen and edited by David Richardson, co-chair of the COSEWIC Mosses and Lichens Specialist Subcommittee.

For additional copies contact:

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

Tel.: 819-938-4125
Fax: 819-938-3984
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur L'érioderme boréal (*Erioderma pedicellatum*), population boréale et population de l'Atlantique, au Canada.

Cover illustration/photo:
Boreal Felt Lichen — Photo credit: Robert Ian Goudie.

Catalogue No. CW69-14/288-2015E-PDF
ISBN 978-1-100-23962-0

COSEWIC
Assessment Summary

Assessment Summary – November 2014

Common name
Boreal Felt Lichen - Boreal population

Scientific name
Erioderma pedicellatum

Status
Special Concern

Reason for designation
This species is widely distributed in Newfoundland and several threats to its survival have been identified including habitat alteration due to invasive species, acid rain and extreme weather events. Despite declines in some areas, new populations continue to be found. More research and monitoring are needed to understand population trends, and the species may become Threatened if threats are not better understood and managed.

Occurrence
Newfoundland and Labrador

Status history
Designated Special Concern in May 2002. Status re-examined and confirmed in November 2014.

Assessment Summary – November 2014

Common name
Boreal Felt Lichen - Atlantic population

Scientific name
Erioderma pedicellatum

Status
Endangered

Reason for designation
This species is believed to be extirpated from New Brunswick, and the remaining population in Nova Scotia is small. Intensive monitoring efforts over the past ten years indicate that both the number of occurrences and number of individuals are declining. These declines are projected to continue in the future. The main threats include habitat loss and deterioration as a result of forest harvesting, air pollution, climate change, and predation by introduced slugs.

Occurrence
New Brunswick, Nova Scotia

Status history
Designated Endangered in May 2002. Status re-examined and confirmed in November 2014.

COSEWIC
Executive Summary

Boreal Felt Lichen
Erioderma pedicellatum

Boreal population
Atlantic population

Wildlife Species Description and Significance

The Boreal Felt Lichen*, Erioderma pedicellatum,* is a leafy lichen that is greenish when moist and grey when dry, with a felt-like upper surface. The thallus grows to about 2-5 cm across, and occasionally to 12 cm. The underside is white, and its edges usually curl upwards, giving it the appearance of having a white fringe. It differs from the two other North American species of *Erioderma* by having small, reddish-brown fruit bodies on its upper surface and no vegetative propagules. The photosynthetic partner in this lichen is a cyanobacterium. The Boreal Felt lichen is an ‘umbrella species’ for a community of rare lichens, mosses and invertebrates found in the Balsam Fir forests of Nova Scotia and Newfoundland in eastern Canada.

Distribution

In North America, the Boreal Felt Lichen is confined to eastern Canada and Alaska. This lichen is believed to be extirpated from New Brunswick. A small population occurs in Nova Scotia and a large population is found on the island of Newfoundland. The Canadian populations are disjunct from those found recently in Alaska. A small population has also been reported from the Kamchatka Peninsula of eastern Siberia. The population in Scandinavia is almost extirpated, with two extant sites being known. No molecular work has been done to show the relationship between the populations in Alaska or Asia and those in eastern Canada. About 88% of the currently known world population is located in Canada.

Habitat

In Canada, the Boreal Felt Lichen occurs in cool, humid coastal coniferous forests dominated by Balsam Fir. Cool summers, relatively warm winters and high rainfall are characteristics of these forests. It grows on the trunks and branches of Balsam Fir, less frequently on Black Spruce, rarely on White Spruce and Red Maple and very rarely on White Birch. It is never found far from wetlands, and usually grows near rainy, fog-bound coasts.

Biology

The Boreal Felt Lichen is a cyanolichen, consisting of a fungal partner and a cyanobacterium, which photosynthesizes and fixes atmospheric nitrogen. Fruit bodies, sexual reproductive structures containing ascospores, are present on mature individuals. The dispersal of the spores is poorly understood but, in addition to wind, may be mediated by arthropod vectors. There are no specialized means of vegetative reproduction unlike many lichens but fragmentation of thalli may allow for very localized spread on a host tree.

Population Sizes and Trends

In Nova Scotia, the known population of the Boreal Felt Lichen is 317 thalli known from 31 occurrences at more than ten, but fewer than 20 locations. (Note: A site is where the lichen is actually found. If sites are less than 1km apart they comprise a single occurrence. A location is a geographically or ecologically distinct area in which a single threatening event can rapidly affect all the individuals present at an occurrence). In Nova Scotia, about 19 (7%) of the 317 thalli have been assessed as juveniles, the remaining thalli are adults. This population has been declining since 2003. There is also a declining trend in the number of occurrences. Eleven of the 41 occurrences found between 2003 and 2011 are now extirpated. This is a 27% decline over 8 years or a 10-year decline of 34%.

In Newfoundland, the population of the Boreal Felt Lichen is relatively large with about 12,660 thalli registered in the Newfoundland and Labrador Wildlife Division database. This is twice the population size recorded in the 2002 COSEWIC Status report for this species. If all potential habitats were searched, the total extant number of thalli may be as high as 15,000 - 20,000 individuals. There are conflicting results from occurrences which have been monitored over extended periods. Conclusions about trends are complicated by the discovery of many thalli in new areas as a result of increased search effort. Occurrences in eastern Newfoundland have shown declines in the population. However, monitoring in south central Newfoundland suggests that the rate of decline may be as low as 5% per year. At one of the occurrences, a large increase in population was found that was interpreted as a recruitment pulse. In the Bay d'Espoir region, where almost 60% of the Canadian Boreal Felt Lichen population is located, some increases have also been recorded but it is not clear whether the increases offset the declines observed at other occurrences.

Threats and Limiting Factors

The threats to the survival of the Atlantic and Boreal populations of the Boreal Felt Lichen were assessed using the Threats Calculator. The threats to the Boreal Population of this species were assessed as high while the threats to the Atlantic Population were assessed as very high to high.

For the Boreal Population, some declines are attributable to natural forest dynamics. For a stable population, declines need to be offset by increases in other areas of the stand, or in other stands that are part of the landscape. On the Avalon Peninsula, at least at Lockyer's Waters and Noseworthy's Gully, much of the mortality can be attributed to the death of the host trees following wind-throw. Some of the mortality in Bay d'Espoir area was connected with severe thallus necrosis, or poor attachment, or no obvious factors. It is not known to what extent microclimate, climate change, acid rain or air pollution, plays a role in this.

In many parts of the island of Newfoundland Balsam Fir is not regenerating to an age where they replace older trees that are the main host for the Boreal Felt lichen. Older trees are frequently wind-thrown and colonizing lichens soon die. In some areas, intense browsing by introduced moose is a serious and widespread threat preventing young Balsam Fir from reaching the 'free to grow stage' after harvest, wind-throw or insect damage to the originally present trees. Even if Balsam Fir regeneration were restored to natural levels predating the introduction of moose, there would be a bottleneck of suitable habitat within the next 50 years in some areas of the island, especially on the Avalon Peninsula. Cottage developments and road construction may alter microclimates and have negative impact on the Boreal felt lichen, but they provide access to more remote areas of forest for hunters, which helps to reduce the moose populations. Other threats to the Boreal Felt Lichen include forest harvesting, localized sources of air pollution and insect outbreaks that kill host trees.

With respect to the Atlantic Population of the Boreal Felt Lichen, high levels of forest harvesting have resulted in the decline in the amount of available lichen habitat. There was a 12% loss in the amount of available habitat between 1988 and 2005 and a projected decline of 25% by 2050. High levels of tree harvesting adjacent to Boreal Felt Lichen occurrences and within the landscapes containing this species have resulted in a decline in habitat quality and subsequent lichen mortality. Large clearcuts lead to a reduction in humidity in adjacent areas as well as changes in incident sunlight, and these have been correlated with thallus mortality. The Boreal Felt Lichen is extremely sensitive to air pollution and acid rain. The levels of acidifying pollutants in Nova Scotia are predicted to decline in the next 12 years, but industrial or mining developments may locally increase pollutants. Climate change is decreasing the frequency of fog in Nova Scotia, an important factor in maintaining humidity in the habitat of this lichen. Habitat disturbance by cottage developments, road construction, spruce budworm and herbivory by introduced slugs are other threats.

Protection, Status, and Ranks

Status and Ranks

The Boreal Felt Lichen is currently listed under *Species at Risk Act* (2002) as Special Concern for the Boreal Population and as Endangered for the Atlantic Population. The lichen is protected by provincial legislation being designated as 'vulnerable' by the Province of Newfoundland and Labrador and as 'endangered' by the provinces of Nova Scotia and New Brunswick.

The Boreal Felt Lichen is ranked globally as G1G2Q "critically imperilled to imperilled" and the Atlantic Population is ranked in Nova Scotia as S1S2 "critically imperilled to imperilled" and in New Brunswick as SH "possibly extirpated" by NatureServe. The status in Newfoundland is S3.

Protection

In Nova Scotia, five occurrences are within or partially within a provincial wilderness area. Two occurrences are partially within the Tangier Grand Lake Wilderness Area and one at MacDonald Lake within the Middle River Framboise Wilderness Area. They are protected under the *Wilderness Areas Protection Act*, which prohibits any developments including forestry, mining or building.

In Newfoundland, 35 of the known occurrences (29%) of Boreal Felt Lichen fall at least partly within provincial protected areas, such as the Avalon Wilderness Reserve, the Bay du Nord Wilderness Reserve or various provincial parks, notably Jipujijkuei Kuespem Provincial Park in Bay d'Espoir. A small number of individuals have also been found in Terra Nova National Park. Within these areas at least 2783 thalli (20% of all registered thalli) are protected. The number of Boreal Felt Lichen thalli in protected areas is probably higher as less than 1% of the area has been searched although much of it is not suitable habitat for this lichen. In both Newfoundland and Nova Scotia, many of the occurrences are on Crown land and have no legal protection.

TECHNICAL SUMMARY #1 – BOREAL POPULATION

Erioderma pedicellatum

Boreal Felt Lichen (Boreal Population) Érioderme boréal (Population boréale)

Range of occurrence in Canada: Newfoundland and Labrador

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used). The estimates are from juvenile and adult growth rates and are consistent with evidence from demographic models.	20 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? While more individuals have been recorded as a result of increased search effort, declines have been observed at most occurrences that have been monitored over the last eight years.	Uncertain
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations]. Inferred or suspected based on the 8 years of monitoring data.	Annual Declines at monitored areas range from 3-15% per year
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future. 3 to 15% decline has been observed over the last 8 years for most of the monitored occurrences but two occurrences have shown an increase	Annual declines at monitored areas range from 3-15% per year
Are the causes of the decline clearly reversible and understood and ceased? Causes understood but not reversible or ceased	NO
Are there extreme fluctuations in number of mature individuals?	NO

Extent and Occupancy Information

Estimated extent of occurrence	74,581 km², which is 66.9% of the island of Newfoundland
Index of area of occupancy (IAO) (Always report 2x2 grid value).	740 km²

Is the population severely fragmented?	Unknown
Number of locations based on distinct ecological units	Unknown
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence? The lichen has disappeared from many occurrences	NO
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy? Although the lichen has disappeared from many occurrences, new sites have been found as a result of increased search effort	NO
Is there an [observed, inferred, or projected] continuing decline in number of populations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in number of locations?	Unknown
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	YES
Are there extreme fluctuations in number of populations?	NO
Are there extreme fluctuations in number of locations?	Unknown
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 population)

Population	**N Mature Individuals**
Estimate (island of Newfoundland)	15,000 to 20,000
Total	15,000 to 20,000

Quantitative Analysis

	Not Done

Threats (actual or imminent, to populations or habitats)

In some areas browsing by introduced moose is preventing regeneration of Balsam Fir, the main host for this lichen and the loss of forest continuity means that the population of host trees for colonization by the Boreal Felt Lichen will decline. Forestry operations, especially clearcut logging with some loss of natural forest regeneration, as well as rotations shorter than the natural life span of Balsam Fir trees, is leading to progressive loss of suitable habitat for this lichen. Climate change leading to extreme weather events is causing more wind-throw and loss of host trees. This, acid rain and reduced humidity may have an impact on the growth and survival of the lichen.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)?	Unknown
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Probably
Is rescue from outside populations likely?	NO

Data-Sensitive Species

Is this a data-sensitive species?	Unknown

Status History – Boreal Population

Designated Special Concern in May 2002. Status re-examined and confirmed in November 2014.

Status and Reasons for Designation – Boreal Population

Status: Special Concern.	**Alpha Numeric Code:** Not applicable
Reason for Designation: This species is widely distributed in Newfoundland and several threats to its survival have been identified including habitat alteration due to invasive species, acid rain and extreme weather events. Despite declines in some areas, new populations continue to be found. More research and monitoring are needed to understand population trends, and the species may become threatened if threats are not better understood and managed.	

Applicability of Criteria

Criterion A: Not applicable. Criteria not met.
Criterion B: Not applicable. Criteria not met.
Criterion C: Not applicable. Criteria not met as there are more than 10,000 mature individuals.
Criterion D: Not applicable. Criteria not met as both the number of individuals and IAO exceed limits.
Criterion E (Quantitative Analysis): Not done.

TECHNICAL SUMMARY #2 – ATLANTIC POPULATION

Erioderma pedicellatum

Boreal Felt Lichen (Atlantic Population) Érioderme boréal (Population de l'Atlantique)

Range of occurrence in Canada: New Brunswick and Nova Scotia.

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used) The estimates are from juvenile and adult growth rates and are consistent with evidence from demographic models.	20 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals? There an observed continuing decline in number of mature individuals.	YES
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations] 2 generations (40 years) with annual decline of 1.364%	42%
[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 in % mature individuals over last ten years	12%
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. Projected decline over three generations	56%
[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. Estimate based on observations over the last ten years, and a projected decline over the next 50 years for a total of 60 years, which is three generations. 1.364% per year = 56% over 3 generations (60 years)	56%
Are the causes of the decline clearly reversible and understood and ceased?	NO
Are there extreme fluctuations in number of mature individuals?	NO

Extent and Occupancy Information

Estimated extent of occurrence	14,424 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	120 km²
Is the population severely fragmented?	Maybe

Number of locations; Uncertain but >10	>10 but <20
Is there an [observed, inferred, or projected] continuing decline in extent of occurrence?	YES
Is there an [observed, inferred, or projected] continuing decline in index of area of occupancy?	YES
Is there an [observed, inferred, or projected] continuing decline in number of populations?	YES
Is there an [observed, inferred, or projected] continuing decline in number of locations?	YES
Is there an [observed, inferred, or projected] continuing decline in [area, extent and/or quality] of habitat?	YES
Are there extreme fluctuations in number of populations?	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 population)

Population	**N Mature Individuals**
	317
Total	<500

Quantitative Analysis

	Not done

Threats (actual or imminent, to populations or habitats)

Forestry operations, air pollution, climate change, introduced slugs.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)?	
Is immigration known or possible?	Very unlikely
Would immigrants be adapted to survive in Canada?	YES
Is there sufficient habitat for immigrants in Canada?	Unlikely – recent analysis shows a declining amount of predicted habitat
Is rescue from outside populations likely?	NO

Data-Sensitive Species

Is this a data-sensitive species?	NO

Status History – Atlantic Population

Designated Endangered in May 2002. Status re-examined and confirmed in November 2014.

Recommended Status and Reasons for Designation – Atlantic Population

Recommended Status: Endangered	**Alpha Numeric Code:** C1+2a(i)
Reason for Designation: This species is believed to be extirpated from New Brunswick, and the remaining population in Nova Scotia is small. Intensive monitoring efforts over the past ten years indicate that both the number of occurrences and number of individuals are declining. These declines are projected to continue in the future. The main threats include habitat loss and deterioration as a result of forest harvesting, air pollution, climate change, and predation by introduced slugs.	

Applicability of Criteria

Criterion A: Not applicable.
Criterion B: Not applicable.
Criterion C: Meets Endangered C1+2a(i) as the total number of mature individuals is < 500; there has been a continuing decline (ca. 56%) in the number of mature individuals as the species is now extirpated at 11 of the 41 occurrences found between 2003 and 2011. No population has been found to contain more than 250 mature individuals.
Criterion D: Meets D1 for Threatened as the total number of mature individuals is < 500.
Criteria E: Not done.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2014)

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 Canada | Environnement Canada
Canadian Wildlife Service | Service canadien de la faune

Canada

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

COSEWIC Status Report

on the

Boreal Felt Lichen
Erioderma pedicellatum

Boreal population
Atlantic population

in Canada

2014

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Scientific Name: *Erioderma pedicellatum* (Hue) P.M. Jørg. (1972).

Synonym: *Pannaria pedicellata* Hue (1911); *E. boreale* Ahln. (1948).

Common Name: Boreal Felt Lichen

Family: Pannariaceae

Major Group: Lichen (Lichenized Ascomycetes)

Erioderma pedicellatum was first collected in 1902 from Campobello Island, Charlotte County, New Brunswick, Canada, by William Gilson Farlow. It was originally identified as a species of *Pannaria* and named *P. pedicellata* by French botanist Auguste-Marie Hue (Jørgensen 2001). It remained in this genus until 1972 when it was re-examined by Per Magnus Jørgensen and placed in the genus *Erioderma* as *E. pedicellatum* (Jørgensen 1972). It is an unusual species, both because of its laminal apothecia (lacking in other *Erioderma*) and its boreal distribution (Jørgensen 2001). *E. pedicellatum* has been incorrectly called *E. boreale* (Jørgensen 1972).

Morphological Description

Erioderma pedicellatum is a cyanolichen, comprising a fungus and a cyanobacterium that was identified as a *Scytonema* sp. but is now thought to be a *Rhizonema* sp. (Cornejo and Sheidegger 2009). The thallus is foliose with lobes 2-5 cm across, and occasionally reaching 12 cm in diameter. It has a distinctively fuzzy upper surface that is greyish-brown when dry and slate-green when moist. The underside is white, and its edges usually curl upwards, giving it the appearance of having a white fringe. It differs from the two other North American species of *Erioderma* by having small, reddish-brown apothecia on its upper surface instead of soredia. It grows on the trunks and the branches of Balsam Fir (*Abies balsamea*), occasionally on Black Spruce (*Picea mariana*), rarely on White Spruce (*P. glauca*) or Red Maple (*Acer rubrum*) and very rarely on White Birch (*Betula papyrifera*).

It is not clear whether the generic name derives from the hairiness of the upper cortex or that of the underside (erion being the Greek name for wool and derma that for skin). Both features are highly characteristic of the genus (COSEWIC 2002). The hairiness of the thalli has earned the species the nickname ‘panda bear’ lichen.

Population Spatial Structure and Variability

A site refers to where an individual or group of *E. pedicellatum* thalli was actually found and the position recorded using Global Positioning System (GPS) data. When two or more sites were less than 1km apart from each other, they comprised a single occurrence. If two sites were more than one km from each other, they were considered to be two occurrences. One or more occurrences that are affected by the same major threat or threats are defined as locations (in the IUCN sense that is used by COSEWIC).

<u>Atlantic Population</u>

Erioderma pedicellatum occurs in Nova Scotia only within 25 km of the Atlantic coast. This coincides with the rainforest belt where annual precipitation exceeds 1400 mm (Clayden *et al.* 2011). The abundance and frequency of occurrence increases from southwest to northeast along this rain belt and this may be a reflection of the increasing precipitation along the same isopleth. Because this lichen is very rare in Nova Scotia, the spatial structure of the *E. pedicellatum* population is difficult to assess there. However, Cameron and Neily (2008) have speculated that *E. pedicellatum* may be a metapopulation species in Nova Scotia. The habitat for *E. pedicellatum* occurs in discrete predictable patches across the landscape. Although "blinking off" (i.e., the sudden loss of a population) has been documented for Nova Scotia subpopulations there has been no documented "blinking on" (i.e., sudden reappearance of a population).

<u>Boreal Population</u>

How the current spatial structure of *E. pedicellatum* has arisen on the landscape in Newfoundland is a matter of current discussion. *Erioderma pedicellatum* is never found far from wetlands. It generally occurs near the coast but can be found up to 50 km inland in areas with a cool moist climate. Records of occurrences in Newfoundland suggest the existence of core areas where hundreds to low thousands of thalli occur. This pattern suggests that *E. pedicellatum* in Newfoundland may be an example of a metapopulation but "blinking on" is difficult to detect.

Erioderma pedicellatum is more abundant in some regions of Newfoundland than others. Most documented occurrences in Newfoundland are within the 1401-1600 mm rainfall contour (Figure 1) which qualify them as boreal rainforest (Clayden *et al.* 2011). The rarity of *E. pedicellatum* e.g. Western Forest Ecoregion, Figure 2) may reflect the lack of sufficient soil moisture especially during drought periods (Roberts 2012).

Field personnel in the Department of Natural Resources believe that the lichen is much more common than believed in the Avalon Wilderness Reserve (eastern Newfoundland) and in the Bay du Nord Wilderness Reserve (eastcentral Newfoundland). Both occurrences have little or no industrial footprint, and support mature forests regardless of cyclic disturbances by insects and wind-throw. Clarke and Roberts (2008) reported that a combined search time of 55 person-hours in the Avalon Wilderness Reserve located 70 thalli of *E. pedicellatum* at 20 sites in less than 1% of the reserve area. In the Bay du Nord Wilderness Reserve, Clarke (2005b) reported that 95 thalli of *E. pedicellatum* were found in less than fifteen person-hours of searching in six of eleven stops over a combined area of approximately four hectares in difficult snow conditions. A total of 3,774 thalli were reported from protected areas in Newfoundland, notably the Bay d'Espoir at Jipujijkuei Kuespem Park (Roberts 2012). However, the number may only be around 2,783 as some sites could have been counted twice and other thalli died. McCarthy (2010) recorded *E. pedicellatum* in the Fitzgeralds Pond Provincial Park Reserve in Eastern Newfoundland. Data from the Newfoundland and Labrador Wildlife Division databases (and Atlantic Canada Conservation Data Centre (Newfoundland and Labrador Satellite office) are provided in Appendices Table 2 and Table 3.

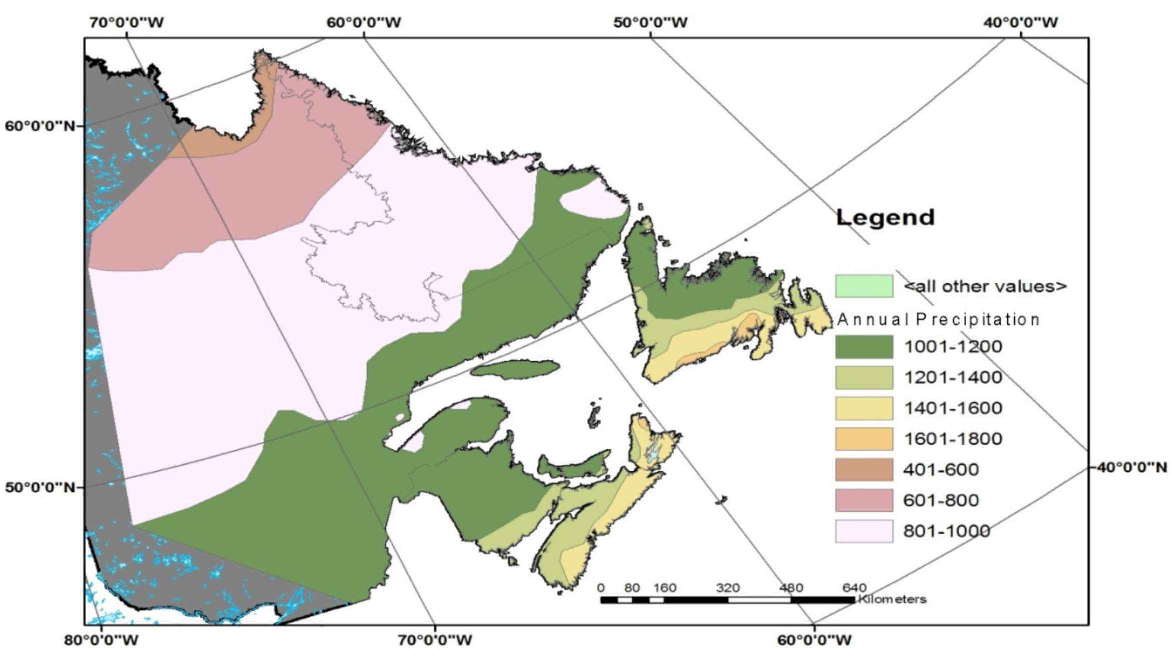
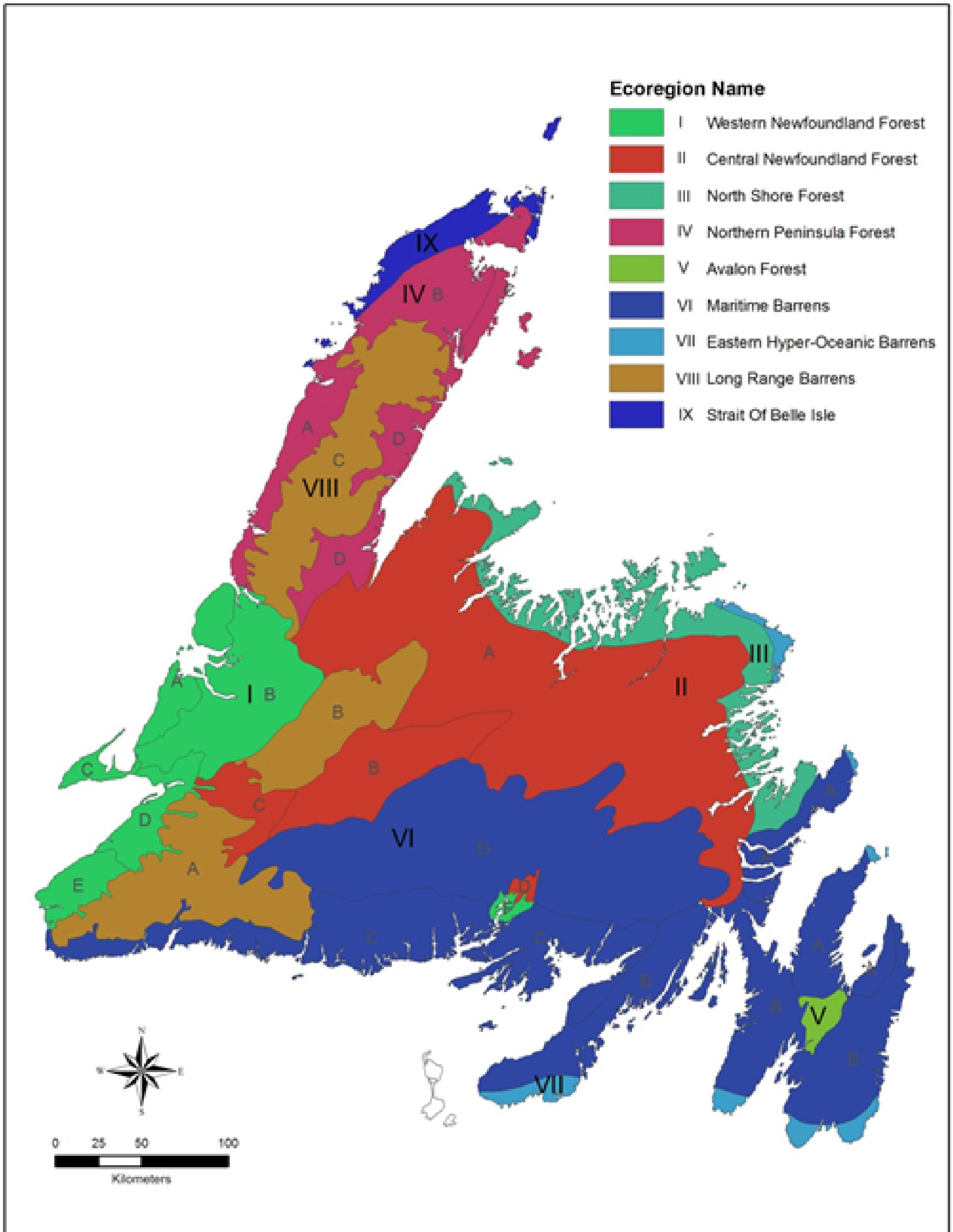


Figure 1. Annual precipitation contours (mm) for Atlantic Canada (Source: Environment Canada).



Ecological subdivision of the island of Newfoundland. (source: Damman, 1983)

Figure 2. Ecoregions of the island of Newfoundland based on Damman (1983).

Designatable Units

The original status report for *E. pedicellatum* accepted two designatable units for *E. pedicellatum:* the Atlantic Population which includes New Brunswick and Nova Scotia, and the Boreal Population for the island of Newfoundland (COSEWIC 2002). The Guidelines for the Identification of DUs distinguish two criteria for discrete populations:

1. Natural disjunction between substantial portions of the species' geographic range, such that movement of individuals between separated regions has been severely limited for an extended period of time. In this context, it is relevant that *E. pedicellatum* reproduces only via ascospores, which to form a lichen would have to be carried from Nova Scotia to Newfoundland (or vice versa), land on a Balsam Fir tree of suitable age, upon which was a compatible cyanobacterium. This is in contrast with *E. mollissimum*, a related lichen which produces numerous vegetative propagules containing both fungus and cyanobacterium, which can be transported more easily on the feet or feathers of migrating birds to a new host.

2. Occupation of differing eco-geographic regions that are relevant to the species and reflect historical or genetic distinction, as may be depicted on an appropriate ecozone or biogeographic zone map. Some dispersal may occur between regions, but it is insufficient to prevent local adaptation. The Atlantic Population occurs within the COSEWIC Atlantic National Ecological Area, while the Boreal Population occurs within the Boreal Ecological Area.

The very limited molecular work done on *E. pedicellatum* suggests a lack of genetic variation between the European and the Canadian Boreal Population of this lichen. Two genotypes were found, one rare and one common (Yetman, Hermanutz & Scheidegger unpub. data). However, samples from the Atlantic Population of *E. pedicellatum* were not included in the study.

Special Significance

Erioderma pedicellatum, the Boreal felt lichen has disappeared in all but two of its occurrences in Europe (Holien 2006) due to a combination of threats that include forestry and habitat disturbance. It is an ancient species whose fungal partner is believed to have evolved almost 500 million years ago (COSEWIC 2002). It generally co-occurs on the landscape with, and therefore acts as an umbrella species for, a suite of rare or uncommon lichens which include *Coccocarpia palmicola, Collema nigrescens, Degelia plumbea, Erioderma mollissimum Fuscopannaria leucosticta, F. ahlneri, Leptogium laceroides, L. corticola, L. saturninum, Lichinodium sirosiphoideum, Moelleropsis nebulosa, Normandina pulchella, Pannaria lurida, P. rubiginosa, Pseudocyphellaria spp., Sticta fuliginosa* and *S. limbata.* (Cameron and Neily 2008, Cameron 2009b, Thompson *et al.* 2003, Claudia Hanel pers. com.).

At least 15 of these species are rare or at-risk cyanolichens (Cameron and Richardson 2006). Seven of these species are considered rare in North America (Brodo *et al.* 2001) or Canada (Goward *et al.* 1998). The above cyanolichens, together with *E. pedicellatum*, constitute an at-risk coastal forest lichen community that is unique to eastern North America.

DISTRIBUTION

Global Range

Erioderma pedicellatum is a disjunct circumpolar species that was once more extensively distributed in Norway and Sweden as well as in the provinces of New Brunswick, Nova Scotia, and Newfoundland in Atlantic Canada (Figure 3). It has almost disappeared from Europe with only two known sites remaining in Norway (Holien 2006). Very recently a large population of at least 2000 individuals (but potentially as many as 100,000 thalli) was discovered in the Denali area of Alaska (Nelson *et al.* 2009, Stehan *et al.* 2013) and a small one in the Kamchatka Peninsula of Siberia (Scheidegger pers. comm.). This increases the known range of *E. pedicellatum.* To date there has been no molecular work to show whether or not the Alaskan population, which grows on the twigs and small branches of *Picea glauca,* rather than trunks of *Abies balsamea,* is genetically distinct. Previous to these findings, more than 95% of the global population was thought to be in Canada, with the known Alaskan population it is now 88% but the percentage may be as low as 10-20% if the lichen proves to be common in the potentially available habitat in Alaska.

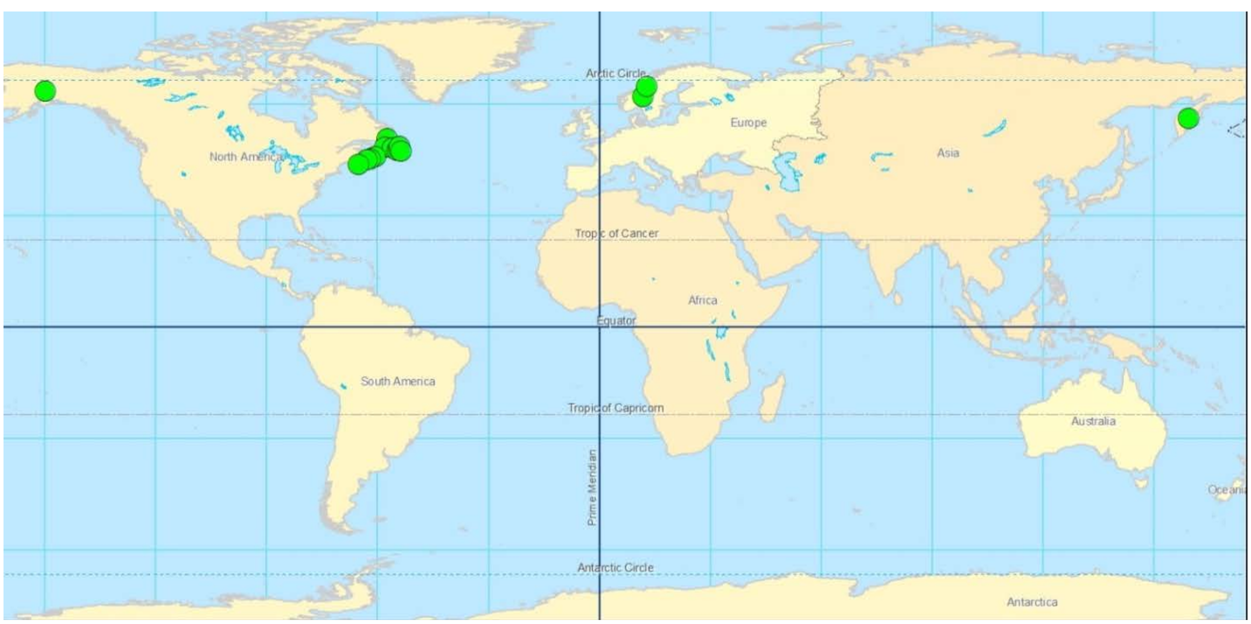


Figure 3. The known current global distribution of *Erioderma pedicellatum* as of 2012; occurrences indicated by green dots.

Canadian Range

The species has not been found in New Brunswick since 1902 despite extensive research effort, and there are only a few hundred individuals known in Nova Scotia (Figure 4) (COSEWIC 2002; Cameron *et al.* 2009). The largest population of *E. pedicellatum* is on the island of Newfoundland, and it is critical for the survival of this species in Canada (Figure 5).

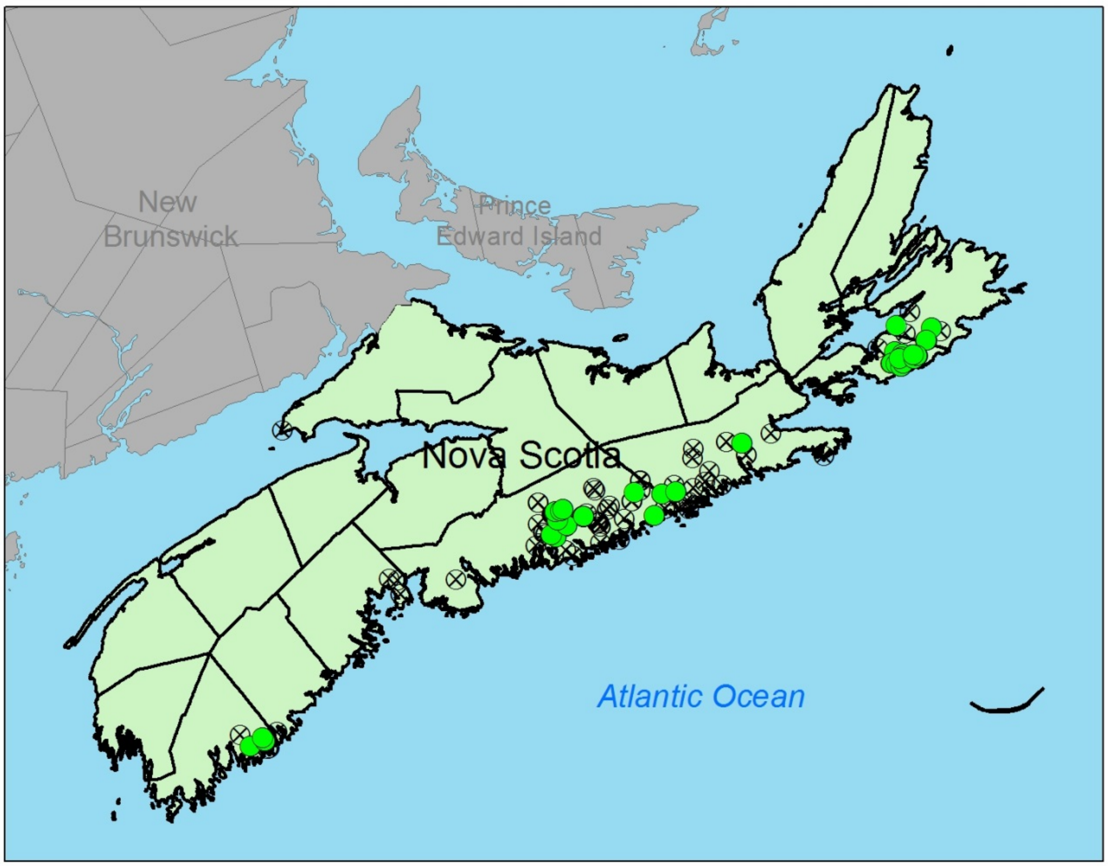


Figure 4. Occurrences of *Erioderma pedicellatum* in Nova Scotia. Green dots indicate occurrences where *Erioderma pedicellatum* is currently known and circles with X indicate occurrences where it was historically known but now no longer occurs.

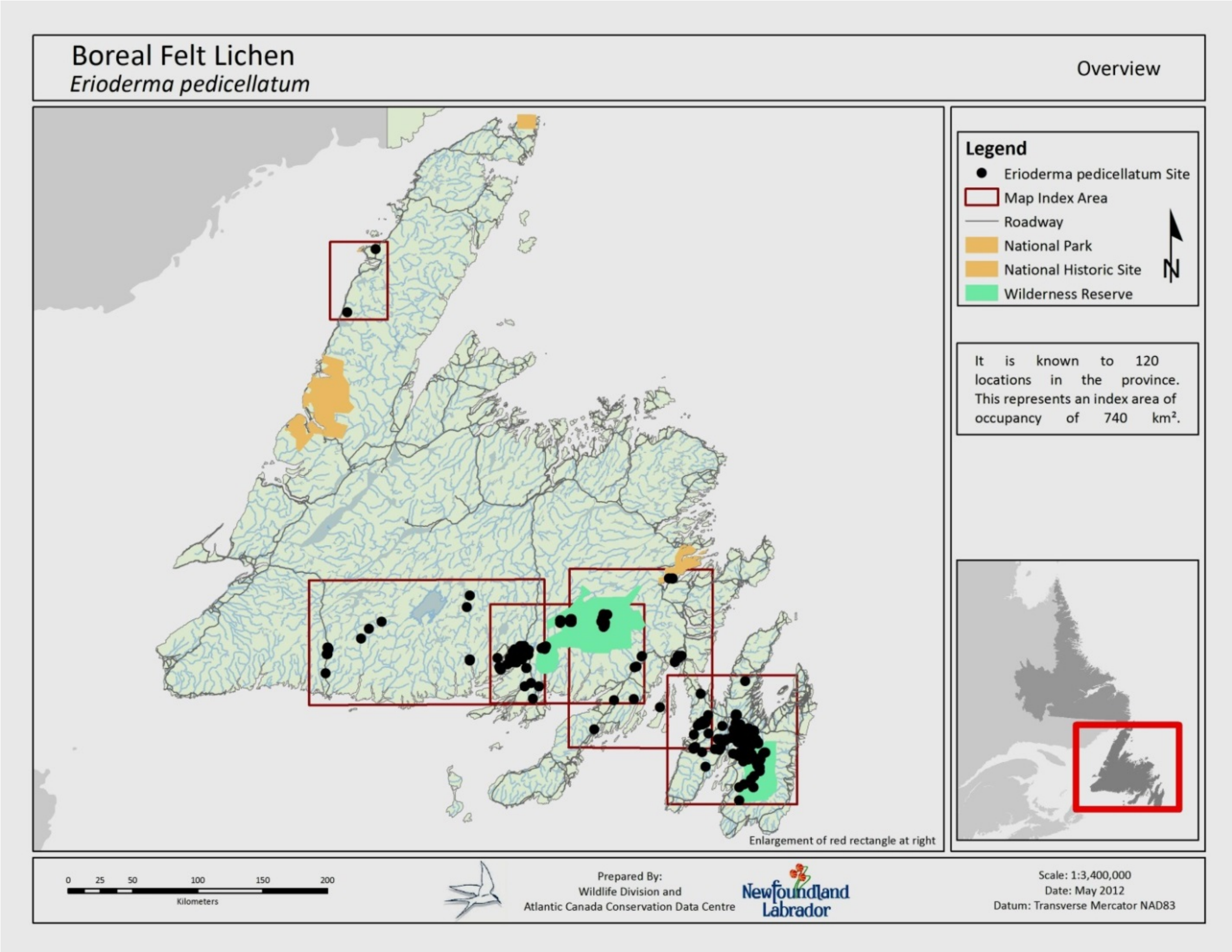


Figure 5. Occurrences of *Erioderma pedicellatum* recorded on the island of Newfoundland. Detailed maps of each of these areas are available from NL Environment and Conservation.

Extent of Occurrence and Area of Occupancy

The Atlantic Population's estimated extent of occurrence (EO) is 14,424 km^2. The EO was calculated as a single polygon within Nova Scotia and excluded the Atlantic Ocean but included all freshwater lakes and rivers. The EO covers 5 counties along the Atlantic Coast of Nova Scotia. Although no current occurrences are known from eastern Halifax, Lunenburg or Queens Counties, these counties were included in the calculation in order to create a single polygon of occurrence.

The index of area of occupancy (IAO) for the Atlantic Population was calculated as the number of squares on a 2x2 grid in which there was an occurrence. The IAO is 120 km^2.

The estimated EO for the Boreal Population is about 74,581 km^2, which is 66.9% of the island of Newfoundland. The IAO is 740km^2, according to information from the Wildlife Division of the Newfoundland and Labrador the Department of Environment and Conservation and Department of Natural Resources.

Search Effort

Boreal Population

The central Avalon Peninsula in eastern Newfoundland has received more investigation than other areas. The area of potential *E*. *pedicellatum* habitat in Newfoundland has not been established, so it is uncertain what proportion of the habitat has been searched to date. Roberts (2012) provides an estimate of the search effort applied to different areas (Table 1). The search effort estimates were based on the number days in the field and included both search time and recording time. While the exact numbers in this table are out of date, it is certain that in the Bay d'Espoir area the thalli are denser and it takes less time to find more of them. On the Avalon Peninsula it takes more time to find an equivalent number of thalli.

Table 1. The search effort in relation to the discovery of *Erioderma pedicellatum* thalli for various areas on the island of Newfoundland (from Roberts 2012).

Regions	Percentage of thalli *	Percentage of search* effort
Avalon Peninsula	39.5 %	77.0 %
Bay d'Espoir	55.8 %	17.5 %
Bay du Nord	2.6 %	1.5 %
Burgeo Road	1.0 %	1.5 %
South Coast	1.0 %	1.7 %
Northern Peninsula	< 1 %	< 1 %

*****Footnote: If the thalli are distributed with the same density across their range, the percentage of search effort for each region should equal the percentage of thalli. If for a given region the percentage of thalli is smaller than the percentage of search effort, the thalli are less dense than average. If the percentage of thalli is larger than the percentage of search effort, the thalli in the region are denser than average.

Attempts have been made to quantify the density of the host trees on which the lichen occurs in the Balsam Fir forests under study. For example Goudie *et al.* (2006) dedicated approximately 300 hours to searching for *E*. *pedicellatum* over a 20-km^2 area in the Long Harbour, Placentia Bay area of the eastern Newfoundland area during a three-month period from 1 June to 6 September 2006. Effective hourly coverage varied from 100 to 300 trees per/hr. Approximately 30,000 trees were surveyed during the 300 hours of survey time dedicated to this area. Sixty-six trees were found hosting 105 thalli of *E*. *pedicellatum*, representing approximately 0.22% of Balsam Fir stems. Thus, at Long Harbour, search effort averaged about one field-day to locate one tree supporting *E*. *pedicellatum*.

A similar density was assessed by McCarthy (2010) during his systematic survey of the Avalon Peninsula forests based on seventy-five sample plots ~25 m in diameter. *E*. *pedicellatum* was detected on thirteen plots, with 21 host trees out of 9,141 trees sampled over a four-and-a-half-month period. This represented a density of 1.1 % of occupied trees on the thirteen plots with detections, and an overall density of 0.24% of Balsam Fir stems for the entire seventy-five plots. Densities of < 1% indicate a rare species (Green and Young 1993) and they provide a formula $n = 3/m$ where m is density for defining a required sample size (n) of a rare species in order to have a 95% probability of detecting the species if it is present.

At other occurrences in eastern Newfoundland, such as Hall's Gullies and Lockyer's Waters, considerably higher densities and higher detection rates per person-hour of searching have been found.

Surveys with the primary objective of increasing the number of known occurrences for *E. pedicellatum* have been carried out in Newfoundland (McCarthy 2010). Clarke (2005b), Clarke and Roberts (2008) and Roberts (2012) assessed *E. pedicellatum* as more common than indicated in the original status report by Maass and Yetman (COSEWIC 2002). This difference may reflect the fact that Clarke and Roberts were sampling habitat (for example, in the Avalon Wilderness Reserve and the Bay Du Nord Wilderness Reserve) likely to contain the *E. pedicellatum*. Experienced lichenologists often locate rare lichens based on their intuitive knowledge of the species' preferred habitat especially in core population areas. A population increase may be inferred from such surveys but the numbers of thalli at an occurrence will asymptote with more field effort.

<u>Atlantic Population</u>

There have been ongoing regular yearly searches in Nova Scotia for *E. pedicellatum* since 2003. Approximately 3,329 hours in search effort have been expended for *E. pedicellatum* in Nova Scotia since 2003. Yearly effort has increased over this time from 244 hours/year between 2003 and 2006 up to an average of 649 hours/year between 2007 and 2009.

Search effort has been guided by a Geographical Information System (GIS) habitat model for *E. pedicellatum* developed by Cameron and Neily (2008). This model helps to focus search effort on predicted habitat. The model identified 13,852 predicted habitat polygons of which approximately 832 have been searched for *E. pedicellatum* between 2003 and 2012. Only about 5% of predicted habitat polygons are occupied by *E. pedicellatum*. Three hundred and forty-seven thalli in 41 occurrences have been found as a result of searches between 2003 and 2010 (Figure 4).

HABITAT

Habitat Requirements

This lichen grows on the trunks and branches of trees on slopes and in flat areas, as well as depressions, and sometimes even on top of low moraine ridges, as long as the site is moist enough. Areas where the lichen occurs generally have a high abundance of mosses (e.g. *Sphagnum* spp. and *Hylocomium splendens*). The lichen is usually associated with liverworts, especially the epiphytic *Frullania tamarisci* (COSEWIC 2002). In Newfoundland at four occurrences in Bay d'Espoir and one on the Avalon Peninsula, eighty percent of thalli on trunks had a visible strand of *Frullania* growing within 5mm of a thallus. The remainder may have had a strand near them when they originated. On branches, only 57% of thalli had *Frullania* underneath or near them and juvenile thalli were even found near the tips of live Balsam Fir branches among green needles (Hanel. pers. comm) (See Life Cycle and Reproduction).

Forest stands in which *E. pedicellatum* occurs are dominated by Balsam Fir and are usually old forests or stands with very old trees (Cameron and Neily 2008, COSEWIC 2002, Maass 1980). Where the Atlantic Population of *E. pedicellatum* occurs, the forests may have a mix of tree ages but with a long continuity of forest cover and a small gap phase disturbance regime (Neily *et al.* 2004). Many occurrences have a high percentage of dead standing trees and wind-throw is common. *E. pedicellatum* tends to deteriorate on dead trees over a period of years, or if habitat succession occurs which changes available light (COSEWIC 2002). Altered microclimatic conditions caused by extensive nearby logging can also cause the lichen to deteriorate (Holien *et al.* 1995, Clayden 2010, Clayden *et al.* 2011, Cameron *et al.* 2013).

<u>Boreal Population</u>

The Boreal Population of *E. pedicellatum* requires relatively cool and moist oceanic climates. It is found both near the coast and further inland than in Nova Scotia but still within areas of high precipitation and low evapotranspiration. Warm winter temperatures ranging from an annual mean of - 4 to - 8°C, and cool summers with a mean temperature of less than 16°C occur in these coastal forests. Precipitation is high, exceeding 1200 to 1400 mm annually in many areas where *E. pedicellatum* occurs (Figure 1). Much of the precipitation falls as rain, averaging 88% of total precipitation. High rainfall, frequent fog and proximity to wetlands indicate the importance of a humid forest habitat. On the Avalon Peninsula *E. pedicellatum* occurs mostly on the lower slopes of extensive rogen (ribbed) moraines that are orientated in an east-west direction with intervening bogs and wetlands. It may also have occurred historically on Balsam Fir occupying better drained sites on moraines but this is uncertain.

The dynamics of the Balsam Fir forests in Newfoundland are not completely understood. Non-equilibrium patch dynamics (disturbance paradigm) has been an ecological paradigm for understanding the relationship between forest- and stand-level structure and disturbance in the boreal forest (Pickett and White 1985, Pickett *et al.* 1992). Field observations suggest that disturbances sometimes result in patches of regeneration that are less than 1 ha in size and not captured by forest inventories. This has large implications when trying to determine how far *E. pedicellatum* spores would need to disperse to renew local populations. The sizes, shapes, spatial arrangement and regeneration patterns of forest disturbances need to be further studied.

Atlantic Population

With respect to the Atlantic Population of *E. pedicellatum*, all the known forest stands in Nova Scotia with this lichen are associated with wetlands. Frequently, these are unmapped poorly drained Balsam Fir and/or Red Maple wetlands usually with an extensive ground cover of *Sphagnum* spp., often *Sphagnum girgensohnii.* In larger wetlands *E. pedicellatum* often occurs on the edges where the upland and wetland meet. The proximity to the coast and to wetlands suggests a need for highly humid conditions. All known occurrences are within 25 km of the Atlantic coast. Maass and Yetman (COSEWIC 2002) documented occurrences on the Bay of Fundy coast in Cumberland County but recent searches there have not found any *E. pedicellatum* (Anderson pers. comm.). Annual precipitation is between 1200 and 1600 mm with a mean July temperature of less than 16^{o}C and a mean January temperature of about - 6^{o}C.

A comparison of unoccupied predicted habitat with occupied habitat indicated that *E. pedicellatum* is found in older forest stands with a lower crown closure, higher tree density, a lower proportion of Black Spruce and low shrub cover (Powers *et al.* unpub. data). *E. pedicellatum* also occurred in microhabitats of the stand where there were more dead trees. In general, the low density of *E. pedicellatum* presents challenges to developing predictive models to aid in management of the habitat (Cameron and Neily 2008, Cameron *et al.* 2013b). Such models are more helpful for predicting where the pecies likely does not occur (Wiersma and Skinner 2011). In future as more intricate ecosite spatial data and anthropogenic history are integrated into forest resource inventories, models may prove to be more valuable.

Habitat Trends

Boreal Population

There is agreement among researchers that the stand dynamics of the Balsam Fir forests in Newfoundland have a large effect on the population and colonization patterns of the Boreal Felt Lichen. Some researchers believe that the required habitat for the Boreal Felt Lichen is uneven-aged mature to old-growth forest, while others think that Balsam Fir forests follow an even-aged stand dynamic and that the Boreal Felt Lichen colonizes at an appropriate stage and then populations decline. The truth may lie between these two hypotheses. A new landscape-level conceptual framework of Balsam Fir forest dynamics, which considers patches at various ages, scales and distances from each other, may be helpful but long-term research on the forest dynamics and the lichen populations is required.

Whatever the dynamics of the Balsam Fir forest, it is evident that intensive industrial forestry practices have led to decreases in available older forests by reversing the age-class structure of the forest landscapes (Boucher *et al.* 2009; Cyr *et al.* 2009). This has an impact on the organisms associated with these forests. Because *E. pedicellatum* tends to be found on older trees, the loss of older age classes affects this lichen. Thompson *et al.* (2003) speculated that if 60-year old forests in Newfoundland regenerated following logging, they would eventually develop the characteristics of old forests but none are old enough to confirm this. There are no published data on the occurrence of *E. pedicellatum* in stands that have been previously harvested although unpublished data and field sampling show that most poorer stands, where *E. pedicellatum* occurs in the Avalon peninsula, were previously harvested or had stand-replacing events and this has been confirmed by tree cores (Clarke pers. comm.).

The extensive area of the 'Henders cut-block' that was clear-cut in the 1950-70s as a fibre-source for the Newfoundland Fibreply Ltd has not yielded any finds of *E. pedicellatum.* However, most parts of the area are more productive and the nearest known *E pedicellatum* site is about 2 km away near Kirks Ridge Road where it is wetter. Existing occurrences on the Avalon Peninsula (e.g. Lockyer's Waters) coincide with areas that were selectively logged or subject to small (<5 hectares) clear-cuts. Traditional logging included some high grading or selective cutting. Clear-cutting was practised in proximity to transportation routes, such as the Newfoundland Railway and rivers that could be used for log driving (Clarke, pers. comm.). Pre-commercial thinning has been practised on higher quality sites, which can increase the occurrence of *Frullania* with which *E pedicellatum* is associated but it may make microclimatic conditions less suitable for this lichen (Cameron 2002). Thinning also increases light levels and the effects on *E. pedicellatum* need to be further assessed. Pre-commercial thinning is widely practised in the Bay d'Espoir area.

In Newfoundland, the majority of *E. pedicellatum* habitat is in areas not under a pulpwood lease. Commercial harvest pressure is also strongly dependent on a rather variable economic climate for forestry. On the Avalon Peninsula in particular, domestic harvesting is carried out over large areas of potential *E. pedicellatum* habitat and while the patch size of the cutovers is usually small, there is probably local overharvesting close to communities. These areas are not being surveyed for *E. pedicellatum*, and it is unknown what effect domestic logging is having on *E. pedicellatum* survival or the extent and quality of the habitat. However, Balsam Fir is regenerating sufficiently to replace older dying or wind-thrown trees but the young trees are not reaching the ‘free to grow’ state’ due to intense browsing of young Balsam Fir by introduced moose. This is a serious and widespread threat. Where the Balsam Fir regeneration fails over large areas following commercial harvesting, wind-throw or insect outbreaks, planting of unpalatable species for moose, mainly spruce, is done. Subsequent infilling by regenerating Balsam Fir has been observed, but it is unlikely that, when mature, the Balsam Fir densities will approach those of natural stands.

<u>Atlantic Population</u>

There is evidence that the quality of the habitat has been decreasing in Nova Scotia as a result of forestry, pollution and climate change (see Threats). Forestry activities between 1988 and 2005 resulted in the clear-cutting of Balsam Fir forests supporting *E. pedicellatum* habitat, e.g. at the Aspotogen and Murchyville occurrences. Satellite data from NSDNR (Bruce 2002) was used to measure historical forest harvesting from 1988 to 2005 and overlaid on *E. pedicellatum* predicted habitat derived from forest cover data from 1988 to 1992 (Cameron and Neily 2008). Habitat loss from harvesting exceeded regeneration for the period between 1988 and 2005 for a total loss of 11.5% of the predicted suitable habitat for *E. pedicellatum.* Continued declines are predicted for the next 50 years with an expected loss of 25% of the habitat (Cameron *et al.* 2013b).

BIOLOGY

Life Cycle and Reproduction

Erioderma pedicellatum is a symbiosis between an ascomycete fungus and cyanobacterium that has been identified as *Scytonema* but is now thought to be a *Rhizonema* sp. (Cornejo and Shiedegger 2009), which is also capable of fixing nitrogen.

It is hypothesized that there is a complex relationship between *E*. *pedicellatum* and its cyanobacterial symbiont that involves a liverwort ‘nursemaid’, *Frullania tamarisci* ssp. *asagrayana.* This liverwort is thought to play a central role in helping *E. pedicellatum* become established on the trunks of its host tree. It is hypothesized that hyphae from the germinating ascospores of *E*. *pedicellatum* invade the water sacs of the liverwort, *F. tamarisci*, and envelop compatible cyanobacteria (COSEWIC 2002). Cyanobacteria are known to fix atmospheric nitrogen and to colonize the water sacks of liverworts. The nitrogen can benefit the liverwort. The fact that juvenile thalli have been found on branches where they seem not to be closely associated with liverwort thalli (Hanel pers.com.) suggests that there may be other ways for germinating ascospores of *E. pedicellatum* to capture the required cyanobacteria to synthesize a new thallus. Clearly more research is needed on this aspect of the life cycle.

The generation time for lichens varies from ten years in rapidly colonizing lichens such as *Xanthoria parietina* to more than 17 years for old-growth forest lichens such as *Lobaria pulmonaria* (Scheidegger and Goward 2002; Larsson and Gauslaa 2010). In Newfoundland, a healthy mature thallus of *E. pedicellatum* can grow at a rate of 11 to 14 mm in radius per year, and populations of this lichen have a generation time estimated at around 30 years (Goudie 2009b). The Nova Scotia data suggest that thalli can grow at about the same rate but that generation time is closer to 20 years (Cameron 2013). For the purposes of this report, 20 years is accepted as the likely generation time. It is uncertain how long it takes for a thallus primordium, formed by the association of the germinating fungal filament and the cyanobacterium, to become a small thallus visible to the naked eye. However, once such juvenile thalli develop, they take about one year before developing primordial apothecia. Once thalli reach about one cm in diameter, they begin to develop abundant short-stalked apothecia up to 1.5 mm in diameter. Mature thalli are usually 2-5 cm diameter and have mature and developing apothecia scattered on the upper surface. Sometimes there are several hundred on a single thallus. A high proportion of apothecia-bearing thalli display some level of necrosis. Population viability in *E. pedicellatum* is especially dependent on survival of apothecia-bearing individuals which eject the spores required for the next generation.

Vegetative propagules in the form of either soredia or isidia are entirely absent in *E. pedicellatum*. However, some vegetative reproduction may occur following fragmentation of adult thalli. Occasionally, the centres of thalli of *E. pedicellatum* become necrotic and die. The outer lobes become separated as a result and persist as separate thalli. They can in some cases resemble juvenile thalli if all the apothecia are lost. This process does not contribute to long-distance dispersal but can locally populate a branch or trunk of a host tree (Cameron 2013).

Physiology and Adaptability

Erioderma pedicellatum, like other lichens, requires liquid water that is obtained via the interception of precipitation, fog or dew that contains dissolved ions, or particulates (Nash 2008). There are no published studies on the physiology of *E. pedicellatum.* However, some inferences can be made from its habitat requirements and distribution. This lichen rarely occurs on trees with very acid bark, such as pine, spruce or White Birch, which indicates sensitivity to acidity (COSEWIC 2002).

Dispersal and Migration

The spores produced in asci within the apothecia of *E. pedicellatum* are simple and colourless. After being ejected they must land on favourable micro-habitat and find a compatible cyanobacterial partner in order to develop into a new thallus. Yetman (1999, 2000) demonstrated that the spores of *E. pedicellatum* are ejected either individually or as groups of 8. Viable spores of some species like *Xanthoria parietina* are ejected at any time of year (Christmas 1980) but those of other lichens such as *Rhizocarpon lecanorinum* have a peak of release at specific times of the year, often the spring (Clayden 1997). Maass and Yetman (COSEWIC 2002) suggested that it is unlikely for *E. pedicellatum* spores to be ejected during the drier summer period but no experimental work has been done.

Spore Dispersal: Wind

Once ejected a few centimetres into the air, lichen ascopores can be carried by strong winds up to a few hundred metres into adjacent woodlands (Scheidegger 1996). The prevailing windstorms on the Avalon Peninsula of Newfoundland blow either from east to west (during the winter months) or in the opposite direction from southwest to northeast (during the summer months). A seasonal variation in prevailing wind direction has also been recorded for Cape Breton Island (data from the Point Aconi Weather Station (Maass and Richardson 1994)). On the mainland of Nova Scotia, e.g., in Halifax County, the winds often come from the north quadrant (during the winter) or from the south quadrant (in the summer and during the hurricane season).

Spore Dispersal: insects.

Maass and Yetman (COSEWIC 2002) suggested that arthropods may be vectors that assist the dispersal of *E. pedicellatum* ascospores*.* This was shown in laboratory experiments where fruit fly (*Drosophila melanogaster*) larvae were allowed to mature and roam for 48 hours in an experimental chamber containing a mature thallus of *E. pedicellatum*. The fruit flies were anaesthetized and viewed under a scanning electron microscope. Spores of *E. pedicellatum* were found adhering to the leg bristles of several fruit flies. These findings were confirmed in the field during the summer of 2001 in mature forest stands in Lockyer's Waters, eastern Newfoundland. Spores of *E. pedicellatum* were identified using SEM on the segmented antennae of *Anapsis rubis*, a small flying beetle (Yetman, pers. comm.). Thus, insects or mites may be important vectors for dispersing viable spores to remote forest stands (Goudie *et al.* 2011). Such dispersal by arthropods could account for the often disjunct nature of *E. pedicellatum* occurrences in the forest landscape.

The preliminary success of transplanted thalli in eastern Newfoundland (Goudie and Jones 2012, 2013) supports the contention that dispersal is a limiting factor for *E. pedicellatum* populations (Sillett *et al.* 2000). It may also indicate a substratum limitation for young "germinants" that might not apply to fragments of older individuals stapled to the trees.

Interspecific Interactions

There appears to be an intricate interplay between the lichen *E. pedicellatum* and several other organisms. The role of *Frullania* is mentioned above (See Life Cycle and Reproduction, above). However, this liverwort can also have a negative effect by overgrowing thalli. Thus, in Newfoundland, 64% of thalli on trunks in the Bay d'Espoir area and 78% of thalli in Hall Gullies were overgrown by this liverwort or by other lichens (Hanel pers. comm). Thalli growing on branches were overgrown less frequently than those on the trunks of trees. In Nova Scotia, Cameron and Neily (unpub. data) examined digital photographs of 31 thalli to determine which epiphytic species might compete with *E. pedicellatum* on tree boles. They found 5 species of lichens (*Parmelia sulcata, Hypogymnia physodes, Platismatia glauca, Cladonia spp., Bryoria* spp*.*) and 2 species of bryophytes (*Frullania tamarisci, Porella platyphylloidea*) had grown over lobes of *E. pedicellatum*. In Newfoundland, *Frullannia tamarisci*, as well as *Platismatia*, *Hypogymnia* and *Parmelia* were found to be the main overgrowing species. Several species of crustose lichens were also observed to be overgrowing or parasitizing *E. pedicellatum* (Hanel pers. comm).

Many groups of arthropods are known to graze lichens including Tardigrades, Thysanurans, Collembolans, Psocopterans, Lepidopteran larvae and orbatid mites (Sharnoff and Rosetreter 1998). Many are endemic to old-growth forests (Thompson *et al.* 2003; Desponts *et al.* 2004). Of 105 *E. pedicellatum* thalli monitored in Nova Scotia between 2004 and 2009, 29% showed evidence of grazing. Grazing patterns were typical of small invertebrates such as orbatid mites or Collembola. Goudie (2011a) noted high rates of browsing on the surface of lobes by arthropods (likely mites) on thalli in eastern Newfoundland. Recently, studies of transplanted thalli in eastern Newfoundland indicated that browsing rates were much higher on transplants in areas with no previous presence of *E. pedicellatum*, compared with transplants in areas with a previous presence of *E. pedicellatum* (Goudie and Jones 2012).

Collins (2014) noted that nematodes and smaller tardigrades were feeding directly on *E. pedicellatum.* The larger tardigrades such as *Macrobiotus hufelandi* and *Milnesium eurystomum* documented in Long Harbour, Newfoundland may control the numbers of potentially harmful herbivorous nematodes and tardigrades like *Echiniscus merokensis* and *E. wendti* which feed directly on the lichen using their stylets. The meiofauna and flora of old-growth temperate Balsam Fir 'rainforests' is likely unique (see Thompson *et al.* 2003; Collins 2014) and maybe important in the life history of *E. pedicellatum* (See Dispersal section above).

Gastropods are another animal group associated with lichens (Sharnoff and Rosetreter 1998). Cameron (2009a) found three species of gastropod feeding on cyanolichens in Nova Scotia. *Pallifera dorsalis* is a small native slug; *Arion subfuscus* and *Deroceras reticulatum* are larger aggressive species introduced from Europe. Cameron found all three species on the Eastern Shore of Nova Scotia feeding on several rare cyanolichens including *E. pedicellatum* and *Coccocarpia palmicola*. Only 20% of the arboreal slugs found were the native *P. dorsalis,* the remainder were mostly *A. subfuscus* (70%) and a few were *D. reticulatum.* These alien slugs may pose a problem to this lichen as they become widely dispersed due to increased human activity in forests. In Nova Scotia, of 449 thalli monitored between 2004 and 2013, 24% had evidence of grazing. The area of grazing ranged from about 4% to 99% of the thallus surface with a mean area of about 24% (Mersey Tobeatic Research Institute Boreal Felt Lichen Monitoring Database 2013).

In Newfoundland, *E. pedicellatum* thalli were examined at all monitoring sites for grazing/browsing on a scale of 1-3, but in most cases it is was unclear whether the damage was caused by arthropods or gastropods. It is not known whether the latter may have been native or introduced species, although Moss and Hermanutz (2010) found 90% of their captured slugs in Terra Nova National Park, were non-native species. In Bay d'Espoir grazing was observed on almost half of the thalli, but only a very small proportion (5.7%) of the thalli were severely grazed. Thalli on branches appear to be somewhat protected from grazing, with almost 70% of branch thalli unaffected, and only 2.8% severely grazed. Of the thalli on trunks 37% were completely ungrazed and 9.4% were severely grazed. In Halls Gullies on the Avalon Peninsula, where almost all thalli are on trunks, the incidence of grazing in general, and severe grazing in particular, was even higher (Hanel pers. comm. 2014). Even heavy grazing may not always result in mortality but the correlation between grazing and increased necrosis or mortality needs to be studied.

POPULATION SIZES AND TRENDS

Atlantic Population: New Brunswick

Sampling Effort and Methods

Searches by lichenologists over the last decade for *E. pedicellatum* on Campobello Island and all along the Fundy Coast and islands of southern New Brunswick have failed to find the lichen. It has not been seen in the province since the early 20th century (Cameron et al 2009).

Abundance

About ten thalli of *E. pedicellatum* were documented in 1902 from the original collection locality on Campobello Island in Passamoquoddy Bay. No thalli have been found at the type locality since the original collections even though searches have been extensive, especially since the locality became widely known as a result of the publication by Jørgensen (1972).

Fluctuation and Trends

Erioderma pedicellatum is believed to be extirpated from New Brunswick. Acid rain and fog and air pollution have likely to have acidified the tree bark there to the point where the lichen cannot survive (New Brunswick Department of Natural Resources 2007).

Rescue Effect

There are no known populations in the northeastern USA, thus there is no chance of rescue effect from there. Rescue is conceivably possible from Nova Scotia. The most likely occurrence would be from Chignecto Provincial Park; however, recent surveys from this area have failed to relocate any occurrences there. Rescue from elsewhere on the Atlantic coast of Nova Scotia seems unlikely because of the large dispersal distance and lack of suitable habitat in between.

Atlantic Population: Nova Scotia

Sampling Effort and Methods

All occurrences found in Nova Scotia since 2003 and 10 thalli from an historical occurrence have been revisited (by T. Neily) every 12 months. Occurrences were permanently marked by staking and tagging all trees hosting *E. pedicellatum*, and recording position (height and orientation) of thalli on trees. Detailed GPS data ensured that thalli can be relocated if still present. Annual data recorded includes size (height and width) and health conditions of individual thalli (amount of grazing, necrosis, and attachment to substrate).

Abundance

There are 317 thalli currently known to occur in Nova Scotia at 31 occurrences. At least 19 (6.9%) of the 317 thalli are juveniles, while the remainder are adults (Appendix Table 1). The number of locations is less than twenty. Each is subject to different patterns of ecological and anthropological threats (see Locations and Threats Sections below).

Fluctuation and Trends

Population trends for Nova Scotia were calculated from monitoring data collected since 2003 (Cameron *et al.* 2010). New juveniles discovered as a result of searches were considered recruits to the population. Thalli that could not be relocated or thalli with most of the surface grazed or necrotic were considered deaths. Annual rate of change at year t was calculated as:

$$A_t = ((NJ_t - D_t)/P_t)*100$$

Where: A_t is annual rate of change of the population at end of year t;
NJ_t is number of new juveniles discovered during year t;
D_t is the number of deaths that occurred during year t and
P_t is the known population at the beginning of year t.

The 10-year decline was calculated first by calculating the decline rate for the monitoring period (2003 to 2011), and then dividing this by the length of the monitoring period (8 years) to get an annual rate of decline. The annual rate of decline, r , was used to calculate the 10-year decline as:

$$10 \text{ year decline} = (100 - r^{10})*100$$

New thalli have been discovered every year since 2003 but previously discovered thalli continued to die. Less than half the number of new juveniles (n = 19) were found in comparison with the number of thalli that died (n = 50) during the monitoring period. The population experienced an increase in annual rate of change in 2006 and 2007, but there has been an increasing annual decline since then (Figure 6). The annual rate of decline is -1.364% and the 10-year trend for Nova Scotia was calculated as r = 0.1284. Thus, based on this, the decline in the number of mature individuals over last ten years is 12.8%, while the decline over two generations is 42%. When extrapolated to three generations, 60 years, the above decline rate indicates a projected reduction of 56% in the number of mature *E. pedicellatum* individuals.

There is also a trend in declining number of occurrences supporting *E. pedicellatum* as eleven of the 41 occurrences found between 2003 and 2011 are now extirpated. Most of the 41 new occurrences have likely existed for some time but were previously undiscovered. The evidence for this is that the occurrences are dominated by adult thalli with abundant fruiting bodies indicating older individuals. The only exceptions were the Melvin Lake occurrence, which had a higher proportion of juveniles than adults. The decline in occurrences is a 24% decline over 8 years or a 10-year decline of <30%. Eighteen historical occurrences, previously documented by Maass (COSEWIC 2002) were revisited between 2004 and 2010. Only one occurrence, Jacket Lake, had thalli and these had all died by October, 2008.

Cameron *et al.* (2010) reported that two occurrences were extirpated due to grazing, two to adjacent forestry and at least one to the effects of acid rain. Half the thalli that had died between 2003 and 2009 died from unknown causes. Such unknown mortality may be linked to adjacent forestry operations because there was a significant relationship between forestry and mortality for *E. pedicellatum* thalli that were studied over a period of years (Cameron *et al.* 2010, 2013a).

With respect to the new thalli discovered in Nova Scotia, most are thought to be previously overlooked as only a portion of the potentially suitable habitat has been surveyed. In Nova Scotia a heuristic model has been used to help find new sites See discussion below (Threats and Limiting Factors, Commercial Forestry, Nova Scotia).

Rescue Effect

Rescue in Nova Scotia, from the island of Newfoundland, is unlikely because of the large dispersal distance and is impossible from New Brunswick or the adjacent states of USA because the lichen has not been found there despite recent surveys.

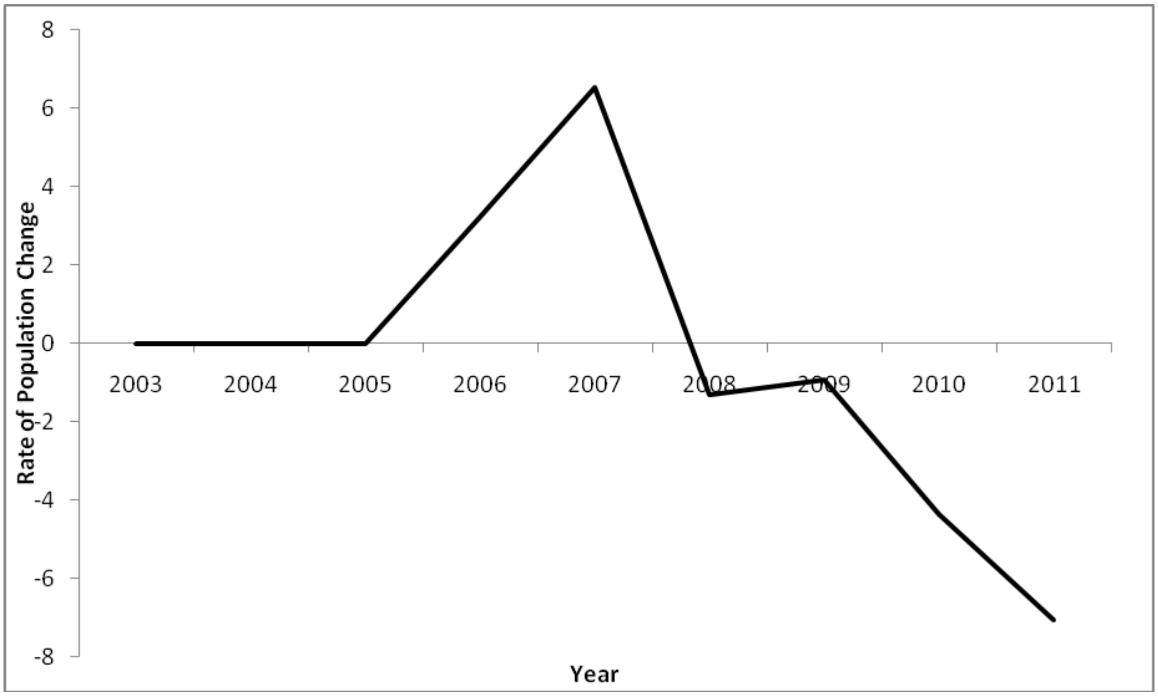


Figure 6. Rate of change of population of *Erioderma pedicellatum* in Nova Scotia.

Boreal Population: Newfoundland

Sampling Effort and Methods

Considerable fieldwork has been completed searching for *E. pedicellatum* on the island of Newfoundland since its status was assessed (COSEWIC 2002). This has been carried out by the Department of Environment and Conservation (Wildlife Division and Parks and Natural Areas Division) (McCarthy 2010); the Department of Natural Resources (Forestry Branch) (Clarke 2005a,b,c; Clarke and Roberts 2008); the Miawpukek First Nation (MFN); Memorial University of Newfoundland (Yetman 2000, Munier 2008; Siegwart 2009; Wiersma and Skinner 2011) and the Newfoundland Lichen Education and Research Group (Goudie 2008b; Goudie and Munier 2007a,b; Goudie 2009a,b; Goudie 2011a; Goudie *et al.* 2010; Goudie and Jones 2012, 2013). Thallus numbers continue to increase with search effort. In some areas, such as Lockyer's Waters an asymptote was reached after a few years, but in the Halls Gullies area of the central Avalon Peninsula and in the Bay d'Espoir area new sites are still being discovered after 5 to 15 years of searching. In both of these areas, sites have coalesced into a limited number of large occurrences spanning several square kilometres. This has made interpretation of population trends much more difficult.

Abundance

Maass and Yetman (COSEWIC 2002) reported a total count for the island of Newfoundland of just under 6,900 thalli. More recently, the Department of Environment and Conservation reported 12,660 thalli in the Newfoundland and Labrador Wildlife Division database (Appendix Table 3), with about 65% of known occurrences being on unprotected Crown land. Many of the thalli listed in the database are no longer likely to be present as some records date back 10 to 20 years. On the other hand, an unknown, but substantial, amount of suitable habitat remains unexplored in remote areas of southern Newfoundland. The Natural Resources suggests that the number of thalli could be as high as 20,000 if all possible habitat were surveyed (Adams pers. comm.). Clearly more studies are needed to resolve the size of the current population. The best conservative estimate for the number of mature extant thalli is 15,000 thalli of *E. pedicellatum* for the island of Newfoundland.

Fluctuations and Trends

The application of autological regression models has revealed annual mean declines for *E. pedicellatum* of about 15% per year for 2005 to 2011 at Lockyer's Waters and at Long Harbour for 2008 to 2011. However, monitoring by the Newfoundland Department of Environment and Conservation in southcentral Newfoundland suggests a slower rate of decline and at most monitored occurrences it may be as low as 5% per year. Further details are provided below and in Appendix Table 3.

Monitored Occurrences

1. Eastern Newfoundland: Lockyer's Waters

Important long-term research continues in the occurrences at Lockyer's Waters, which acts as a control site for the Long Harbour occurrence where a nickel processing facility has been constructed and is scheduled to begin operations in 2014 (Goudie 2009a, Goudie and Jones 2012, 2013). Surveys of the sites at an occurrence in Lockyer's Waters, eastern Newfoundland for *E. pedicellatum* were repeated in 2005, and results were compared with data from 1997, 2002 and 2003 (Goudie and Conway 2005). Declines indicated previously for 1997 to 2003 (C-CORE 2004) continued in 2005. Goudie and Conway (2005) reported that there was little regeneration of *E. pedicellatum* within the stands previously identified although 15 new trees with 18 thalli (1.2 thalli per tree), and 7 new trees with 11 thalli (1.6 thalli per tree) at two separate sites were added to the database. Because new finds were generally adult specimens it was concluded that these were previously present but not detected. Goudie and Conway (2005) were not successful at locating new sites within the proximity (< 500m) of established occurrences.

Demographic monitoring commenced in 2005 by applying a protocol reported in detail elsewhere (Goudie *et al.* 2011). The projected annual (fall to fall) population growth rates for the Lockyer's Waters were negative (n = 6 years) with a mean annual decline of 0.1587 + 0.078 (SD). There was not a large annual variability in the projected annual population growth rates which have been documented for 8 years (see Goudie and Jones 2012, 2013). Recruits per adult demonstrated a declining trend in Lockyer's Waters from fall 2005 to fall 2011 (Figure 7). Nevertheless, elasticity analyses suggested that population growth rate was mainly influenced by adult survival (Goudie *et al.* 2011).

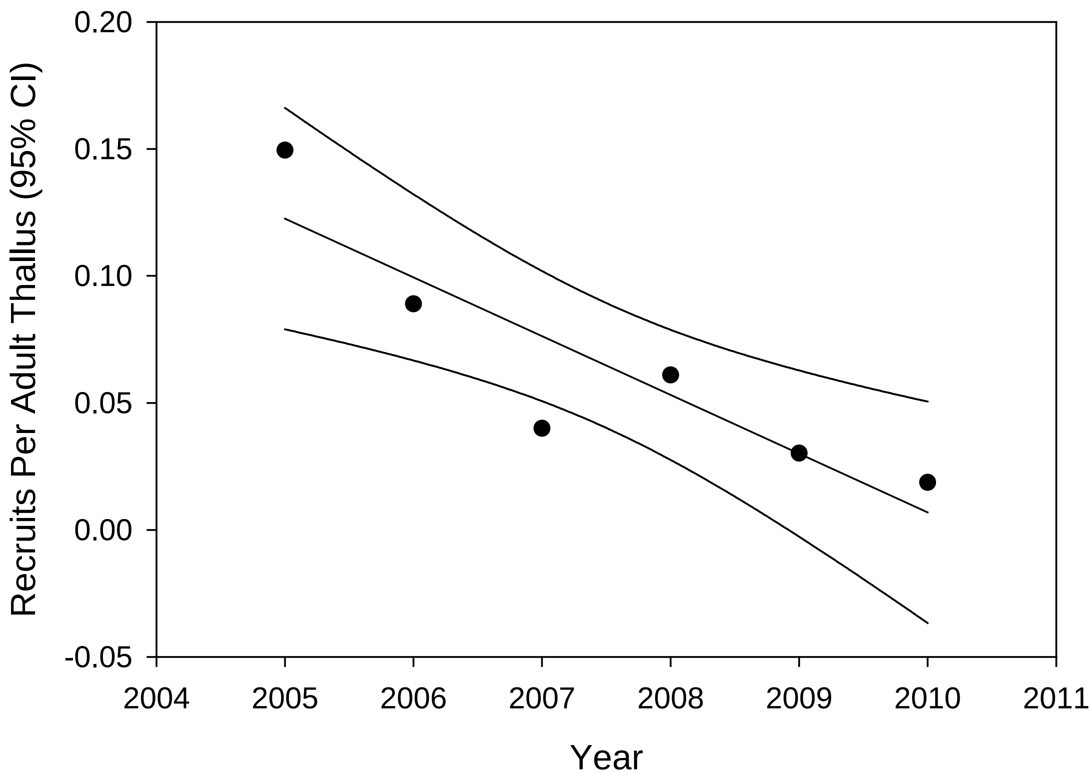


Figure 7. Recruits per adult thalli of *Erioderma pedicellatum* on tagged trees at Lockyer's Waters, eastern Newfoundland, fall 2005 to fall 2011.

2. Eastern Newfoundland: Southeast Placentia

Goudie and Conway (2005) reported on a small concentration of thalli in the Southeast Placentia area approximately 50 km southwest of Lockyer's Waters, expanding the findings of Maass and Conway (2004). In October and November 2005, 27 trees with 60 thalli (2.14 thalli per tree) were documented, but by the spring 2006 this population had declined by 33.3% to 40 thalli (Goudie and Conway 2006). For fall 2006 to spring 2007, a 12.7% decline was reported (Goudie and Conway 2007b), and for spring 2007 to fall 2007 a further 9.1% decline (Goudie and Conway 2008).

3. Eastern Newfoundland: Long Harbour

In spring 2006, extensive ground-based surveys were done in the Long Harbour area of Placentia Bay, Newfoundland. These found *E. pedicellatum* in the general project area of the proposed Nickel Processing Plant proposed by INCO Ltd (Goudie *et al.* 2006). Following from the Environmental Impact Statement, the proponent initiated biannual demographic monitoring of *E. pedicellatum* in spring 2008 in Long Harbour. Of ninety-five thalli monitored at Long Harbour in spring 2008, three (4.5%) were not found and presumed dead in fall 2008 (Goudie 2009a). Demographics analyses similar to those conducted for Lockyers Waters and Southeast Placentia revealed annual population declines of - 0.113, - 0.159, - 0.261 for the periods fall 2008 to fall 2009 (Goudie *et al.* 2010), fall 2009 to fall 2010 (Goudie 2011a), and fall 2010 to fall 2011 (Goudie and Jones 2012), respectively. Recruits per adult were reported as 0.033, 0.043 and 0.092 for 2008-2009, 2009-2010, and 2010-2011, respectively. These patterns of declines were similar to the control site at Lockyer's Waters (see above). Additional occurrences of *E. pedicellatum* on the Avalon Peninsula include sites supporting smaller numbers of thalli that are also in apparent decline (Appendix Table 2).

4. Eastern South Central Newfoundland: Bay d'Espoir

The application of the standard protocol for demographic monitoring to eight Bay d'Espoir sites also detected a low proportion of juveniles and low rates of recruitment as at Lockyer's Waters. Negative projected population growth rates based on one annual cycle by Goudie *et al.* (2011) have been confirmed for 6 years (spring 2007 to spring 2013) by the Department of Environment and Conservation with mean lamda (λ) as 0.9387 per year (Squires 2014). At one occurrence a recruitment pulse has occurred but its contribution to the maintenance of the population needs to be assessed with the passage of time. The optimistic outlook for the *E. pedicellatum* in southcentral Newfoundland reported by COSEWIC (2002) requires to be confirmed.

Although monitoring in Bay d'Espoir indicates a declining population, the Department of Environment and Conservation believes that the monitoring protocol may not capture all new recruits as the search for them has been inconsistent, and in most cases minimal and restricted to the already-tagged trees. Because of this, an intensive search was carried out in spring 2012 at the 5-year mark of monitoring. To obtain a rough standardization with respect to population size, the number of tagged trees at each site was multiplied by four, and this number of untagged trees was searched, mostly for the first time since monitoring commenced five years earlier. At five sites between 1 and 7% of the searched trees were found to be occupied by *E. pedicellatum*. At the sixth and seventh sites the number of additional occupied trees found was between 20 and 30% of searched trees, and approached or even exceeded the number of already-tagged trees. At the sixth site large numbers of previously undetected thalli were found but the life-stage distribution of the "new" thalli resembled that of the rest of the site. This indicated that the new discoveries were actually a lateral site expansion into previously unexamined areas. At the seventh site 53% of the new thalli on the newly discovered host trees were juveniles (as compared to 0 to 39% at the other sites). This indicated that a recruitment pulse had taken place in the 5 years and this recruitment was concentrated on the new trees. Finally at an eighth site the search was not completed. A large proportion of the recruitment pulse could not be enumerated or included in the population model because thalli were located too high in the trees to determine the life stage with confidence. Squires (2014) concluded that 175 recruits per year are required at the 8 sites combined for a stable population under the best case scenario. If the missing thalli were dead, the number of recruits necessary for a stable population increased to 425. It is believed that due to their small size many new recruits appear and die undetected and only a proportion survive to the Juvenile-two and adult stages, where they are more likely to be recorded.

The results from the recent intensive research demonstrate that recruitment pulses are possible and may be responsible for the majority of recruitment. However, the frequency, magnitude and distribution of these pulses is not yet known. It cannot be assumed that the population of *E. pedicellatum* is stable until large numbers of recruits are consistently found to appear and survive. Thus, research needs to be continued for a much longer time period and in more sites to overcome the weaknesses of the monitoring program.

Trend Observations Based on Resurveys

Resurveys have been informally conducted at a number of *E. pedicellatum* occurrences in Newfoundland after various time intervals. Declines, some of them precipitous, were reported for the majority of them. Resurvey data for nine occurrences were examined by the Newfoundland Department of Environment and Conservation (Appendix Table 2). Only occurrences where it was believed that 90% of the previously marked trees were relocated were considered, and both the initial and final survey had to be known to be thorough, and not confined to only previously marked trees. Some of the sites were later included in the monitoring program, and in this case the trend reported in Appendix Table 3 only applied to the period before the initiation of regular monitoring. For sites with a mixed trend history only the most recent trend direction was considered.

The data in Appendix Table 3 shows that at six occurrences, there was an annual decline of between -5.8% to -17.4%. Three occurrences showed an annual increase of 2.4, 2.8 and 21.9%. The largest increase of 21.9% was at Jipujijkuei Kuespem Provincial Park subsite 48 and was due to the addition of three times the original number of trees found with thalli. The other two occurrences with increases were also at Jipujijkuei Kuespem Provincial Park. However, two other subpopulations at the same park showed an annual decline of -5.8% and -10.0%.The resurveyed area at Lockyer's Waters examined by the Newfoundland Department of Environment and Conservation partially overlapped the area of study by Goudie *et al.* (2011). The annual decline of 17.4%, for the 1997 to 2005 time period, closely matches the annual decline of 15.87% found by Goudie *et al.* (2011) between 2005 and 2009.

Resurveys provide a snapshot of a small number of sites and cannot fully capture the landscape dynamic of *E. pedicellatum.* As natural forest stands age, and the number of dead trees increases, the number of thalli in an individual stand is expected to decline. Most resurveys have shown populations are declining at various rates, with some increases being observed, especially in the Bay d'Espoir area. However, the resurveys suffer from the same weakness as monitoring studies. Many of the stands that have been monitored or resurveyed have been at occurrences with large lichen populations that may have been at or near their peak at the time of discovery. It is not possible, at this time, to distinguish natural declines from declines accelerated by human actions. More studies of the smaller populations in younger stands of Balsam Fir are required to get a clearer picture of the population dynamics of *E. pedicellatum.*

Rescue Effect

The island of Newfoundland is isolated from Nova Scotia by the Gulf of St. Lawrence and Grand Banks. Dispersal of ascospores over this distance is extremely improbable and the endangered status of population in Nova Scotia is an indication of the low number of thalli and hence limited number of spores available for dispersal to any areas, let alone being carried as far as Newfoundland.

THREATS AND LIMITING FACTORS

The threats to the survival of the Atlantic and Boreal populations of *E. pedicellatum* were assessed using the International Union for the Conservation of Nature's (IUCN) Threats Calculator and the output is appended to this status report. The threats to the Atlantic Population were assessed as very high to high while the threats to the Boreal Population of this species were assessed as high. The major threats faced by the two populations of *E. pedicellatum* are discussed in the following subsections.

Effects of Moose Herbivory

On the island of Newfoundland several rare cyanolichens colonize Balsam Fir. There is a population of approximately 117,000 moose on the island of Newfoundland (Newfoundland and Labrador Dept. of Environment and Conservation, unpub. data). The continuity of Balsam Fir forests has been compromised by extensive moose browsing. The effects of moose browsing in Newfoundland have been evaluated by Bergerud *et al.* (1968), Thompson and Curran (1993) and McLaren *et al.* (2004). The moose inhibit regeneration of Balsam Fir seedlings in canopy gaps left by dead and collapsing trees, some of which host thalli of *E. pedicellatum* (Goudie *et al*. 2011). Due to the intensity of browsing, the mixed coniferous woodlands are gradually being converted into forests in which spruces are the dominant species. This reduces the continuity of viable habitats for *E. pedicellatum* and its associated rare lichens (Goudie 2011b) (See Special Significance). The effect of severe moose browsing on Balsam Fir is particularly evident in Lockyer's Waters but it has also been observed in other *E. pedicellatum* occurrences on the Avalon Peninsula.

Commercial Forestry

Newfoundland

Commercial forestry continues, but has been reduced as two paper mills have closed in the last eight years (2006 Stephenville and 2009, Grand Falls). Furthermore, in an effort to mitigate the impact of commercial harvest where *E. pedicellatum* occurs in Newfoundland, preharvest surveys have been done since 1997 for this lichen prior to harvesting. An uncut buffer of 20m is left around trees known to be occupied by *E. pedicellatum*. The large area and dispersed activity where domestic cutting is taking place for firewood and other purposes in Newfoundland means that preharvest surveys for the presence of *E. pedicellatum* are not feasible everywhere. Surveys are not mandatory (prescribed by law), but are currently done prior to commercial cutting in areas with a high density of *E. pedicellatum* (Regions 1 and 7). Hence it is likely that some sites where this lichen occurs are being lost each year (Hanel pers. comm.).

The use of rotations modelled on the lifespan of Balsam Fir, on higher quality sites, indirectly targets over-mature stands and this is reducing optimal habitat for rare biota including *E. pedicellatum*. The 2013 Sustainable Forest Management Strategy (SFMS) provides a policy for conserving of a minimum of 20% of old Balsam Fir forests and their associated biodiversity. Roberts (2012), in a review of occurrences in Newfoundland, argues that *E. pedicellatum* is less susceptible to forestry impacts than previously indicated by Maass and Yetman (COSEWIC 2002) and Goudie (2011a). However, Roberts' evidence is not strong because the occurrences studied were not surveyed prior to the human activity. Old stumps present at a number of *E. pedicellatum* occurrences in the Bay d'Espoir area indicate that *E. pedicellatum* can regenerate in stands where forest harvesting has taken place, but it is unknown whether it was the small scale of the clearcutting or partial cutting that maintained some canopy cover and perhaps a spore source within the stand. On higher capability sites, a minimum of 20% of the oldest growth is currently left on site, projected over a 160-year modelling period (Provincial Forest Management Strategy, and District Plans).

Where natural regeneration is impeded by moose browsing, planting of Black Spruce and White Spruce or mixtures of Red Pine, White Pine and Eastern Larch has been done. Some infilling with Balsam Fir has been observed by DNR staff, but it is unlikely that the proportion of Balsam Fir at maturity will be as high as prior to harvest. As a result, the potential habitat for the cyanolichen community, which includes *E. pedicellatum*, will be reduced because younger even-aged stands do not provide suitable light conditions for *E. pedicellatum* (COSEWIC 2002). The habitat reduction caused by planting non-host species is probably minimal but should to be quantified.

Nova Scotia

In Nova Scotia, Cameron *et al.* (2013a) found a significant relationship between *E. pedicellatum* mortality and adjacent forestry, and forestry in the landscape. Occurrences where dead thalli were found had significantly higher cumulative areas of adjacent harvesting and significantly greater area of harvest in the landscape than occurrences without mortality. They suggest that adjacent tree harvesting can increase solar radiation, wind, and temperature, which have a negative effect on *E. pedicellatum* survival. Effects of commercial forestry on other lichens have been well documented in temperate and boreal regions (Esseen & Renhorn 1998, Kuusinen 1994, Lesica *et al.* 1991, Pettersson *et al.* 1995) including Nova Scotia (Cameron 2002). Edge effects have been shown to impact fruticose lichens up to 50 m from an edge (Rheault *et al.* 2003; Esseen & Renhorn 1998) and microclimate effects have been found as far as 240 m into the forest from the edge (Chen *et al.* 1992). The presence of logging immediately adjacent to the reserve boundary, and the subsequent desiccation of habitat was one of the suspected causes for the eventual extirpation *E. pedicellatum* in Varmland, Sweden (Ahlner 1948; Purvis 2000). Cameron *et al.* (2013b) found that habitat in Nova Scotia is being harvested faster than can be regenerated. They suggested a 12% decline in the amount of available habitat between 1988 and 2005 and a projected 25% decline between 2005 and 2055 if harvest patterns remain the same.

Preharvest surveys for *E. pedicellatum* are done only for Crown land and for some large private areas such as those owned by Northern Pulp. The surveys started in about 2005 but were not fully instituted until about 2008. However, the currently required buffer zones in Nova Scotia are 100m around each *E. pedicellatum* occurrence. When the occurrence is in a peatland, a 20 m buffer zone is also to be maintained around the peatland and all buffer zones are to be clearly flagged (Nova Scotia DNR 2012).

Atmospheric Pollution

Lichens, particularly cyanolichens, are one of the groups most sensitive to air pollution and acid rain (Geiser *et al.* 2010, Glavich and Geiser 2008, Showman and Long 1992, McCune 1988, Hawksworth and Rose 1976, Ammann *et al*. 1987, Hultengren and Gralen 2004, Ruisi *et al.* 2005).

Acid Rain and Acid Fog

Although air pollution has been decreasing in Atlantic Canada over the last 2 decades, transboundary air pollution in the form of acid rain and acid fog is still affecting the environment (Canadian Council of Ministers of the Environment, 2011, 2013, Cox *et al.* 1989). Cyanolichens are extremely sensitive to acid rain (Richardson 1992, Richardson & Cameron 2004). Already naturally acidic substrata can be further acidified by acid rain thereby overwhelming the buffering capacity of the bark (Nieboer *et al.*, 1984). Other cyanolichens associated with habitats supporting *E. pedicellatum,* such as *Coccocarpia palmicola* and *Erioderma mollissimum*, are also sensitive to air pollution (Gauslaa 1995). Acid rain may contribute to an acceleration of the partial die-back of *E. pedicelletum* thalli observed by Goudie *et al.* (2011). The loss of thalli begins with a central necrotic zone and eventually spreads in all directions (Moberg and Holmasen 1982). However, a causal relationship between acid rain and necrosis has not yet been established with certainty in Newfoundland.

Acid fog is even more of a problem than acid rain because plants remain enveloped in fog for extended periods of time (Cox *et al.*1998; Kouterick *et al.*1998). This could be the major factor leading to the gradual disappearance of sensitive cyanolichens from southern Nova Scotia and the Bay of Fundy regions of New Brunswick and Nova Scotia. In the Bay of Fundy region the average fog pH was 3.6, one pH unit lower (i.e. ten times more H^+ ions) than the average rain in the same area. Nova Scotia is prone to acid fog because it is 'downwind' of cities such as Boston and New York as well as industrial centres of the northeastern U.S.A. and southern Ontario. In Newfoundland, long-range transported air pollution is ameliorated by marine aerosols and is far less significant than pollution from local sources.

Sulphur Dioxide

Cyanolichens are particularly vulnerable to sulphur dioxide because the nitrogen-fixing enzyme, nitrogenase, contained in the thalli, is remarkably intolerant of this pollutant (James 1973 Farmer *et al*. 1992). In Nova Scotia, the impact of sulphur dioxide *on E. pedicellatum* may be less than that of acid rain. Studies from Ireland suggested critical values of 10µg/m^3 for lichen containing cyanobacteria (Richardson 1992). Cameron *et al.* (2007) found no cyanolichens present in the Halifax area, and suggested a critical limit of less than 18.62µg/m^3 for these lichens in Nova Scotia.

In Newfoundland sulphur dioxide levels are lower than in Nova Scotia. For example, St John's and Corner Brook report a mean of 3.7 and 3.2µg/m^3 for February 2012 (Newfoundland Department of Environment and Conservation 2012). Nevertheless, local sources of sulphur dioxide pollution are a concern for some populations of *E. pedicellatum* near the Come by Chance Refinery, the Holyrood Generating Station, the Long Harbour nickel processing facility and the liquid natural gas plant in eastern Newfoundland as well as the Pulp and Paper Mills on the West Coast (Wadleigh & Blake 1999; Goudie 2011c).

Forest Pests and Aerial Sprays

In Nova Scotia, spruce budworm outbreaks on Balsam Fir are forecast to occur in the near future as part of the natural cycle. High mortality of the trees is expected so there will be increased pressure to use pesticides to control the insect. The upper cortex of *E. pedicellatum* does not appear to have significant water-repelling properties so that its cyanobacterial layer could be readily accessible and harmed by droplets containing chemicals. Newmaster *et al.* (1999) found lichen and bryophyte abundance and diversity were reduced by two common silvicultural herbicides on plots in Ontario.

In Newfoundland, the pesticides trichlorfon and azadirachtin (an extract from the Indian Neme tree *Azadirachta indica*) are no longer used and have been replaced by the biological agent *Bacillus thuringiensis* (BT), which is used for the control of the Hemlock Looper and other moths. Areas in the Bay d'Espoir region experienced an upsurge in hemlock looper and tussock moth in 2013 but the known *E. pedicellatum* sites were not affected. While there may be some interaction between the BT spray and the microfauna associated with *E. pedicellatum*, a direct effect on the lichen is most unlikely.

Droughts and Hurricanes

Extreme weather events, such as drought or windstorms, can affect populations of *E. pedicellatum*. Prolonged periods of drought may lead to the death of thalli through exposure to heat-induced desiccation. The susceptibility of *E. pedicellatum* to desiccation may be the result of an upper cortex that lacks a vapour barrier (Piervittori *et al.* 1997) so that the thalli lose water faster than other lichens during dry weather (Fos *et al*. 1999). *E. pedicellatum,* like several other cyanolichens occurring mainly in coastal fog forests, is a very drought-sensitive species (Gauslaa & Solhaug 1999).

Erioderma pedicellatum can be severely affected by high winds along the edges of the forests causing tree falls (Boyce, 1988). One storm that moved across the Avalon Peninsula from the northeast in November of 1994 caused considerable windfall in Salmonier Nature Park (SNP), the Lockyer's Waters Area and in the Halls Gullies area. It caused about 2,000 hectares of forest blowdown in Ecoregion V alone. The hurricanes in 2011 and 2012 also caused considerable windfalls in these areas. There was also an extensive blowdown from hurricane force winds in the Long Harbour study area (Goudie and Jones 2012).

In Nova Scotia, high winds are also a problem. At least one of the original habitats, Jacket Lake, supporting *E. pedicellatum* was destroyed by a severe storm that caused extensive windfalls when it hit the eastern shores of Guysborough County near Wine Harbour.

Climate Change

Birch die-back in Eastern Canada and in the adjacent parts of the U.S.A. has been viewed as a direct result of climate change associated with global warming (Auclair 1987, Auclair *et al.* 1992 and the review by Braathe 1995). The effects of climate change upon lichens are not as easy to measure. Research is needed to assess the degree to which *E. pedicellatum* declines in the Avalon peninsula, Newfoundland, are linked to changes in the overall climate, to the microclimate where the lichen occurs, or both. Preliminary analyses of fog frequency along the Atlantic coast of Nova Scotia indicate that a significant decline has occurred over the past several decades (Beauchamp *et al*. 1998, Muraca *et al*. 2001). However, the data for the Avalon Peninsula in Newfoundland were less conclusive; the first author documenting an increase in hours of fog, and the second a decrease in the number of days with some observed fog. If the number of fog-days continue to decline, *E. pedicellatum* is likely to be negatively affected.

Bourque *et al*. (2010) suggested that Balsam Fir will decline in area of occupancy in Nova Scotia as a result of a warming climate. They used spatially explicit modelling that relates modelled climatic variables and potential tree and shrub species' response to potential species' distribution. The models suggest that Balsam Fir will retreat to the coolest parts of Nova Scotia, and its distribution will decline from 99% of the province to 7% by 2100. This would severely limit available habitat as Balsam Fir is the only substratum currently used by *E. pedicellatum* in Nova Scotia, and is the predominant host tree in Newfoundland.

Effects of the Microfauna Herbivory

Mites and springtails often feed on lichen. Browsing by gastropods can also lead to partial removal of the upper cortex and the photobiont layer beneath. In Newfoundland herbivory on *E. pedicellatum* thalli is often observed, but the proportion attributable to mites and to slugs is not known. Grazing by non-native aggressive gastropods maybe a serious problem in Nova Scotia (See: Interspecific Interactions).

Land Development and Road Construction

In Newfoundland, the area where *E. pedicellatum* is found at Lockyer's Waters is surrounded by cottage country (with over 1,500 cottages). Trees around most cottage sites are cleared and/or pruned or thinned. *E. pedicellatum* depends on old forest or forests with old trees, which are reduced by these activities (Goudie 2011c). The cottage industry is also making the more remote parts of the forests more accessible for tree cutting for domestic purposes, recreational activities such as all-terrain vehicles, trail construction, and increased vehicle traffic (Brawn and Ogden, 1977). Increased cottage development can result in development of informal ATV trails through *E. pedicellatum* habitat but this is not compliant with the Crown lands registration process. *E. pedicellatum* has been found within the area of the former Salmonier Correctional Institute where cottage developments are happening. A stewardship approach is being tried with cottage owners in an attempt to protect the habitat and *E. pedicellatum.* In this area, the effect of the nearby cottages will be evaluated (Hanel pers. comm.).

The Newfoundland and Labrador Department of Natural Resources (Anon. 2006) estimates a conversion rate of forest to other uses (cottages, agriculture, residential, roadways and other) of about 240 ha annually in the Avalon Peninsula. This trend will likely increase in the next few years but the percentage of *E. pedicellatum* habitat affected is believed to be small. Other human-caused disturbances include road construction which allows access to forest. Forest harvesting began soon after the opening of the Burgeo Road. However, developments, from short access roads to the Long Harbour Nickel processing facility, are preceded by *E. pedicellatum* surveys if suitable habitat is believed to be present. If the lichen is found, mitigations are applied; if not present, the project proceeds. The cumulative effect of a number of projects could lead to a habitat reduction over time. Surveys of new utility corridors, in their entirety, are not possible and a small number of *E. pedicellatum* individuals and a small amount of habitat may be lost in consequence. Land development is a much less of a threat in the Bay d'Espoir area than in the Avalon Peninsula.

In Nova Scotia, cottage development is also occurring but no data is available on the rate of forest loss. In the Halifax Regional Municipality, the fastest growing community in Nova Scotia, the number of new subdivisions has more than doubled from 429 in 1998 to 883 in 2005, resulting in estimated forest losses of 700 to 5,000 ha. Road construction in the province associated with the development of subdivisions, cottages, wind farms, mines and forest harvesting can affect the microclimate of surrounding forests, reducing humidity and changing water flow and groundwater patterns which are key to the survival of *E. pedicellatum*. The renewal of gold mining activity in the province also has the potential to affect nearby occurrences where *E. pedicellatum* has been found (Anon. 2014).

Forest Fire and Fire Suppression

Due to the area's moist climate, forest fires are less common in the Avalon Peninsula than in central Newfoundland. A network of resource roads has increased the potential for human-caused fires, but fire remains a fairly minor threat. The potential for increased fire severity and spread are provided by the extensive areas of blowdown resulting from severe windstorms over the last few decades and a reduction in the hardwood component of the forest due to moose browsing.

Chemical fire retardants are not used in Newfoundland. Foam increases the wetting time of water on trees and is used in areas where the turnaround times of water bombers are long and where homes, etc. are threatened. In areas where *E. pedicellatum* populations occur, lakes are abundant and the use of foam is generally not necessary (Eric Earle, pers. com.).

NUMBER OF LOCATIONS

Locations are defined as a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the species.

Atlantic Population

There are between nine and twenty locations in Nova Scotia for *E. pedicellatum,* which occur in three main areas in distinct habitat patches, where *E. pedicellatum* populations are found clustered in small groups or as individuals. Threats such as acid rain and climate change occur over a large scale but threats such as forestry and development are much more localized. The following paragraphs list nine areas and provide information on the population of *E. pedicellatum* found and the major threat that pertains to each. The severity of the various threats was assessed as very high to high using the Threats Calculator.

Cape Breton Island

There are 142 thalli known from Richmond and Cape Breton counties on the island of Cape Breton. This is the largest and most recently discovered population in Nova Scotia. Commercial forestry is the greatest concern for this population as most of the thalli on Cape Breton Island were found as a result of pre-harvest inventories for Port Hawkesbury Paper Ltd. Pollution (SO_2) from the industrial area of Sydney may have some impact although the prevailing winds generally blow away from this area, and this may reduce the threat. Climate change may impact this population but less so than other populations in Nova Scotia because this population occurs in the area of coolest climate.

Eastern Shore

There are 154 thalli known from the Eastern Shore area in Halifax and Guysborough counties. This population has been monitored the longest and therefore there is more information known about the threats. Cameron *et al*. (2013a) found that mortality of this population was linked with high rates of forest harvesting in the landscape. Cameron (2009a) found non-native gastropods grazing *E. pedicellatum* in this area but did not assess the effect this may have at the population level. Air pollution may be a concern for this population from transboundary and Halifax City sources as the area is downwind of the sources of air pollution. A proposed gold mine within several kilometres of the nearest thalli of this population may also be a local source of air pollution once it is in operation (EAR, 2007). Because of the low buffering capacity of the bedrock, acid rain is also a threat and climate change is also a concern.

South Shore

There are 21 thalli known from the South Shore, all in Shelburne County. Climate change is likely a greater threat here than any other area because *E. pedicellatum* is at the southern extent of its range here, where warming trends in climate are especially apparent. Acid rain is a threat because of the low buffering capacity of the bedrock here, and the precipitation is frequently from continental air masses carried by the prevailing winds. Forestry is now less of a threat here than at the other two areas because of the recent closure of the local pulp mill.

Boreal Population

The number of locations on the island of Newfoundland cannot be determined easily because the threats act at several spatial scales. There is no one major threat affecting all occurrences equally or simultaneously. The severity of the various threats was assessed as high using the Threats Calculator.

Six regions where the threats are similar have been identified but the number of locations is much greater because, for example, forest logging takes place in limited areas at different times in each of the regions (See **Threats** section). Some threats, such as forest harvesting and blowdown also act very locally, at a site scale, while others, such as climate change and moose browsing, affect much larger areas. A variable level of moose browsing with the resultant negative effect on Balsam Fir regeneration is a feature of all six regions. Hence, the number of locations for *E. pedicellatum* is reported as unknown in the technical summary. A summary is included below for each of the six regions and summarizes the size of the population and the various threats faced in each area.

<u>Great Northern Peninsula</u>

Great Northern Peninsula (western slope)

Maass and Yetman (COSEWIC 2002) reported a total of 23 thalli recorded before 1995 and only 3 after 1994, all on Balsam Fir. There have been no recent observations in this area, so suitable habitat may be infrequent (Hanel, pers. comm.). No occurrences with more than 7 thalli are known (Appendix Table 2). There has been extensive industrial logging throughout much of this area. The forests are heavily impacted by browsing moose.

<u>Western South Central Newfoundland</u>

Burgeo Road (northern areas)

Maass and Yetman (COSEWIC 2002) reported 22 thalli on Balsam Fir and 1 thallus on Black Spruce between the Trans-Canada Highway and Peter Strides Pond, all before 1995.

Burgeo Road (Headlands of Grandy Brook). Maass and Yetman (COSEWIC 2002) reported 88 thalli on Balsam Fir. A partial resurvey in 2006 of one occurrence formerly containing >40 thalli revealed that the few remaining *E. pedicellatum* were in a severely necrotic state.

Pincent's Pond to upper White Bear River

Forty-two thalli have been found in this area since the last status report (COSEWIC 2002) but this region has not been revisited. There are 170 thalli currently in the database (Appendix Table 2).

The large expanses of the Maritime Barrens and Long Range Barrens Ecoregions are outside industrial logging activities. Domestic cutting occurs in more accessible regions and remote cottage development is frequent. The forests are heavily impacted by moose browsing. The area is poorly surveyed and population trends are not known.

Eastern South Central Newfoundland

The Eastern South Central Newfoundland area has been subjected to considerable industrial forestry, as well as domestic cutting. The forests are also heavily impacted by browsing moose, and are not regenerating in many areas. In spite of this, it is the only region where occurrences with an increasing population have been observed in the last 10 years (Appendix Table 3).

This area includes occurrences between Great Burnt Lake, the Twin Brooks area, Jipujijkuei Kuespem Park, Hermitage Bay and Belle Bay areas. The Bay du Nord area is also included. Some 2,671 thalli were reported on Balsam Fir and 5 on black (COSEWIC 2002). Additional surveys have greatly increased that number in the park with more being recorded from the Salt Pit-Twin Brooks area. The Miawpukek First Nation also discovered thousands of thalli in their Forest Management Area near Conne River. At the present time a total of 7,715 thalli are recorded in the Wildlife Division Database from this area (Appendix Table 2).

Salt Pit - Twin Brooks Road Population

Maass and Yetman (COSEWIC 2002) noted that this area was under intensive logging operations in the area and annual declines of 6-12% have been estimated (Appendix Table 3).

Jipujijkuei Kuespem Park Population

The population inside the park is contiguous with a number of large sites outside the park. Out of the 1,021 thalli examined in this area, 338 (33.1%) were reported as juvenile, which is an exceptionally high percentage compared to other populations in Newfoundland. One occurrence had 57% of its population in the juvenile stage in 1999; however, by 2007, the proportion of juveniles had declined to 18%. The threats in Jipujijkuei Kuespem Park are blowdowns and browsing of Balsam Fir by moose. Some occurrences have declined by up to 10% annually; others have increased by about 2% and at one occurrence there was a 21% increase (Appendix Table 3).

South of Conne River Road

This population is in the Forest Management Area of the Miawpukek First Nation. While commercial cutting has taken place in the past, the present forest harvesting is mostly for firewood, and buffers of 20 m around trees with *E. pedicellatum* are now being used.

Bay-du-Nord Wilderness Reserve Population

Six occurrences containing 16 sites were reported (Clarke 2005b). Half of the total area, about 28 km^2, where E. pedicellatum is encountered is forested. This area supports a core lichen population of several thousand thalli (Appendix Table 2) (Adams pers. comm.). Much of this area is remote and not affected by industrial forestry activities. The forests are impacted by browsing moose.

<u>Burin Peninsula</u>

This region includes the Burin Peninsula and nearby islands in Placentia Bay and has a combined number of 32 thalli, of which eight thalli are on Merasheen Island in Placentia Bay. None of the occurrences have been resurveyed or monitored. The area is not under industrial forestry. Local domestic cutting may be a threat to some occurrences. Remote cottage development is frequent. The forests are impacted by moose browsing.

<u>East Central Newfoundland</u>

This area encompasses the Terra Nova National Park and Come By Chance as well as the Bay du Nord Wilderness area. Before 1995, 125 thalli were recorded on Balsam Fir, mostly near Goobies. No site revisits have been done and trend information is not available. The total population of *E. pedicellatum* for this area in the database is less than 100 thalli (Appendix Table 2).

Come By Chance

E. pedicellatum was discovered as part of the fieldwork associated with the development of a new oil refinery at Southern Head near Come By Chance (Goudie 2007, Goudie and Munier 2007 a,b). Thirty-five thalli were found on twenty Balsam Fir trees located in the Southern Head area of the proposed new oil refinery. Air pollution is the threat in this area and sulphur uptake by lichens has been recorded and monitored (Wadleigh and Blake 1999).

Eastern Newfoundland

The Avalon Forest Ecoregion has been subjected to considerable industrial logging activities over the past four decades. Conflicts have emerged when clearcut logging has been proposed in old forest stands that supported relatively large numbers of *Erioderma pedicellatum*. A second threat is air pollution. The population of *E. pedicellatum* in the northern part of the central Avalon Peninsula is downwind of the Holyrood Thermal Generating Plant that releases large volumes of sulphur dioxide into the atmosphere (Goudie *et al.* 2011). The forests of the Avalon Peninsula are also affected by browsing moose, and are not regenerating in many areas (Goudie 2008a) and cottage development in the area is extensive. Maass and Yetman (COSEWIC 2002) reported the post-1995 total count for *E. pedicellatum* for the Avalon Peninsula as 2,148. Since that time, there has been the discovery of over 2,000 additional thalli at Hall's Gullies and surrounding areas. The population is now estimated as 5,000 thalli (Appendix Table 2).

Lockyer's Waters

Maass and Yetman (COSEWIC 2002) reported more than 900 thalli on about 500 Balsam Fir trees in the Lockyer's Waters within the 20 ha study area. Recent monitoring has found a continuing decline in thallus numbers to less than 300 (Goudie *et al*. 2011). In 2006, a large concentration of *E. pedicellatum* was discovered in the area of Hall's Gullies south of Ocean Pond. Over 2,000 thalli have been documented in the last 8 years in an area that is about 15 km in length and 7 km in width. This population area may be even larger, but surveys in adjacent areas have not been completed. The cutover areas of the Clam River operating area are within this occurrence. The area was surveyed prior to harvesting and 20m buffers were left around known *E. pedicellatum* occurrences, but the effects of the harvesting in 1998 have not yet been evaluated.

Long Harbour

The area southeast of Long Harbour was surveyed prior to the construction of the proposed nickel processing facility and 328 thalli were found. Thalli, which were located in the direct footprint of the development, were separated to form 265 transplants and transplanted into 8 sites. Half were transplanted into stands where *E. pedicellatum* was already present, and half into unoccupied sites. In 2012 only 149 transplants remained alive and preliminary analysis indicated that the mortality of the transplants was higher in the sites where no *E. pedicellatum* was previously present (Goudie and Jones 2013).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

The Atlantic Population of *Erioderma pedicellatum* is listed as Endangered under the Nova Scotia *Endangered Species Act* (1998) and as Endangered under New Brunswick *Species at Risk Act* (2013). It is also listed as Endangered on Schedule 1 of the federal *Species at Risk Act*.

The Boreal Population *Erioderma pedicellatum* is listed as Vulnerable under the Newfoundland and Labrador *Endangered Species Act* and is listed as Special Concern on Schedule 1 of the federal *Species at Risk Act*. A five-year management plan has been completed for this population (Keeping and Hanel 2006).

Non-Legal Status and Ranks

Erioderma pedicellatum is ranked globally as G1G2Q “critically imperilled to imperilled” and the Atlantic Population is ranked in Nova Scotia as S1S2 “critically imperilled to imperilled” and in New Brunswick as SH “possibly extirpated” by NatureServe 2013 (http://www.natureserve.org/explorer/ranking.htm)

Atlantic Population.

Five occurrences are within or partially within a provincial wilderness area in Nova Scotia. Two occurrences partially within a wilderness area are Bear Lake with 5 of 14 thalli within the Tangier Grand Lake Wilderness Area and MacDonald Lake with 10 of 26 adult thalli within the Middle River Framboise wilderness area. A total of 15 thalli are within wilderness areas (Appendix Table 1). Wilderness Areas are protected under the *Wilderness Areas Protection Act* (1998) and prohibit any developments including forestry, mining or building.

Boreal Population

In Newfoundland, *E. pedicellatum* occurs on trees in the Avalon Wilderness Reserve and Bay du Nord Wilderness Reserve. It is also found in Terra Nova National Park and there are some occurrences in provincial parks, notably in Jipujijkuei Kuespem Provincial Park, Bay d’Espoir. Many of the occurrences, in both Newfoundland and Nova Scotia, are on Crown land and have no legal protection.

ACKNOWLEDGEMENTS AND AUTHORITIES CONTACTED

The report writers would like to acknowledge the exceptional contribution made by the late Mr. Eugene Conway (Jan. 11, 1946 - to Dec. 5, 2014), who voluntarily worked tirelessly for fifteen years as an ambassador for the Boreal Felt Lichen and its associated habitat in Newfoundland. Eugene can be credited with having first discovered many of the known Newfoundland Boreal Felt Lichen populations and for sharing his passion for the species with the world.

In Nova Scotia the report writers would like to thank the Tom Neily and Brad Toms of the Mersey Tobeatic Research Institute for making available their long-term research data. The report writers also thank Frances Anderson, Research Associate with the Nova Scotia Museum of Natural History, for providing information. The report writers also acknowledge the earlier work of Dr. Wolfgang Maass, which made this re-assessment possible.

In Newfoundland, considerable data support was provided by Shelley Pardy and Claudia Hanel of the Wildlife Division of the Department of Environment and Conservation; Bill Clarke and Blair Adams of the Centre for Forest Innovation and Science, Department of Natural Resources, Forestry and Agrifoods Agency. André Arsenault provided valuable comments on a draft of this status report, as did the Department of Natural Resources. David Yetman and Eugene Conway (Newfoundland Lichen Education and Research Group, NLERG) and Mac Pitcher also provided clarification on various aspects of distribution and past fieldwork. Finally the report writers thank Christoph Scheidegger who supervised the implementation of the monitoring protocol in Eastern Newfoundland with continued support of Vale Newfoundland and Labrador Limited.

INFORMATION SOURCES

Ahlner, S. 1948. Utbredningstyper bland Nordiska Barrträdslavar (i.e. Distributional Patterns for Fennoscandinavian Lichens growing on Coniferous Trees). Ph.D. Thesis, Uppsala. Almquist & Wiksells Boktryckeri AB.

Ammann, K., R. Herzig, L. Liebendorfer and M. Urech. 1987. Multivariate correlation of deposition data of 8 different air pollutants to lichen data in a small town in Switzerland. pp. 401-406. *In* G. Boehm and R. M. Leuschner (eds.), Advances in cdcAerobiology. Birkhauser Verlag, Base.

Anonomyous. 2006. Sustainable forest management plan for Forest Management District 1 (The Avalon Peninsula). Newfoundland and Labrador Department of Forest Resources and Agrifoods. St. John's. 35 pp.

Anonymous 2014. Mining firm crushes ore at N.S. operation. Halifax Herald, May 9th, p. B2.

Auclair, A.N.D. 1987. The climate change theory of forest decline. - IUFRO Conference on Woody Plant Growth in a Changing Physical and Chemical Environment, Vancouver. Environment Canada, 29 pp.

Auclair, A.N.D., R.C. Worrest, D. Lachance and H.C. Martin. 1992. Climatic Perturbation as a General Mechanism of Forest Dieback. pp. 38-58 *In* Forest Decline Concepts, P.D. Manion and D. Lachance (eds.). The American Phytopathological Society, St. Paul, Minnesota.

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

Bergerud, A.T. and F. Manuel. 1968. Moose Damage to Balsam Fir - White Birch Forests in Central Newfoundland. Journal of Wildlife Management 32: 729-746.

Boucher, Y., D. Arsenault, L. Sirois, and L. Blais. 2009. Logging pattern and landscape changes over the last century at the boreal and deciduous transition in eastern Canada. Landscape Ecology 24: 171-184.

Bourque, C.P.A., Q.K. Hassan and D.E. Swift. 2010. Modelled potential species distribution for current and projected future climates of the Acadian Forest Region of Nova Scotia, Canada. Report for the Nova Scotia Department of Natural Resources.

Boyce, R.L. 1988. Wind Direction and Fir Wave Travel. Canadian Journal of Forest Research 18: 461-466.

Braathe, P. 1995. Birch Dieback - Caused by Prolonged Early Spring Thaws and Subsequent Frost. Norwegian Journal of Agricultural Sciences. Supplement No. 20 (59 pages). Norwegian Forest Research Institute, Ås, Norway.

Brawn, K. and J.G. Ogden III. 1977. Lichen Diversity and Abundance as Affected by Traffic Volume in an Urban Environment. Urban Ecology 2: 235-244.

Brodo, I.M., S.D. Sharnoff and S. Sharnoff. 2001. Lichens of North America. Yale University Press, New Haven.

Bruce, J. 2002. Application of satellite imagery to create a digital clear-cut layer for the Province of Nova Scotia. Nova Scotia Department of Natural Resources.

Cameron, R. P. 2002. Habitat associations of epiphytic lichens in managed and unmanaged forests in Nova Scotia. Northeastern Naturalist 9: 27-46.

Cameron, R.P. 2009a. Are non-native gastropods a threat to endangered lichens? Canadian Field Naturalist 123: 169-171.

Cameron, R.P. 2009b. Red maple, *Acer rubrum*, wetland composition and structure in Nova Scotia. Canadian Field Naturalist 123: 221-229.

Cameron, R.P. 2013. A summary of the ecology, current status and conservation issues of boreal felt lichen in Canada. Report to the Canadian Boreal Forest Initiative. Halifax, 19 pp.

Cameron, R.P. and D.H.S. Richardson. 2006. Occurrence and abundance of epiphytic cyanolichens in protected areas in Nova Scotia. Opuscula Philolichenum 3: 5-14.

Cameron, R. P. and T. Neily. 2008. Heuristic model for predicting habitat of *Erioderma pedicellatum* and other rare cyanlichens in Nova Scotia, Canada. The Bryologist 111: 650–658.

Cameron, R.P., T. Neily, D.H.S. Richardson. 2007. Macro-lichen indicators of air quality in Nova Scotia. Northeastern Naturalist 14: 1-14.

Cameron, R., C. Hanel, I. Goudie, and N. Neily, 2009. Boreal Felt Lichen; Current Status, Conservation Issues and Future Prospects Botanical Electronic News.

Cameron, R.P., T. Neily and F. Anderson. 2010. Observations of mortality in a small population of the endangered lichen *Erioderma pedicellatum*. Opuscula Philolichenum 8: 67-70.

Cameron, R.P., T. Neily and H. Clapp. 2013a. Forest harvesting impacts on mortality of an endangered lichen at the landscape and stand scale. Canadian Jounral of Forest Research 43: 507-511.

Cameron, R.P., I. Goudie and D.H.S. Richardson. 2013b. Habitat loss exceeds habitat regeneration for an IUCN flagship lichen epiphyte: *Erioderma pedicellatum*. Canadian Jounral of Forest Research 43: 1075-1080.

Canadian Council of Ministers of the Environment. 2011. 2008-2009 Progress report on the Canada-wide acid rain strategy for post-2000. PN 1458.

Canadian Council of Ministers of the Environment. 2013. 2010-2011 Progress report on the Canada-wide acid rain strategy for post-2000. PN 1490.

C-Core. 2004. Lockyer’s Waters *Erioderma* resurvey project. Contract report to the Newfoundland Lichen Education and Research Group. C-Core Report R-03-069-257.

Chen, J., J.F. Franklin and T.A. Spies. 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. Agricultural and Forest Meteorology 63: 219-237.

Clarke, W.M., 2005a. Report on foray to Bay d’Espoir February 28 to March 4, 2005. Internal document. Newfoundland and Labrador Department of Natural Resources. 3 pp.

Clarke, W. M., 2005b. Report on *Erioderma* Search in Bay du Nord Wilderness Reserve. Internal document. Newfoundland and Labrador Department of Natural Resources. 7 pp.

Clarke, W. M. 2005c. A brief report on the April 11 to 15, 2005 resurvey in Bay d’Espoir. Internal document. Newfoundland and Labrador Department of Natural Resources. 4 pp.

Clarke, W. M and B. A. Roberts. 2008. Report on Field Work in relation to lichen sites in the Avalon Wilderness Reserve in 2008. Internal report submitted to Parks and Natural Areas Division of Department of Environment and Conservation. 7 pp.

Clayden, S. R. 1997. Why caribou disappeared from New Brunswick. New Brunswick. Tree and Forest 1(3):14–15.

Clayden, S. R. 2010. Lichens and allied fungi of the Atlantic Maritime Ecozone. pp. 153-178. *In* D. F. McAlpine and I. M. Smith (eds.), Assessment of Species Diversity in the Atlantic Maritime Ecozone. NRC Research Press, National Research Council Canada, Ottawa.

Clayden, S. R., R. P. Cameron and J. W. McCarthy. 2011. Perhumid boreal and hemiboreal forests of eastern Canada. pp. 111-131. *In* D. DellaSala (ed.), Temperate and Boreal Rainforests of the World: Ecology and Conservation. Island Press, Washington.

Collins, M. 2014. A preliminary study of the meiofauana of the lichen *Lobaria scrobiculata* from old growth forest on the Avalon Peninsula, with particular reference to the Tardigrades. Unpublished report to LGL Limited Environmental Consultants. 5 pp.

Cornejo and Shiedegger 2009. Does photobiont availability limit the spread of the critically endangered lichen *Erioderma pedicellatum*? Poster presented at ECCB 2009.

COSEWIC 2002. Assessment and Status Report on the Boreal Felt Lichen (*Erioderma pedicellatum*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Cox, R.M., J. Spavold-Tims and R.N. Hughes.1989. Acid Fog and Ozone: Their Possible Role in Birch Deterioration around the Bay of Fundy, Canada. - Water, Air, and Soil Pollution 48: 263-276.

Cyr, D., S. Gauthier, Y. Bergeron, and C. Carcaillet. 2009. Forest management is driving the eastern North American boreal forest outside its natural range of variability. Frontiers in Ecology and Environment 7(10): 519-524.

Damman, A. W. H. 1983. An ecological subdivision of the Island of Newfoundland. pp. 163-206 *In* G. R. South (ed.), biogeography and ecology of the Island of Newfoundland. Dr. W. Junk Publishers, The Hague, Netherlands.

Desponts, M., G. Brunet, L. Bélanger, and M. Bouchard. 2004. The eastern boreal old-growth balsam fir forest: a distinct ecosystem. Canadian Journal of Botany 82: 830–849.

Environmental Assessment Report. 2007. Focus report Touqouy Gold project Moose River Gold Mines, Nova Scotia. Conestoga-Rovers and Associates, Halifax.

Esseen, P.A. and K.E. Renhorn. 1998. Edge effects on an epiphytic lichen in fragmented forests. Conservation Biology 12: 1307-1317.

Farmer, A.M., J.F. Bates and J.N.B. Bell. 1992. Chapter 11. Ecophysiological Effects of Acid Rain on Bryophytes and Lichens, pp. 284-313. *In*, .W. Bates and A.M. Farmer (eds.) Bryophytes and lichens in a changing environment. J. Clarendon Press, Oxford.

Fos, S., V.I. Deltoro, A. Calatayud, and E. Barreno. 1999. Changes in water economy in relation to anatomical and morphological characteristics during thallus development in *Parmelia acetabulum*. Lichenologist 31(4): 375-387.

Gauslaa, Y. 1995. The Lobarion, an epiphylic community of ancient forests threatened by acid rain. Lichenologist 27(1): 59-76.

Gauslaa, Y. and K.A. Solhaug. 1999. High-light damage in air-dry thalli of the old forest lichen *Lobaria pulmonaria*-interactions of irradiance, exposure duration and high temperature. Journal of Experimental Botany 50: 697-705.

Geiser, L.H., S.E. Jovan, D.A. Glavich, M.K. Porter. 2010. Lichen-based critical loads for atmospheric nitrogen deposition in Western Oregon and Washington Forests, USA. Environmental pollution 158: 2412-2421.

Glavich, D.A. and Geiser, L.H. 2008. Potential approaches to developing lichen-based critical loads and levels for nitrogen, sulfur and metal-containing atmospheric pollutants in North America. Bryologist 111: 638-649.

Goudie, I. 2008a. Moose Matters. The Osprey 39(3): 102-105.

Goudie, I. 2008b. Research Strategies for Boreal Felt Lichen (*Erioderma pedicellatum*) in Newfoundland. Report SA986 by LGL Limited, St. John's, NL, prepared for Harris Centre of Regional Policy & Development, Memorial University, St. John's, NL. 13 pp.

Goudie, I. 2009a. Environmental Effects Monitoring for Epiphytic Lichens in the Vale Inco Project Area at Long Harbour, Placentia Bay: Spring - Fall 2008. LGL Report No. SA992/SA1003. Prepared for Vale Inco Newfoundland and Labrador Limited, St. John's, NL. 24 pp. + appendices.

Goudie, I. 2009b. Compendium of Studies of the Boreal Felt Lichen (*Erioderma pedicellatum*) funded by Vale Inco Newfoundland and Labrador Limited in Eastern Newfoundland, 2005 to 2008. LGL Report No. SA992/SA1003 Supplement. Prepared for Vale Inco Newfoundland and Labrador Limited, St. John's, NL. 7 pp. + appendices.

Goudie, I. 2011a. Final Report: Environmental Effects Monitoring for Epiphytic Lichens in the Vale Project Area at Long Harbour, Placentia Bay: Fall 2009 - Fall 2010. LGL Report No. SA1045. Prepared for Vale Newfoundland and Labrador Limited, St. John's, NL. 29 pp. + appendices.

Goudie, I. 2011b. Re-defining old growth and biological diversity in the boreal forest. The Osprey 42(4): 8-15.

Goudie, R. I. 2011c. Review of: The pre-industrial condition of the limits of Corner Brook Pulp and Paper Limited: Report prepared by Corner Brook Pulp & Paper Ltd to address the requirements of the Forest Stewardship Council, National Boreal Standard by E. D. Wells and Brown. 15 pp.

Goudie, I. and E. Conway. 2005. Status of *Eriodema pedicellatum* at Lockyer's Waters - Avondale, Newfoundland during 1997, 2002, 2003 & 2005. *In* Compendium of Studies of the Boreal Felt Lichen (*Erioderma pedicellatum*) funded by Vale Inco Newfoundland and Labrador Limited in Eastern Newfoundland, 2005 to 2008. LGL Report No. SA992/SA1003 Supplement. Prepared for Vale Inco Newfoundland and Labrador Limited, St. John's, NL. 7 pp. + appendices.

Goudie, I. and E. Conway. 2006. Progress Report of Monitoring of *Erioderma pedicellatum* at Lockyer's Waters and Southeast Placentia Study Areas, Avalon Peninsula, Newfoundland: Spring 2006. Prepared for Voisey's Bay Nickel Company Ltd., St. John's, NL. 13 pp. + appendices.

Goudie, I. and E. Conway. 2007a. First Annual Report of Monitoring of *Erioderma pedicellatum* at Lockyer's Waters and Southeast Placentia Study Areas, Avalon Peninsula, Newfoundland: Fall 2006. Prepared for Voisey's Bay Nickel Company Ltd., St. John's, NL. 16 pp. + appendices.

Goudie, I. and E. Conway. 2007b. Monitoring of *Erioderma pedicellatum* at Lockyer's Waters and Southeast Placentia Study Areas, Avalon Peninsula, Newfoundland: Fall 2006-Spring 2007. Prepared for Voisey's Bay Nickel Company Ltd., St. John's, NL. 8 pp. + appendices.

Goudie, I. and E. Conway. 2008. Monitoring of *Erioderma pedicellatum* at Lockyer's Waters and Southeast Placentia Study Areas, Avalon Peninsula, Newfoundland: Spring 2007-Fall 2007. Prepared for Voisey's Bay Nickel Company Ltd., St. John's, NL. 14 pp. + appendices.

Goudie, I. and C. Jones. 2012. Environmental Effects Monitoring for Epiphytic Lichens in the Vale NL Limited Project Area at Long Harbour, Placentia Bay: Fall 2010 - Fall 2011. LGL Report No. SA1045. Prepared for Vale Newfoundland and Labrador Limited, St. John's, NL. 42 pp.+ appendices.

Goudie, I. and C. Jones. 2013. Environmental Effects Monitoring for Epiphytic Lichens in the Vale Project Area at Long Harbour, Placentia Bay: Fall 2011 - Fall 2012. LGL Report No. SA1045. Prepared for Vale Newfoundland and Labrador Limited, St. John's, NL.44 pp. + appendices.

Goudie, I. and Munier, A. 2007a. Baseline Surveys and Recommendations for Monitoring Epiphytic Lichens on Southern Head, Placentia Bay, Newfoundland and Labrador. LGL Rep. SA914D/G. Rep. by LGL Limited, St. John's, NL, for SNC Lavalin, St. John's, NL. 14 pp. + Appendices.

Goudie, I. and Munier, A. 2007b. Baseline Surveys for Epiphytic Lichens in Come By Chance Area and Eastern Side of Southern Head, Placentia Bay, NL, 30-31 January 2008. Rep. by LGL Limited, St. John's, NL, for SNC Lavalin, St. John's, NL. 11 pp.

Goudie, I., C. Scheidegger, and E. Conway. 2006. A Report on the Status of the Boreal Felt Lichen (*Erioderma pedicellatum*) at Long Harbour, Site of the Proposed Nickel Production Plant. Prepared for Voisey's Bay Nickel Company Ltd., St. John's, NL. 8 pp.

Goudie, I., E. Conway and C. Jones. 2010. Environmental Effects Monitoring for Epiphytic Lichens in the Vale Inco Project Area at Long Harbour, Placentia Bay: Fall 2008 - Fall 2009. LGL Report No. SA1045. Prepared for Vale Inco Newfoundland and Labrador Limited, St. John's, NL. 29 pp. + appendices.

Goudie, R. I, C. Scheidegger, C. Hanel, A. Munier, E. Conway. 2011. New population models help explain declines in the globally rare boreal felt lichen *Erioderma pedicellatum* in Newfoundland. Endangered Species Research 13: 181-189.

Goward, T., I.M. Brodo, and S.R. Clayden. 1998. Rare lichens ofCanada: a review and provisional listing. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 74 pp.

Green, R. H. and R. C. Young. 1993. Sampling to detect rare species. Ecological Applications 3: 351-356.

Harper, K; C. Boudreault; L. DeGrandpre; P. Drapeau; S. Gauthier; and Y. Bergeron. 2003. Structure, composition, and diversity of old-growth black spruce boreal forest of the Clay Belt region in Quebec and Ontario. Environmental Reviews 11: S79-S98.

Hawksworth, D. L. and F. Rose.1976. Lichens as pollution monitors. Institute of Biology's Studies in Biology No. 66. Edward Arnold, London.

Hinds, J.W.and Hinds, P.L. 2007.The Macrolichens of New England. New York Botanical Garden Press, New York, pp 51 and 123.

Holien, H. 2006. Trøderlav *Erioderma pedicellatum*. Artsdatabankens Faktaark nr. 3.

Holien, H., G. Gaarder, and A. Hapnes. 1995. *Erioderma pedicellatum* still present, but highly endangered in Europe. Graph Scr. 7:79–84.

Hultengren, S. and H. Gralen. 2004. Recovery of the epiphytic lichen flora following air quality improvement in southwest Sweden. Water, Air, and Soil Pollution 154: 203-211.

James, P.W. 1973. The Effects of air pollutants, other than hydrogen fluoride and sulphur dioxide on lichens. *In*, Air Pollution and Lichens. Athlone Press of the University of London, London, pp. 143-175..

Jørgensen Per M. 1972. *Erioderma pedicellatum* new combination equals *Erioderma boreale* in New Brunswick Canada. Bryologist 75: 369-71.

Jørgensen, M. 2001. The present status of the names applicable to species and infraspecific taxa of *Erioderma* (lichenised Ascomycetes) included in Zahlbruckner's "Catalogus". Taxon 50: 525-541.

Keeping, B. and C. Hanel. 2006. A five-year (2006-2011) management plan for the Boreal Felt Lichen (*Erioderma pedicellatum*) in Newfoundland and Labrador. Department of Environment and Conservation, Wildlife Branch. 44 pp.

Kouterick, K. B., J. M. Skelly, S. P. Pennypacker and R. M. Cox. 1998. Acidic fog and *Septoria betulae* Pass. Impacts on two birch species along the Bay of Fundy, Canada. Conference on Fog and Fog Collection. Vancouver, Canada, 19-24 July 1998.

Kuusinen, M. 1994. Epiphytic lichen flora and diversity on *Populus tremula* in old-growth and managed forests of southern and middle boreal Finland. Annales Botanici Fennici 31: 245–260.

Larsson, P. and Gauslaa, Y. 2010. Rapid juvenile development in old forest lichens. Botany 89:65-72.

Lesica, P. *et al.* 1991. Differences in lichen and bryophyte communities between old-growth and managed second growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745–1755.

Maass, W.S.G. 1980. Erioderma pecidellatum in North America: a case study of a rare and endangered lichen. Proceedings of the Nova Scotia Institute of Science 30: 69-87.

Maass, W.S.G. and D.H.S. Richardson. 1994. A natural vegetation baseline study involving lichens and *Sphagnum* mosses as bioindicators. Report to Nova Scotia Power Inc. as part of the Air Effects Monitoring Program around the Point Aconi Generating Station (Unit No 1). 69 pp.

Maass, W. S. G. and E. Conway. 2004. On the present status of *Erioderma pedicellatum* and associated air pollution sensitive lichens in the Southeast Placentia area of the Avalon Peninsula of Newfoundland. Report to Voisey's Bay Nickel Company Ltd. by Newfoundland Lichen Education and Research Group, P.O. Box 16, Conception Hr., NL, A0A 1Z0. 55 pp.

McCarthy, J. 2010. The distribution and abundance of the Boreal Felt Lichen (*Erioderma pedicellatum* (Hue) P.M. Jørg) in the forests of the Avalon Peninsula, Newfoundland. Contract report to Wildlife Division and Parks and Natural Areas, Department of Environment and Conservation, Government of Newfoundland and Labrador. 90 pp. Obtained under the Access to Information and Protection of Privacy Act (Department of Environment and Conservation File No. ENV/047/2010).

McCune, B. 1988. Lichen communities along 03 and S02 gradients in Indianapolis. The Bryologist 91: 223-228.

McLaren, B.E., B.A. Roberts, N. Djan-Chekar and K.P. Lewis. 2004. Effects of overabundant moose on the Newfoundland landscape. Alces 40: 45-59.

Moberg, R. and I. Holmåsen. 1982. Lavar. En fälthandbok - Interpublishing, Stockholm.

Moss, M. and L. Hermanutz. 2010. Monitoring the small and slimy – protected areas should be monitoring native and non-native slugs (Mollusca: gastropoda). Natural Areas Journal 30: 322-327.

Munier, A. 2008. Erioderma research forum. Unpublished report of the Harris Centre, Memorial University of Newfoundland. 31 pp.

Muraca, G. D.C. MacIver, N. Urquizo and H. Auld. 2001. The climatology of fog in Canada. pp. 513-516 in R. S. Schemenauer and H. Bridgman (eds). First International Conference on Fog and Fog Collection, Vancouver, Canada, July 19-24, 1998 [Proceedings].

Nash III, T.H. 2008. Lichen Biology, 2nd Edit. Cambridge University Press, Cambridge.

Nelson, P., J. Walton and C. Roland. 2009. *Erioderma pedicellatum* (Hue) P.M.Jorg, New to the United States and Western North America, Discovered in Denali National Park and Preserve and Denali State Park, Alaska. Evansia 25: 19 – 23.

Neily, P. D. McCurdy, B. Stewart and E. Quigley. 2004. Coastal forest communities of the Nova Scotian Eastern Shore ecodistrict. Nova Scotia Department of Natural Resources Report FOR 2004-4.

New Brunswick Department of Natural Resources. 2007. Recovery Strategy for the Boreal Felt Lichen (*Erioderma pedicellatum*) in New Brunswick. Natural Resources. Fredericton. http://dsp- sd.pwgsc.gc.ca/collection_2007/ec/En3-4-20-2007E.pdf

Newfoundland Department of Environment and Conservation. 2012. Air quality data accessed 21 February 2012, http://www.env.gov.nl.ca/env/env_protection/science/airmon/index.html.

Newmaster, S.G., F.W. Bell and D.H. Vitt. 1999. The effects of glyphosate and triclopyr on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 1101-1111.

Nieboer, E., J. D. McFarlane and D. H. S. Richardson. 1984. Modification of plant cell buffering capacities by gaseous air pollutants. pp. 313-333, *In* Koziol, M., and F.R. Whatley (eds.), Gaseous Air Pollutants and Plant Metabolites, Butterworths, London.

Nova Scotia Department of Natural Resources (2012) Endangered Boreal Felt Lichen Special Management Practices. http://novascotia.ca/natr/wildlife/habitats/terrestrial/pdf/SMP_Boreal_Felt_Lichen.pdf.

Pettersson, R. B., J. P. Ball, K.-A. Renhorn, P.-A. Esseen, and K. Sjöberg. 1995. Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biological Conservation 74:57–63.

Pickett, S.T.A. & White, P.S. (eds.). 1985. The ecology of natural disturbance and patch dynamics. Reprint ed. Academic Press, San Diego.

Pickett, Parker, V.T. and Fiedler, P.L. 1992. The new paradigm in ecology: implications for conservation biology above the species level. In The Theory and Practice of Nature Conservation,. (P. Fiedler and S. Fain eds.) Chapman Hall, NY, pp. 65-88.

Piervittori, R., L. Usai, F. Alessio and M. Maffei. 1997. The effect of simulated acid rain on surface morphology and n-Alkane composition of *Pseudevernia furfuracea*. Lichenologist 29(2): 191-198.

Purvis, W. 2000. Lichens. Smithsonain Institution Press, Washington in association with the Natural History Museum, London.

Rheault, H., P. Drapeau, Y. Bergeron, and P.A. Esseen. 2003. Edge effects on epiphytic lichens in managed black spruce forests of eastern North America. Canadian Journal of Forest Research 33: 23–32.

Richardson, D.H.S. 1992. Pollution Monitoring with Lichens. Richmond Publishing, Slough, UK.

Richardson, D.H.S. and R.P. Cameron. 2004. Cyanolichens: their response to pollution and possible management strategies for their conservation in northeastern North America. Northeastern Naturalist 11: 1-22.

Roberts, B. A. 2012. Ecology of the Boreal Felt Lichen (*Erioderma pedicellatum*) (Hue) P.M. Jørg, and implications for forestry and forest management. Contract Report to the Department of Natural Resources, Government of Newfoundalnd and Labrador. 71 pp.

Ruisi, S., L. Zucconi, F. Fornasier, L. Paoli, L. Frati and S. Loppi. 2005. Mapping environmental effects of agriculture with epiphytic lichens. Israel Journal of Plant Sciences 53: 115-124.

Scheidegger, C. 1996. Letter to the Honourable Brian Tobin, Prime Minister of NF, dated October 30, 1996. - The letter contains ideas about the complex reproductive strategies of *Erioderma*, about the limited life span of its thalli, and about its life cycles being intimately tied to certain ecological stages in the growth of coniferous trees within a more or less undisturbed forest environment.

Scheidegger, C. and Goward, T. (2002) Monitoring lichens for conservation: red lists and conservation action plans. In Monitoring with lichens – Monitoring lichens (P.L. Nimis, C. Scheidegger and P.A. Walseley eds.) Kluwer Academic, Dordrecht pp. 163-181.

Sharnoff, S. and R. Rosentreter. 1998. Wildlife use of lichens in North America. Website http://www.lichen.com/fauna.html

Showman, R. E. and R. P. Long. 1992. Lichen studies along a wet sulfate deposition gradient in Pennsylvania. The Bryologist 95: 166-170.

Siegwart, L. 2009. A Research Plan for The Newfoundland Boreal Felt Lichen (*Erioderma pedicellatum)* (2009-2013). Contract report to the Wildlife Division, Department of Environment and Conservation, Government of Newfoundland and Labrador Corner Brook, NL. 36 pp.

Sillett, S. C., B. McCune, J. E. Peck, T. R. Rambo, and A. Ruchty. 2000. Dispersal limitations of epiphytic lichens result in species dependent on old-growth forests. Ecological Applications 10(3): 789-799.

Squires, S. 2014. Boreal felt lichen population viability analysis. Internal Report Newfoundland Department of Envrionment and Conservation. 6 pp.

Stehn, S,E., P.R. Nelson, C.A. Roland, and J.R. Jones 2013. Patterns in the occupancy and abundance of the globally rare lichens Erioderma pedicellatum in Delali National Park and Preserve, Alaska. Bryologist 116:1-14.

Thompson, I.D. and W.J. Curran. 1993. A reexamination of moose damage to balsam fir-white birch forests in central Newfoundland 27 years later. Canadian Journal of Zoology 23: 1388-1395.

Thompson I.D., D.J. Larson, and W.A. Montevecchi. 2003. Characterization of old “wet boreal” forests, with an example from balsam fir forests of western Newfoundland. Environmental Reviews 11: S23-S46.

Wadleigh, M.A. and D.M. Blake. 1999. Tracing Sources of Atmospheric Sulphur Using Epiphytic Lichens. - Environmental Pollution 106: 265-271.

Wilton, W. C. 1956. Forest Resources of the Avalon Peninsula, Newfoundland, Department of Northern Affairs and Natural Resources. Forestry Branch, Forest Research Division. Technical Note No. 50.1956 Clear cutting.

Wiersma, Y. F. and R. Skinner. 2011. Predictive distribution model for the Boreal Felt Lichen *Erioderma pedicellatum* in Newfoundland, Canada. Endangered Species Research 15: 115-127.

Yetman, D., 1999. The health and population viability of *Erioderma pedicellatum* ((Hue) P.M. Jørg.) in Jipujijkuei Kuespem Provincial Park and the proposed Lockyer's Waters Ecological Reserve. Contract Report to Parks and Natural Areas, Department of Environment and Lands, Government of Newfoundland and Labrador.

Yetman, D. 2000. Youth as environmental leaders: science and education towards conservation of a rare lichen in Newfoundland. Forest, Snow and Landscape Research 75 (3): 407-414.

BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Robert Ian Goudie, Ph.D. is an experienced scientist in wildlife demography, ecology, and behaviour who has worked extensively throughout Newfoundland and Labrador and western Canada. In recent years he has worked extensively with monitoring globally rare lichens as indicators of environmental health for old-growth boreal forests. Through involvement with environmental non-government conservation groups, over the past three years he has been Forest Science Advisor for the Newfoundland and Labrador Chapter of the Canadian Parks and Wilderness Society. He is currently promoting ecosystem-based planning and the application of the Canadian Boreal Forest Agreement.

Robert Cameron is the ecologist with the Protected Areas Branch of Nova Scotia Environment. He holds a Master's degree from Acadia University, where he studied the effects of forestry on epiphytic lichens. He also has a forestry degree from the University of New Brunswick with a specialty in wildlife biology. Lichen research has focused on conservation of rare and at risk species, particularly forest species. Mr. Cameron has been conducting research on lichens for over 15 years and research on *Erioderma pedicellatum* for almost 10 years.

COLLECTIONS EXAMINED

No collections were examined for this report.

Appendix 1: Threats Calculator Assessments for the Boreal Felt Lichen

Threats Calculator Assessment for the Boreal Population of *Erioderma pedicellatum*

Species or Ecosystem Scientific Name	*Erioderma pedicellatum*: Boreal Population Designatable Unit		
Element ID		**Elcode**	
Date of Assessment:	09/05/2014		
Assessor(s):	David Richardson, Dwayne Lepitzki, Mary Sabine, Julie McKnight, Frances Anderson, Rob Cameron, Shelley Pardy, Ruben Boles, Tom Neily, Claudia Hanel, Julie Perrault		
References:			

Overall Threat Impact Calculation Help:

Threat Impact		**Level 1 Threat Impact Counts: high range**	**low range**
A	Very High	0	0
B	High	1	0
C	Medium	1	1
D	Low	5	6
Calculated Overall Threat Impact:		High	High
Assigned Overall Threat Impact:			

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 - Moderate (11-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious - Moderate (11-70%)	High (Continuing)	Cottage development is popular in the Avalon Peninsula and other parts of Newfoundland. This often leads to clearing or thinning of forests in the surrounding area which result in microclimate changes that may affect the boreal felt lichen; estimated impact 1,200 ha per year in Avalon peninsula. With respect to the impact of cottage development, the scope is probably closer to the lower end of the range (1%) and current mitigations reduce the threat, but if not the severity may be high
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	ATV and trail construction has increased across the province leading to habitat disturbance. However, new trails are not allowed in areas where the Boreal Felt lichen occurs (an Environmental Review would be required). However, not everyone is compliant with the regulation, so some new trails may be constructed with an unknown impact.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture	D	Low	Small (1-10%)	Extreme - Serious (31-100%)	High - Moderate	
2.1	Annual & perennial non-timber crops						Agricultural expansion is subject to Environmental Review and if the Boreal Felt lichen is found, such developments are not permitted.
2.2	Wood & pulp plantations	D	Low	Small (1-10%)	Extreme – Serious (31-100%)	High - Moderate	Planting Black and White Spruce in areas where Balsam Fir regeneration is being inhibited by moose browsing is leading to loss of future host trees for the Boreal Felt Lichen. This may be happening now but will definitely occur on a larger scale within the next 60 years.
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						
3.1	Oil & gas drilling						
3.2	Mining & quarrying						Some activity may occur in future and have an impact but the scope, severity and timing are all uncertain.
3.3	Renewable energy						
4	Transportation & service corridors	D	Low	Small (1-10%)	Moderate (11-30%)	High - Moderate	
4.1	Roads & railroads	D	Low	Small (1-10%)	Moderate (11-30%)	High - Moderate	Road construction related to cottage developments or access roads for commercial forest harvesting leads to microclimate changes in the adjacent forest which are known to lead to damage and death of the boreal felt lichen. On the other hand roads can increase access and thus moose harvesting which could decrease the browsing impact of moose on Balsam Fir.
4.2	Utility & service lines		Negligible	Negligible (<1%)	Serious - Slight (1-70%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Construction will occur sometime in the next two years although the area impacted may be small and the severity is uncertain.
4.3	Shipping lanes						
4.4	Flight paths						
5	Biological resource use	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Domestic wood cutting is a large dispersed activity that can both remove host trees and open up the forest causing microclimate changes that can affect the Boreal Felt Lichen. The use of shorter rotation forests can also reduce the number of old Balsam Fir trees, the preferred host for this lichen. Commercial forestry adjacent to identified occurrences can also change the microclimate of the habitat in which the lichen grows, and while buffer zones and pre harvest surveys are done on Crown land, they may not be done or effective on private land. No cutting is allowed on sites which are known to contain the Boreal Felt lichen.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Scientific research on the Boreal Felt Lichen continues. The impact and effects of this are negligible. Though research may benefit the species by leading to a better understanding of its ecology, etc,. and improvement in conservation, it would be unlikely to lead directly to an increase in the population.
7	Natural system modifications	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	
7.1	Fire & fire suppression						Fire is not a serious threat as the Boreal Felt Lichen grows where fire is unknown or in habitats that are non-fire prone or conducive to fire. We have a prescribed burn program in TNNP and we target Black Spruce sites and not Boreal Felt Lichen sites.
7.2	Dams & water management/use						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	The moose population has increased from 25,000 to 150,000 animals since 1980. They are preventing regeneration of Balsam Fir in many areas. The result is a forest in which spruces are the dominant tree. Thus, moose browsing modifies the ecosystem as young trees are targeted which will lead to a lack of suitable mature trees in future for the Boreal Felt Lichen. There is no regeneration of the Balsam Fir forest in TNNP where moose are present (except for offshore islands which are usually inaccessible to moose). The moose are being actively managed and silviculture is being used to ensure future Balsam Fir forests for the Boreal Felt Lichen to colonize. The same pattern likely applies in other protected areas in Newfoundland. Incidentally, the moose do not browse the Boreal Felt Lichen directly from older trees. Other non-native species also browse regenerating Balsam Fir including red squirrel, snowshoe hare, and slugs. They are contributing to the lack of Balsam Fir regeneration.
8	Invasive & other problematic species & genes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Harvesting of the increased moose population is currently occurring but the degree to which this will mitigate the impact of moose browsing in the future is uncertain.
8.2	Problematic native species						Control of Sawflies has occurred using a variety of pesticide sprays and *Bacillus thuringiensis* (BT). The impact of these on the microfauna which may play a role in dispersal of the BorealFfelt Lichen spores, or indeed on the lichen itself are not known.
8.3	Introduced genetic material						
9	Pollution	CD	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.4	Garbage & solid waste						
9.5	Air-borne pollutants	CD	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	The Boreal Felt Lichen is very susceptible to damage by sulphur dioxide emitted locally and also from transboundary acid rain and acid fog but levels of the last two are low compared with Nova Scotia. Pollution from the Come By Chance refinery, Holyrood generating station, Long Harbour Nickel Processing facility and from the city of St. Johns may affect nearby boreal felt lichen populations.
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)	
11.1	Habitat shifting & alteration		Unknown	Large - Small (1-70%)	Unknown	High (Continuing)	Predictions include increases in fog frequency which might benefit this lichen.
11.2	Droughts						Increased periods of drought could be a potential threat to the Boreal Felt Lichen but the timing and likelihood is uncertain and more research is needed.
11.3	Temperature extremes						Predicted increases in temperature extremes may also be a threat to the Boreal Felt Lichen but more research is needed.
11.4	Storms & flooding	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	The increasing incidence of extreme weather events, like the hurricanes of 2011 and 2012, linked with climate change, have had a serious impact on the forests where the Boreal Felt Lichen occurs leading to windfalls of old Balsam Fir, the main host of this lichen, and also opening up the forest to microclimate change. Hurricane damage (e.g. from Hurricane Igor) has accelerated Balsam Fir stand breakup in many parts of TNNP, thus potentially limiting the amount of Boreal Felt Lichen habitat

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).

Threats Calculator Assessement for the Atlantic Population of *Erioderma pedicellatum*

Species or Ecosystem Scientific Name	*Erioderma pedicellatum:* Atlantic Population Designatable Unit			
Element ID				**Elcode**
Date:	09/05/2014			
Assessor(s):	David Richardson, Dwayne Lepitzki, Mary Sabine, Julie McKnight, Frances Anderson, Rob Cameron, Shelley Pardy, Ruben Boles, Tom Neily, Claudia Hanel, Julie Perrault			
References:				

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	low range
A	Very High	0	0
B	High	3	1
C	Medium	1	1
D	Low	2	4
	Calculated Overall Threat Impact:	Very High	High
	Assigned Overall Threat Impact:	**A = Very High**	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	
1.1	Housing & urban areas	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Cottage development close to the habitat where this lichen grows can change the microclimate nearby and lead to habitat degradation and impact on the Boreal Felt Lichen. The scope is likely more towards the lower end of the range, i.e. 1%.
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3	Energy production & mining		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	
3.1	Oil & gas drilling		Negligible	Negligible (<1%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Fracking and natural gas transmission by pipelines both have the potential to cause habitat and microclimate disruption. Pipelines can lead to ground water changes affecting habitats where the Boreal Felt Lichen grows. Fracking activity will probably take place in the near future. Boreal Felt Lichen habitat is present in the area although this lichen has not been found in surveys carried out to date.
3.2	Mining & quarrying		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Habitat disturbance as a result of renewed gold mining activity in Halifax county can affect Boreal Felt Lichen sites which are within five km. Twenty to three hundred thalli could be impacted by mine-related activities although no thalli occur under the footprint of the mine.
3.3	Renewable energy		Negligible	Negligible (<1%)	Extreme (71-100%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	The wind farm construction requires a considerable footprint and is increasing in Nova Scotia. Construction is occurring in areas where the Boreal Felt Lichen occurs.
4	Transportation & service corridors	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Restricted (11-30%)	Moderate (11-30%)	High (Continuing)	Road construction related to mining, fracking, wind farms, cottage development, and forestry leads to alteration in microclimate of adjacent woodlands, streamflow, and water table changes. New logging roads are added every year and are proposed in areas where the Boreal Felt Lichen is known to occur. Access roads are also needed for fracking or the construction of wind farms.
4.2	Utility & service lines						
4.3	Shipping lanes						
4.4	Flight paths						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
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						
5.3	Logging & wood harvesting	B	High	Large (31-70%)	Extreme (71-100%)	High (Continuing)	Wood harvested for biomass energy production amounts to greater than 500,000 tons a year. It removes trees including Balsam Fir, the host for the Boreal Felt Lichen. Due to a shortage of supply, host trees are increasingly being harvested on private land, where pre-harvest Boreal Felt Lichen surveys are not required. This can reduce populations of this lichen. The logging of trees both removes potential host trees available for colonization and removes part of the population of the Boreal Felt Lichen, if it is actually growing on the tree.
5.4	Fishing & harvesting aquatic resources						
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities						
6.2	War, civil unrest & military exercises						
6.3	Work & other activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
7	Natural system modifications						
7.1	Fire & fire suppression						
7.2	Dams & water management/use						
7.3	Other ecosystem modifications						
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.1	Invasive non-native/alien species	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Two invasive slug species have become widespread in Nova Scotia and have caused grazing damage to lichens. Such damage has been observed on the Boreal Felt Lichen. Though grazing has often been observed and seems to cause real damage to this lichen, more research is needed to assess the overall impact on the population.
8.2	Problematic native species						Spruce budworm outbreaks on Balsam Fir are forecast to occur in the near future as part of the natural cycle. High mortality of the trees is expected in Nova Scotia. Grazing damage by native gastropods and lichen feeding arthropods is also known to cause damage to the Boreal Felt Lichen. It is possible that the impact of native slugs on the Boreal Felt Lichen may be less as they are being out-competed by the two alien species.
8.3	Introduced genetic material						
9	Pollution	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	
9.1	Household sewage & urban waste water						
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents						
9.4	Garbage & solid waste						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.5	Air-borne pollutants	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Acid rain, sulphur dioxide and acid fog are considered to be the cause of the extirpation of the Boreal Felt Lichen from New Brunswick. While levels of these pollutants have declined, the Boreal Felt Lichen, as a cyanolichen, belongs to a very sensitive group of lichens. Furthermore, even reduced levels of these pollutants can overcome the buffering capacity of the host trees and lead to bark acidification which can make it unsuitable for colonization by this lichen. The impact of acid fog in terms of direct effects on the Boreal Felt Lichen and on the host tree bark acidity likely has an impact on the Nova Scotia populations of this lichen, but at a reduced level.
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						
10.3	Avalanches/landslides						
11	Climate change & severe weather	BD	High - Low	Large - Small (1-70%)	Serious - Slight (1-70%)	High (Continuing)	
11.1	Habitat shifting & alteration	BD	High - Low	Large - Small (1-70%)	Serious - Slight (1-70%)	High (Continuing)	Climate change is predicted to cause Balsam Fir populations to migrate north of Nova Scotia leading to loss of host trees in the medium to long term. Milder winters may also increase the survival and activity of grazing slugs. Secondly, documented and predicted reductions in coastal fog levels in Nova Scotia are expected to reduce the humidity and cause alteration of the Boreal Felt Lichen habitat so that it is less suitable for this lichen to thrive.
11.2	Droughts						
11.3	Temperature extremes						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.4	Storms & flooding	D	Low	Small (1-10%)	Extreme (71-100%)	High (Continuing)	Extreme wind events can cause wind-throw that results in loss of host trees and destruction of surrounding habitat that also result in changes to microclimate.

Appendix Table 1. Known occurrences of *Erioderma pedicellatum* in Nova Scotia. Available upon request from the COSEWIC Secretariat.

Appendix Table 2. Sites and other information on Boreal Felt Lichen contained in the Newfoundland and Labrador Wildlife Division Databases (and Atlantic Canada Conservation Data Centre (Newfoundland and Labrador Satellite office). Available upon request from the COSEWIC Secretariat.

Appendix Table 3. Population trend assessment provided by Department of Environment and Conservation[1]. Available upon request from the COSEWIC Secretariat.