

**A 5 Year (2006 – 2011) Management Plan For the
Boreal Felt Lichen (*Erioderma pedicellatum*)
In Newfoundland and Labrador**



Prepared by

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Common Name (population): Boreal Felt Lichen (Boreal Population)

Scientific Name: *Erioderma pedicellatum*

Current status and most recent date of assessment: Special Concern (Federal), Vulnerable (Provincial), 2002

Reason for designation: A population restricted to regions having a cool, humid oceanic climate, highly sensitive to atmospheric pollutants such as acid precipitation; numerous losses of populations have been documented as a consequence of habitat loss and/or degradation but the species is still widely dispersed throughout its traditional range with some very large populations in protected areas.

Assessment Criteria: Not applicable

Occurrence: Insular Newfoundland

Status history: Federal - Special Concern 2002; Provincial - Vulnerable 2002.

Disclaimer

The Management Plan for the Boreal Felt Lichen was prepared by the Wildlife Division, Department of Environment and Conservation in collaboration with the Boreal Felt Lichen Working Group to identify management strategies, based on sound ecological principles that will ensure the continued survival of this species. It does not necessarily represent official positions of agencies and/or the views of individuals involved in the document's preparation. The goals, objectives and management actions identified in the management document are subject to program priorities, policies and budgetary constraints of the participating agencies and organizations. Goals, objectives, and management approaches may be modified in the future to accommodate new objectives or findings.

The Working Group is made up of members from the general public, government agencies, non-government organizations and Miawpukek (Conne River) First Nation. A list of participants and their respective organizations is found in Appendix 1.

Executive Summary

Document Goal

The goal of this document is to outline what is known about Boreal Felt Lichen (*Erioderma pedicellatum* (Hue) P.M. Jørg) within the Province of Newfoundland and Labrador (lifecycle, distribution, habitat requirements, potential threats and current research) and to identify Boreal Felt Lichen management goals and objectives and the measures needed to attain them.

Introduction

The Boreal Felt Lichen is a conspicuous, foliose arboreal lichen which is restricted to regions having a cool, humid oceanic climate. It is an epiphytic cyanolichen that is easily identified by its slate-grey color, the minute hairs on the upper surface of the thallus, the absence of a lower cortex and distinctive fruiting bodies (apothecia). It is a globally rare species, included in the IUCN Red List of Lichens [www.redlist.org], and has been historically documented in Atlantic Canada, Sweden, and Norway. Currently, there are no known occurrences of Boreal Felt Lichen in Sweden and the survival of the one known Norway thallus is in doubt.

There are two disjunct populations in Canada: the Boreal population (the island of Newfoundland) and the Atlantic population (Nova Scotia and at one time, New Brunswick). The Atlantic population is in imminent danger of disappearing, having undergone a 90 percent reduction over the past 20 years.

There are over 5000 known thalli in Newfoundland. Informal monitoring indicates that there is a substantial decrease in thalli numbers over part of the Avalon Peninsula, suggesting that if not balanced by sufficient regeneration the Boreal population of the species may be under localized stress. Lack of sufficient knowledge on the life cycle, habitat requirements and potential threats to the species has provided challenges in the development of an effective management strategy.

Legal Designation

The Boreal population of the Boreal Felt Lichen is listed as Special Concern under the federal *Species at Risk Act* (SARA). The Province of Newfoundland and Labrador listed the Boreal Felt Lichen as Vulnerable under its *Endangered Species Act* in July 2002. While a listing of Vulnerable does not offer immediate additional protection, it mandates the development of a management plan and periodic status assessment.

Habitat

The vast majority of Boreal Felt Lichen has been found on stems of balsam fir; while few individual thalli have been found on black spruce, red maple and white birch.

The majority of Boreal Felt Lichen thalli are found in wetter forest types but the lichen also occurs to a lesser extent in drier areas. Field data indicate that known Boreal Felt Lichen sites may include slightly different habitat types on the Avalon Peninsula than elsewhere; however, the data reflect search effort to date and are not conclusive. A

review of known and potential sites by a method such as the Damman Forest Site Classification should elucidate the situation.

The forest types where Boreal Felt Lichen is known to occur are typically stable but change to spruce types when disturbed by fire. However, intense moose browsing destabilizes the normal succession by limiting regeneration of the primary host tree, balsam fir.

Current Distribution, Status and Trends

Current knowledge suggests that there are two main centres of concentrations of Boreal Felt Lichen in Newfoundland that appear to be relatively isolated. One of these is located in the centre of the Avalon Peninsula, and the other in the Bay d'Espoir area in and around Jipujikuei Kuespem Provincial Park. Outside of the two known concentrations, known locations are scattered throughout southern Newfoundland and on the western portion of the Great Northern Peninsula. Current knowledge of the distribution and location of concentrations reflects search effort. Given the restricted range of surveys, other unknown, but important, areas may exist for the species.

The pattern of distribution in Newfoundland appears to be controlled by climatic factors such as those that characterize the oceanic boreal and hemi-boreal climatic zones. These areas are cool, moist, and often foggy near the coast. The entire northern portion of central Newfoundland and the eastern part of the Great Northern Peninsula appear to lie within climatic zones that are unsuitable for Boreal Felt Lichen.

With the exception of the Avalon Peninsula and several sites in the Bay D'Espoir area, population trends cannot be assessed using the non-standardized survey methodologies employed to date. Significant declines in numbers of thalli have been recorded on the Avalon Peninsula, indicating a need to quickly establish a Boreal Felt Lichen inventory and population monitoring program throughout the province.

Threats to Populations

A number of threats to Boreal Felt Lichen have been identified. Some of these are of anthropogenic origin, and others are natural processes. The natural stressors, including stand senescence, forest blow down, insect outbreaks and perhaps invertebrate herbivory, represent the natural disturbances with which the lichen has evolved. Acting alone they may not be threats, but, when combined with anthropogenic processes that reduce general ecosystem health and change the species composition and age class structure of the surrounding forest, they may contribute to Boreal Felt Lichen declines.

Anthropogenic threats include wood harvesting, development, moose herbivory, fire, air pollution, pesticides, and climate changes. All of the identified threats and stressors may be found throughout the entire Boreal Felt Lichen range and several threats may act concurrently on a single population of thalli.

Current Management Actions and Protection

Forest Management

Mitigations and pre-harvest plans in place since 1998 have been revised to consider a Landscape Management approach based on ecological forest site types whereby suitable sites for potential Boreal Felt Lichen colonization adjacent to fertile Boreal Felt Lichen thalli are left to cycle naturally. Pre-harvest Boreal Felt Lichen surveys and mitigation measures are also being adopted by the Miawpukek First Nation.

Existing and Candidate Protected Areas

At present, formal protected areas contain over half of the known number of Boreal Felt Lichen thalli. Over 3,000 Boreal Felt Lichen thalli are protected in Jipujikuei Kuespem Provincial Park, and 294 thalli within the Avalon and Bay Du Nord Wilderness Reserves. The Cataracts Provincial Park and Salmonier Nature Park also contain small numbers of thalli. With the exception of Jipujikuei Kuespem Park, Boreal Felt Lichen populations within formally protected areas have not been rigorously inventoried or monitored and the extent and stability of the populations are not known.

Ripple Pond and Lockyer's Waters currently contain a significant proportion of the known Boreal Felt Lichen thalli on the Avalon Peninsula. As candidate ecological reserves they are afforded interim protection.

Management Plan Goal

The goal of the Management Plan is to maintain and enhance where necessary, self sustaining populations of the Boreal Felt Lichen within its current geographic distribution in Newfoundland.

Management Plan Objectives

A number of objectives have been identified that will help ensure the attainment of the Management Goal. These objectives include research, habitat management and protection, education and stewardship and collaboration.

Research

Scientific research will be conducted to fill in critical information gaps on the distribution, life cycle and ecology of Boreal Felt Lichen. A comprehensive threat assessment will also be conducted.

Habitat management and protection

In the interim, a number of management strategies have been adopted. These include an expansion of forest planning and management activities considering Boreal Felt Lichen throughout its range, increased inventory and monitoring efforts, improved data collection and management, protection of transition forest, threat assessment, Boreal Felt Lichen surveys and mitigation plans in areas where larger developments are planned, and possibly moose management. It is expected that these strategies will be modified as our understanding of Boreal Felt Lichen increases.

Education and Stewardship

To ensure the long term survival of Boreal Felt Lichen, it is imperative to involve land owners, users and others who may have an effect on or may be affected by the management of Boreal Felt Lichen. Where feasible, initiatives will be undertaken that include training of Provincial Park staff and development of information material for the general public. Stewardship initiatives will also be explored.

Collaboration

Wildlife Division will maximize the benefits of multiple initiatives by coordinating research within the various organizations and individuals operating within the province.

Evaluation

Implementation will be evaluated every year for level of completion and where necessary, resources will be redirected. It is expected that priorities may change as our understanding of Boreal Felt Lichen biology and management increases.

The overall Management Plan will be reviewed every 5 years and adjusted as required to ensure attainment of the stated goal.

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1. Introduction

The goal of this document is to outline what is known about Boreal Felt Lichen (*Erioderma pedicellatum* (Hue) P.M. Jørg) within the Province of Newfoundland and Labrador (lifecycle, distribution, habitat requirements, potential threats and current research) and to identify Boreal Felt Lichen management goals and objectives and the measures needed to attain them.

The Boreal Felt Lichen is conspicuous, foliose arboreal lichen which is restricted to regions having a cool, humid oceanic climate. It is an epiphytic cyanolichen that is easily identified by its slate-grey color, the minute hairs on the upper surface of the thallus, the absence of a lower cortex and distinctive fruiting bodies (apothecia). It is a globally rare species, included in the IUCN Red List of Lichens [www.redlist.org], and has been historically documented in Atlantic Canada, Sweden, and Norway. Currently, there are no known occurrences of Boreal Felt Lichen in Sweden and the survival of the one known Norwegian thallus is in doubt.

There are two disjunct populations in Canada: the Boreal population (the island of Newfoundland) and the Atlantic population (Nova Scotia and at one time, New Brunswick). The Atlantic population is in imminent danger of disappearing after having undergone a 90 percent reduction over the past 20 years. A total of 32 Boreal Felt Lichen thalli are known to exist in Nova Scotia (Robert Cameron pers. comm. 2005) and the species is now considered extirpated in New Brunswick. The reported primary threats to Boreal Felt Lichen in Nova Scotia are logging and land development with speculation that climate change may be a particular threat during the establishment phase of juvenile thalli (Robert Cameron pers. comm. 2006). The wholesale disappearance of Boreal Felt Lichen from all of the southern parts of Nova Scotia was interpreted as having been caused by long-range transported air pollutants from the industrial areas in the northeastern U.S.A. and in southern Ontario (Maass 2004).

Informal monitoring indicates that there is a substantial decrease in the number of known thalli in parts of the Avalon Peninsula, which is likely due to the progression of its life cycle. If these localized declines are not balanced by regeneration in nearby areas, this may suggest that these areas may be under unnatural stress. Lack of sufficient knowledge about the life cycle and habitat requirements and potential threats to the species has provided challenges in the development of an effective management strategy thus far.

After the 2002 assessment, the Atlantic population of Boreal Felt Lichen was listed as Endangered and the Boreal population as Special Concern under the federal *Species at Risk Act* (SARA). The difference in designation between the two populations reflects the difference in population sizes between Newfoundland (Boreal) and Nova Scotia and New Brunswick (Atlantic).

The Province of Newfoundland and Labrador listed the Boreal Felt Lichen as Vulnerable under its *Endangered Species Act* in July 2002. While a listing of Vulnerable does not

offer immediate additional protection, it does mandate the development of a management plan and periodic status assessment. With the Boreal Felt Lichen now extirpated over most of its global range the significance of remaining Newfoundland populations is all the more important for the long term survival of the species.

2. Background

Reproductive Biology

Boreal Felt Lichen, when fertile, displays numerous plush purple/orange apothecia on the surface of the upper cortex and along the periphery of the upper lobes. Reproduction is sexual in this species (Maass and Yetman 2002) and the lack of vegetative propagules makes the Boreal Felt Lichen dependent upon a *de novo* synthesis of new thalli. This means that initiation of a new life cycle is a chance encounter between the single and sometimes full complement of eight spores of a single ascus (Yetman 2006) and a suitable strand of the free-living form of the cyanobacterium, *Scytonema*. The process of lichenization then begins.

It is speculated that the hepatic liverwort, *Frullania tamarisci* ssp. *asagrayana* plays a key role in the early development of the lichen thallus (Maass and Yetman, 2002). The symbiotic fungal hyphae and the cyanobacterium, *Scytonema*, begin early lichenization in the aseptate water sacs of this liverwort. The lichen eventually develops and anchors to the trunk or branch of its host tree, most often balsam fir (*Abies balsamea*). Of the approximately five percent of thalli not observed to be in association with *Frullania*, almost all were on branches of balsam fir implying that liverwort may also play a significant role in the establishment of the thalli's holdfasts. The early stage of the life cycle of the species is one of the few documented processes. Little is known about the other stages of the species life cycle.

Recent research (Yetman 2006) indicates that common boreal insects such as the small flying beetle *Anapsis rubis* may act as key dispersal agents of the Boreal Felt Lichen by picking up passively discharged spores from the surface of the lichen thallus and transporting them into adjacent forest stands. Maass and Yetman (2002) also mention the possibility of dispersal by strong moisture-laden winds, mosquitoes, and, over longer distances, by birds. Additional research is required to document how dispersal biology interacts with the disturbance regime of the inhabited stands and the successful colonization of host trees. Investigation of the relationship of gap dynamics and spore dispersal is also required.

Habitat - Forest Ecology

Meades and Moores (1989, after Damman, 1983) describe nine ecoregions in Insular Newfoundland and Boreal Felt Lichen has been recorded in six of these: Long Range Barrens; Maritime Barrens; Central Newfoundland Forest (Bay d'Espoir area only);

Western Newfoundland Forest (Bay d'Espoir area only); Avalon Forest; and Northern Peninsula Forest (Figure 1).

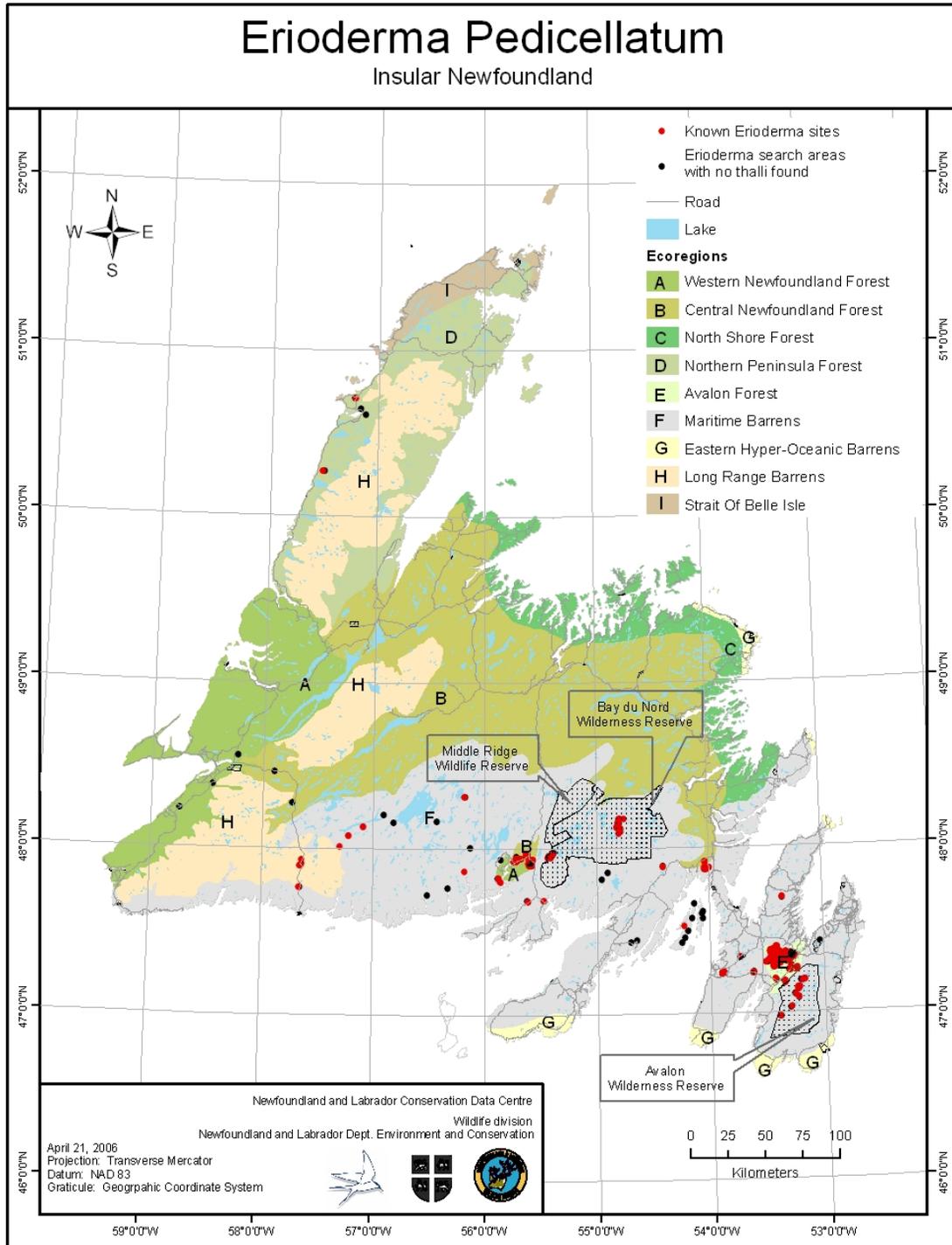


Figure 1. Known Range of Boreal Felt Lichen (boreal population) on the Island of Newfoundland as of July 2006. Some (but not all) search areas where no thalli were found are also indicated.

Boreal Felt Lichen is typically found in cool, moist, *Sphagnum*-rich sites in a variety of conditions and associated with other cyanolichens (Maass and Yetman 2002). Maass (2004) describes these sites as half-open wetlands and woodlands adjacent to nutrient poor fens and bogs. Boreal Felt Lichen is considered phytophilic (Maass 2004) and has been observed and recorded generally in stands of crown cover between 25 and 75 percent, although occurrences in lower than 25 percent crown cover have been recorded, mainly in wetter areas throughout insular Newfoundland (Clarke, unpublished data, 2002 to 2005).

Boreal Felt Lichen has largely, but not exclusively, been found in transitional (wetter) forest zones between bogs and dry upland forest (forest areas classified as scrub, or poorer Damman forest) and forested wetlands as described by Maass previously. Positions on lower slopes are moist for longer periods than those upslope in the same climate. Differences in air and soil temperatures and soil water retention exist across as small a scale as two hundred metres (Clarke, 1979; Chow and Roberts unpublished data 1978 and 1979). However, field observations to date suggest that Boreal Felt Lichen may also occupy other habitat types. Unpublished data by Conway (2005) indicates that on the Avalon Peninsula at least, Boreal Felt Lichen also occurs to a lesser degree in moderately dry mid-slope forests and more rarely in dry forests along ridge tops.

Field data for areas outside of the Avalon Peninsula indicate less variability in habitat with few observations of Boreal Felt Lichen in moderately dry and dry forest types. However, it is possible that these observed differences are, at least in part, due to differences in search effort. Whether there are differences in habitat preferences between the Avalon Peninsula and the remainder of the island could be elucidated by classifying known Boreal Felt Lichen sites, as well as sites without Boreal Felt Lichen, to Damman Forest types and keeping search effort constant throughout all slope positions.

Early work by Ringius (1997) attempted to link Damman Forest types with Boreal Felt Lichen occurrence. The Damman forest types where Boreal Felt Lichen is known to occur are stable (i.e. they are self perpetuating) after logging and windthrow but go to spruce forest types when disturbance is by fire (Meades and Moores, 1989). However, high densities of moose and subsequent high browsing intensity destabilizes the successional replacement of balsam fir after natural and anthropogenic disturbance (McLaren and Hermanutz, unpublished data) limiting advanced regeneration of this forest type, and hence potential host tree availability (McLaren et al. 2004).

The vast majority of Boreal Felt Lichen has been found on stems of balsam fir; few individual thalli have been found on black spruce (*Picea mariana*), red maple (*Acer rubrum*) and white birch (*Betula papyrifera*). Thalli are usually found on stems but have also been observed on the branches of fir and spruce. Boreal Felt Lichen has been found in Norway on Norway spruce (*Picea abies*). Norway spruce is currently used in re-forestation in Newfoundland.

The liverwort *Frullania tamarisci* spp. *asagrayana* appears to play a central role in helping Boreal Felt Lichen become established on the trunks of suitable conifers as it contains small water sacs, in which lichenization is believed to occur (Maass and Yetman 2002). *Frullania* has been observed on forty year old thinned stands on the Avalon, but not in high density naturally regenerating stands forty years old, except within three metres of the edge of the stand (Clarke, unpublished data from Central Avalon areas).

Of the approximately 5 percent of thalli not observed to be in association with *Frullania*, almost all were on branches of balsam fir. This may imply that *Frullania* also plays a role in the thallus holdfast. The lack of observed *Frullania* in dense natural forest regeneration may indicate a preference of the species for more open stands although this hypothesis warrants further testing.

The duration of the lifecycle of balsam fir dominated forests vary depending on forest types; poorer quality sites generally take longer to cycle than sites with higher productivity. Butt rot may begin in balsam fir as early as 40 years and will increase as the tree gets older. Butt rot, insect herbivory and the resulting susceptibility to wind throw disturbance, is the decisive factor in setting the rotation of balsam fir at 70 years. Generally, the drier the site, the greater the damage from rot (Fowells, 1965). Trees on better sites (higher forest growth capacity) cycle more quickly. Transitional forests are suppressed and generally take much longer to move through the typical life cycle (i.e. individual trees may remain on the landscape for a period exceeding 140 years) (Bruce Roberts pers. comm.).

The Boreal Felt Lichen has been observed on naturally regenerating stands of balsam fir at age 60 (Clarke, unpublished data from the Bay d'Espoir area, 2005) and has been recorded on 45 year old thinned stands (Clarke, 2005a). During the approximately 15 to 25 years of the senescent to decaying phase of the forest, when gaps begin to appear within the stand, previously established Boreal Felt Lichen thalli are able to achieve a high growth rate due to increasing favourable light conditions in the forest. Scheidegger (1996) suggested that the reproductive phase of the lichen is restricted to this period when vectors disperse the minute spores of the lichen. It is theorized that the life cycle of the species would begin again in another stand of suitable ecology and successional stage. A complete second life cycle of the species has never been observed on the same trees.

Boreal Felt Lichen growth has been measured in the exponential phase of growth at 11 to 14 mm/year (Maass 2004). Observed thalli have rarely been greater than 80 mm in size. Persistence of thalli has been documented for a period of 23 years (Mac Pitcher pers. comm.).

Research is still required to determine what, if any, is the relationship between thallus size (and maturity) and stand phase and the spatial variability throughout the distribution range.

Survey and Monitoring History

Until Ahti (1959), lichen exploration in Newfoundland was largely unknown. From Ahti's extensive initial collections in 1957 and subsequent visits, Ahti produced a number of additional papers including (Ahti and Jørgensen 1971), the first in a numbered series on Notes on the Lichens of Newfoundland 1- *Erioderma boreale*, New to North America. This was the first report of Boreal Felt Lichen being collected (under the synonym *Erioderma boreale*) in Newfoundland. Extensive reviews of the more than 600 local lichen species and distributions & ecology are found in Maass (1980) and Ahti (1983). The value of lichens as pollution monitors was also reviewed by Ahti (1983), including local work (Roberts and Thompson 1980) and national work, as well as the sensitivity of certain lichen species to various pollutants.

In the early 1980's Dr. Wolfgang Maass of the National Research Council undertook surveys of the lichen flora of Atlantic Canada with particular emphasis on Boreal Felt Lichen and found Boreal Felt Lichen in many sites around the province, including the Great Northern Peninsula, the Avalon Peninsula and in the St. Alban's and Bay d'Espoir area. (Maass 1980, 1983).

The Newfoundland Department of Forest Resources and Agrifoods (DFRA) (now Department of Natural Resources) made substantial contributions to Boreal Felt Lichen discoveries beginning in 1997 by surveying a number of existing parks and wilderness reserves and some areas proposed for forest operations. Subsequent to the award of a contract for completion of a status report on Boreal Felt Lichen, information was provided to the DFRA on the general location of sites previously recorded by Dr. Maass and others. A number of these sites were revisited on opportunistic forays in five main areas of insular Newfoundland which resulted in the location of some 200 sites and 5,000 thalli by the DFRA. Search effort was mainly concentrated close to existing highways and forest access roads, supplemented by one day's helicopter flying and two forays by canoe. Mapping of locations visited where Boreal Felt Lichen was found (and where not found) was provided to the Wildlife Division. The combined search effort was less than 1,000 person hours, and this effort decreased after 2002 to the level of continued inclusion in pre-harvest surveys and two forays in 2005 to address specific questions on Boreal Felt Lichen management (Clarke 2005a, b and c).

An initial survey conducted by provincial Wildlife Division staff confirmed the presence of Boreal Felt Lichen in Lockyer's Waters in 1996. An informal non-government organization (later to become the Newfoundland Lichen Education and Research Group - NLERG) and the Newfoundland and Labrador Wildlife Federation conducted several more surveys in the area that extended the known distribution of Boreal Felt Lichen. In 1996 and 1997 several hundred more Boreal Felt Lichen thalli were located by the NLERG in Lockyer's Waters and McGee's Gully areas of the Avalon Peninsula).

Voisey's Bay Nickel Company (VBNC) in 2002, 2003 and 2005 funded a re-survey of the previously documented sites in Lockyer's Waters. Those surveys were facilitated by NLERG. From September 1996 to October 2005 Youth Services Canada, VBNC and NLERG funded several visits of a lichenologist to Newfoundland.

Little is known about the population of Boreal Felt Lichen outside of the Bay d'Espoir and Avalon Peninsula areas. For example, the Burgeo Road and Great Northern Peninsula sites have had limited survey effort. Vast areas of potential Boreal Felt Lichen habitat have never been systematically surveyed, especially between the Burgeo Road and Bay du Nord populations. Also, the entire north east coast (North Shore Forest Ecoregion) has yet to be surveyed.

Reconnaissance level surveys were carried out in February 2006 near sites where Boreal Felt Lichen had previously been observed along the Burgeo Road and further south to the town of Burgeo. Two mature thalli were found near a previously recorded population of 88. However, it is unknown whether those two thalli were all that remained of the original population or represented a new population.

A helicopter foray was carried out in March 2006 to survey and delineate the distribution of Boreal Felt Lichen in remote areas from Conne River west to the Burgeo Road. New discoveries were made of Boreal Felt Lichen populations near White Bear Bay Brook and Bay d'Espoir Brook in the southern interior of the island.

In surveys of areas adjacent to where Boreal Felt Lichen had been found, 11 new sites with 95 thalli in 15 person hours searching of approximately an additional five hectares of the Bay du Nord Wilderness Reserve; an additional three new sites with 226 thalli in 22 person hours over 15 hectares adjacent the Salt Pit area in Bay d'Espoir; and an additional five sites with 79 thalli across the road from Jipujijkuei Kuespem Park (Clarke 2005a and b).

Three sites in the Salt Pit area and three sites in Jipujijkuei Kuespem Park were resurveyed seven years after the initial Boreal Felt Lichen discovery. Results showed three sites had more thalli and three sites less, than during the initial survey. Overall the population within these survey areas remained nearly stable (Clarke 2005c).

Two extensive lichen surveys, which were not directed especially at Boreal Felt Lichen, also deserve to be mentioned. Four students from Imperial College in London, England, performed an extensive seven week arboreal lichen survey in Salmonier Nature Park in 1980. Their specimens, which are located at the British Museum in London, England, have not yet been catalogued and it is not known at this time whether they collected any Boreal Felt Lichen (Mac Pitcher, pers. comm., 2006). As part of the Newfoundland Rare Plant Project the Finnish lichenologist Teuvo Ahti visited the Soufflets and Main River Valleys in 2000 where he spent eight days performing lichen surveys and tentatively identified 124 lichen species. However, he did not observe Boreal Felt Lichen in these areas.

Current Research

A project to determine the photobiont partner of Boreal Felt Lichen and to detect if free-living colonies of this cyanobacterium are present in possible Boreal Felt Lichen habitats has been initiated and will involve the development and testing of a molecular probe.

Hypotheses about the role of *Frullania asagrayana* in the early life cycle of the fungal partner of Boreal Felt Lichen will also be tested. A study will also be conducted at Lockyer's Waters to determine whether Boreal Felt Lichen can establish new thalli within a stand that is already colonized by this lichen.

NLERG will study the life cycle of Boreal Felt Lichen at Lockyer's Waters and southeast Placentia by assessing growth and death rates of, as well as transition probabilities between, the developmental stages of Boreal Felt Lichen. To achieve this, they will monitor four times each year several hundred Boreal Felt Lichen thalli that were documented and photographed throughout the proposed Lockyer's Waters Reserve and Southeast Placentia during October and November 2005. The thalli will be photographed again after one year and at the end of the project.

Current Distribution, Status and Trends

Current knowledge suggests that there are two disjunct centres of concentration, one on the Avalon Peninsula and the other in the Bay D'Espoir area (Figure 1). However, there have been limited surveys in the area between these two population concentrations and at least some of this intervening area appears to be suitable habitat. It is likely that the two centres of concentration are at least somewhat divergent, and they may be completely isolated. The habitat requirements and ecology of Boreal Felt Lichen seem to be slightly different between the two centres of concentration and it is possible that there are genetic differences as well.

Search effort has not been constant across the range of the lichen and it is possible that some of the high concentrations of thalli, such as that found at Lockyer's Waters, strongly reflect the intensive survey effort in these areas. However, during many surveys search effort has not been quantified and is therefore not directly comparable among areas. Given the restricted range of surveys, it is possible that some important concentrations of the species are currently still unknown.

However, some of the gaps in the distributional maps of Boreal Felt Lichen in Newfoundland represent real disjunctions based on the presence of extensive areas of open heath habitat unsuitable for this species. In the southern coastal and central regions of Newfoundland, the potential still exists of finding additional populations of the lichen in sheltered forested valleys within the extensive heath barrens.

The pattern of distribution in Newfoundland appears to be controlled by climatic factors such as those that characterize the oceanic boreal and hemi-boreal climatic zones representing cool, moist and often foggy conditions in the more coastal areas. The entire central northern portion of Newfoundland and the eastern region of the Great Northern Peninsula, although largely forested, appear to lie within climatic zones that are either warmer, colder and/or drier during the growing season than areas where Boreal Felt Lichen populations currently are known to exist.

So far, trends could only be determined for populations on the Avalon Peninsula and six sites in the Bay D'Espoir area. Where resurveys have been done six to eight years after initial survey in areas of known concentrations of Boreal Felt Lichen, some populations, most noticeably at Lockyer's Waters on the Avalon Peninsula, have found to have declined up to 80 percent from initially recorded numbers (Conway, unpublished data, 2005). Other resurveys over this time in the Bay D'Espoir area have reported declines in numbers of initially observed thalli. However, new (young) thalli were located so that the total numbers in specific areas have remained the same or even increased (Clarke, 2005c). It is thought that this may be due to the age/condition of the mature stand, the presence of younger stands cycling through required age classes, and the possibility of a number of "waves" of thalli going through a stand in its period of suitable declining phase.

Although a scientifically rigorous procedure has not yet been devised to assess the trend of all Boreal Felt Lichen population within the province, a substantial decrease in parts of Avalon Peninsula seems obvious and indicates a need to quickly establish a Boreal Felt Lichen inventory and population monitoring program throughout the province.

Threats to Populations

A number of factors may, either alone or acting in combination, reduce the abundance of Boreal Felt Lichen and perhaps threaten the lichen's survival in an area. These potential threats can be natural processes, such as stand senescence, forest blow down, insect outbreaks and perhaps slug/mite herbivory, or of anthropogenic origin, such as wood harvesting, development, moose herbivory, fire, air pollution, pesticides, and climate changes. All of these identified threats may be found throughout the entire Boreal Felt Lichen range.

A summary of the identified threats is presented in Appendix 2.

Natural Stressors

Generally, the natural stressors represent the natural disturbance regimes resulting in stand death and renewal. On the Avalon Peninsula the average maximum age of balsam fir is approximately 70 years. While the existing thalli in a stand are periodically lost as the trees die, collapse and are being replaced, the lichen would be expected to have had sufficient chance to establish a new generation on different trees or even in different stands. These natural cycles and the resulting sizes and distribution of age class patches, represent the conditions that Boreal Felt lichen has evolved in. In the absence of anthropogenic factors we suspect that these natural processes would not be considered threats to the persistence of Boreal Felt Lichen.

However, in combination with stressors of anthropogenic origin, these processes have the potential to cause serious declines of the lichen. The anthropogenic threats either shorten the time that the thalli are producing spores, change the size and distribution or species composition of regenerating stands, possibly reducing the availability of spore receiving

areas, and/or make the microclimate or chemical environment unsuitable for the lichen or its reproductive process.

Stand Senescence

Stand senescence is the natural phenomenon of aging of the trees on particular sites. As trees near their biological lifespan, crowns and root systems cease to function and bark eventually sloughs off the trees. Mortality is often hastened by rot, insects and disease. The physical deterioration of trees is also assisted by wind, freezing rain, snow loads and other weather influences which bring bark, other portions of trees and eventually main stems to the ground to decay. In several areas on the Avalon Peninsula a large loss of Boreal Felt Lichen thalli has been observed in senescent stands. The site becomes unsuitable as Boreal Felt Lichen habitat until a new stand of appropriate age and species composition is established.

Blowdown

Blowdown is an agent of renewal in forests that have reached a senescent state. Boreal species, notably the main phorophytes of Boreal Felt Lichen, are shallow rooted (Fowells 1965) and are in areas frequently subjected to high winds. Gale force winds from non-prevailing wind directions frequently result in catastrophic blowdown or windthrow events. Blowdown most frequently occurs in senescent stands and in areas where risk is increased by defoliation or disease that has weakened rooting systems. In the central Avalon Peninsula approximately 5,000 hectares of forest blew down in one event in the mid-1990's. The incidence of extreme weather events, including violent windstorms, is predicted to increase as a result of climate change.

Insect outbreaks

Major tree defoliators in the region include spruce budworm (*Choristoneura fumiferana* Clem.) and hemlock looper (*Lambdina fiscellaria fiscellaria* Gn.), of which balsam fir, the main Boreal Felt Lichen phorophyte, is the preferred host. Outbreaks are generally cyclic and mainly affected by the age and contiguity of stands, species composition and weather, although other variables such as wind and topographic position can have significant effect. Tree mortality can result in as little as one year for severe hemlock looper infestation to five or more years for light to moderate budworm infestation. (Otvos and Moody, 1978; Otvos et al, 1979). Generally, thalli can persist on insect damaged phorophytes until the bark is sloughed off the trees killed through defoliation. The consequence of insect outbreak combined with other natural and non-natural disturbances is not well understood.

Slug/mite herbivory

Mites often feed on mosses and on the decaying parts of bark. The effects of browsing by mites on Boreal Felt Lichen thalli are also quite evident in certain field sites although, in general, they do not impose a threat to existing populations of the lichen. Yetman (2006) has identified at least one species of mite from the Lockyer's Waters locality that was collected from the surface of a moist Boreal Felt Lichen thallus.

Browsing by snails has also been observed but is a minor threat (could be significant in some localized areas) that occasionally leads to partial removal of the upper cortex and the photobiont layer beneath (Maass and Yetman 2002). According to John Maunder (Curator Emeritus, Provincial Museum of Newfoundland and Labrador, pers. comm. 2006) no snail species are commonly found on trees in remote forested areas, but a native slug, *Deroceros laeve*, occurs in this habitat. Introduced species of snails and slugs may be encountered in areas close to human habitation. Efforts should be made to collect and identify any invertebrate herbivores feeding on Boreal Felt Lichen.

Anthropogenic Threats

Known or potential threats that are either entirely anthropogenic, or whose frequency and severity are increased as a direct result of human activities are included in this category. Presently some Boreal Felt Lichen thalli are located in remote areas of south-central Newfoundland where the likelihood of anthropogenic impacts is low.

Wood harvesting

The presence of mature, senescent and regenerating stands of suitable phorophytes is a condition necessary for Boreal Felt Lichen to persist on the landscape. Any land use which precludes suitable phorophytes will have an adverse affect on Boreal Felt Lichen populations.

Generations of selective cutting and clear cutting (Wilton 1956 ; Baker and Pitt 1998; and DFRA Records) (combined with relatively small stand sizes and other disturbances) have resulted in a mosaic of small even-aged stands interspersed with wetlands and transitional forest zones in most areas where the Boreal Felt Lichen has been located in Insular Newfoundland.

Current data suggest that Boreal Felt Lichen primarily inhabits forest stands found in the transitional zone between wetlands and drier upland sites and forested wetlands. These same forest stands are typically less valuable to both industrial and domestic wood harvesters due to the lower volumes of wood found in these areas as compared to up-slope forests.

Thus far, the harvesting of transitional forest types has largely been avoided by commercial operators. Should the value of these stands increase, the potential exists for the destruction of Boreal Felt Lichen thalli and the temporary removal of important Boreal Felt Lichen habitat. The specific forest habitat requirements for Boreal Felt Lichen are still not clearly understood and warrant further research.

Domestic wood harvesters are typically restricted to non-commercial forest stands and as such, may harvest a disproportionate amount of wood from transitional areas. In the Bay D'Espoir area a stand bearing 75 thalli on black spruce was lost due to a small patch cut attributed to domestic firewood harvest (Wolfgang Maass, pers. comm. to Mac Pitcher, 1996). However, the overall significance of domestic wood cutting on Boreal Felt Lichen persistence is not known.

Although, as described previously, Boreal Felt Lichen primarily inhabits transitional forest types, the lichen has also been documented in drier mid-slope and dry crest position forests (Conway 2006, unpublished data). The harvesting of these forest types may result in the destruction of Boreal Felt Lichen thalli and the removal of secondary habitat for a period of possibly forty years from natural regeneration to mature stand conditions. As with the primary Boreal Felt Lichen habitat, transitional forests, the specific conditions that allow Boreal Felt Lichen to inhabit these upslope sites and the role of these sites in Boreal Felt Lichen survival have not yet been clearly defined.

It should be further investigated whether drier forest types in mid- and upper slope positions play a significant role in the survival of viable populations of Boreal Felt Lichen and whether the temporary removal of this habitat could represent a threat to the lichen.

Aside from the potential removal of Boreal Felt Lichen thalli and habitat, wood harvesting can also temporarily alter the micro-climate in adjacent areas. An alteration of micro-climate may affect the survival of existing thalli, as well as colonization or survival of Boreal Felt Lichen in the adjacent areas. The degree to which gap sizes, and the resulting alterations in microclimate, differ from those produced by natural disturbances, has not yet been quantified in areas inhabited by Boreal Felt Lichen. Also, the sensitivity of Boreal Felt Lichen to such alterations in micro-climate is not yet understood and warrants further research.

Boreal Felt Lichen exists in association with other cyanolichens such as *Lobaria scrobiculata*, *Coccocarpia palmicola* and *Lichinodium sirosiphoideum*. The latter two, like Boreal Felt Lichen, have *Scytonema* as the photobiont. Several other cyanolichen associates occur with Boreal Felt Lichen, including *Parmeliella parvula*, *Fuscopannaria ahlneri* and *Moelleropsis nebulosa ssp. frullaniae*. Although the relationship between Boreal Felt Lichen and the associated lichens is not well understood, the removal of host trees and the associated lichens may affect the survival of Boreal Felt Lichen in adjacent areas.

Development

Many different types of development have the potential to affect Boreal Felt Lichen. In contrast to most natural disturbance and to cutting, development and changes in land use often result in a permanent loss of habitat and/or reduced site quality. An analysis of cabin development patterns and trends is ongoing to determine to which extent cabin development may have affected Boreal Felt Lichen habitat in the past and whether it is likely to impact the lichen in the future. The potential impacts of other types of development, including road building and industrial development, will also be examined.

Moose herbivory

Moose were successfully introduced in central Newfoundland in 1904 and had made their way throughout insular Newfoundland by 1941 (Pimlott 1953) when they were first reported on the Avalon Peninsula. In some areas, moose populations have occasionally

grown to densities such that natural regeneration of tree species, notably yellow birch (*Betula alleghaniensis*), white birch (*Betula papyrifera*) and balsam fir, has been browsed out of the regenerating forest. Repeated browsing has been observed to restrict and to cause death of balsam fir seedlings and regeneration up to one meter in height. In places, repetitive browsing appears to have occurred over a period of ten to twenty years and has effectively halted the forest regeneration process.

Moose browsing generally does not damage thalli-bearing mature phorophytes but does prevent stands of young trees from becoming Boreal Felt Lichen habitat as the senescent stands collapse. Minor numbers of thalli may be lost from mechanical damage as the animals move through the forest. Further studies are needed to determine to which extent moose herbivory is affecting the species composition and age class distribution in or near the centres of concentration of Boreal Felt Lichen (the central Avalon Peninsula and the Bay D'Espoir area).

Fire

Fire is the natural forest renewal agent in the portion of the known range of Boreal Felt Lichen dominated by black spruce. However, most fires in Newfoundland are caused by humans. Wildfire on Campobello Island of New Brunswick, resulted in the loss of Boreal Felt Lichen there; while at Long Pond, on the Burin Peninsula of NL, destruction of habitat by fire and considerable spread of thick smoke apparently removed known sites in that area (Maass 2004). While fire may not be the main natural disturbance in much of Boreal Felt Lichen's range, heavy slash loadings from blow down combined with the main cause of fires (human carelessness) create, in these and other areas, real threats to stands of various ages in much of the forested landscape where Boreal Felt Lichen occurs. Wetter areas, more favourable to Boreal Felt Lichen colonization, are less prone to effects of fire spread; however, predictions on the occurrence, spread and severity of future fires forecast in consideration of global warming may confound the reprieve on wetter sites.

Air pollution

In general, it is clear that Boreal Felt Lichen and other lichens possessing the cyanobacterium symbiont *Scytonema* are highly sensitive to atmospheric pollution. The following description has been taken from the Boreal Felt Lichen COSEWIC Status Report (Maass and Yetman 2002).

It has long been suspected that acid rain eliminates sensitive lichens from suitable ecosystems for two reasons (Hawksworth and Rose 1976; Richardson 1992). First the already naturally acidic substrates are further acidified, thereby reducing the buffering capacity of the bark (Nieboer et al. 1984). Second the lichen thallus is immediately affected by the uptake of air pollutants (Farmer et al. 1992). Cyanolichens, in particular, are more vulnerable to the effects of air pollution. All of the cyanophilic lichens are capable of trapping and utilizing molecular nitrogen from the air for the generation of nutrients containing nitrogen. A common characteristic of theirs is that the nitrogen-fixing enzyme, nitrogenase, has a remarkable intolerance for the presence of SO₂ (James 1973).

The presence of acid rain appears to contribute to the loss of Boreal Felt Lichen from some substrates, particularly spruce, which has a more acidic bark than balsam fir. The damage to the holdfast areas has been exceptional among the cyanophilic lichens, and therefore Boreal Felt Lichen is ranked highest on the list of sensitive species of Nova Scotia.

Acid fog is more dangerous than acid rain because the thalli remain enveloped in stagnant acid fog for extended periods of time. This could be one of the two determining factors in the gradual disappearance of sensitive cyanophilic lichens from southern Nova Scotia. Acid deposition studies by Cox et al. (1989) in the Bay of Fundy region have shown that the average fog pH was 3.6, i.e., one pH unit lower than the average rain pH in the same area. Although no direct evidence has been shown for the effects of acid fog on lichens, evidence gathered in recent years (Cox et al. 1996; Cox et al. 1998; Kouterick et al. 1998) indicates that foliar browning in many of the natural stands of heartleaf birch (*Betula cordifolia*) and white birch in the outskirts of the Bay of Fundy is, either directly or indirectly, caused by acidic fog.

The contribution of long range transported air pollution is far less significant than pollution from local sources, including the Come-by-Chance Refinery and the Holyrood Generating Station on the Avalon Peninsula as well as the pulp and paper mills on the west coast (Wadleigh et al. 1999). The trends in acid deposition and other air pollution, and the possible role of pollution in the disappearance of several Boreal Felt Lichen populations, will be further investigated.

Pesticides

Trichlorfon (which is known under the trade name "DYLOX") had been approved by the Pest Management Regulatory Agency of Health Canada in 1998 as a spray reagent.

Since the upper cortex of Boreal Felt Lichen does not appear to have significant water repelling properties, its cyanobacterial layer would be readily accessible to aqueous droplets containing this chemical, which could then do damage to the cellular membranes and to the nitrogenase of *Scytonema* under dry weather conditions. Fortunately, the use of Trichlorfon as a spray reagent against the sawflies in Newfoundland has been abandoned for the time being. A far less harmful agent, azadirachtin, an extract from the Indian Neme tree (*Azadirachta indica*), is currently being used (Maass and Yetman 2002).

Major insect and disease pests of balsam fir have been first reported in NL in the period of the early 1900's to the 1960's. It is possible that several of those species which utilize the main Boreal Felt Lichen phorophyte may have populated the area for longer than a century. The degree of adaptation with some of these species is not known: however, where species have co-existed for extended periods and demands on the system remain relatively balanced, pesticides could be more damaging to Boreal Felt Lichen than insect infestations.

Climatic changes

On a macro-scale, the birch die-back in Eastern Canada and in the adjacent parts of the U.S.A. can be viewed as being the immediate result of global warming, according to the work by Auclair (1987) and Auclair et al. (1992). See the explicit review by Braathe (1995). Even though the effects of global warming upon lichens are not as easy to measure as the extent of the birch die-back in Eastern North America (through aerial reconnaissance), they may manifest themselves in having given rise to partial losses of earlier established distributional ranges. In particular, those respective lichens that largely depend on a particular tree species (such as birch) as its main phorophyte, or lichens that are extremely dependent upon high humidity habitats, such as Boreal Felt Lichen, may be sensitive to climate change.

Current Management Actions and Protection

Forest Management

In early 1997, DFRA engaged a consultant to conduct Boreal Felt Lichen site visits to record habitat information, potential threats and to make recommendations for the conservation of Boreal Felt Lichen. That report included specific recommendations on cut size, road construction, buffering and surveys. These recommendations (Robertson 1998) as summarized in Appendix 3, were implemented in 1998 by the DFRA and have continued in addition to pre-harvest plans that designate (and flag) buffers and areas to be avoided. These mitigations and pre-harvest plans in place since 1998 have been revised on an interim basis to consider a landscape management approach based on ecological forest site types whereby stands with concentrations of fertile Boreal Felt Lichen thalli and nearby suitable sites for potential colonization are left to cycle naturally (see Appendix 3).

The Miawpukek First Nation (MFN) has obtained funds from Environment Canada's Species at Risk Critical Habitat Protection Program to monitor the population of BLF within the Jipujikuei Kuespem Park and its Forestry Management Area (FMA). The Miawpukek First Nation's main objectives are to determine the population status of these populations, to determine if more Boreal Felt Lichen is present within its FMA, and to incorporate the Boreal Felt Lichen Management Plan into its Land Use Management Plan. All areas slated for development are being assessed for the presence of Boreal Felt Lichen, and if detected, all measures specified in this management plan are being utilized to protect this species.

Protected Areas

At present, formal protected areas, including Wilderness Reserves, Provincial Parks and Salmonier Nature Park, contain over half of the known Boreal Felt Lichen thalli. Additional thalli are located within two candidate ecological reserves on the Avalon Peninsula. The majority of the protected thalli are found in the Bay D'Espoir area. Less than 5 % of currently known thalli in existing parks and reserves are found on the Avalon Peninsula.

In 1986 and 1990, the Avalon and Bay du Nord Wilderness Reserves covering areas of 2,895 km² and 1070 km² respectively, were established to protect caribou herds and representative portions of the Maritime Barrens ecoregion. Within these two reserves approximately 47 ha were surveyed in 116 person hours of searching, and 294 Boreal Felt Lichen thalli at 43 sites were found during these efforts. These thalli are currently protected within these reserves under the *Wilderness and Ecological Reserves Act*, associated Wilderness Reserve Regulations, and respective management plans. This legislation prohibits industrial activity such as mining, agriculture and forestry as well as the removal of plant material. The management plans state specific policies to be implemented within the reserves to protect the reserves' natural features.

Over 3,000 Boreal Felt Lichen thalli on 41 sites are also protected in a number of provincial parks including Jipujikuei Kuespem (6.69 km²) and the Cataracts (1.72 km²). Approximately 335 ha were covered in 340 person hours of searching. The *Provincial Parks Act* and associated Provincial Parks Regulations prohibit the harmful destruction or removal of any object in a park. Boreal Felt Lichen has been documented within the former boundaries of Fitzgerald's Pond Provincial Park; however, the portion of the park with the lichen has since been decommissioned.

In Salmonier Nature Park (14.55 km²) 25 thalli were found at three sites. At the larger site, which has been visited three times after its discovery and initial survey in 1980, the number of thalli had declined from 17 to 5 in 2006, and at one site all four observed thalli had disappeared by 1993. Less than 10% of the park has been surveyed for Boreal Felt Lichen on an opportunistic basis concentrating on suitable habitat, with a search effort of approximately 4 person days. It is not known at this time whether the expedition from Imperial College in 1980 encountered any Boreal Felt Lichen.

With the exception of Jipujikuei Kuespem Park, Boreal Felt Lichen populations within formally protected areas have not been rigorously inventoried or monitored and the extent and stability of the populations is not known. The majority of the surveys within protected areas in the province have been carried out by the DFRA. It is suspected that significant areas of potential habitat within protected areas have yet to be surveyed.

Candidate Protected Areas

Ripple Pond and Lockyer's Waters are candidate protected areas currently contributing to the existing protection of Boreal Felt Lichen on the Avalon Peninsula. Lockyer's Waters is proposed specifically for the protection of Boreal Felt Lichen while Ripple Pond is proposed for ecoregion representation. Activities such as cutting are not permitted while the proposed reserves are under consideration for protection. Parks and Natural Areas Division intends to consult with the Boreal Felt Lichen Working Group prior to the development of management plans for proposed protected areas containing Boreal Felt Lichen populations.

Prior to the recently observed declines, approximately 1/4 of the Boreal Felt Lichen thalli known on the Avalon Peninsula were observed within Lockyer's Waters. The large

concentration of thalli in this area indicates that the potential for Boreal Felt Lichen is high.

The ongoing and planned research at Lockyer's Waters builds on a large body of knowledge produced during nine years of intensive studies and monitoring. This research will greatly increase the understanding of the population dynamics of the species and aid in the production of critical habitat models for the Avalon Peninsula. The value of Lockyer's Waters as a Boreal Felt Lichen study area would be difficult to duplicate.

In spite of the recently documented declines of Boreal Felt Lichen observed in Lockyer's waters the area is still considered important to the long term conservation of this lichen. As such it requires protection to maintain ecological integrity. Protection can be achieved through a variety of mechanisms, which include ecological reserves, wildlife reserves and the resource management planning process. The final and most appropriate protection measure will be determined after additional research, inventory and consultation.

Knowledge Gaps

Critical information is still lacking in our understanding of Boreal Felt Lichen and its interaction within the environment. Those information gaps are as follows:

1. Critical Habitat requirements –forest types required for each stage of the Boreal Felt Lichen life cycle.
2. Demography - population size and trends; relationship to natural and anthropogenic disturbance regimes; optimal habitat; Minimal Viable Population and dispersal ecology.
3. Genetic – understanding of taxonomic relationships to other species; determine levels of genetic variation among and within populations.
4. Ontogeny – understand the development and lichenization process and identify photobiont and mycobiont and their uniqueness.
5. Threats – rank population-specific threats and impacts on persistence.
6. Restoration – protocols for transplantations and habitat suitability.

The filling of these information gaps is essential to the development of informed management decisions.

3 Management Goals and Objectives

Goal

To maintain and enhance where necessary, self sustaining populations of the Boreal Felt Lichen within its current geographic distribution in Newfoundland.

Objectives

- I. **Research:** To facilitate and fund, where feasible, the research necessary to fill the identified knowledge gaps.
- II. **Habitat Management and Protection:** Develop and implement adaptive management strategies that ensure the protection and management of Boreal Felt Lichen critical habitat areas by addressing the identified threats.
- III. **Education and Stewardship:** Increases awareness of Boreal Felt Lichen protection and management.
- IV. **Collaboration:** Coordinate work with other organizations and individuals to assist in national and global recovery by sharing of information and the provision of support to research projects conducted in the province.

4. Implementation

A number of mitigative measures are required to ensure the successful attainment of the stated management goal. Those measures are outlined below.

Research

To effectively implement a Boreal Felt Lichen management plan, the critical information gaps identified above need to be filled. The critical research areas are:

1. Define Critical Habitat using Habitat Suitability models.
2. Determine the mechanism of persistence of species on the landscape in the context of the natural and human disturbance regimes; specifically to understand reproductive biology, colonization and persistence in current and new habitats.
3. Assess impacts of the suite of identified threats and their possible interactions on Boreal Felt Lichen persistence.
4. Further assess patterns of genetic variations across the geographic distribution of Boreal Felt Lichen.

Habitat management and protection

Until the results of further research are available, a number of management strategies have been adopted. It is expected that these strategies will be modified as our understanding of Boreal Felt Lichen increases. The strategies include tasks associated

with the collection and management of distributional and population data expected to improve habitat management. The strategies are:

1. Transition areas around wetlands and bogs are critical areas in the landscape for the persistence of Boreal Felt Lichen. Within the known Boreal Felt Lichen range, buffers on these wetlands should be increased from the current 5 m to take in the entire transition area which would generally correspond to scrub sites. No development or occupation of land should occur in these areas until an appropriate evaluation has occurred. For Crown Lands this can be done through relevant land management processes. On private land landowners will be encouraged to leave these areas undisturbed.
2. Evaluate the effect of existing forestry mitigation on Boreal Felt Lichen in relation to natural decline.
3. Natural forest regeneration is preferable to plantation of forest trees.
4. Where it has been reasonably demonstrated that natural regeneration, particularly of balsam fir, is browsed so as to significantly delay or to preclude its regeneration to an extent where an age class of fir important to Boreal Felt lichen is significantly reduced in abundance, management measures to control moose densities should be considered. Management measures need to be considered while balsam fir regeneration is susceptible to moose browsing. Management options could include increased moose hunting quotas, consideration of subdivision of Moose Management Units (MMU), increasing access, fencing of localized areas, or other valid moose management measures. These options will be discussed with the senior manager responsible for game management. The Boreal Felt Lichen Working Group will meet with game managers to discuss the rationale, options and specific areas for moose control so as to ensure long term survival of Boreal Felt Lichen in local areas under stress from moose browsing.
5. Within its known range, assessment for potential Boreal Felt Lichen habitat must be considered in the sustainable forest management planning process, including annual and 5-year plans.
6. Within the known range of Boreal Felt Lichen, pre-harvest planning, as currently carried out for commercial cutting areas in Forest Management District 1, should be extended to all areas with a high likelihood of locating Boreal Felt Lichen in other Forest Management Districts. Pre-harvest planning should also be expanded to include domestic cutting areas.
7. In areas of current tree spacing trials the relationships between stand density and the presence of *Frullania* and Boreal Felt Lichen should be investigated.

8. In potential Boreal Felt Lichen habitat within the known range of this lichen, Boreal Felt Lichen surveys should be carried out prior to any proposed developments of sufficient scope to require an environmental assessment.
9. Interim Best Management Practices as identified in Appendix 3 will be applied in areas where Boreal Felt Lichen occurs.
10. Management agencies and crown corporations operating within the current known range of Boreal Felt Lichen will be advised of Boreal Felt Lichen locations and appropriate protection measures.
11. The Boreal Felt Lichen inventory will be expanded to include areas that have not yet been surveyed for this lichen. Every attempt will be made coordinate and integrate efforts by the various government departments and other individuals and organizations involved in Boreal Felt Lichen surveys and research.
12. Monitoring efforts will be expanded from current isolated efforts to regular re-surveys of locations distributed throughout the range of Boreal Felt Lichen in Newfoundland. To evaluate persistence on the landscape, monitoring efforts need to include not only re-surveys of stands with existing thalli, but also re-surveys of stands that are currently without thalli but that are considered to have a high likelihood of colonization by applying the best available biological information. These data would greatly aid management efforts as it would make it possible to detect population trends within single stands and shifts of the species on the landscape.
13. Standardized data collection protocols for inventory and monitoring will be developed and their use by all parties will be encouraged.
14. The Atlantic Canada Conservation Data Centre will be the central repository for distributional, habitat and population data collected on Boreal Felt Lichen. Efforts will be made to include all historical information, as well as new data, in the Boreal Felt Lichen database as soon as it becomes available. Data quality checks will be made to avoid duplication or omission of data and to assist with standardization of data.

Education and Stewardship

To ensure the long term survival of Boreal Felt Lichen, it is imperative to involve land owners, users and others who may have an effect on or be affected by the management of Boreal Felt Lichen. Where feasible, the following initiatives will be undertaken:

1. An overview of Boreal Felt Lichen ecology and management should be incorporated into the Sustainable Forest Management Planning process.

2. Training on select arboreal lichen species should be conducted for forest inventory staff, field biologists and staff of other agencies likely to spend time in potential Boreal Felt lichen habitats throughout the province.
3. Interpretive and educational material should be developed and distributed to Provincial Parks and Natural Areas with known Boreal Felt Lichen populations. Those areas include:
 - Salmonier Nature Park
 - Jipujikuei Kuespem Provincial Park
 - Cataracts Provincial Park
 - Avalon Wilderness Reserve
 - Bay du Nord Wilderness Reserve
4. When feasible, a pilot project of displays and interpretive walks for Boreal Felt Lichen and other lichens should be developed for Salmonier Nature Park and eventually adapted to the other Boreal Felt Lichen inhabited parks.
5. An information package should be developed for delivery to schools, domestic wood harvesters, and the general population.
6. A simplified key to the major species of arboreal lichens likely to be encountered within the range of Boreal Felt Lichen should be produced for the use by field staff of various departments, naturalists and other potential lichen locators.
7. Stewardship agreements will be explored in areas where Boreal Felt Lichen is found on private lands and/or in situations where multiple stakeholders, including municipalities, first nations, research or other institutions, organizations, businesses, land and cabin owners and private citizens have interests in areas with Boreal Felt Lichen. The goal of these agreements would be to facilitate awareness and collaboration among these stakeholders and to create local initiative for Boreal Felt Lichen protection.

Collaboration

Wildlife Division will maximize the benefits of multiple initiatives by coordinating research within the various organizations and individuals operating within the province. The Wildlife Division will:

1. Develop partnership agreements with interested parties.
2. Investigate and develop where feasible, data sharing mechanisms for all Boreal Felt Lichen research programs within the province. Potential mechanisms include the development of a Boreal Felt Lichen Information Website listing past, current and proposed research initiatives, and researcher contact information.

A summary of the identified management activities is presented in Table 1.

Table 1. Management Summary Table.

| Priority | Objective No. | Broad Approach / Strategy | Threat addressed | Specific Steps/Actions | Outcomes or Deliverables |
|----------|---------------|---------------------------|---------------------------|--|--|
| High | I | Research | Loss of genetic diversity | <ul style="list-style-type: none"> Support genetic research | <ul style="list-style-type: none"> Development of genetic diversity indicators. |
| High | I | Research | Lack of knowledge | <ul style="list-style-type: none"> Support population ecology research | <ul style="list-style-type: none"> Linkage of population dynamics to disturbance regime. |
| High | I, II | Research | Lack of knowledge | <ul style="list-style-type: none"> Develop habitat suitability models | <ul style="list-style-type: none"> Definition and distribution of critical habitat Habitat map |
| High | II | Habitat protection | Moose herbivory | <ul style="list-style-type: none"> Consider moose control in areas where moose density is clearly reducing balsam fir regeneration to an extent that it is affecting Boreal Felt Lichen | <ul style="list-style-type: none"> Increase in fir regeneration |
| High | II | Habitat protection | Wood harvest | <ul style="list-style-type: none"> Within the known range of Boreal Felt Lichen exclude transitional zones from wood harvest and development | <ul style="list-style-type: none"> Increased protected area of potential Boreal Felt Lichen critical habitat |
| Moderate | II | Habitat protection | Loss of habitat | <ul style="list-style-type: none"> Evaluate suite of threats on Boreal Felt Lichen persistence | <ul style="list-style-type: none"> Quantification of various individual threats and cumulative interactions Incorporation of information into the management of the species. |
| High | II | Habitat protection | Forestry | <ul style="list-style-type: none"> Incorporate Boreal Felt Lichen critical habitat in the sustainable forestry management planning process (annual and 5-year plans) within the known range of Boreal Felt Lichen | <ul style="list-style-type: none"> District Management plans reflective of Boreal Felt Lichen critical habitat |
| High | II | Habitat protection | Forestry | <ul style="list-style-type: none"> Extend 5-year Pre-harvest plans similar to those currently used in Forest District 1 to other districts within the known range of Boreal Felt Lichen | <ul style="list-style-type: none"> Incorporation of Boreal Felt Lichen in pre-harvest plans within the known range of Boreal Felt Lichen |
| Moderate | II | Habitat protection | Forestry | <ul style="list-style-type: none"> Evaluate tree spacing trials to determine relationship between stand density and the presence of <i>Frullania</i> and Boreal Felt Lichen | <ul style="list-style-type: none"> Incorporation of findings in Boreal Felt Lichen management |
| Moderate | II | Habitat protection | Loss of Habitat | <ul style="list-style-type: none"> Develop Boreal Felt Lichen management plans within Parks and Natural Areas | <ul style="list-style-type: none"> Incorporation of Boreal Felt Lichen into Park and Natural Areas management plans |
| High | II | Habitat protection | Development | <ul style="list-style-type: none"> Within the range of the species, survey for Boreal Felt Lichen at sites where larger developments are proposed and the habitat is potentially suitable. | <ul style="list-style-type: none"> Knowledge of Boreal Felt Lichen occurrence Mitigation plans that consider |

| | | | | | |
|----------|--------|---------------------------|-------------------|--|--|
| | | | | <ul style="list-style-type: none"> Develop mitigation plans where Boreal Felt Lichen is found | Boreal Felt Lichen |
| High | II | Habitat protection | Wood harvest | <ul style="list-style-type: none"> Implement, monitor and evaluate newest interim Best Management Practices in areas where Boreal Felt Lichen occurs | <ul style="list-style-type: none"> Increased protection for existing and future Boreal Felt Lichen habitat |
| High | II | Habitat protection | Lack of knowledge | <ul style="list-style-type: none"> Inform management agencies and crown corporations operating within the range of Boreal Felt Lichen of Boreal Felt Lichen locations and appropriate protection measures | <ul style="list-style-type: none"> Land managers and crown corporations are aware of Boreal Felt Lichen locations and protection measures |
| Moderate | II | Habitat protection | Lack of knowledge | <ul style="list-style-type: none"> Expand the inventory program to include areas not yet surveyed for this lichen | <ul style="list-style-type: none"> Improved Boreal Felt Lichen distribution data, range mapping and trend assessment |
| High | II | Habitat protection | Lack of knowledge | <ul style="list-style-type: none"> Establish a long term monitoring program throughout the known range of Boreal Felt Lichen in Newfoundland | <ul style="list-style-type: none"> Detection of Boreal Felt Lichen populations trends, both on the stand and landscape level |
| Moderate | II, IV | Habitat protection | Lack of knowledge | <ul style="list-style-type: none"> Develop, and encourage the use of, standardized data collection protocols | <ul style="list-style-type: none"> Data collected by different observers are comparable Improved trend assessments |
| High | II | Habitat protection | Lack of knowledge | <ul style="list-style-type: none"> Designate the Atlantic Canada Conservation Data Centre as the repository for distributional, habitat and population data collected on Boreal Felt Lichen Perform data quality checks for duplication and omission of data | <ul style="list-style-type: none"> Increased availability of data on Boreal Felt Lichen from all sources Increased data quality |
| Moderate | III | Stewardship and education | Lack of knowledge | <ul style="list-style-type: none"> Develop educational material and stewardship initiatives for Parks and Reserves | <ul style="list-style-type: none"> Interpretative walks and displays Increased awareness of Boreal Felt Lichen by Parks and Reserve staff and visitors |
| Moderate | III | Stewardship and education | Lack of knowledge | <ul style="list-style-type: none"> Develop educational material for log harvesters, domestic cutters and schools and general public | <ul style="list-style-type: none"> Increased awareness and of Boreal Felt Lichen in general public Change in land use practices by general public |
| High | III | Stewardship Agreements | Development | <ul style="list-style-type: none"> Explore the possibility of stewardship agreements with private landowners who have Boreal Felt Lichen on their property or in multi-stakeholder situations | <ul style="list-style-type: none"> Stewardship agreements have been established |
| High | III | Stewardship and education | Forestry | <ul style="list-style-type: none"> Incorporate Boreal Felt Lichen ecology and management into the Sustainable Forest | <ul style="list-style-type: none"> Increased consideration given to Boreal Felt |

| | | | | | |
|----------|-----|---------------------------|-------------------|---|--|
| | | | | Management Planning process | Lichen management in long-term forest management |
| Moderate | III | Stewardship and education | Wood harvest | <ul style="list-style-type: none"> • Conduct training sessions on select arboreal lichen species for forest inventory staff, field biologists and others likely to spend time in potential Boreal Felt Lichen habitats throughout the province | <ul style="list-style-type: none"> • Increased awareness of Boreal Felt Lichen among staff. • Increase in annual lichen survey numbers |
| Moderate | IV | Research coordination | Lack of knowledge | <ul style="list-style-type: none"> • Initiate interagency collaboration with organizations and individuals on research projects within the province • Share research information with research bodies | <ul style="list-style-type: none"> • Partnership agreements and mechanisms for information sharing in place |

5. Evaluation

The Implementation Schedules will be evaluated every year for level of completion and where necessary, resources will be redirected. It is expected that priorities may change as our understanding of Boreal Felt Lichen management issues increases.

The overall management plan will be reviewed every 5 years and adjusted as required to ensure attainment of the stated goal.

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- Bruce Roberts, Canadian Forest Service. Natural Resources Canada.

Appendix 1. Boreal Felt Lichen Working Group

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Appendix 2. Threats Summary Table for Boreal Felt Lichen

| Stress | Threat | S-E Information | Causal Certainty | | Timing | Frequency | Extent | Severity | | Level of Concern |
|---|--|--|------------------|------------|-----------------------------------|------------|------------|----------|------------|------------------|
| | | | Local | Range Wide | | | | Local | Range Wide | |
| Reduced abundance of Boreal Felt Lichen | C: Habitat loss/degradation. G: Removal of suitable host trees. S: Destruction of thalli and prevention of colonization, increased distance to next suitable habitat | Se: Forestry and Logging, Provincial Administration A: Logging and associated road building St: Forestry companies, domestic wood harvesters, Provincial government | High | Medium | Historic/ Current/ Imminent | Continuous | Localized | Medium | Low | High |
| Reduced abundance of Boreal Felt Lichen | C: Habitat loss/degradation. G: Alteration of forest tree species composition S: Loss of suitable phorophytes for future colonization | Se: Provincial Administration A: Reduction of balsam fir regeneration due to moose browsing St: Provincial government, General public, Hunters and outfitters | Medium | Medium | Historic/ Current/ Imminent | Seasonal | Widespread | High | Medium | High |
| Reduced abundance of Boreal Felt Lichen | C: Habitat loss G: Removal of suitable host trees. S: Destruction of thalli and prevention of colonization, increased distance to next suitable habitat | Se: Provincial and Municipal Administration A: Development St: Provincial and Municipal governments, Land developers, Cabin owners, industry, General public | High | Medium | Historic/ Current/ Imminent | Continuous | Localized | Low | Low | Medium |

| Stress | Threat | S-E Information | Causal Certainty | | Timing | Frequency | Extent | Severity | | Level of Concern |
|--|--|--|------------------|------------|-------------------|-----------|-----------|----------|------------|------------------|
| | | | Local | Range Wide | | | | Local | Range Wide | |
| Reduced abundance of Boreal Felt Lichen | C: Habitat loss/degradation. G: Removal of suitable host trees. S: Destruction of thalli and prevention of colonization, increased distance to next suitable habitat | Se: Provincial Administration A: Forest fire St: Forestry companies, domestic wood harvesters, Provincial government | Low | Low | Unknown | Seasonal | Localized | Medium | Medium | Low |
| Reduced abundance of Boreal Felt Lichen | C: Habitat loss/degradation. G: Removal of suitable host trees. S: Destruction of thalli and prevention of colonization, increased distance to next suitable habitat | Se: Provincial Administration A: Insect outbreaks St: Forestry companies, domestic wood harvesters, Provincial government, General public | Low | Low | Unknown | Unknown | Localized | Medium | Low | Low |
| Disruption of chemical processes | C: Modification of natural processes G: Exposure to harmful chemicals S: Destruction of thalli, decrease in health and prevention of colonization, increased distance to next suitable habitat | Se: Provincial Administration A: Pesticides St: Forestry companies, domestic wood harvesters, Provincial government, general public | Medium | Medium | Unknown | Unknown | Localized | Medium | Medium | Low |
| Reduced abundance of Boreal Felt Lichen Habitat fragmentation | C: Climate and natural disasters. G: Removal of suitable host trees. S: Destruction of thalli and prevention of colonization, increased distance to next suitable habitat | Se: Climate A: Blowdown St: Forestry companies, Domestic wood harvesters | High | Low | Historic, Unknown | Unknown | Localized | Medium | Low | Low |

| Stress | Threat | S-E Information | Causal Certainty | | Timing | Frequency | Extent | Severity | | Level of Concern |
|---|---|---|------------------|------------|-----------------------------|------------|------------|----------|------------|------------------|
| | | | Local | Range Wide | | | | Local | Range Wide | |
| Reduced abundance of Boreal Felt Lichen Habitat fragmentation | C: Natural processes and activities G: Removal of suitable phorophytes S: Death of thalli, habitat becomes unsuitable | Se: Sector not applicable A: Stand senescence St: Provincial administration, Forest industry | High | Medium | Historic, current, Imminent | Continuous | Widespread | High | Medium | High |
| Reduced abundance of Boreal Felt Lichen Disruption of chemical processes | C: Pollution G: Exposure to toxins S: Destruction of thalli, decrease in health | Se: Oil and Gas, Utilities A: Atmospheric Pollution St: Federal Government, General public, industry | Low | Low | Current/ Imminent | Continuous | Widespread | High | High | Medium |
| Habitat alteration | C: Changes in ecological dynamics G: Modification of habitat S: Unknown | Se: Climate A: Climate change St: Federal administration, General Public | Low | Low | Unknown | Continuous | Widespread | Unknown | Unknown | Medium |
| Reduced abundance of Boreal Felt Lichen | C: Exotic species / Natural processes and activities G: Herbivory S: Reduction in health, decrease in population | Se: Sector not applicable A: Slug/mite herbivory St: Provincial government | Low | Low | Unknown | Seasonal | Localized | Low | Low | Low |

C= Threat category; G= General threat; S= Specific threat
Se= Sector; A= Activity; St= Stakeholder

Terms used in Threat Classification Table

Potential threat categories:

- Habitat loss or degradation
- Consumptive use
- Pollution
- Exotic Species
- Modification of natural processes
- Changes in ecological dynamics
- Accidental mortality
- Disturbance and persecution
- Climate and natural disasters
- Natural processes and activities

Potential Sector Categories:

- Aboriginal public administration
- Animal production
- Climate
- Construction
- Crop production
- Federal government public administration
- Fishing, hunting and trapping
- Forestry and logging
- Manufacturing
- Mining (except oil and gas)
- Oil and gas
- Private and non government lands and organizations
- Provincial , territorial and municipal public administration
- Recreational activities and travel
- Sector unknown or non- applicable
- Transportation
- Utilities
- Waste management and remediation services
- Wholesale and retail trades

Causal certainty:

- High – Evidence causally links the threat to stresses on population viability.
- Medium – The correlation between the threat and population viability is derived from expert opinion.
- Low – Considered a putative or plausible threat only.

Timing:

- Historic – Likely contributed to population declines, but is no longer affecting the species.

- Current – Is likely affecting the species at the present time.
- Imminent – Is expected to affect the species in the near future unless mitigation is undertaken.
- Anticipated – May affect the species in the future.
- Unknown – Unknown if factor has or will affect the species.

Frequency:

- One-time occurrence
- Seasonal – Either because the species is migratory or the threat only occurs at certain times of the year.
- Continuous – Ongoing
- Unknown

Severity:

- High – Very large population effect expected.
- Medium – Intermediate population effect expected.
- Low – Very low population effect expected.

Appendix 3. Interim Best Management Practices

In the interim, while habitat suitability models are being developed to define critical habitat, a landscape approach will be used. There is promise in the use of the Damman site classification to standardize the assessment of site type.

The landscape approach will ensure that source areas of spore producing thalli are preserved in conjunction and association with potential spore receiving areas. Current knowledge indicates that *Frullania* bearing trees of forest types suitable for colonization are at least 40 years old. The most important stands for consideration would be those with concentrations of robust thalli with spore producing potential adjacent to age appropriate trees. Prevailing wind, condition of thalli, condition of phorophytes, species composition and the expected persistence of forest stands should all be considered. It is understood that with this landscape approach not every thallus will be preserved.

If any Boreal Felt Lichen thalli are found in stands where an activity potentially affecting the survival of Boreal Felt Lichen is proposed, this will trigger an evaluation of the importance of this stand to Boreal Felt Lichen by the Wildlife Division in collaboration with the developer/management agency.

The following Best Management Practices based on Robertson's (1998) recommendations have been employed by DFRA as a stop gap measure and are superseded by the abovementioned landscape approach. They were put in place to provide guidance in the absence of detailed researched management strategies and were used on a site-by-site basis.

- Limit patch cutting to ≤ 5 ha on the Avalon Peninsula, which may be applicable to other areas of the province with Boreal Felt Lichen.
- Salvage operations in large wind throw areas (generally more than 5 ha) in the vicinity of Boreal Felt Lichen, especially on areas where the prevailing wind blows away from the phorophytes, should be carried out no closer than 10 m from the edge of the thalli-bearing stands in order to regenerate the type of stands which may become potential habitats for Boreal Felt Lichen 50-60 years hence.
- Routes for new extraction routes and roads should naturally avoid Boreal Felt Lichen sites.
- Leave a buffer zone of at least 20 m around Boreal Felt Lichen sites and restrict high-grading to trees greater than 12 cm diameter at breast height.