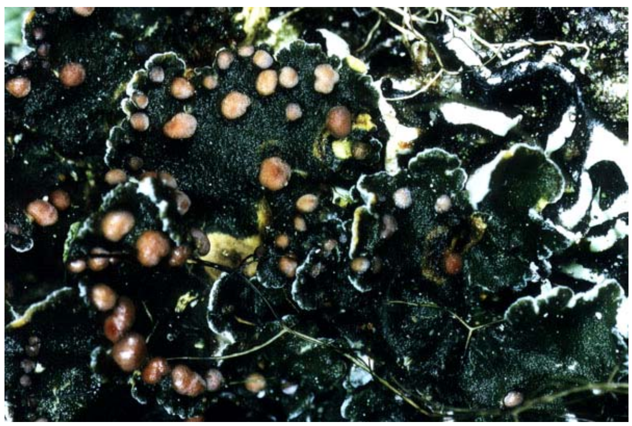
# COSEWIC
# Assessment and Status Report

on the

# Boreal Felt Lichen
## *Erioderma pedicellatum*

Atlantic population
Boreal population

**in Canada**



**ENDANGERED - Atlantic population**
**2002**
**SPECIAL CONCERN - Boreal population**
**2002**

**COSEWIC**
COMMITTEE ON THE STATUS OF ENDANGERED WILDLIFE IN CANADA

**COSEPAC**
COMITÉ SUR LA SITUATION DES ESPÈCES EN PÉRIL AU CANADA

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# COSEWIC
# Assessment Summary

**Assessment Summary – May 2002**

**Common name**
Boreal Felt Lichen (Atlantic population)

**Scientific name**
*Erioderma pedicellatum*

**Status**
Endangered

**Reason for designation**
A population restricted to regions with a cool, humid oceanic climate, highly sensitive to atmospheric pollutants such as acid precipitation. It has experienced a dramatic decline of over 90% in occurrences and individuals over the last two decades due, in particular, to air pollution and other sources of habitat loss and/or degradation. Extirpation of the few remaining individuals at three sites is imminent.

**Occurrence**
New Brunswick, Nova Scotia

**Status history**
Designated Endangered in May 2002. Assessment based on a new status report.

**Assessment Summary – May 2002**

**Common name**
Boreal Felt Lichen (Boreal population)

**Scientific name**
*Erioderma pedicellatum*

**Status**
Special Concern

**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.

**Occurrence**
Newfoundland-Labrador

**Status history**
Designated Special Concern in May 2002. Assessment based on a new status report.

# COSEWIC
# Executive Summary

## Boreal Felt Lichen
*Erioderma pedicellatum*

### Species Information

Boreal felt lichen (*Erioderma pedicellatum*) is a globally threatened, conspicuous foliose cyanolichen belonging to the Pannariaceae. It is the only boreal counterpart of a mainly tropical genus. The thallus is of a grayish brown colour when dry and a slate blue colour when moistened. It has a characteristic white underside, lacking a lower cortex. The curled to upturned lobes give it a unique appearance when viewed from a distance. New biochemical evidence suggests that the genus may be among the oldest of foliose lichens, hybridized from ancestral types, perhaps well over 400 million years ago (mya). Hybridization between an ancestral species and a mutant of it in South America likely gave rise to the boreal felt lichen. This new entity could have been transported on the microcontinent of West Avalonia to present day New England, New Brunswick, Nova Scotia and Newfoundland, and to the British Isles on the microcontinent of East Avalonia during Mid- to Late Ordovician (450-440 mya, departure time) and Devonian (360 mya or less, arrival time).

### Distribution

The species once had a global Amphi-Atlantic distribution with populations occurring in New Brunswick, Nova Scotia and Newfoundland in Eastern Canada and Sweden and Norway in Scandinavia. Currently the species is only known from Nova Scotia and Newfoundland.

### Habitat

Habitats of the boreal felt lichen may be referred to as the Suboceanic Lichen Forests of Atlantic Canada both because of the moist, *Sphagnum*-rich sites and because of the presence of a distinct cyanolichen community including *E. pedicellatum*. These suboceanic sites where *Erioderma* is found are generally on north or east-facing slopes that have a constant supply of moisture. Within these sites, the species is found mostly on balsam fir (*Abies balsamea*) and to a lesser extent on black spruce (*Picea mariana)* with rare occurrences on white spruce (*Picea glauca*), red maple (*Acer rubrum*) and white birch (cf. *Betula cordifolia*). On the coniferous trees mentioned, it can be found on both branches and trunks depending on the relationship between the level of moisture and light. It is known that this lichen shares an intimate relationship with the liverwort *Frullania tamarisci* ssp. *asagrayana*. The co-occurrence of *Erioderma* and *Frullania* is a visible external manifestation of the widespread internal symbiosis between *Frullania* and its cyanobacteria. Both *Scytonema* and *Nostoc* have been found to occur within the watersacs of *Frullania*. This intimate external symbiosis represents one of the delicate and complex relationships that this lichen shares with its ecosystem and for that reason its ecological balance is fragile and readily impacted by logging, air pollution and other factors.

**Biology**

Boreal felt lichen is a large foliose lichen with a generation time of about 30 years. It reproduces by sexual spores that are carried, likely, primarily by wind but also by other vectors such as flying insects and woodpeckers. No special asexual propagules are produced. One study has suggested that lichenization between the germinating ascospore and free-living *Scytonema*, a cyanobacterium (blue-green alga), can occur only in the water sacs of *Frullania*, a small, epiphytic, leafy liverwort. The relationship is such that the early synthesis of the lichen begins in the watersacs of *Frullania* wherein the free-living, cyanobacterial counterpart, *Scytonema*, is contained and comes into physical contact with *Erioderma* hyphae. Here under aseptic conditions the juvenile *Erioderma* thallus is formed and may take anywhere from 5-10 years to reach a visible size. Because of the presence of *Scytonema*, the lichen is particularly sensitive to acid rain, acid fog and other air pollutants. It requires relatively cool and moist oceanic climates within certain tolerances and open canopy for juvenile thalli to develop. Mature thalli deteriorate on trees that are mature to overmature or dead, seemingly in a span of only a few years. Thalli also deteriorate when habitat succession occurs that reduces light availability and when microclimatic conditions seem to be altered by extensive logging in close proximity to the lichen. Its occurrence on the particularly acidic bark of spruce trees reduces its ability, compared to fir trees, to survive when stressed by acidic air pollutants.

**Population Sizes and Trends**

Historically, *E. pedicellatum* occurred in Scandinavia but is now seemingly extirpated there. In considering all past and present confirmed occurrences, the range of the lichen in North America covers Campobello Island in New Brunswick, Cape Chignecto (alt. 136 m), the Atlantic slope of Nova Scotia at altitudes between 8 and 150 m, and the suboceanic parts of Newfoundland to an elevation of ~ 427 m. In Newfoundland, it is conspicuously absent from the eastern parts of the Great Northern Peninsula and from the northern central parts of the island. All of the 6 previously known localities for *E. pedicellatum* in southern Nova Scotia have been lost within the past 8-18 years. Environmental deterioration of the habitats through air pollution rather than through logging is the underlying cause for this change. Only 14 thalli are presently known to occur in Nova Scotia, as opposed to 169 thalli that had been encountered before 1995. In Newfoundland, about 6900 thalli of *E. pedicellatum* have been counted during the period after 1994, with about 35% of these having been documented in early 2002 by provincial foresters. The vast majority of the thalli were found on balsam fir with a much lower number on black spruce, the occasional thallus on white spruce, and a few on red maple and white birch. The total area of occupancy within which thalli have been documented in Newfoundland is about 30 $km^2$ of habitat but likely consists of a much larger area when inaccessible areas along the south coast are included.

## Limiting Factors and Threats

The species is in danger of population loss due to a number of threats. Perhaps the greatest threat is from logging, which is presently a major concern in Newfoundland. Clear-cutting is not conducive to the sustainability of *Erioderma* populations since clearcuts of 100 m x 100 m or more may act to desiccate local populations. This was historically the case in Või̇rmland, Sweden, where logging in the immediate vicinity of the park where the *Erioderma* thalli occurred was the suspected cause of the eventual extirpation of this species. Other threats involve air pollution, forest pesticides, forest fires, climatic changes including global warming and moose herbivory on balsam fir seedlings.

## Special Significance of the Species

Boreal felt lichen has served as a landmark species drawing attention to the need for lichen conservation. It is an ancient species whose fungal partner is believed to have evolved almost 500 mya. Its high susceptibility to air pollutants, perhaps more so than any other lichen species, makes it a prime candidate for monitoring changes in air quality.

## Existing Protection or Other Status Designation

The species had originally been listed in 1995 as critically endangered in the “Red List of Lichenized Fungi of the World” by the Species Survival Commission (SSC) of the Lichen Specialist Group, International Union for the Conservation of Nature (IUCN).

No official status is recognized for *Erioderma pedicellatum* in any of the three Atlantic Provinces where it has occurred historically. Preliminary conservation measures had only been initiated in Newfoundland in response to recent suggestions by Dr. Christoph Scheidegger. Legal protection has existed for the large population in Jipujijkuei Kuespem Provincial Park as well as for populations in the Bay du Nord Wilderness Area and the Avalon Wilderness Area although these areas were not established specifically to protect this lichen. Interim protection was afforded, also, through an earlier promise made to Dr. Christoph Scheidegger and the ICCL in 1996, by then Premier Brian Tobin, that the Lockyer’s Waters Forest Area would not be harvested until the status of the boreal felt lichen had been determined by COSEWIC.

## Summary of Status Report

Boreal felt lichen is a conspicuous foliose lichen that is found primarily on balsam fir in a very restricted type of cool moist suboceanic habitat. It is extirpated from its type location in New Brunswick where it was first reported in Canada. This species occurs now at only 3 sites with about 13 thalli in Nova Scotia and about 67 known sites on the island of Newfoundland. Only about 6900 extant thalli have been documented in total for the species in Canada. Of these, about 35% were discovered in Newfoundland in the spring of 2002 with renewed efforts to locate additional thalli. Considering that there are many forested riparian valley habitats with balsam fir in remote areas of the south coast of Newfoundland, it is highly likely that there are many more sites and numerous thalli yet to be discovered. Continued threats remain from the loss or modification of habitats through lumbering activities and from air pollutants.

For assessment purposes, the mainland populations in Nova Scotia and those of insular Newfoundland have been recognized as distinct COSEWIC populations due to the fact that they occur in different ecological regions and are subject to different degrees of risk, especially from atmospheric.

## COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determines the national status of wild species, subspecies, varieties, and nationally significant populations that are considered to be at risk in Canada. Designations are made on all native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fish, lepidopterans, molluscs, vascular plants, lichens, and mosses.

## COSEWIC MEMBERSHIP

COSEWIC comprises representatives from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership), three nonjurisdictional members and the co-chairs of the species specialist groups. The committee meets to consider status reports on candidate species.

## DEFINITIONS

| | |
|---|---|
| Species | Any indigenous species, subspecies, variety, or geographically defined population of wild fauna and flora. |
| Extinct (X) | A species that no longer exists. |
| Extirpated (XT) | A species no longer existing in the wild in Canada, but occurring elsewhere. |
| Endangered (E) | A species facing imminent extirpation or extinction. |
| Threatened (T) | A species likely to become endangered if limiting factors are not reversed. |
| Special Concern (SC)* | A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events. |
| Not at Risk (NAR)** | A species that has been evaluated and found to be not at risk. |
| Data Deficient (DD)*** | A species for which there is insufficient scientific information to support status designation. |

* 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.

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.

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# COSEWIC Status Report

on the

# Boreal Felt Lichen
## *Erioderma pedicellatum*

Atlantic Population
Boreal Population

**in Canada**

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2002

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## SPECIES INFORMATION

### 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) |

It is not clear whether the generic name of the lichen was derived from the hairiness of the upper cortex or from the eriostratum of the underside (erion being the Greek name for wool and derma that for skin). Both features are highly characteristic of the genus.

### Brief Introduction to Evolutionary History

In general, Erioderma is one of the most primitive genera of foliose lichens that may have originated in the Southern Hemisphere, on the Supercontinent of Gondwana (Jørgensen, 1990). It may have arrived in Laurentia (present day North America) on the microcontinent of West Avalonia, which had previously been in contact with the north-west coast of South America during the late Ordovician (Caradoc-Ashgile, 450-440 mya, see Figure 6, Benedetto et al., 1999). Its arrival in the British Isles is likely as a result of the previous contact of the microcontinent of East Avalonia with the Colombian Coast during the Late Ordovician (Arenigian, 490-480 mya, see Figure 5 in Benedetto et al. 1999). This hypothesis of the origin of the genus in the Southern Hemisphere is based on the hybrid chemistry of the lichen depsidone eriodermin (Connolly et. al., 1984; Figure 2) found in *Erioderma pedicellatum* and several closely related species in South America and South Africa (Maass, 2003b). To confirm the hybrid nature of this species, it would be logical to search for and identify suitable fertile species that would have been able to donate the A and B rings present in eriodermin. These include species that contain either argopsin or pannarin or both as potential donors for ring A, i.e., *E. groendahlianum* (= *E. polycarpum*), *E. leylandii* ssp. azoricum, *E. leylandii* ssp. *leylandii*, *E. leylandii* ssp. *velligerum* (=*E. chilense*) and *E. meiocarpum*. Through the loss of genes in producing the β-orcinol substituents (via C-methylation or C-formylation), any of the above species could have generated a mutant producing the orcinol depsidone conwrightiin instead of the original β-orcinol depsidone. This mutant would have been a most suitable ring B donor for the metabolite eriodermin in hybrids formed through back-crossing with any of the above mentioned original species. The postulated mutant is one of the ancestors of today's *E. wrightii*. The latter species contains one orcinol depside, i.e., wrightiin (Maass and Hanson, 1986) and one insufficiently characterized orcinol depsidone that accompanies the depside as a minor constituent and has therefore been named conwrightiin (Maass, unpublished). This minor constituent, characterized by its mass spectrum (in preparations extracted from lichens collected in Jamaica) was also encountered by Elix et al. (1986) in *E. wrightii* collected in Ecuador. Even the morphology of *E. wrightii*, with its concave apothecial disks (which appear to be present also in *E. leylandii*, according to the doctoral thesis by Ahlner 1948) makes the ancestor of this species a good candidate for having donated the genes for making the orcinol type of ring B in eriodermin.

## Description

Boreal felt lichen (Figure 1) is a foliose lichen that is usually between 2-5 cm in diameter but can attain a diameter of up to 12 cm. Smaller thalli have a relatively small holdfast area that is loosely attached to the substrate, most often to the mats of the hepatic *Frullania tamarisci* ssp. *asagrayana* rather than to the naked bark itself. On larger thalli, some of the radiating lobes are able to develop their own holdfasts. This may result in subdivision of the thallus.

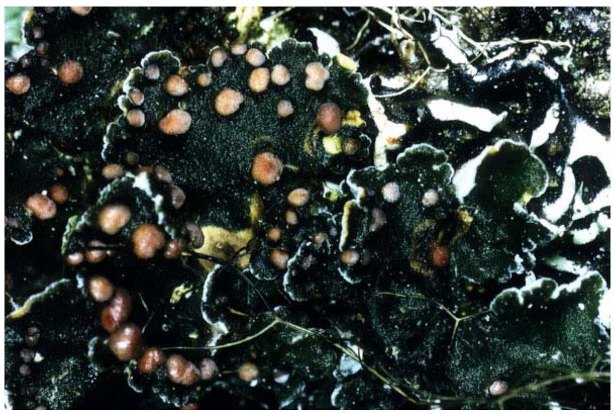

Figure 1. A large healthy and mature to over-mature thallus of *Erioderma pedicellatum* photographed in the Lockyer's Waters Forest Reserve by Dr. C. Scheidegger (x 5.7). The hairiness on the upper cortex of the lichen is clearly visible and is a characteristic feature of all species of *Erioderma*. The upturned margins reveal the whitish underside that is devoid of a lower cortex.

The thallus lobes are slightly involute, (i.e., curled upwards along their margins) exposing their whitish undersides. These appear felted by bundles of pale to darkish gray to bluish-gray branched hapteres (often discoloured) that form a dense eriostratum under optimal conditions. The hapteres have a dual function in anchoring the thallus to its substrate and taking up the nutrients from either stemflow or branchflow, whenever it rains. In the hydrated state the thallus has a bluish gray appearance due to the cyanobacterium, *Scytonema*. In the dry state its colour is dark gray to grayish brown.

The hairs on the upper surface of the thallus are commonly poorly developed but may be quite prominent in some specimens. In the generic key for the distinction between *Erioderma*, *Leioderma* and *Parmeliella* these hairs are described as being stiff and prominent (Galloway and Jørgensen 1987). Those in *E. pedicellatum* are often moderately branched, even in the centre of the thallus. Along the edges of the thallus they can form a semi-arachnoidal tomentum, whereas on older thalli this feature may be missing.

In cross-section, the lichen thallus is distinctly stratified. The upper cortex of the thallus consists of 2-4 layers of very thick-walled irregular colourless cells (30-50µ thick), with funnel-shaped gaps found to almost penetrate the cortical layer. The function of these intercellular spaces may be to promote the gas exchange required for photosynthesis and nitrogen fixation. Immediately below a narrow darkish transition zone of less than one cell layer thickness, the curled chains of the large-celled photobiont *Scytonema* are recognized. The algal layer is only between 45-90µ thick, in comparison with the well developed medulla in which the thickness varies between 200-600µ. A morphologically distinct lower cortex is absent. Thin-walled and branched septate rhizines can reach 1.5 mm in length.

Each thallus, after having reached at least 1.0 cm in diameter, develops an abundance of short-stalked apothecia up to 1.5 mm in diameter when reaching maturity. Mature thalli are usually at least 2-5 cm, and in rare cases, up to about 10 cm or more in diameter. Upon reaching this stage, young apothecia, whose margins are often fringed with whitish hairs, may be spotted along the growing edges of the thallus. More mature and varying developmental stages of apothecia will eventually be found scattered all over the upper surface, with up to nearly 100 per thallus. Whilst the apothecial stalk may be slightly compressed, the hymenial surfaces of the apothecia are initially flat but become conspicuously globose when mature. They are then dark brown and between 0.5-1.5 mm in diameter. Vegetative propagules in the form of either soredia or isidia are conspicuously absent in the life cycle.

Boreal felt lichen is distinguished chemically by the presence of a chlorinated depsidone called eriodermin (Figure 2; Maass, 1980). This constituent was first isolated in pure form from specimens of *E. sorediatum* D.J. Gall. & P.M. Jørg. (which is the sorediate counterpart of the fertile tropical species *E. physcioides* Vain). Eriodermin is an aromatic aldehyde in which the aldehyde group is in ortho position to a phenolic hydroxyl group, accounting for the PD+ (orange) reaction. Most other conventional colour test reagents give negative results (K-, C-, KC, I-).

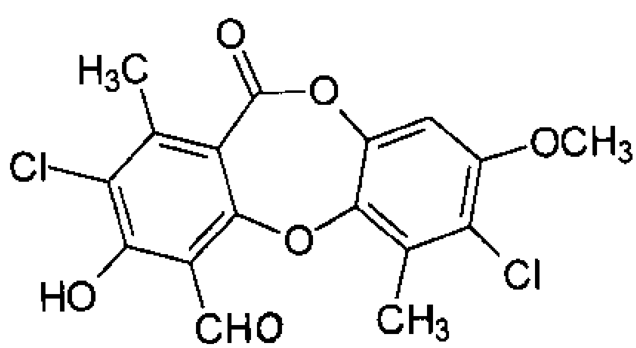


Figure 2. The chemical structure of the mixed depsidone eriodermin (which is the only secondary metabolite in *Erioderma pedicellatum* and related species of South and Central America, the Caribbean and/or Southeastern Africa).

## DISTRIBUTION

### Global Range

*Erioderma pedicellatum* is an Amphi-Atlantic species that was historically present in Europe and in Canada. Currently, *E. pedicellatum* is only found in eastern Canada (Nova Scotia and Newfoundland).

In Norway, four localities were originally identified in the early 20th century. Alhner identified the lichen at three localities in the Grong region in 1938 and 1939 (Holien, 1995) and one locality in North Trondelag in 1948 (Maass, 1980b). Alhner believed that the species was new to science and gave it the name *Erioderma boreale*. More recently, two additional sites, in the Grong and Overhalla regions, were discovered in 1994 (Holien et al., 1995). Tor Tonsberg (pers. com.) had confirmed in 1999 that one thallus remained from these recent discoveries; however, it is currently his opinion that the species has become extirpated in Norway.

In 1948, Ahlner discovered a site in Vãrmland, Sweden, consisting of 100+ thalli. This site was designated a nature reserve in 1952 (Holien, 1995). Holien states that the last reported sighting of thalli here was in 1956. Maass (1980) reported that Degelius (pers. comm.) had revisited the site and may have been the last to see it in 1962. Necrotic thalli from this last visit of his were deposited in various Swedish herbaria (GB, UPS). A colour photograph of bleached and corrosion-damaged thalli from this collection was included in the Fieldbook on Lichens by Moberg and Holmåsen (1982).

### Canadian Range

1) New Brunswick

J.G. Farlow made the earliest known collection of *Erioderma pedicellatum* in Canada on Campobello Island in 1902. This consisted of about 10 thalli. Farlow, realizing he had something unique, sent it to Hue for identification. Nine years later, Hue published it in an obscure journal under the name *Pannaria pedicellata* thereby reaching only a narrow audience. It is for this reason that a further sixty years would transpire before the original description of the species became known (Jørgensen 1972). To date, Stephen Clayden (1997), in his capacity as a curator at the New Brunswick Museum in St. John, NB, has, like the senior author, been unable to relocate or confirm the presence of *E. pedicellatum* on Campobello Island and in other parts of New Brunswick.

2) Nova Scotia

Most historic occurrences of *E. pedicellatum* in Nova Scotia were on the Atlantic Slope not more than 30 km from the coast in balsam fir (*Abies balsamea*) forests. The only exception was one dead thallus in the Cape Chignecto area above the Bay of Fundy on red maple (*Acer rubrum*) in site NS-46 (Maass, 1991). Further occurrences on phorophytes other than balsam fir include one thallus located in a white spruce (*Picea* *glauca*) grove about 100 m to the North of Toms Brook (NS-42) and one thallus (NS-6) on red maple.  Most of the remaining occurrences had been in the northeastern parts of Halifax County and in Guysborough County. Only four (NS-42 to NS-45) had been located on Cape Breton Island, a considerable distance away from major centers of industrial activity such as Sydney and Glace Bay. All of the confirmed localities for *E. pedicellatum* are between 9 and 152 m above sea level. A total of 46 historic populations plus three sub-populations are known from this province.

<u>3) Newfoundland</u>

Very limited lichenological exploration has been undertaken in Newfoundland. Ahti and Jørgensen first collected *Erioderma pedicellatum* in Newfoundland in 1971 under the synonym *Erioderma boreale*. Ten years would pass before additional attempts would be made to establish a distribution pattern for the species in Newfoundland (Maass 1980, Ahti 1983). Field crews of the Newfoundland Department of Forest Resources and Agrifoods made substantial contributions to *Erioderma* discoveries beginning in1997. Altogether, about 67 principal localities have been listed for Newfoundland with almost as many sub-populations identified.

The total distributions of boreal felt lichen before 1995, after 1994, the total historic and current distribution and occurrences on balsam fir and on spruces are recorded in Figures 3-6.

Gaps in the distributional maps of this species in Newfoundland represent, for the most part, 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, however, of finding additional populations of the lichen in protected forested valleys within the extensive heath barrens. The pattern of distribution along the Atlantic coastline of Nova Scotia and in Newfoundland appear 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 too warm or too cold and/or too dry during the growing season (see Figures 7, 8).

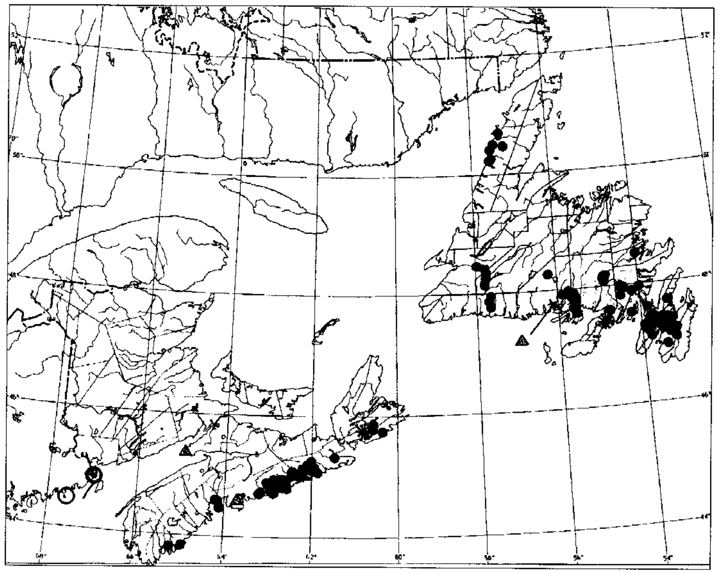

Figure 3. Overall distributional map for occurrences of *Erioderma pedicellatum* on balsam fir (Abies balsamea) in Atlantic Canada, based on observations made both before 1995 and after 1994. - Occurrences on red maple (*Acer rubrum*) have been indicated by a dotted triangular symbol and those on white spruce (*Picea glauca*) by an asterisk. In contrast, the occurrences of *E. pedicellatum* on black spruce have always been accompanied by occurrences of *E. pedicellatum* on balsam fir trees. The open circle on the coast of Maine indicates a possible former occurrence of the lichen, as explained in the legend for Figure 4.

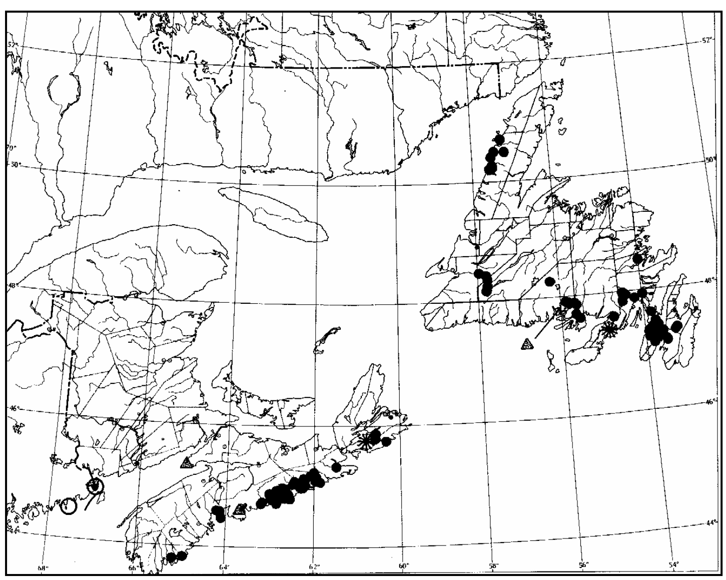

Figure 4. Distributional map for all of the occurrences of *Erioderma pedicellatum* in Atlantic Canada that had been known prior to 1995. - Occurrences on red maple (Acer rubrum) have been indicated by a dotted triangular symbol and those on white spruce (*Picea glauca*) by an asterisk. - The type locality of *E. pedicellatum* has been highlighted by a circle around the dot. A possible former habitat of this species on Head Harbour Island SE of Jonesport in Washington County of the State of Maine, also, has been highlighted by an open circle. Herbarium specimens of both *Coccocarpia palmicola* and *Lobaria scrobiculata* are known to have been collected from balsam fir barks on this island (FH). These are the most characteristic habitat indicators for occurrences of *E. pedicellatum* on balsam fir trees.

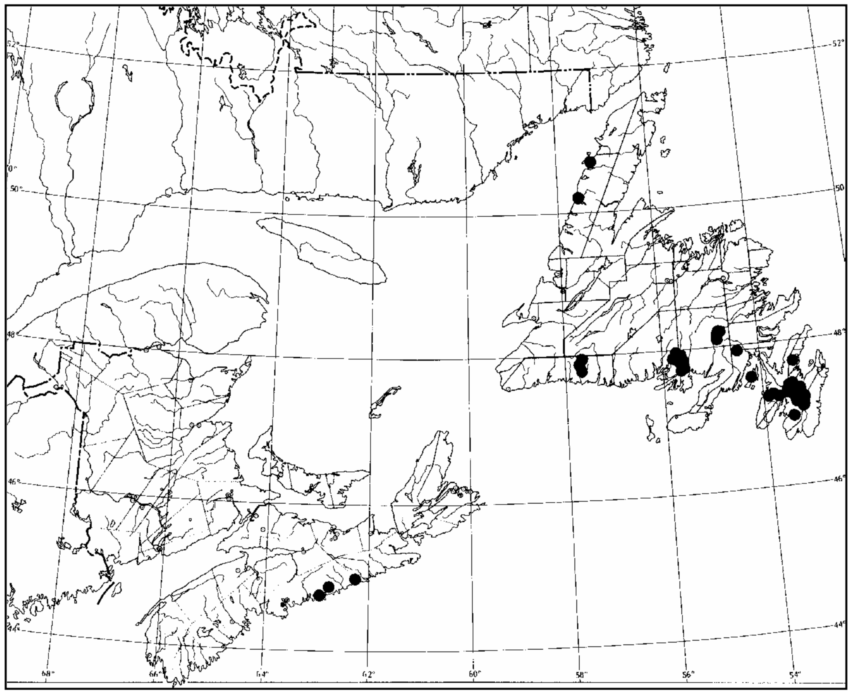

Figure 5. Distributional map for all of the occurrences of *Erioderma pedicellatum* in Atlantic Canada that have been based on confirmed observations made after 1994.

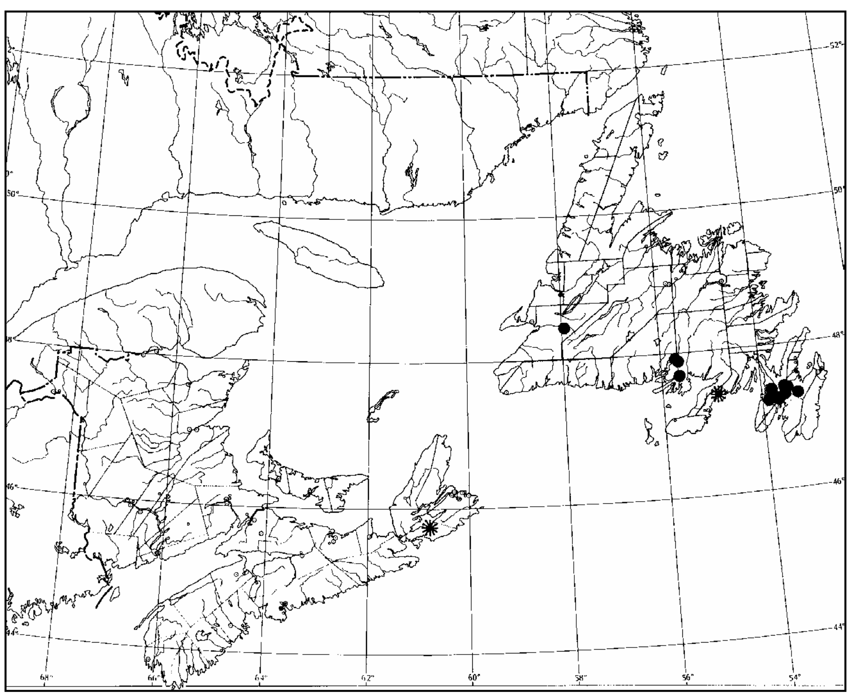

Figure 6. Distributional map for occurrences of *Erioderma pedicellatum* on spruce trees in Atlantic Canada: On *Picea mariana* (represented by solid dots) and on *Picea glauca* (represented by an asterisk).

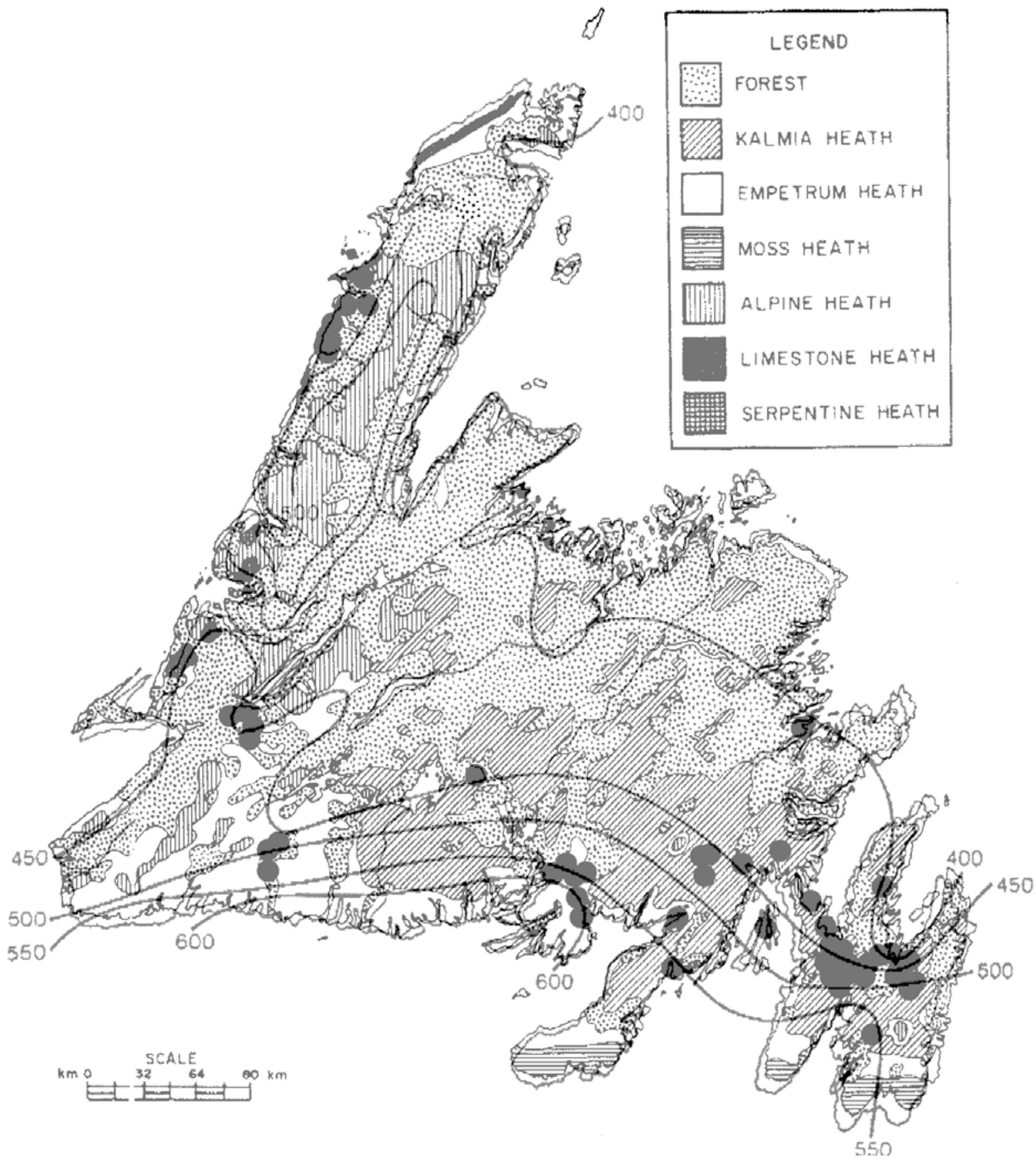


Figure 7. Newfoundland vegetational map and *Erioderma pedicellatum* total occurrences (localities approximated) plus May-Sept precipitation averages in mm. Black areas along the southwestern region near the coast are limestone heath. Localities occur primarily in regions with > 450 mm precipitation in the growing season.

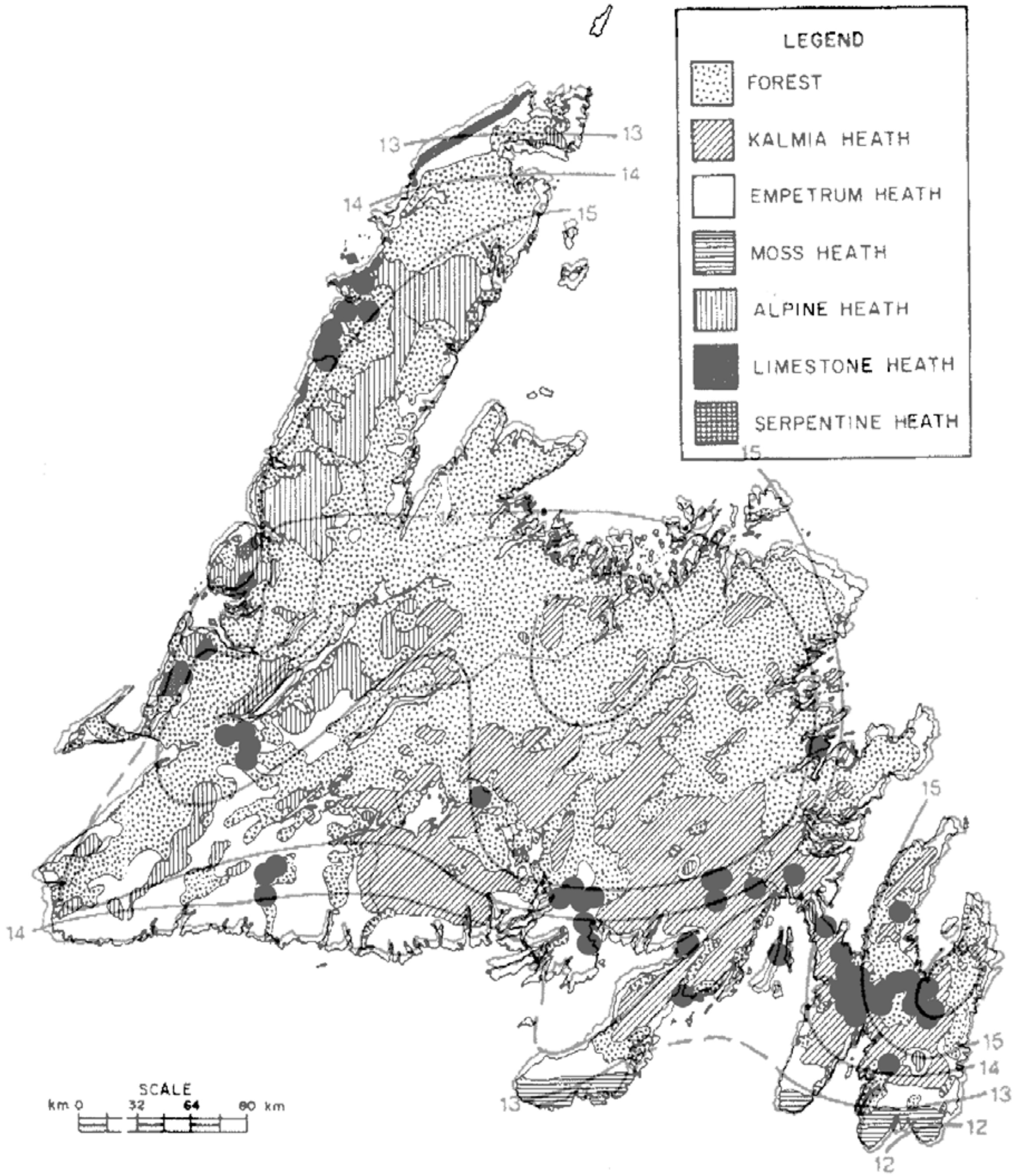


Figure 8. Newfoundland vegetational map and *Erioderma pedicellatum* total occurrences (localities approximated) plus average July air temperature in degrees centigrade. Black areas along the southwestern region near the coast are limestone heath. Localities occur primarily in regions having temperatures below the July average of 16º C.

# HABITAT

## Habitat Requirements

General Overview

Generally, most habitats of *Erioderma pedicellatum* are found on northerly exposed slopes where cool and moist habitat conditions prevail, throughout much of the year. Under exceptional circumstances in Newfoundland, *E. pedicellatum* habitats are also found on or near the East-West running forested ridges of special geological formations (Ahti, 1983; Delaney and Cahill, 1977). Here too, there is acontinuous supply of moisture provided by the flow of cool air across the ridges, rising from adjacent valley wetlands to the South or Southwest. Such situations have been encountered, e.g., in the headlands of Hermitage Bay, on Ripple Pond Ridge and in Lockyer's Waters. Because of the predominance of cyanophilic lichens, such as *E. pedicellatum*, in this wet variant of the Boreal Forest, the authors have named this unique habitat: The "Suboceanic Lichen Forest of Atlantic Canada".

In these suboceanic forest types, *Erioderma pedicellatum* is most commonly found on the trunks of balsam fir. In Newfoundland it also occurs on black spruce, although to a much lesser extent. Because the early stages in thallus development is photophilous ("light-loving"), the lichen is most often found on these trees at or near the bottom of slopes, where the habitat is open and, as well, adjacent to *Sphagnum*-rich wetlands. *Sphagnum* species are important in maintaining moisture levels in these forest habitats during periods of drought.

*Erioderma pedicellatum* is, in phytosociological terms, a species of the "Lobarion" a lichen association that contains, amongst many other epiphytic lichens, several species of *Lobaria*, most importantly *L. scrobiculata*. Since *L. scrobiculata* can be spotted from a distance, on account of its size and colour (brownish yellow in the dry state and bluish green in the wet state), it was a useful guide in the surveys conducted to study the distribution of *E. pedicellatum* in the boreal forests of Nova Scotia as well as those of Newfoundland (Maass 1983). It continues to be a good indicator for suitable microhabitats for *E. pedicellatum* on balsam fir. Other members of the Lobarion include *Lobaria pulmonaria*, *L. quercizans* and *Pseudocyphellaria crocata*, all of which commonly occur on a wide range of deciduous trees and shrubs and even on conifers. Whereas these species may often be found in abundance on spruces (along with *Lobaria scrobiculata*) in nutrient-rich forested slopes and flood-plain habitats, they are only exceptionally present on balsam fir, which is the principal phorophyte for *Erioderma pedicellatum*.

The mature forest habitat in which *Erioderma pedicellatum* is found is characterized by distinct herbaceous flowering plants and cryptogam species. The herb layer is characterized by the presence of such species as: C*lintonia borealis, Coptis trifolia, Cornus canadensis, Gaultheria hispidula* and most importantly by the moisture dependent *Osmunda cinnamomea*. In half-open alluvial woods the latter may be replaced by *Onoclea sensibilis*. *Sphagnum* mosses include *S. girgensohnii, S. fallax, S. nemoreum* and/or *S. russowii*. Other bryophytes that predominate include the hepatic *Bazzania trilobata,* the pleurocarpous mosses *Hylocomium splendens, Pleurozium schreberi*, *Ptilidium crista-castrensis* and *Rhytidiadelphus triquetrus* and the acrocarpous mosses *Dicranum majus* and *D. scoparium*. The crowns of the trees are typically covered by a very lush growth of beard lichens, including *Usnea longissima*, *Alectoria sarmentosa* and *Bryoria trichodes* ssp. *trichodes*. The presence of these beard lichens in the canopy of the forest can act as a moisture buffer to maintain high humidity conditions.

It is assumed that the limit of distribution for *Erioderma pedicellatum* is reached where the climatic conditions are not sufficiently cool and humid to maintain a constant supply of moisture during the warmer and drier parts of the year. The northernmost locality where *E. pedicellatum* had been sighted on black spruce (*Picea mariana*) is in the northernmost section of the Burgeo Road (just below lat. 48º30'N; see Figure 6). The northernmost limit of the known distribution of *E. pedicellatum* is reached on the western side of the Northern Peninsula of Newfoundland just north of Hawkes Bay (lat. 50º43') (Figure 3).

Regardless of the distributional limits of this species, certain generalized statements can be made regarding its ecological requirements. In well-lit forests, *E. pedicellatum* is found mostly on trunks, in contrast to shaded habitats where the species is found predominately on branches. An important ecological balance may explain the preference of trunks or branches namely in those niches where the requirements for light are being balanced against those for uninterrupted conditions of high humidity. It is possible that in Nova Scotia the humidity levels in suitable woodland habitats for *Erioderma* have been too discontinuous during the warmest parts of the year to allow the branches to be colonized, even those on *Abies*. Only two exceptional thalli had been encountered on branches within the lowlands of Richmond County in southeastern Cape Breton Island (localities NS-42 and NS-43).

<u>Symbiosis with *Frullania*</u>

The hepatic *Frullania tamarisci* ssp. *asagrayana* plays a central role in helping *Erioderma pedicellatum* become established on the trunks of suitable conifers (Maass, 1986). *Frullania* species are distinguished by the possession of more or less helmet-shaped involutions on the underside of the dorsal leaves. These water sacs are important for a prolonged supply of moisture, and contain growth inhibitors, bacteriostatic compounds and insect-feeding deterrents (Burnett et al., 1974; Asakawa et al., 1976). Within these aseptic watersacs it is believed the process of lichenization begins in such a way that the *E. pedicellatum* fungus genetically recognizes the free-living *Scytonema.* Subsequent to lichenization, *Frullania* provides suitable nursery beds for the establishment and growth of the juvenile stages of *E. pedicellatum*, which would otherwise be difficult on the naked barks of phorophytes. In exceptional cases in which *Erioderma pedicellatum* has been found on red maple, this function may be performed also by *Frullania bolanderi* or *F. oakesiana*.

Conversely, *Frullania* may benefit from the products of nitrogen fixation supplied by the newly formed thalli of cyanophilic lichens and by the still free-living cyanobiont cells within the watersacs. *Frullania* may even benefit from certain metabolites of the lichen fungi being released, such as growth hormones (IAA, gibberellic acids). Even the secretion of some polyketide-derived aromatic lichen acids might be of some use to *Frullania.*

Dr. Tomas Hallingbäck observed, in the forests of southern Sweden some years ago, that leafy hepatics like *Frullania, Porella, Ptilidium pulcherrimum* and *Radula* are good micro-environmental substrates for cyanobacteria (unpublished data). He also placed emphasis on his findings that some epiphytic mosses can likewise serve as a good microenvironment for cyanobacteria. *Leucodon sciuroides* was quoted as having the highest concentration of *Nostoc* species (pers. com.). *Leucodon brachypus* var. *andrewsianus* has been reported as *Leucodon sciuroides* in *Erioderma* habitats in Newfoundland (Crum and Anderson, 1981).

<u>Brief Note on Bark Acidities</u>

The acidities (Figures 9-11) and buffering capacities of the barks of the lichen phorophytes play a key role in accommodating or rejecting nitrogen-fixing lichen epiphytes on account of their high sensitivity to air pollution. The effect of bark acidity on the colonization of Lobarion lichens had been observed in the wet forest habitat of the Musquodoboit River Valley adjacent to the Limestone Quarries at Upper Musquodoboit (Maass 1983). Here, in an inland area where *Lobaria scrobiculata* does not normally occur on this substrate, the fir trunks had become literally covered by this lichen due to the neutralizing effects of limestone on the bark. However, more astonishing was the fact that black spruce trees in the same habitat had not been colonized at all, in spite of the neutralizing effects of the limestone. Higher bark pH (Figure 11), together with the greater water retention capacity of balsam fir bark (Figure 12), could explain why this species is the preferred phorophyte for *Erioderma pedicellatum*, both in Nova Scotia and in Newfoundland. This same phenomenon on spruce was also observed in Oslo, Norway, in the Ostmarka Forest Reserve (Gauslaa, 1995; Holien, 1982).

Numerous samples of *Frullania* were collected from Upper Musquodoboit, on both black spruce and balsam fir for sectioning and microscopic examination of the contents of their water sacs. No evidence was found for the presence of cyanobacteria in the *Frullania* samples from spruce, whereas more often than not the healthy random samples of *Frullania* from firs contained cyanobacterial cells.

## Protection/Ownership

The boundaries of Jipujijkuei Kuespem Provincial Park were amended in 1997 to allocate a 213 ha portion to the Conne River Mi'gmaw Band to operate a private campground. Development is possible in this area; however, any proposal has to go through the provincial regulatory review process. The remaining 669 ha are still under the jurisdiction of the provincial government and protected under the Provincial Park Act. Much of the *Erioderma* population occurs within the new park boundaries.

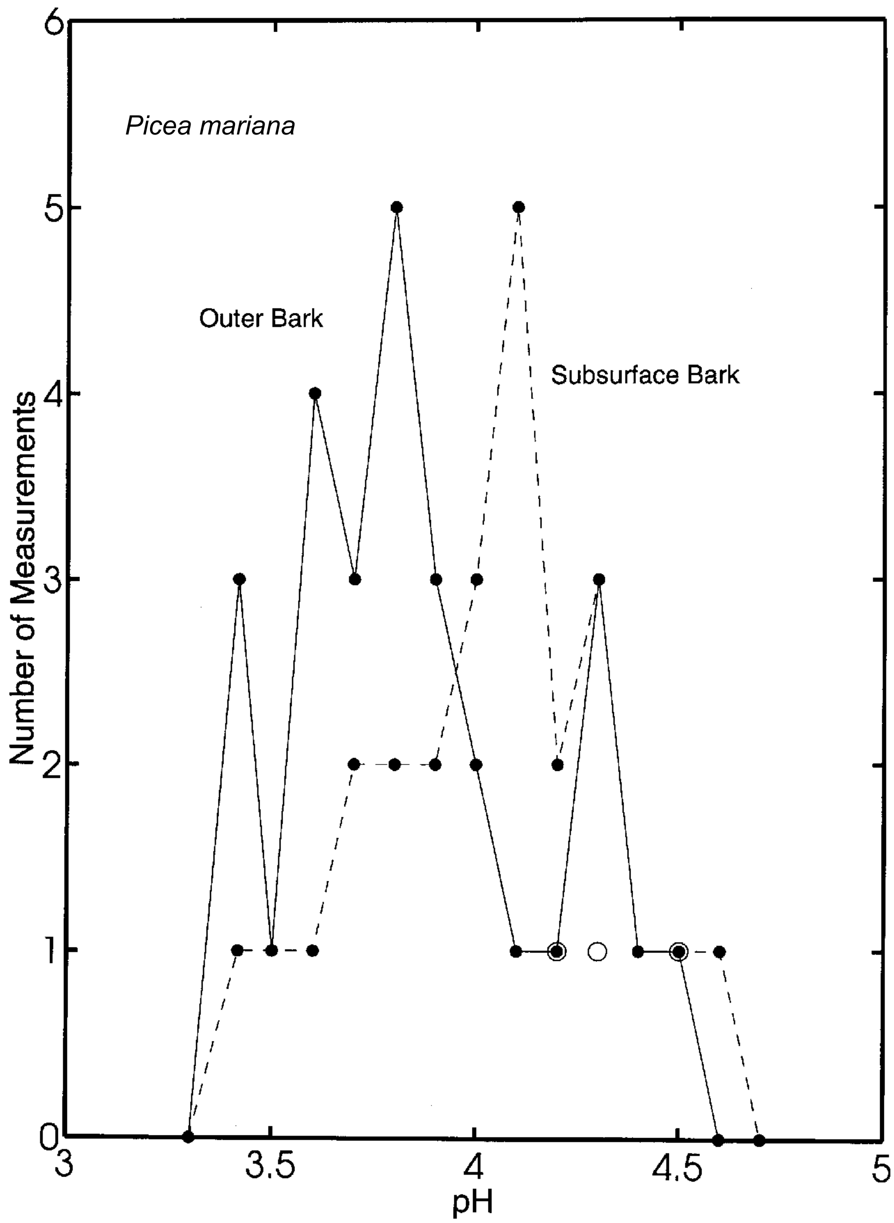


Figure 9. pH Values recorded for the outer and sub-surface barks which had been sampled from trunks of *Picea mariana* during 1983 and 1984 in Nova Scotia and processed as well as measured under standardized conditions. The scale of pH values has been plotted on the x axis, whereas the numbers of equivalent measurements obtained above the baseline are being shown on their respective coordinates parallel to the y axis.

Note that the actual numbers of measurements correspond to n+1 (as far as measurements have been plotted on the baseline).

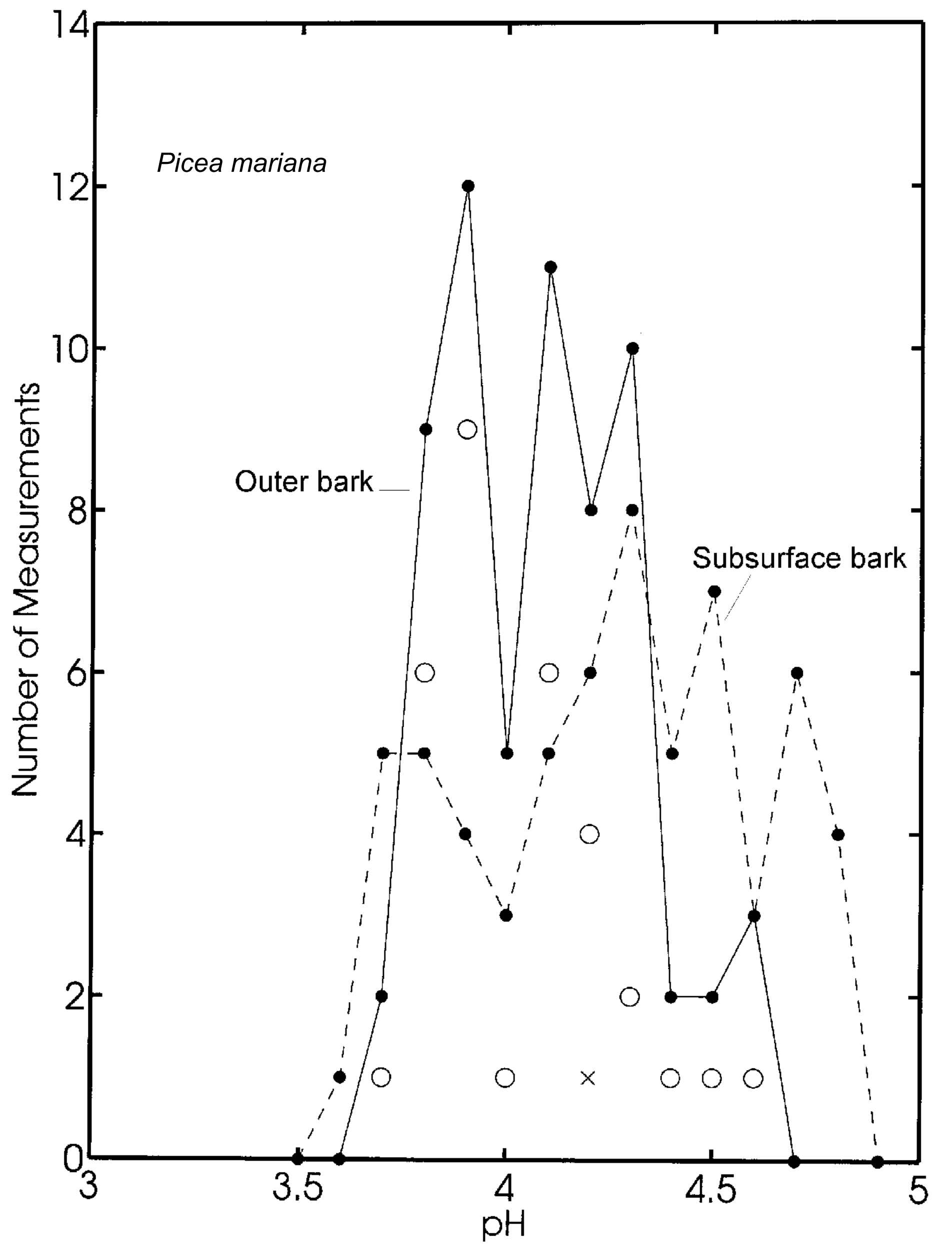


Figure 10. pH Values recorded for the outer and sub-surface barks which had been sampled from the trunks of *Picea glauca* during 1983 and 1984 in Nova Scotia and processed as well as measured under standardized conditions. The frequencies for the occcurrence of *Coccocarpia palmicola* (x) and *Lobaria scrobiculata* (o) on the tree barks sampled have been indicated by the symbols shown in brackets.

Note that the actual numbers of measurements correspond to n+1 (as far as measurements have been plotted on the base line).

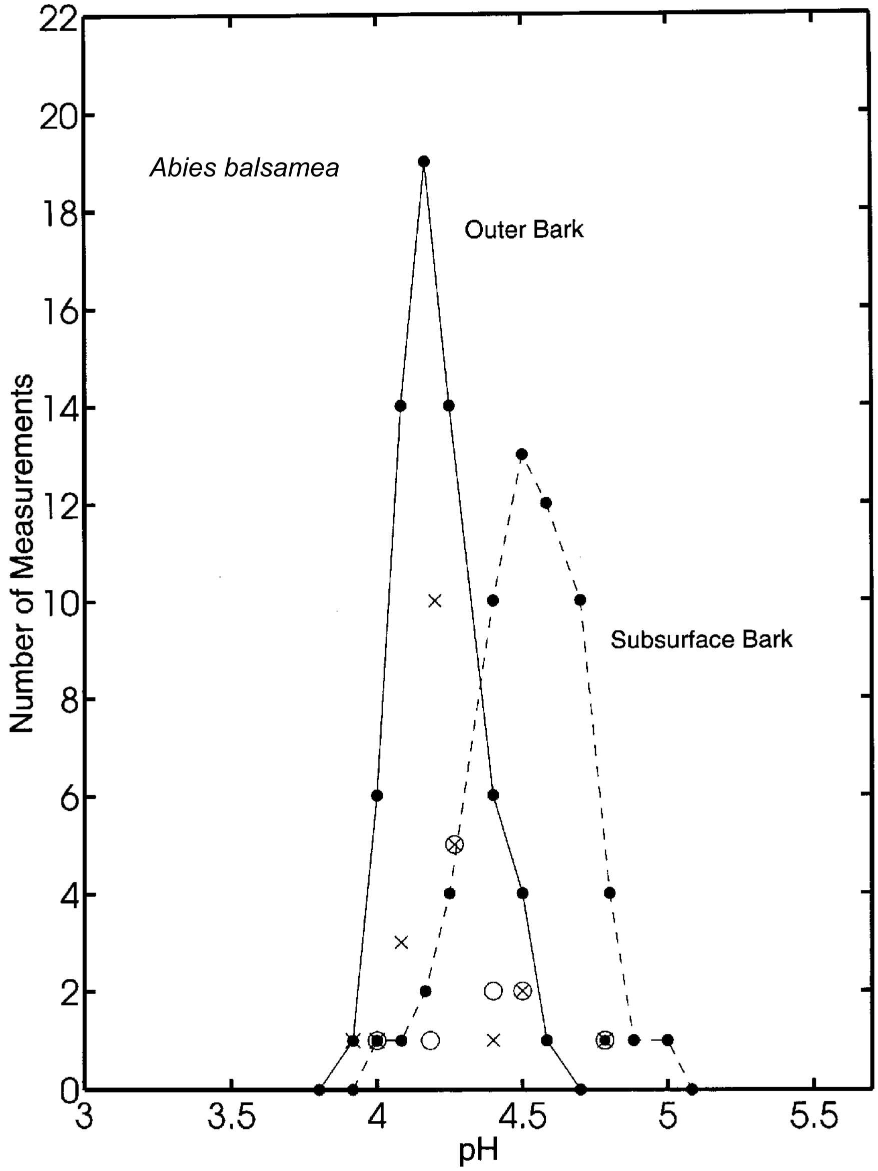


Figure 11. pH Values recorded for the outer and sub-surface barks which had been sampled from the trunks of *Abies balsamea* during 1983 and 1984 in Nova Scotia and processed as well as measured under standardized conditions. The frequencies for the occurrence of *Coccocarpia palmicola* (x) and *Lobaria scrobiculata* (o) on the tree barks sampled have been indicated by the symbols shown in brackets.

Note that the actual numbers of measurements correspond to n+1 (as far as measurements have been plotted on the baseline).

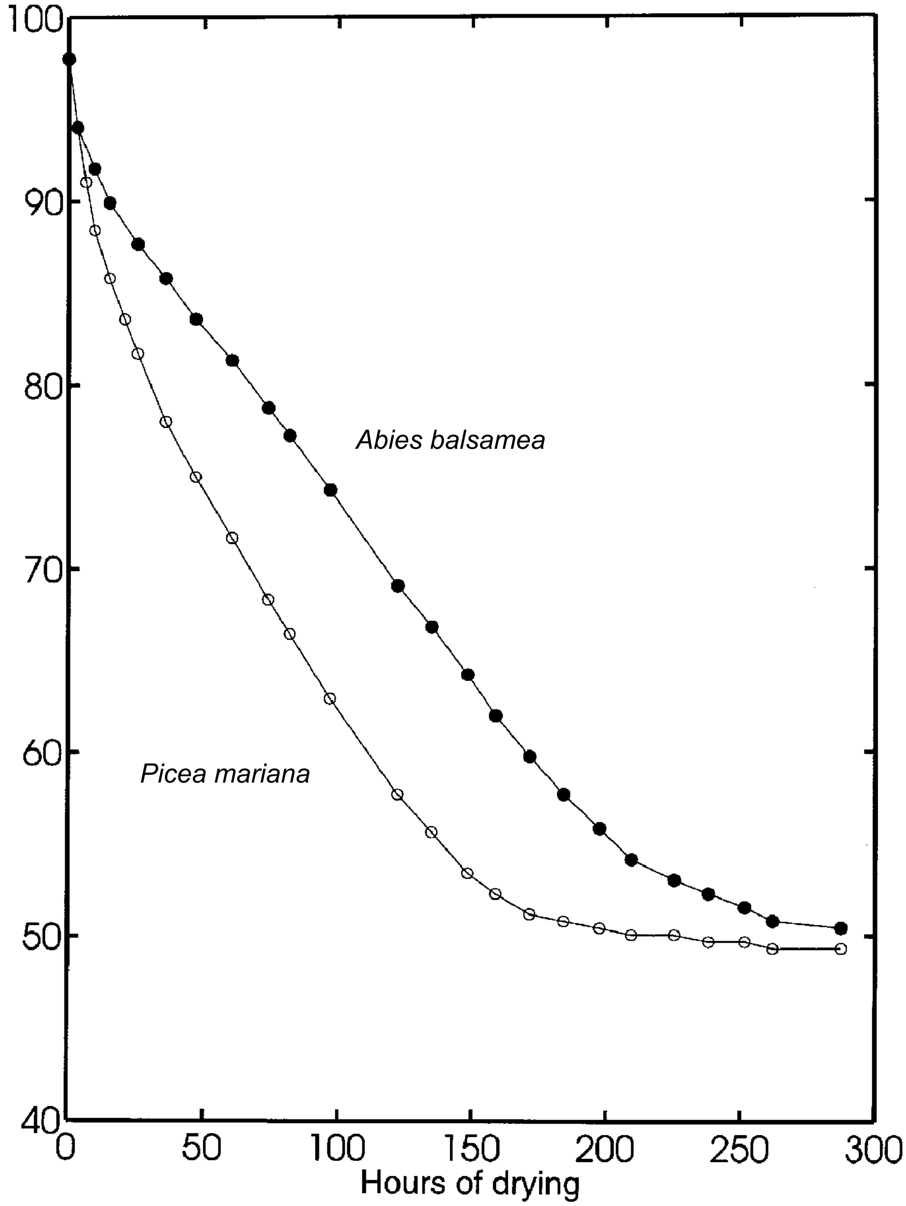


Figure 12. The water retention capacities for the freshly collected and water saturated trunk barks of *Abies balsamea* and *Picea mariana* respectively. The measurements plotted have been based on barks sampled in the former *Erioderma* habitat between Clam Harbour and Owls Head Harbour. The respective trees had been very healthy and had been growing under comparable conditions. Their DBH had been comparable at. about 15 cm.

## BIOLOGY

### General

The life cycle of *E. pedicellatum* is still incompletely known and will remain so until the life cycle of its photobiont *Scytonema* has been studied in detail. The distribution and micro-ecology of this cyanobacterium within the forests containing *E. pedicellatum* are presently insufficiently known. Even the vectors for the distribution of the spores of *E. pedicellatum* have not been fully recognized; however, the junior author has investigated flying insects as potential vectors of *Erioderma* spores in a Masters thesis currently under completion. For most components of the life cycle, only hypothetical considerations can be given.

### Reproduction

Only sexual reproduction is known for *E. pedicellatum*. Therefore the lack of vegetative propagules makes *E. pedicellatum* dependent upon a *de novo* synthesis of new thalli. This means that initiation of a new life cycle is a chance encounter between the more or less full complement of eight spores from a single ascus and a suitable strand of the free-living form of the cyanobacterium, *Scytonema*. The process of lichenization then begins. Such chance encounters would have a much greater probability of being successful if both the spores and the photobiont partners were to find refuge in a microbiologically suitable microenvironment, such as in the watersacs of *Frullania* (Scheidegger, 1996).

### Dispersal

Most recently Yetman (unpublished data from Masters thesis) has shown that the spores of *E. pedicellatum* are ejected either individually or as groups of 8 per ascus. This has been confirmed using scanning electron micrograph imaging. Based on recent laboratory experiments, it is likely the spores are ejected under suitable weather conditions, usually after a dry weather period when the humidity of the air goes up and fog is rolling in or when the first drops of rain are falling.

Favoured by the frequent incidence of fog or rain, by the favourable characteristics of the lichen forest's understory and tree canopy, as well as by the availability of adjacent wetlands, it may be assumed that the primary spore dispersal mechanism of *E. pedicellatum* is operative during most if not all parts of the year. Exceptions to this rule may be imposed by the few weeks of hot weather during the summer and during snowy and frosty periods in the winter. Studies on *Xanthoria parietina* in the British Isles and Oregon have shown that viable spores of this species can be obtained throughout the year (Christmas 1980). On the other hand, there are lichens such as *Rhizocarpon lecanorinum*, that show a peak performance in the spore dispersal during a specific time of the year (Clayden 1997b). So far, according to the junior author (unpublished data for Masters thesis) it seems that at least *E. pedicellatum* does not disperse over the hot, dry months of summer.

The following vectors may assist in spore dispersal of *E. pedicellatum* to adjacent or more distant suitable habitats:

1) **Strong moisture-laden winds that will carry the released spores up to a few hundred metres into an adjacent younger woodland (Scheidegger, 1996).** The prevailing windstorms on the Avalon Peninsula blow either from East to West (during the winter months) or in the opposite direction from Southwest to Northeast (during the summer months). Analogous prevailing wind directions have also been recorded for Cape Breton Island, according to data from the Point Aconi Weather Station (see Maass and Richardson 1994). On the mainland of Nova Scotia, e.g., in Halifax County, the winds often come directly from the North (during the winter) or from the South (in the summer and during the hurricane season). The presence of variable and moderate winds in these semi-closed canopy forests would undoubtedly carry spores to adjacent younger balsam fir stands.

2) **Insects as possible dispersal agents.** Through a series of studies it was shown that insects could be dispersal agents of *Erioderma* spores (unpublished data for Masters thesis by Yetman). Initially in laboratory experiments, fruit fly (*Drosophila melanogaster*) larvae were allowed to mature and roam for 48 hours in an experimental chamber containing a mature *Erioderma* thallus. Following this, the fruit flies were anaesthetized and viewed under a scanning electron microscope. *Erioderma* spores were positively identified, adhered to the leg bristles of several fruit flies. These findings were reconfirmed in the field in the summer of 2001 in mature forest stands in Lockyer's Waters, Newfoundland. *Erioderma* spores were identified on the segmented antennae of *Anapsis rubis*, a small flying beetle, using SEM. It is probable that such flying insects disperse viable spores to far reaching forest stands; this may result in the creation of a thallus but only if at least two spores remain adhered in a clump while landing on a *Frullania* to germinate and make contact with a suitable *Scytonema* symbiont in the water sacs of this hepatic. Although spores of *E. pedicellatum* also adhere to the legs of mosquitoes, no proof has yet been obtained as to how far these insects can travel (Yetman, unpublished data). We suspect that mosquitoes do not get air-borne during windstorms.

3) **Birds.** Woodpeckers, and possibly other birds, are an additional potential vector for the long distance dispersal of viable spores of *E. pedicellatum* from over-mature balsam firs. Spores could be picked up involuntarily on their front and/or tail feathers while the birds forage for bark-inhabiting insect larvae immediately following a brief dry weather period when most of the ripened spores are normally ejected.

**Life Cycle**

Scheidegger (1996) states the following concerning the life cycle of *Erioderma pedicellatum.* [The following life cycle scenario has not been conclusively demonstrated.]

1) Only one generation of *Erioderma* occurs during one successional cycle of the so-called lichen forest.

2) During the approximately 15 to 25 years of the over-mature to decaying phase of the forest, previously established thalli of *E. pedicellatum* are able to achieve a high growth rate due to favourable light conditions. The reproductive phase of the lichen is restricted to this period when microscopically small diaspores are dispersed [each spore measuring about 4-6 µm in length, Yetman, unpublished] through hypothetical vectors to a considerably younger tree, possibly in an adjacent stand corresponding to an earlier successional stage of the fir-dominated coniferous forest.

3) The life cycle of *Erioderma* would therefore begin again in another stand of suitable ecology and successional stage, at a distance of up to a few hundred meters from the original population. The capture of a suitable cyanobacterium (*Scytonema*) would lead to the development of minute individuals by a process that could last for more than ten years, whilst the stand might be reaching its optimal phase of growth.

Scheidegger's life cycle model has validity in as far as it applies to those forests that have adjacent blocks of even-aged trees at different developmental stages. Such a model would then apply to stands selectively cut during the past two hundred years, such as the forests in Lockyer's Waters, Newfoundland. The same might be accomplished by epidemic outbreaks of forest pests and forest fires. The "wave forests" on the West Coast of the Great Northern Peninsula of Newfoundland also show alternating strips of synchronized tree growth. The same applies to the wave forests on St. Paul's Island and those in the most north-easterly region of Cape Breton, although the wind velocities in most of these highly exposed habitats are too forbidding for the establishment of a new generation of thalli.

Young regenerating forest stands within which new life cycles of *E. pedicellatum* are initiated have rarely been encountered. The only possible exception is site NF-21b in Jipujijkuei Kuespem Park where a fairly large juvenile population of *E. pedicellatum* has been discovered (Yetman, 1999). The earliest stages in the colonization of a synchronized young woodland site by *E. pedicellatum* have so far remained undetected.

Scheidegger's scenario of the amount of available light becoming increasingly greater during the life cycle of *Erioderma* may not be totally inclusive. The presence of adult thalli in half-open very hydric habitats appears to support the claim that the *de novo* re-synthesis of thalli of *E. pedicellatum* requires a fair amount of light. Older well-established thalli of *E. pedicellatum* are probably quite adaptable to changes in the light intensity as long as sufficiently high levels of humidity are supplied. Such changes in the light intensity might be caused by opening or closing of the canopy, by the death of individual trees adjacent to the phorophyte, or by the maturation of younger trees in the understory beneath the canopy of the forest.

Concerning the life cycle of *Erioderma pedicellatum*, it seems more relevant to conclude that as relatively young and small natural stands of balsam fir continue to grow, the amounts of light available to the lichen (or its free living photobiont) might either increase or decrease to the point below which *E. pedicellatum* and *Scytonema* containing *Frullania* can survive depending on the stability of the moisture regime. Such occasional habitats are encountered in high humidity areas of Newfoundland (sites NF-2 and NF-25) where *E. pedicellatum* thalli have remained exclusively confined to the branches.

Nevertheless, based on numerous field observations it is important to maintain either a mosaic of forest stand age classes adjacent to one another or multi-age stands.

**Growth Rate**

Growth rates of mature thalli, in the exponential phase of growth, are somewhat comparable on balsam fir and spruce. The highest annual growth rates had been observed on balsam fir, with growth index (g.i.) values of up to 13 and 14 mm/yr on branches and trunks respectively (thallus # 2-b on balsam fir, # 2 at Salmonier Nature Park (SALM); thallus # 2-t on balsam fir, # 13 at Fitzgerald Pond Park (FITZ)). The largest g.i. value on black spruce was recorded for thallus # 3-b on tree # 4 at SALM, i.e., 11 mm/yr. This was in spite of the fact that the thallus had become strongly necrotic above its holdfast area during the growth period of a little over 11 months between subsequent measurements.

The growth rate measurements on balsam fir had also included two immature thalli. One of them (thallus # 2-t on tree # 8) had been encountered at FITZ and the other one (thallus # 1-t on tree # 3) at Goobies, NF. The initial measurements, taken on two consecutive days in October of 1980, had been the same for both thalli, namely 6 x 4 mm/yr. The subsequent annual growth increments had been 3 x 4 mm/yr at FITZ and 3 x 2 mm/yr at Goobies, NF. In addition, a juvenile thallus had been studied on spruce at SALM (thallus # 2-b on tree # 3). During the 11-month period between 2 Oct.1980 and 7 Sept.1981 it had increased its growth in length and width by about 50% (12 mm= x 10 mm per yr). This is similar to growth rates measured for young thalli on balsam fir during a comparable time interval.

## POPULATION NUMBERS, SIZES AND TRENDS

The numbers of thalli of *E. pedicellatum* in the Maritime Provinces and insular Newfoundland have been summarized for the periods before 1995 and after 1994 and are provided below

### New Brunswick

Only about 10 thalli were documented in 1902 from the original collection locality on Campobello Island. No thalli have been found at the type locality since the original occurrence of this species in New Brunswick became more widely known through the publication by Jørgensen (1972).

### Nova Scotia

The total number of thalli counted before 1995 in Nova Scotia had been 169. Of these, two had been found on the trunks of red maple, one on the fairly thick branch of a white spruce and one on a thin branch of balsam fir. The remaining 165 thalli occurred on the trunks of 102 balsam firs. The average number of thalli per trunk of balsam fir was therefore approximately 1.6. The total number of thalli that could be located in Nova Scotia in the late 90s was only 13, amounting to a reduction in numbers by about 92%. Accordingly, the total number of balsam fir trees colonized had shrunk from 102 to 7. It had been hoped that the habitat in the Moser River Valley (loc. NS-27) would have had the potential of maintaining itself for another ten or more years, since the present thallus to tree ratio was close to 2 per tree and since the habitat was relatively sheltered against receiving pollutants from the road. In spite of the high humidity at the site, caused by moisture rising from the adjacent swampy and wooded bottom of the river valley, the entire population had collapsed by the end of September 2002.

Within only a couple of years after 1979, when the senior author had begun to search for the presence of *E. pedicellatum* in all accessible suitable habitats of Nova Scotia, the lichen had disappeared from the southern parts of the province, even though the respective habitats had remained intact upon superficial inspection. Of the 46 localities originally found in Nova Scotia, only 3 localities (NS-12, NS-16 and NS-27, all in the eastern sub-coastal parts of Halifax County) have retained a viable habitat. Degraded habitats include all of those that had originally contained between 9 and 20 thalli.

Only 2 thalli had been encountered on branches, both of these in the most humid parts of the lowlands of Cape Breton Island. One had occurred on balsam fir near Enon (in loc. NS-43) and one on a white spruce in a very moist valley habitat (loc. NS-42). Two other exceptional occurrences had been on the trunks of red maple (locs. NS-6 and NS-46).

**Newfoundland**

The population counts for the Island of Newfoundland are summarized below. Supplementary data compiled by provincial foresters based on fieldwork conducted in early 2002 subsequent to the completion of this report are now also included in this final draft. [This supplementary information of thalli counts was provided to COSEWIC members by the range jurisdiction representatives during discussions on status designation.]

Areas and Significant Populations

Occurrences of *Erioderma pedicellatum* have been documented in the following geographical areas of Newfoundland (in progressive order from Northwest to Southeast).

*Area 1: Great Northern Peninsula (western slope)*

A total of 23 thalli were recorded before 1995 and only 3 after 1994, all on balsam fir.

*Area 2: Burgeo Road (northern areas)*

Only 22 thalli have been documented on balsam fir and 1 thallus on black spruce between the Trans Canada Highway and Peter Strides Pond, all before 1995.

*Area 3: Burgeo Road (Headlands of Grandy Brook)*

Boreal felt lichen was only recorded after 1994 in this area; 88 thalli were found on balsam fir.

*Area 4: South Central Newfoundland*

This area includes regions between Great Burnt Lake, the Twin Brooks area to the Northwest of Hwy. 362, Jipujijkuei Kuespem Park, Hermitage Bay and Belle Bay areas (280 thalli on balsam fir, 199 on black spruce and 4 on red maple, for a total of 483 before 1995; 2671 thalli on balsam fir and 5 on black spruce for a total of 2675 found after 1994. [Additional surveys by provincial foresters on 13$^{th}$ and 14$^{th}$ of March 2002 in Jipujijkuei Kuespem Park added 1068 more thalli (1065 on balsam fir and 3 on white birch). Also, new surveys on 12$^{th}$ and 15$^{th}$ March, 2002 added 746 new thalli to the Salt Pit-Twin Brooks area, all found on balsam fir (pers. com. to Natalie Djan-Chekar from Bill Clarke, Forestry & Wildlife, 25 Apr. 2002). This totals about 4489 thalli in this region found after 1994.]

Salt Pit - Twin Brooks Road Population

The habitat for this population is about 3-4 km inland from Head of Bay D'Espoir and within about 1 km to the Northwest from Hwy. 361. The population number of 518 thalli is based on counts made by members of Newfoundland and Labrador Department of Forest Resources and Agrifoods (NFS). This area is not likely to receive protection of any kind, since intensive logging operations are being carried out in the general area on a continuing basis. The six sub-sites occupy an area of about 2 $km^2$. Some of the studies by Robertson (1998) have highlighted wave forests where well-illuminated niches are created that may or may not become subsequently colonized by *E. pedicellatum*

Jipujijkuei Kuespem Park Population

The total number of *E. pedicellatum* thalli encountered within the former boundaries of the Park on balsam fir is 2107, and the approximate number of trees colonized is ~1088, which corresponds to a ratio of about 2 thalli / tree. The potential *E. pedicellatum* habitats in the Park cover an area up to 4,000,000 $m^2$. So far, 13 more or less discrete sub-sites with a minimum of 30 thalli in each have been studied, which includes all areas on both sides of the River Pond. The most recent survey is that by Yetman (1999) who discovered a relatively juvenile habitat of 201 thalli on balsam fir in a former gravel pit that may have been used for the construction of Hwy.360. The respective sub-site (NF-21b) contained 57 % juveniles. In general out of the 1021 thalli found here, 33.1% (338) are juvenile. This is an exceptionally high percentage compared to other populations in Newfoundland. The survival rate of these 338 immature thalli to spore-bearing maturity cannot be determined. However, the importance of their presence is that they attest to the healthy condition of the free-living forms of the *Scytonema* in these forests during those years when the immature thalli had been formed. Obviously, the creation of these juveniles demanded relatively pollution-free conditions.

There is a mix of serious and relatively minor threats in the Park, when considering other areas in Newfoundland. Moose browsing does occur in the Park but has not become as serious a factor as in Lockyer's Waters. In contrast, however, aerial spraying of pesticides can be harmful to *E. pedicellatum* and has in the past been considered for this area.

*Area 5: Burin Peninsula*

This includes the peninsula and nearby islands in the Placentia Bay; 12 thalli were recorded on balsam fir and 1 thallus on the trunk of a white spruce before 1995 and 11 thalli after 1994, without specific information on substrates.

*Area 6: East Central Newfoundland*

This is the pond-rich sub-oceanic Bay-du-Nord Wilderness area that had not been visited before 1995, and the areas between Glovertown and Come-By-Chance; 125 thalli were recorded on balsam fir, mostly near Goobies, before 1995 and 128 thalli, all in the Bay-du-Nord lake district, after 1994.

*Bay-du-Nord Wilderness Reserve Population*

Habitats are located about 58 - 63 km to the West of Clarenville and North East of Meta Pond. They are distributed over 6 sites that contain altogether 16 sub-sites. The total number of thalli recorded for this Reserve was 128. The total area within which these newly found populations of *E. pedicellatum* were encountered lies within an area approximately 28.25 $km^2$. Of the nearly 30 $km^2$ mentioned, much of the land is occupied by heath-lands and rocky barrens, thereby giving a more approximate estimation of less than 15 $km^2$. Based on this type of calculation for habitat size and considering our preliminary knowledge of this area, it remains a matter of uncertainty whether the Bay-Du-Nord Wilderness area should be considered as one of the major habitats or whether it is not better treated as a large area with numerous meta-populations.

*Area 7: Avalon Peninsula*

Lockyer's Waters Population

The total count of thalli in the Lockyer's Waters by the end of 1997 had surpassed 900; these had been found on close to 500 balsam fir trees, within 10 subsites (McHugh, 1998). This count has recently been adjusted to 953 (Yetman, 1999). The average ratio of thalli of *E. pedicellatum* on the occupied trees in the Lockyer's Waters was close to 2:1.

Nine well-established and distinctly different sub-populations with respect to exposure, stand age and canopy density are present (McHugh, 1998). These sites cover an area of about 20 hectares whilst the trees themselves bearing *Erioderma* would cover only 5.54 hectares. Important long-term research in these areas is presently being conducted in order to learn more about the life cycle of *Erioderma* and the impact of environmental stress.

A number of factors currently threaten the population. First, the remote area to the southeast of Lockyer's Waters is surrounded by cottage country (with over 1,500 cottages). Second, the high density of moose in the area has stunted the regrowth of suitable stands of balsam fir for recolonization by second-generation *Erioderma* thalli. Third, during windstorms from a southwesterly direction, pollutants from the industrial areas of Holyrood may reach the wooded hills of Lockyer's Waters and affect some of the populations of the lichen on northwesterly exposed slopes. And finally, the threat of logging in the area is still of concern. In 1997, logging was halted pending status designation for *Erioderma pedicellatum* by COSEWIC. Despite this interim protective measure, the future use of Lockyer's Waters forests has not been determined.

Ripple Pond Ridge Road Population

Ripple Pond Ridge Road, which was built in 1997 for the purpose of salvaging wind-fallen timber, is about 3.5 km long and contains some very steep sections. The *E. pedicellatum* sites recorded (NF-80x to NF-80e) are discontinuously distributed along the length of this road, the great majority of them are within only a 50 m distance from the road. For an estimation of the area covered by these sub-populations, a 200 m broad strip of land was chosen as the basis for the following calculation: 3,500 m x 200 m = 700,000. A total of about 350 thalli had been present originally, including 18 thalli on black spruce. This is or was the second largest habitat for occurrences of *E. pedicellatum* on black spruce during the period after 1994. It is uncertain what impact logging operations will have on the long-term survival of this population.

Ripple Pond Population

Two sub-populations (NF-79a and NF-79b) were found in the woodlands about 300-350 m behind the western shores of Ripple Pond, more exactly 150-200 m to the Southwest and Northeast of a small pond which is located about halfway between the Ripple Pond and a narrow strip of sloping peatland to the West. The sub-populations are about 600 m apart from one another and contain a total of 154 thalli. The habitats for *E. pedicellatum* cover areas up to 300,000 $m^2$ (= 0.3 $km^2$).

Ninth Fox Pond Population

The two sub-sites combined contain 95 thalli on 70 trees of balsam fir and 39 thalli on the branches of 9 trees of black spruce. The area covered by the two sub-sites is about 100,000 $m^2$. In the lower part of sub-site NF-80w some manual thinning had been carried out that might provide a future experimental research site.

Noseworthy's Gully Population

Behind the East side of Noseworthy's Gully or Pond lies site NF-81b. It consists of an interesting mosaic of fens and forest habitats on a mix of level ground and slopes (Ringius 1997; Robertson 1998). Here, 122 thalli of *E. pedicellatum* have been seen on an estimated number of 65 trees of balsam fir in one locality, and a few thalli on several trees of black spruce. The habitats encompass a total area of about 200 x 200 m (4 ha).

As a matter of curiosity, a few thalli have been found much farther to the north at Pegs Pond on the Carbonear Line (loc. NF-84).

The total count of thalli seen or recorded on the Avalon Peninsula during the past 3-4 years is 2148 (i.e., 2085 on balsam fir and 63 on black spruce), whereas before 1995 it was 107 thalli (19 on black spruce). This difference reflects the intensified search for this lichen in the woodlands of Newfoundland since 1996.

A revised total count for Newfoundland, including discoveries in March 2002, amounts to just under 6900 extant thalli. With many suitable habitats remaining in unexplored remote areas of the southern coast of insular Newfoundland, it is anticipated that there may be many more extant thalli.

Comparing Newfoundland's Two Largest Populations

A comparison between the two largest populations of *E. pedicellatum* in Newfoundland sheds some light on the chances for long-term survival of the species. The largest and healthiest population occurs within Jipujijkuei Kuespem Park. The Park, excluding small adjacent populations to the North and East, has a total of 2112 thalli (including 5 morbid thalli on black spruce). When considering only populations of thalli in which distinctions were made between adult and juvenile thalli, the percentage of juveniles is 31.75% (327:1030 = x100). Perhaps anomalous to the trend was the high percentage of juveniles (57%) encountered by Yetman (1999) in subsite NF-21b. [NFS new records for this park found on 13th and 15th March, 2002 total 1068 thalli (pers. com. Newfoundland Forest Service)]

In comparison, the populations in Lockyer's Waters consist of 952 thalli on balsam fir and 1 dead thallus on black spruce. According to data provided by McHugh (1998), 165 juveniles and 698 mature thalli had been documented in "sites 1 to 9". Upon applying the same ratio to the updated figure for thalli found on balsam fir (952), the total number of juveniles in Lockyer's Waters may be close to 182.

The Jipujijkuei Kuespem Park contains more than twice the number of thalli on balsam fir (2107) as compared to those that are present in Lockyer's Waters on the same substrate (952). Approximately 31.75 % of those in the Jipujijkuei are juveniles, which translates into 669 young thalli, on the basis of extrapolations. This means that there are ~3.7 times more young thalli in the Jipujijkuei Kuespem Park than in Lockyer's Waters. This figure, in the absence of mortality, reflects the possibility of long-term survival of the species in Jipujijkuei Kuespem Park.

## Population Trends on Black Spruce

Because of the heightened air pollution sensitivity of the lichen on this substrate the health and long-term persistence of thalli on spruces is in question (see Limiting Factors).

In former times, under largely pollution-free conditions, black spruce trees served as much better substrates for colonization by *E. pedicellatum* than presently. In the early 1980s, the average size of the colonies of *E. pedicellatum* on individual black spruces was nearly 4 times greater than the colonies on individual balsam fir trees. For instance, at least 50 healthy thalli had been observed on a single spruce in sub-site NF-27a of which 40% had been juveniles. The largest number of thalli observed on the trunk of a single balsam fir had been 16 (in site NF-15). Before 1995, 28.3% of the thalli found were on black spruce, whereas after 1994, only 1.5% of the thalli occurred on the same substrate.

The occurrences of *E. pedicellatum* on the black spruces of Newfoundland is therefore a good monitoring system to forecast problems in the environment that may become a threat to the long-term survival of the species as a whole, especially regarding air pollution. It is particularly important to maintain records on the health status of *E. pedicellatum* on this particular substrate.

## A Note on the Misinterpretation of "Numbers"

There is a misconception as population numbers grow, as with *E. pedicellatum*, that the species is well distributed, essentially "everywhere". It is appropriate, however; to take a more cautious approach in assessing the present situation. Thallus counts, as with all population assessments, are by no means static entities. This is particularly true when data are accumulated over a short period of time (1996-1999). This scenario becomes more complicated when populations are not distinct and therefore sub and meta-populations exist. For example, localities in Nova Scotia with meta-populations containing up to 20 thalli have been lost within only ten years. True to the nature of meta-population biology, such isolated and therefore vulnerable minor occurrences hold little hope for the long-term survival of the species.

Aside from that, no one can *control* and maintain the well-being of small populations, even with the best of intentions. The intimate cross-connections between the life-cycles of *E. pedicellatum, Scytonema, Frullania* and their host trees is a very vulnerable system that is difficult to conserve. We are far from understanding the population dynamics of this species and its complex ecological requirements.

Therefore, our present assessment of the status of *Erioderma pedicellatum* in Newfoundland is that it is a highly threatened species, not so much in terms of its present thallus numbers but largely in consideration of the outstanding vulnerability of this lichen and of its cyanobacterial symbiont towards air pollutants, global warming and clear cutting operations. Much more needs to be learned to fill in the enormous gaps in our current knowledge about the complexity of the life-cycle of *E. pedicellatum,* upon which the survival of this lichen depends.

## LIMITING FACTORS AND THREATS

The major threats to the survival of the suboceanic boreal lichen forest habitats of Atlantic Canada and hence to the survival of the cyanophilic lichen communities contained are outlined in the following sub-sections:

### A) Clearcuts and Tree Plantations

Commercial tree harvesting on the Avalon Peninsula and elsewhere in Southern Newfoundland has exceeded the annual quotas set by about 20% and has led to a shortage in forest resources [Data compiled by the senior author for the years 1992-1999: harvested roundwood data taken from Compendium of Forest Statistics for the Council of Forest Ministers (http://nfdp.ccfm.org) and Annual Allowable Cut for insular Newfoundland taken from the Twenty Year Development Plans (1990-2009 and 1996-2015), Department of Forest Resources and Agrifoods].

In many parts of Newfoundland, clear-cutting has led in recent years, since about 1970, to the replacement of many natural to semi-natural forest communities by black spruce and balsam fir plantations. Any of the epiphyte-bearing phorophytes would have been lost during the establishment of clearcuts. The Lobarion community as a whole would not have the capability to regenerate. Even if sufficiently high number of spores of *E. pedicellatum* were to arrive from distant places, no new thalli could be formed due to the lack of *Frullania* in tree plantations.

The colonization within established spruce plantations by the above mentioned lichen species and by *Frullania* is also made difficult by the following factors:

a. Under the present environmental conditions, the low buffering capacity and rather strong acidity of black spruce barks make it difficult for *E. pedicellatum* to become established on the trunks of these trees and even on the branches. Even balsam fir plantations are not colonized by *E. pedicellatum* or *Frullania*. The reason for this may have something to do with the death of the original mycorrhizal fungi in clear-cut areas. In contrast, black spruce in natural, more or less well-lit but highly humid *Sphagnum*-rich forests, is occasionally colonized, although considerable decreases in their populations have been observed in recent years. Trunk occurrences have become virtually non-existent and even on the branches the health of the thalli has deteriorated and their numbers have dwindled along with the regenerative capacity to form juvenile thalli. Two exceptional thalli of *E. pedicellatum* on the trunks of black spruce next to the Ripple Pond Ridge logging road have remained in healthy condition due to the fact that a steady stream of clear humid air keeps rising from the low-lying wetland immediately to the south during the milder parts of the year. The reasons for these losses lie in the increasing threats from acid fog and acid rain, which seem to affect the chemistry of black spruce bark even under low level impact conditions to such an extent that the barks become unsuitable for colonization by *Erioderma*. This postulated scenario is supported by the complete absence of *E. pedicellatum* from otherwise ecologically suitable stands of black spruce in Nova Scotia. Such low level impact of air pollutants seems to have sealed also the fate of this lichen on Norway spruce in Europe.

b. The dark shade that exists in recently established tree plantations during the first 10-15 years prior to pre-commercial thinning is not conducive to the reintroduction of viable colonies of *Scytonema* - enriched *Frullania*, or to the re-synthesis and development of thalli of *E. pedicellatum.* Not even traces of *Frullania* had been found on the barks of black spruce in the plantations to the North of Fundy National Park (Veinotte, 1998 and Maass, personal observations), even though this hepatic commonly occurs in natural woodlands of New Brunswick on both coniferous and deciduous trees.

An added problem is that clear-cuts hardly ever get fertilized leading to the loss of symbiotic mycorrhizal fungi. This could lead to a gradual depletion of nutrients in the thin acidic glacial soils in Newfoundland, Nova Scotia and New Brunswick.

The retardation in the development of the lichen epiphyte floras in tree plantations has been observed and studied in areas to the north of Fundy National Park, as a contribution to an understanding of the Greater Fundy Ecosystem in New Brunswick (Veinotte 1998). Whereas almost all of the four Reference Stands, which were representative of the mature mixed forests in the northern half of Fundy National Park, contained species of *Nephroma* and *Lobaria* (almost exclusively on deciduous trees but very exceptionally also on trunks of red spruce (*Picea rubens*), these cyanophilic species had been absent from all of the black spruces in the 6, 10, 15, 18 and 23 year old plantations studied. Only exceptional thalli of *Leptogium cyanescens* had been found on an occasional deciduous shrub encountered in the 10 and 15 years old plantations. The latter species is only marginally a component of the Lobarion.

Finally it has been shown that large-scale logging greatly reduces internal stand moisture levels by altering the stand's ability to buffer periods of desiccation. This is believed to have contributed to the demise of *Erioderma pedicellatum* in Sweden. As mentioned earlier, one of the original localities in Värmland, Sweden, was designated as a nature reserve in 1952 shortly after a mass occurrence of the species was discovered there by Ahlner in 1941 and 1946 (Ahlner 1948). The presence of logging immediately adjacent to the park boundary and the subsequent desiccation of habitat was one of the suspected causes for the eventual extirpation of the species in this locality (http://www.nhm.uio.no/botanisk/bot-mus/lav/factshts/eriopedi.htm).

**B) Atmospheric Pollution**

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 $SO_2$ (James, 1973).

The presence of acid rain appears to contribute to the loss of *Erioderma pedicellatum* from its spruce substrates. Even on the slightly less acidic bark of balsam fir, a partial die-back of *Erioderma* thalli has been observed. The eventual loss of thalli begins with a necrotic zone around the holdfast area and eventually spreads in all directions (Moberg and Holmasen, 1982). Damage to these holdfast zones is pronounced on thalli found on the highly acidic barks of black spruce. The damage to the holdfast areas of *Erioderma pedicellatum* has been exceptional among the cyanophilic lichens, and therefore is ranked highest on the list for sensitive species of Nova Scotia. In addition, community lichens associated with *E. pedicellatum* habitats such as the Lobarion are also given a relatively high ranking and have been shown to be sensitive to air pollution (Gauslaa, 1995), including *Coccocarpia palmicola*, *Erioderma mollissimum*, *Parmeliella parvula* and *Fuscopannaria ahlneri*.

Acid fog is more dangerous than acid rain because sensitive plants 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. Nova Scotia is prone to acid fog since it is closer to the influx of air pollution from the industrial centers of the northeastern U.S.A. and southern Ontario (Maass, 2001). This is in contrast to Newfoundland where 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 collapse of the *Erioderma pedicellatum* - phorophyte connection has probably resulted from the gradual lowering of the buffering capacity of the spruce bark over a period of time, during acid rain or acid fog episodes that would of course simultaneously inhibit the activity of the nitrogenase system. The undernourished hyphae of the holdfast area, after having been deprived of the supply of essential nitrogenous substances (including vitamins), may then become highly susceptible to the presence of SO2 and NOx or to the strong acids derived from them in the stemflow.

In general, it is clear that *Erioderma* and other lichens possessing the cyanobacterium symbiont *Scytonema* are highly sensitive to atmospheric pollution. The impact on *Erioderma pedicellatum*, of the proposed development of a hydrometallurgical plant by INCO at Argentia, using new technology, warrants close monitoring.

### C) Pest Control and the Use of Harmful Aerial Sprays

The recent threats to the coniferous woodlands and black spruce plantations in the Bay D'Espoir areas around Jipujijkuei Kuespem Park by the Yellow-headed Spruce Sawfly (*Pikonema alaskanensis*) have been of great concern. As an interim measure, because of BT having been shown to be ineffective in the elimination of the larval stages of this pest, the use of 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 *E. pedicellatum* 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. Such a mode of action could seriously decimate the *E. pedicellatum* populations in the Bay D'Espoir area.

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.

Likewise, trichlorfon sprays have not been approved for the Nova Scotia or New Brunswick regions. Instead, efforts are currently underway, in cooperation with the Federal Forestry Service in Fredericton, N.B., to investigate the suitability of specific BT strains (such as BT-i).

It is sometimes difficult to judge whether a particular insect infestation is more harmful to the lichens growing on a tree or the spray reagent that is to be used to reduce the spread of that insect. It probably depends on the extent of the defoliation of the tree and on the annual fluctuations in the population numbers of the insect.

**D) Forest Fires**

Many areas of Newfoundland have been strongly affected by forest fires. A particularly extensive fire had raged through large tracts of land behind the base of the Burin Peninsula in 1960. This fire may account for the absence of viable *E. pedicellatum* communities from this general area.

In addition to the obvious impacts of fire, the presence of SO2 in the smoke from burning woodlands is well known and is able to destroy the nitrogen-fixing lichens that happen to be downwind from the burn (see Denison et al. 1976).

**E) Droughts and Hurricanes**

Extreme weather induced 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 *Erioderma* to desiccation may be the result of an upper cortex that appears to lack a vapour barrier in the form of a lipophilic layer of alkanes (see Piervittori et al. 1997). The absence of such a “boundary layer” would promote losses in thallus moisture during dry weather periods (Fos at al. 1999). *E. pedicellatum* and other lichen populations can also be severely decimated through tree windfalls along the edges of the forests (Boyce, 1988). One such storm had blown across the Avalon Peninsula from a northeasterly direction in November of 1994 and caused considerable wind-fall, in Salmonier Nature Park (SNP), the Lockyer’s Waters Area and on the Ripple Pond Ridge (see NF-62b).

At least one of the original habitats of *Erioderma pedicellatum* in Nova Scotia was completely destroyed by a windfall when a severe storm traveled from a southwesterly direction and hit the eastern shores of Guysborough County near Wine Harbour (NS-40).

## F) Global Warming

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 *Erioderma pedicellatum*, may be sensitive to climate change.

## G) Effects of Herbivory on the Growth of Balsam Fir Seedlings

The effects of moose browsing in central Newfoundland have been discussed and evaluated over a period of time by Bergerud and Manuel (1968) and Thompson and Curran (1993). Due to the density of browsing on balsam fir seedlings by moose the mixed coniferous woodlands are gradually being converted into forests in which spruces are the dominant species. The suppression of balsam fir regrowth, based on the current hypothesized life cycle of *Erioderma*, places limitations on the regeneration of viable *E. pedicellatum* habitats. There is little doubt that black spruce had once played an important role in providing alternative phorophytes for *E. pedicellatum* thalli. However, the high acidity of the spruce bark can become in itself a limiting factor to the distribution of *E. pedicellatum* in Newfoundland, accelerated in the presence of long range transported or locally generated pollutants.

The effect of severe moose browsing on balsam fir is quite evident in Lockyer's Waters. This could have detrimental effects on the regeneration of young balsam fir stands adjacent to sites containing *Erioderma* and could therefore inhibit the ability of the formerly large population of more than 953 documented thalli to renew itself through the initiation of new life cycles on nearby trees of suitable age, illumination and environmental health. [According to careful recounts of thallus numbers by Mr. Eugene Conway during the fall of 2002, considerable losses have occurred, leaving only about 20% of the originally counted thalli in place.]

## H) Effects of the Microfauna Herbivory on *Erioderma*

Mites often feed on mosses and on the decaying parts of bark. The effects of browsing by mites on *Erioderma* 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 (unpublished data from Masters thesis) has identified at least one species of mite from the Lockyer's Waters locality that was collected from the surface of a moist *Erioderma* thallus.

Browsing by snails has also been observed but is a minor threat that occasionally leads to partial removal of the upper cortex and the photobiont layer beneath.

Large-scale mono-cultures also raise the question whether the fungal endo-symbionts in the needles of conifers are naturally introduced. These micro-fungi appear to play an important role in the life of the tree by increasing the resistance of the foliage to attacks by foraging insect larvae (Calhoun et al. 1992, Clark et al. 1989, Todd 1988). The presence of such natural insect feeding deterrents in the needles may not only provide a certain amount of protection against defoliation of the conifers but may also moderate the activities of the micro-fauna on the barks on which the lichens grow.

**I) Land Development**

Road building and the spread of both tourism and industrial activities, such as the harvesting of forests that had not been accessible previously, often go hand in hand. A good example of this had been the building of the Burgeo Road where forest harvesting began soon after the opening of the road. It also opened up the possibilities for conducting a survey of the rare lichens in the area. Unfortunately, what had been gained would soon be lost, which had included the northernmost occurrence of *Erioderma pedicellatum* on black spruce.

The spread of the cottage industry is similarly taking its toll, mostly in making the more remote parts of the forests more accessible to their utilization. This would include domestic cutting, recreational activities and increased vehicle traffic (Brawn and Ogden, 1977). This is no doubt a legitimate threat in Lockyer's Waters.

## SPECIAL SIGNIFICANCE OF THE SPECIES

This "Panda Bear" amongst the lichens (Dr. Teuvo Ahti, in litt.) — a nickname which *E. pedicellatum* deserves from the conservation point of view — is a symbol of nature's rapidly vanishing treasures, in the boreal forest. The complexity of its life cycle, which depends upon the foliose hepatic *Frullania* as a cyanobacterial donor, is unique among lichens. The species *Erioderma pedicellatum* has challenged us to improve our understanding of this particular ancient symbiotic life form whose fungal partner is assumed to have evolved through hybridization of two chemically distinct taxa in the north-west corner of South America on the ancient land mass of Gondwana.

The persistence of this lichen throughout hundreds of million years is sharply contrasted by its having been brought to near extinction, within the past 10-20 years, with the notable exception of two core populations from Newfoundland that have remained viable for the time being.

In addition*, E. pedicellatum*, perhaps more than any other lichen species, can signify changes in local air quality. It has been given the highest rank on the relative scale of sensitivities of cyanophilic lichens towards air pollution, together with species belonging to the genus *Lichinodium*.

# EXISTING PROTECTION OR OTHER STATUS

## International Status

*Erioderma pedicellatum* had originally been listed in 1995 as critically endangered in the “Red List of Lichenized Fungi of the World”, in the absence of a thorough distribution pattern for eastern North America. This had been determined by the Lichen Specialist Group of the Species Survival Commission (SSC), the International Union for the Conservation of Nature (IUCN).

Even though many of the details upon which the justification for this decision had been based need to be revised and updated, there is still sufficient reason to retain the species on the Red List. For any re-assessment of the status of the species on an international level, it is significant to note that its presence in Europe had been confirmed twice since its presumed disappearance at around 1970 and 1995 (see Distribution).

## National and Provincial Status

No official status has been proclaimed yet for the past and present occurrences of *Erioderma pedicellatum* in any of the three major Atlantic Provinces. Preliminary conservation measures had only been worked out and agreed upon in Newfoundland, in response to suggestions by Dr. Christoph Scheidegger (see Ringius 1997 and Robertson 1998).

For Nova Scotia, the status of *E. pedicellatum* has become that of a critically endangered lichen. In contrast, *E. pedicellatum* has remained in apparently viable condition in several parts of Newfoundland, with significant numbers being found in Lockyer’s Waters on the Avalon Peninsula and especially within the boundaries of the Jipujijkuei Kuespem Park in the greater Bay D’Espoir area. These are key areas of known sites that may hold the greatest promise for the longer-term preservation of this species.

Legal protection has existed in Newfoundland for the large population in Jipujijkuei Kuespem Provincial Park as well as for populations in the Bay du Nord Wilderness Area and the Avalon Wilderness Area although these areas were not established specifically to protect this lichen. On the basis of an earlier promise made to Dr. Christoph Scheidegger and the International Committee for the Conservation of Lichens (ICCL) in 1996, by then Premier Brian Tobin, interim protection from logging was also afforded the Lockyer’s Waters Forest Area until the status of this lichen had been determined by COSEWIC.

# SUMMARY OF STATUS REPORT

In total, the number of extant and extirpated localities documented for boreal felt lichen in Canada include about 94 occurrences in about 7 regions of Newfoundland and

46 occurrences from about 4 coastal Atlantic regions of Nova Scotia and 1 locality from New Brunswick. The species no longer exists at the type locality in New Brunswick. In Nova Scotia, it is now known at only 3 of the 46 sites where it was observed formerly. Air pollution rather than loss of habitat is thought to be the main stressor in Nova Scotia. In Newfoundland, where the major concentrations of the species now occur, the senior author has documented losses from such causes as successional changes, logging, major air pollution point source (at Goobies from refinery at Come-by-Chance), possible local air pollution, and biotic impacts (1 major spruce budworm infestation killing balsam fir trees and lichens). The species is now documented from about 50 remaining sites on insular Newfoundland.

Including discoveries in March 2002 in Newfoundland, the total count of documented extant thalli in Canada is about 6900. In view of the many suitable habitats remaining in unexplored remote areas of the southern coast of insular Newfoundland, there are likely as many as twice or more this number, considering the rate of recent discoveries in more accessible areas with increased search effort. The greatest concentrations of thalli currently known are in Jipujijkuei Kuespem Park and in the Lockyer's Waters area, both in Newfoundland.

For assessment purposes, the mainland populations in Nova Scotia and those of insular Newfoundland have been recognized as distinct COSEWIC populations due to the fact that they occur in different ecological regions and are subject to different degrees of risk, especially from atmospheric pollution [E. Haber, co-chair, SSC Plants and Lichens, COSEWIC].

# TECHNICAL SUMMARY (BOREAL POPULATION)

***Erioderma pedicellatum* (boreal population)**
Boreal Felt Lichen Érioderme boréal
Range of Occurrence in Canada: Newfoundland

| | |
|---|---|
| **Extent and Area information** | |
| • *extent of occurrence (EO)(km²)* | <50,000 |
| • *specify trend (decline, stable, increasing, unknown)* | decline |
| • *are there extreme fluctuations in EO (> 1 order of magnitude)?* | no |
| • *area of occupancy (AO) (km²)* | < 100 |
| • *specify trend (decline, stable, increasing, unknown)* | decline |
| • *are there extreme fluctuations in AO (> 1 order magnitude)?* | no |
| • *number of extant locations* | 50? |
| • *specify trend in # locations (decline, stable, increasing, unknown)* | decline |
| • *are there extreme fluctuations in # locations (>1 order of magnitude)?* | no |
| • *habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat* | decline |
| **Population information** | |
| • *generation time (average age of parents in the population) (indicate years, months, days, etc.)* | 30 |
| • *number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)* | <10,000? |
| • *total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals* | decline |
| • *if decline, % decline over the last/next 10 years or 3 generations, whichever is greater (or specify if for shorter time period)* | ? |
| • *are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?* | no |
| • *is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?* | ? |
| • *list each population and the number of mature individuals in each* | too numerous; smallest pop. 1 thallus; largest pop. >1000 thalli; many extirpated in NL |
| • *specify trend in number of populations (decline, stable, increasing, unknown)* | decline |
| • *are there extreme fluctuations in number of populations (>1 order of magnitude)?* | no |
| **Threats (actual or imminent threats to populations or habitats)** | |
| - air pollution; logging; moose browsing and other natural forest pest and fire impacts | |
| **Rescue Effect (immigration from an outside source)** | unlikely |
| • *does species exist elsewhere (in Canada or outside)?* | Nova Scotia |
| • *status of the outside population(s)?* | endangered |
| • *is immigration known or possible?* | ? |
| • *would immigrants be adapted to survive here?* | ? |
| • *is there sufficient habitat for immigrants here?* | likely |
| **Quantitative Analysis** | |

## TECHNICAL SUMMARY (ATLANTIC POPULATION)

***Erioderma pedicellatum* (Atlantic population)**
Boreal Felt Lichen Érioderme boreal
Range of Occurrence in Canada: Nova Scotia, New Brunswick (extirpated)

| | |
|---|---|
| **Extent and Area information** | |
| • *extent of occurrence (EO)(km²)* | <5,000 |
| • *specify trend (decline, stable, increasing, unknown)* | Decline |
| • *are there extreme fluctuations in EO (> 1 order of magnitude)?* | No |
| • *area of occupancy (AO) (km²)* | < 20? |
| • *specify trend (decline, stable, increasing, unknown)* | Decline |
| • *are there extreme fluctuations in AO (> 1 order magnitude)?* | No |
| • *number of extant locations* | 3 |
| • *specify trend in # locations (decline, stable, increasing, unknown)* | Decline |
| • *are there extreme fluctuations in # locations (>1 order of magnitude)?* | No |
| • *habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat* | Decline |
| **Population information** | |
| • *generation time (average age of parents in the population) (indicate years, months, days, etc.)* | 30 |
| • *number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)* | <15 |
| • *total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals* | decline |
| • *if decline, % decline over the last/next 10 years or 3 generations, whichever is greater (or specify if for shorter time period)* | ? |
| • *are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?* | no |
| • *is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?* | yes |
| • *list each population and the number of mature individuals in each* | NS-12, 1 thallus<br>NS-16, 1 thallus<br>NS-27, 11 thalli |
| • *specify trend in number of populations (decline, stable, increasing, unknown)* | decline |
| • *are there extreme fluctuations in number of populations (>1 order of magnitude)?* | no |
| **Threats (actual or imminent threats to populations or habitats)** | |
| - air pollution; logging | |
| **Rescue Effect (immigration from an outside source)** | unlikely |
| • *does species exist elsewhere (in Canada or outside)?* | Newfoundland |
| • *status of the outside population(s)?* | special concern |
| • *is immigration known or possible?* | ? |
| • *would immigrants be adapted to survive here?* | ? |
| • *is there sufficient habitat for immigrants here?* | no |
| **Quantitative Analysis** | |

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## THE AUTHORS

### Senior Author

Wolfgang S.G. Maass was born on 23 October 1929 in Helsinki/Finland to a German father and a Swedish Finnish mother and went to Primary School both in Finland and Germany and to Highschool in Greifswald on the Baltic Sea. For two years he studied Botany and Chemistry at the Ernst-Moritz-Arndt University in Greifswald (East Germany) and then at the Eberhard Karl's University in Tübingen (West Germany). He was fortunate in having had outstanding teachers in biochemistry and plant physiology, Professor Adolph Butenandt (who had received the Nobel Prize in chemistry for his work on testosterone and who later became the Director of the Max Planck Gesellschaft) and Professor Erwin Bünning (the re-discoverer of the biological clock). He obtained his doctoral degree (Dr.rer.nat.) in 1957, based on a thesis entitled "Light growth reactions and Phototropism in *Phycomyces blakesleanus*". For half a year he was employed as a Research Assistant in the Botanical Institute of the University of Tübingen. From 1958-1960 he worked at the Max Planck Institut für Eiweiss -und Lederforschung on the chemistry of tannins in Norway spruce (*Picea abies*) and isolated the stilben glucoside "piceatannol" from its needles. This compound had previously been shown to be present in the bark where the aglycone was held responsible for the formation of tannins.

Through having taken part in one of Professor Bünning's traditional field trips to Torne Lappmark and in field trips with Professor Helmut Gams to Lule Lappmark and the Monte del Vesuvio near Naples, he had been introduced to the Floras of the Arctic and of the Mediterranean. He had also been commissioned to make a contribution to the “Kleine Kryptogamenflora von Helmut Gams” by supplying a key to the identification of *Sphagnum* mosses.

In 1960 he applied for a Postdoctoral Fellowship, got married to Regine Bürgener and emigrated to Canada. For about half a year he worked at Dalhousie University with Professor Kraft von Maltzahn on gametophyte cultures of *Sphagnum* and tissue cultures from the cambium of Norway spruce but these projects were abandoned after Professor von Maltzahn had left for Europe on his sabbatical leave. He then went to work as a guest researcher in the “Atlantic Regional Laboratory” of the N.R.C. with Jim Craigie on ion exchange in peatmosses and on the distribution of peatmosses in Atlantic Canada.

After his having been offered a staff position at the same Institution he began to work, under the inspiring influences of the late Dr. Arthur Neish and Dr. Neil Towers, on the biosynthesis and chemistry of lichen substances. In 1971-1972 he had been on an outside staff posting in Munich to learn enzymological techniques at the Max-Planck-Institut für Zellchemie under Professor F. Lynen. Unfortunately, work on the pulvinic acid synthetase in *Pseudocyphellaria crocata* and in *Letharia vulpina* ran into unsurmountable difficulties because of interferences by the large amounts of metabolites in these lichens. It would be necessary to grow large batches of mycobiont cultures under controlled conditions before activating the pulvinic acid synthetase for the isolation of the enzyme. In 1975 he published the first 2-directional thin layer chromatography system for the separation of lichen acids - a technique which was subsequently refined by the Culbersons at Duke University (see Can.J.Bot. 1975 and J. Chrom. 1976, 1979 and 1981). During his years with N.R.C., he had begun to conduct surveys of the lichen flora of Atlantic Canada, especially after the presence of *Erioderma pedicellatum* in North America had become known (Ahti and Jørgensen 1971, Jørgensen 1972). Subsequent work had led him to investigate the type locality of *E pedicellatum* and to conduct several expeditions to Newfoundland and the adjacent coast of Labrador.

In 1986 he took early retirement but continued fieldwork in the Maritime Provinces. As a Research Associate of Dalhousie University, he participated in surveys and research on the watershed chemistry of southern Nova Scotia and on the Thread-leaved Sundew *Drosera filiformis*, as well as on the Model Forest Project in and adjacent to the Fundy National Park. In addition, he was given a contract by the Nova Scotia Power Corporation to make use of lichens and peatmosses as potential biomonitors of atmospheric pollution around the newly constructed Point Aconi Power Plant. A letter of agreement by COSEWIC had been awarded to him in 1996 and had kept him busy until now.

Information on the chemistry of *Erioderma* and on the biochemical evolution of the species has been provided by the senior author, who is also responsible for the distributional maps, the growth measurements of young rapidly expanding thalle, for the bark acidity measurements and the water retention capacities for even-aged barks of balsam fir and black spruce.

**Junior Author**

David Jason Yetman was born in Red Bay Labrador on November 26, 1973. He received a Bachelor of Arts in Psychology from Carleton University of Ottawa in June 1995 and a Bachelor of Science with Honours, in Biology from Memorial University of Newfoundland in May 2000. He received an NSERC research scholarship in 1999 to complete a Masters degree on the genetic variability of *Erioderma pedicellatum* within Newfoundland and between extirpated Swedish populations. The research was carried out both in Newfoundland and Switzerland, at the Swiss Federal Research Institute. All the data have been collected and a draft of the Masters thesis is near completion. Currently David is the executive director of the Labrador Straits Development Corporation where he is working on several environmental research projects.