COSEWIC
Assessment and Status Report

on the

Blue Felt Lichen
Degelia plumbea

in Canada

SPECIAL CONCERN
2010

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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

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COSEWIC
Assessment Summary

Assessment Summary – November 2010

Common name
Blue Felt Lichen

Scientific name
Degelia plumbea

Status
Special Concern

Reason for designation
Within Canada, this lichen occurs only in the Atlantic region. It is very rare in New Brunswick, uncommon in Newfoundland, but more frequent in Nova Scotia. It grows as an epiphyte, predominately on hardwoods in woodlands and is vulnerable to disturbance that leads to a reduction in habitat humidity. The species is also very sensitive to acid rain. Forest harvesting is a threat to the species through direct removal or through the creation of an edge effect, leading to reduced humidity within the stand. In Newfoundland, the browsing of the lichen's host tree by a high density of moose is also of concern. Air pollution is a threat, especially in New Brunswick, but also in Nova Scotia.

Occurrence
New Brunswick, Nova Scotia, Newfoundland and Labrador

Status history
Designated Special Concern in November 2010.

COSEWIC
Executive Summary

Blue Felt Lichen
Degelia plumbea

Wildlife species description and significance

The Blue Felt Lichen*, Degelia plumbea* is a large, blue-grey, leafy lichen that has longitudinal ridges and crescent-shaped curves which often give it a scallop-like shape. A prominent beard-like fungal mat (hypothallus) that is usually blue-black protrudes beyond the margin of the thallus, which may exceed 10 centimetres in diameter. Vegetative propagules are lacking. Sexual reproductive structures are usually present and numerous. The fruit bodies are red-brown but often darken with age. The spore sacs (asci) within the fruit body contain 8 non-septate, colourless, oval ascospores. The photosynthetic component of this lichen is *Nostoc*, the most common cyanobacterial partner found in lichens.

Distribution

The Blue Felt Lichen, like the Boreal Felt Lichen, *Erioderma pedicellatum*, is one of the lichens that occurs in both eastern North America and western Europe. In North America the Blue Felt Lichen is restricted to the northeast being found in three Canadian three provinces: New Brunswick, Nova Scotia, and the island of Newfoundland and Labrador (Island of Newfoundland). The Blue Felt Lichen is relatively common in Nova Scotia, uncommon in Newfoundland, and rare in New Brunswick. In the U.S. it is known from just two occurrences in Maine.

Habitat

The Blue Felt Lichen is usually found on the trunks of old broad-leaved trees growing in moist habitats or close to stream and lake margins. In Canada and northwestern Europe, this lichen occurs in coastal suboceanic areas but also some distance inland in damp valleys. It prefers cool, humid woodlands that may be mixed coniferous/hardwood or dominated by deciduous trees. The Blue Felt Lichen seems to prefer mature deciduous trees, particularly maple, ash and yellow birch. In New Brunswick at two of the three known occurrences, its substratum is eastern cedar and in Newfoundland it grows mainly on yellow birch but very occasionally occurs also on white spruce. At its northerly limit of distribution in Nova Scotia, the Blue Felt Lichen has once been found on moss-covered rocks.

Biology

The Blue Felt Lichen is part of a group of lichens known as cyanolichens. Such lichens consist of a fungal partner and a cyanobacterium, which photosynthesizes and fixes atmospheric nitrogen providing the necessary carbohydrates and amino acids for growth. The Blue Felt Lichen reproduces via fruit bodies from which spores are shot into the air. If these land on a suitable substratum and encounter a compatible cyanobacterium of the genus *Nostoc* then a new lichen becomes established.

Population sizes and trends

Currently there are 100 occurrences of the Blue Felt Lichen in Canada. More than 771 lichen thalli have been identified from 88 current occurrences in Nova Scotia, 61 thalli from 3 occurrences in New Brunswick, and more than 102 thalli from 8 natural-habitat occurrences in Newfoundland. A ninth occurrence at Sir Robert Bond Park, Newfoundland, has 821 thalli growing on non-native trees. Only two current occurrences are known in the U.S.: one from Mt. Desert Island, Maine, with a single thallus and a second near Cobscook Bay State park close to the border with New Brunswick. An “occurrence” is defined as a place where this lichen occurs that is more than 1 km from a second occurrence. There is evidence to suggest a decline in populations, particularly in New Brunswick (on Grand Manan and Campobello Islands) and in Maine. A trend of becoming rare or vanishing has also been noted for the Blue Felt Lichen in other countries. For example, in SW Sweden, it is still common at some sites but has disappeared from many where it once occurred. It has also disappeared from Luxembourg and many locations in France, North Africa and Eastern Europe.

Threats and limiting factors

The Blue Felt Lichen prefers locations where there is high humidity. Most lumber and pulp companies concentrate on forests dominated by fir, spruce and pine and avoid swampy conditions. Furthermore, riparian boundary regulations have also helped maintain Blue Felt Lichen habitat. However, any loss of forest continuity through logging increases light levels and decreases humidity in its habitat. This has and will affect the persistence of this lichen in Nova Scotia. The habitat and substrate preferences of the Blue Felt Lichen have generally kept it from being directly harvested, Land development for housing and cottages, plus policy changes in the forest industry leading to increased biomass may also open forests that are Blue Felt Lichen habitats up to harvest. While the need for landscape-level measures is acknowledged, there are currently no accepted strategies to sustain the lichen communities that include the Blue Felt Lichen.

In Nova Scotia there are more than 80 current occurrences of the Blue Felt Lichen and for the reasons given above, it is unlikely to disappear from counties where it presently occurs. However, the number of occurrences may well decline over the next decade if forest removal continues at its current rate. Microclimate changes on the edge of cut areas are likely to affect this lichen adversely. The Blue Felt Lichen is most frequently found on deciduous trees in red maple swales and forestry activities in or around these will likely increase with the new focus on the use of forest biomass for electricity generation. To date maple swales have not been mapped in the province or considered for protection.

The Blue Felt Lichen is much rarer in New Brunswick and Newfoundland. In the latter province, some occurrences are in blocks approved, until recently, for commercial harvesting. The Newfoundland harvest of mature hardwood for firewood and browsing by the large populations of moose will limit the future availability of old yellow birch, the main host for this lichen.

Like other cyanolichens, the Blue Felt Lichen is very sensitive to air pollution and acid rain. Although acidifying pollutants in eastern North America are predicted to decline over the next 12 years, planned industrial developments in Newfoundland, New Brunswick and Nova Scotia may locally increase pollutant levels in some areas. Such developments may pose a threat to existing populations of this lichen.

A further threat is changing climate. Preliminary analyses of fog frequency along the Atlantic coast of Nova Scotia and the Avalon Peninsula of southeastern Newfoundland suggest that a significant decline has occurred over the past several decades. The Blue Felt Lichen is particularly sensitive to changes in moisture regimes so that declines in fog frequency could negatively affect it.

Protection, status, and ranks

The Blue Felt Lichen has not yet been assigned protected status by any of the Canadian provinces, although it is one of 14 yellow-listed (sensitive) lichens in Nova Scotia. Funding has recently been provided for its conservation in Newfoundland. Its occurrence in two provincial parks and three protected wilderness areas in Nova Scotia ensures that in those areas, at least, forest harvesting is not a threat. No current legislation in Atlantic Canada protects the swampy habitat of this lichen. In Newfoundland it has protection at the Sir Robert Bond Park. Elsewhere, riparian buffers related to commercial forestry developments are required but are modest (~20-50m) and unlikely to conserve adequately the macro- and micro-habitat needs of the Blue Felt Lichen and other rare lichens like the Boreal Felt Lichen and Vole Ears.

TECHNICAL SUMMARY

Degelia plumbea
English common name: Blue Felt Lichen   Nom commun français : Dégélie plombée
Range of occurrence in Canada (province/territory/ocean): NL, NS, NB

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2008) is being used)	Uncertain, but may be 10 to 30 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased?	No, threats are predominantly anthropomorphic (i.e., forestry, air pollution)
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	165,510 km²
Index of area of occupancy (IAO) **Sum of separate estimates (using 2x2 km^2 grids) for** **NB** (12 km²)**, NS** (336 km²) and **NL** (36 km²). Estimates use all locations from three provinces (NOTE: As calculated as the forest stand in which it occurs as indicated by provincial GIS Forest Cover data. **NS** (~100 km²) and **NL** (~10 km²) **NB** (<1 km²)**,**. Total = ~ 110 km²))	384 km² (96 grids)
Is the total population severely fragmented? Sparsely scattered occurrences on the New Brunswick coast, primarily coastal in NS, and only known from the eastern side of Newfoundland	No
Number of "locations∗"	100
Is there an [**observed**, inferred, or projected] continuing decline in extent of occurrence?	Probable decline; no longer occurring in southwestern NB
Is there an [observed, **inferred**, or projected] continuing decline in index of area of occupancy?	**NS**: direct and indirect threats to several locations, **NB**; direct and indirect threats to several locations **NL**: evidence of decline; direct and indirect threats to several locations

∗ See definition of location.

Is there an [observed, **inferred**, or projected] continuing decline in number of populations?	Stable in NS; unknown in NB; declining in NL
Is there an [**observed**, inferred, or projected] continuing decline in number of locations? 3 occurrences of 17 discovered before 1999 in NS could not be found, though not all 17 were searched. 88 current occurrences are known.	**NS**: 88 locations + 4 extirpated; **NB**: 3 locations + 1 extirpated; **NL**: 9 locations + 4 extirpated Certain loss of 9 locations
Is there an [**observed**, **inferred**, or projected] continuing decline in [area, extent and/or quality] of habitat? Habitat alteration from a variety of forestry operations suggests a decline in extent and quality; a declining fog frequency as well as the effects of acid rain and pollution affect quality	Decline in habitat quality from forestry activity, decline in fog frequency. Acid rain and pollution particularly in NS and NB.
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
NB - 61 thalli; 12 mature	12
NL - 923+ thalli; incomplete information on # of mature individuals, but estimated at 80 - 85% of total (740-787 mature)	740+ (1666+ minimum est*)
NS - 771 thalli; incomplete information on # of mature individuals, but estimated at 85-90% of total (655-694 mature)	655+ (1029+ minimum est*)
Total	1407+ (2707+ minimum est*)

*Estimated numbers of mature thalli based on extrapolating known numbers of mature thalli in sites where thalli were counted to obtain a total number of thalli for all sites.

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	Not applicable

Threats (actual or imminent, to populations or habitats)

Reduction in humidity of current habitat as a result of forest harvesting, industrial, road and housing development as well as decline in fog frequency and the impact of acid precipitation and air pollution.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? **U.S.:** no status assigned nationally or in any U.S. states	
Is immigration known or possible?	Very unlikely, only 2 locations for this lichen in the U.S. in Maine, the other nearest location the Azores.
Would immigrants be adapted to survive in Canada?	Not known
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	No

∗ See definition of location.

Current Status

COSEWIC: Designated Special Concern in November 2010

Status and Reasons for Designation

Status: Special Concern	
Reason for Designation: Within Canada, this lichen occurs only in the Atlantic region. It is very rare in New Brunswick, uncommon in Newfoundland, but more frequent in Nova Scotia. It grows as an epiphyte, predominately on hardwoods in woodlands and is vulnerable to disturbance that leads to a reduction in habitat humidity. The species is also very sensitive to acid rain. Forest harvesting is a threat to the species through direct removal or through the creation of an edge effect, leading to reduced humidity within the stand. In Newfoundland, the browsing of the lichen's host tree by a high density of moose is also of concern. Air pollution is a threat, especially in New Brunswick, but also in Nova Scotia.	

Applicability of Criteria

Criterion A: Not applicable: no decline data.
Criterion B: Not applicable. Although meets threshold for EN B2 (IAO) < 500 km² (actual = 460 km²), meets only 1 subcriterion a-c as follows. Does not meet threshold for B2a (the species is not severely fragmented). While there is support for continuing decline observed and inferred (B2b) in (ii) (index of area of occupancy, (iii) area, extent and/or quality of habitat, (iv) number of locations, and (v) number of mature individuals, does not meet threshold for B2c (no extreme fluctuations).
Criterion C: May meet threshold for total number of mature individuals for TH (<10000, actual = 1500+), but there is no evidence for decline.
Criterion D: Not applicable: does not meet thresholds for TH (<1000, actual = 1407+ mature) and EN (<250).
Criterion E: Not applicable: analysis not performed.

COSEWIC HISTORY

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

COSEWIC MANDATE

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

COSEWIC MEMBERSHIP

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

DEFINITIONS
(2010)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada — Environnement Canada
Canadian Wildlife Service — Service canadien de la faune

Canada

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

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Degelia plumbea (Lightf.) P. M. Jørg. & P. James *Bibliotheca Lichenologica* (1990) 38:253-276.

Basionym

Type specimen - Great Britain, J. Dillenius, undated, without locality (second specimen from the left of 179, 73 p.p., OXF-DILL, lectotype *fide* Jørgensen 1978:54.

Classification

Lichen names apply formally only to their fungal components, but by convention serve as a short-hand for the symbiosis that involves both the fungal and photosynthetic components. The photosynthetic partners of *Degelia* species are cyanobacteria in the genus *Nostoc* (N. Hemisphere) and *Scytonema* (S. Hemisphere).

The genus *Degelia* is classified in the family Pannariaceae, order Peltigerales, class Lecanoromycetes, and division Ascomycota (Ekman & Jørgensen 2002; Miadlikowska *et al.* 2006). *Degelia,* which includes 20 species, was separated in 1981 from *Parmeliella* and *Coccocarpia* from which it differs in its anatomy, fruit body development, and ascus structure (Arvidsson & Galloway 1981) .

In North America, a single species of the genus, *Degelia plumbea,* is recognized.

Common name

The name “Blue Felt Lichen” is a reference to the grey-blue colour of the thallus when wet and the felty blue-black hypothallus. This name derives from a translation of that accepted in Scandinavia (Holien and Tønsberg 2006). This lichen has also been called the “Leaden Lichen” a reference to the dull grey colour of the dry thallus (Hinds and Hinds 2007). It is a translation of the Latin specific name which was originally given to this lichen by the English lichenologist Lightfoot in 1777.

Morphological description

Degelia plumbea is a foliose macrolichen with a thick blue-grey thallus that may exceed 10 cm in diameter but is usually about half this size. The upper surface of a *D. plumbea* thallus has longitudinal ridges that are sometimes crossed by very fine concentric growth lines. It has rounded lobes with thickened upturned edges. These features often give the thallus a scallop-like shape. The upper cortex is about 40µm thick. The 60-100µm thick photobiont layer is comprised of *Nostoc* clusters, the cells of which are 6-8µm in diameter. *Nostoc* is the most common cyanobacterium found in lichens. The medulla is made of parallel hyphae 140-200µm thick (Carballal *et al.* 2007;

Jørgensen 1978, 2000, 2007). The lower surface is covered by a thick beard-like hypothallus which protrudes beyond the margin of the thallus (Figure 1). This felt-like hypothallus is made of whitish, bluish or black rhizohyphae that are usually dark but can be quite pale in some fresh specimens or in herbarium specimens that have been stored for extended periods.

Figure 1. Thallus of *Degelia plumbea* on the trunk of an *Acer rubrum* at Tidney Meadows, Nova Scotia.

Sexual reproductive structures are usually present and numerous, except on small thalli. The disc is red-brown, up to 1mm in diameter, with a pale proper margin but this often becomes obscured as the fruit bodies darken and often become convex with age. The hymenium of the fruit body stains deep blue with iodine. The apical apparatus in the ascus of *Degelia* consists of an amyloid apical sheet rather than a ring structure which is found in *Parmeliella*. The clavate asci are thickened at the apex which stains blue in Lugols iodine. The outer parts of the ascus also sometimes stain. There are 8 spores per ascus which are simple, ellipsoid, colourless and (17) 20-22 (25) x 6-10μm in size. They are smooth-walled and often become pointed at one end (Carballal *et al.* 2007; Jørgensen 2000; Jørgensen & Sipman 2006).

Vegetative propagules (soredia, isidia) are lacking although, occasionally, knoblike lobes develop, especially in the centre of the thallus but these appear not to provide a means of dispersal. Because there is no means of vegetative reproduction, the ascospores must find a suitable cyanobacterial partner at every generation.

No lichen substances have been identified in *D. plumbea* in extracts analysed by thin layer chromatography and there are no reactions with the commonly used chemical spot tests (Jørgensen 2000, 2007).

Population spatial structure and variability

There are no published studies on the genetic relationships of *D. plumbea* at the population level. Studies have been done on the genetics of the photosynthetic component of *D. plumbea*. The importance of this is presented in the section of this report dealing with life cycle and reproduction. No long-term data are available for known North American occurrences of *D. plumbea* to show how populations have changed over time. However, *D plumbea* thalli have the ability to persist for long periods in favourable habitats. This is indicated by the presence of *D. plumbea* on the islands of Grand Manan in New Brunswick and Mt Desert Island in Maine. In Nova Scotia, we have been able to confirm the current presence of *D. plumbea* at a site at Cape Chignecto, where Maass collected it in the early 1990s, and at the site near Cobscook Bay State Park Maine, where he found it in 1981. One reason why more information is not available is the lack of accurate locations until GPS systems became available.

Designatable units

One designable unit is recognized for *Degelia plumbea*. There is no genetic, ecological, or morphological information to suggest differentiation between populations in Atlantic Canada.

Special significance

Degelia plumbea is part of a group of rare cyanolichens found in the humid coastal forests of eastern North America (Cameron & Richardson 2006; Cameron *et al.* 2007). The Canadian populations of *D. plumbea* are disjunct from other world populations, which are centred in northwestern Europe and in the mountainous areas around the Mediterranean. *D. plumbea* belongs to the Lobarion community (Gilbert, 2000). This community is a conspicuous component of the lichen flora of Atlantic Canadian woodlands and one which is useful for biomonitoring acid precipitation and air pollution. This lichen community also provides sustenance and protection for a wide range of invertebrates that, in turn, provide food for resident and migratory birds (Pettersson *et al.* 1995, Thompson *et al.* 2003).

DISTRIBUTION

Global range

Degelia plumbea like *Erioderma pedicellatum* is a member of the eastern North America-western European (Amphi-Atlantic) lichen taxa *(*Galloway 2008; Maass & Yetman 2002*)*.

The distribution is well documented for the British Isles, Scandinavia and the Iberian peninsula where *D. plumbea* is reasonably common and locally abundant (Jørgensen 2007; Carballal *et al.* 2007; Seaward, pers. comm., 2008). It occurs off Africa on the Azores, Canaries and Madeira, as well as on islands in the Mediterranean (Corfu, Corsica, Crete, Sardinia and Sicily) (Grube 2008; Tønsberg 1999; Coppins, pers. comm., 2008). Around the Mediterranean, *D. plumbea* occurs in Spain, Portugal, Italy, Greece, Syria and Turkey. It has been recorded as far east as the Ukraine and Georgia (Elenkin 1901; Nakhutsrishvili 1986; Tufan *et al.* 2006). Around the Mediterranean, *D. plumbea* is mainly found at altitudes from 500-900m and occasionally up to 1500m (Anon. 2008b; Jørgensen 1978; Zedda pers. comm., 2008). *D. plumbea* also occurs in Croatia, Slovenia, Montenegro, Bosnia, Herzegovina (Savic 2001, Bilovitz *et al.* 2008; Mayrhofer, pers. comm., 2008). Finally, it is reported, though very rare, from Tunisia, Algeria and Morocco in North Africa where most collections were made between 1909 and 1930 (Degelius 1935, p. 140; Jørgensen 1978).

Degelia plumbea is the only species in this genus found on the North American continent, where it is restricted to the northeast. In the U.S.*, D. plumbea* is known only from two coastal locations. The first is on Mount Desert Island in Maine. It was first found on Newport Mountain (Tuckerman 1872). A single thallus of *D. plumbea* was re-found on Mount Desert Island in 2005 and another smaller thallus of *D. plumbea* at the same site in 2008 (Weirer and Cleavitt pers. comm., 2008). The second U.S. location is close to Cobscook Bay State Park, Maine. *A* thallus discovered in 1981 by Maass was still extant in 2010. Searches for additional *Degelia* occurrences on the islands off the Maine coast including Bois Bubert Island, Head Harbour Island and Roque Island have failed to discover any further occurrences (Richardson and Seaward pers. comm. 2010). The record of *D. plumbea* from Alaska (Thomson & Ahti 1994) is an error as the specimen proved to be *Coccocarpia erythroxyli* (Jørgensen 2000). In Canada, *D. plumbea* has only been found in New Brunswick, Nova Scotia and the island of Newfoundland.

Canadian range

The current known distribution of *D. plumbea* is restricted to three provinces in Atlantic Canada where 100 current occurrences are known. It occurs frequently in Nova Scotia (88 occurrences), rarely in Newfoundland (9 occurrences) and very rarely in New Brunswick (3 occurrences). An occurrence is defined as a site where this lichen occurs that is more than 1 km from a second occurrence. No estimate of the number of locations is given since the scale of extirpation events (forest harvest or air pollution) is difficult to estimate relative to the scale of occurrence of the lichen. There are no current or historical records from Prince Edward Island, Quebec or Labrador. The Canadian population represents approximately 15% of the known world total area.

<u>Nova Scotia</u>

The only historical records are from Mackenzie Lamb, who collected *D. plumbea* from Cape Breton in 1952 (CANL 2881) and Wolfgang Maass, who collected it from approximately 30 sites in Atlantic Canada, between 1970 and 2000 (Lamb 1954; Maass, pers. comm., 2008). Recent field research from 1999 to 2008 (Tables 1-3) has resulted in further discoveries of *D. plumbea* (Tables 1-3). The lichen is now known from some 88 current occurrences in Nova Scotia (Figure 2). Attempts to relocate the Mackenzie Lamb site have been unsuccessful as the location information was not adequate (Table 4 provides information on occurrences discovered before 1999).

Table 1. Summary of the distribution details of *Degelia plumbea* occurences discovered since 1999 in Nova Scotia. An occurrence was defined as place where this lichen occurs that is more than 1 km from a second occurrence. Data is given only where information was available. Where recent survey dates are given, these are also the first discovery dates. Number of thalli marked with an asterisk(*) are confirmations of the species presence at that site; no thallus counts were made.

Occurrence	Survey Date	Host	Number of thalli
Angus Farqhuar's Brook	2006	sugar maple	15
Ash Hill Lake	2008	red maple	1
Bear Lake	2006	red maple	1*
Big Deadwater		red maple	6
Big Lake		red maple	
Big Squambo Lake		red maple	3
Black Point Brook	2008	sugar maple	8
Bloody Creek	2008	red maple	1*
Blue Duck Hole	2008		9, 1 juvenile
Blue Mountains		red maple	8
Bogart Lake	2007	white ash	1*
Bon Mature Lake		red maple	
Brown Lake			
Cameron Flowage	2008	red maple	1
Canada Hill Road		red maple	
Canada Meadow	2008	red maple	1*
Cape Chignecto 1	2007	red maple	30+
Cape Chignecto 2	2005	red maple	30+
Cape Chignecto 3	2006	red maple	15
Comeau's Mill Brook	2008	red maple	8
Cooks Pond	2008	red maple	1*

Occurrence	Survey Date	Host	Number of thalli
Cordwood Piles Point			
Cornings Lake	2006	red maple	1*
Dauphinee's Mill Lake	2006	red maple	3
DND Mill Cove	2008	red maple	4
Douglasville		white ash	
Duck Hole	2008	red maple	2
East River	2008	red maple	1
East Sable Road	2008		14
Egypt Brook	2008		
Feather Pond	2006	red maple	2
Fishing Lake		red maple	
Flintstone Rock	2008	red maple	8
Fungi Ground	2008	red maple	1*
Goose Harbour Lake			12
Gray's Hollow Brook	2008	sugar maple	6
Grimm Road	2008	red maple	10
Gully Lake	2006	red maple	1*
Hagen Meadow Brook		red maple	6
Haley Lake Brook	2008	red maple	7
Haydens Hay Meadow	2008	red maple	19
Hectanooga	2008	red maple	1*
Hollahan Lake Brook	2006	red maple	15+
Johnston's Beach	2008	red maple	1*
Jones Harbour	2008	red maple	82+
Lauchlin Lake	2008	red maple	1*
Little Harbour	2008	red maple	3
Little Rock Lake		yellow birch	2, many
Log Brook			13+, many small
Logging Lake		yellow birch	with juveniles
Long Lake		red maple	
Long Lake Bog		red maple	
MacEachern's Lake	2008	sugar maple	5
Martin Brook		red maple	8
Melvin Lake	2005	red maple	7
Middle Clyde	2008	red maple	11
Misery Lake			106
Moose Lake		red maple	12+
Mystery Lake		red maple	16+
New Harbour		red maple	1
Northwest Brook			abundant

Occurrence	Survey Date	Host	Number of thalli
Norwood			
Otter Pond		red maple	
Payzant Brook		red maple	1
Rat Lake		red maple	3
Red Duck Hole			many, 2
Reid Hill	2007	white ash, sugar maple	1
Rhodes Lake			2
Rickers Lake		red maple	3
Robart's Pond	2008	red maple	83
Rocky Lake	2006	red maple	11
Rocky Lake Brook	2006	red maple	4
Ruggles Lake			
Skull Lake			
Spotted Mountain			
Square Lake			
Steele's Brook	2008	red maple	6
Terence Bay	2006	red maple	5
The Long Bog			
Thomas Raddall Park	2008	red maple	60+
Thumbhill Creek		red oak	3
Tidney River	2008	red maple	31+
Tom's Tidney Meadows	2008	red maple	15
Twin Lakes	2008	white ash	1*
Upper Clyde River	2008	red maple	1
Upper Clyde Road	2008	red maple	1*
Webber Lake	2005	red maple	11+, 5 juvenile
Young's Mountain		white ash, sugar maple	

Table 2. Summary of the distribution details of *Degelia plumbea* occurrences discovered since 1999 in New Brunswick. Note that the last occurrence is no longer extant, so that there are three current occurrences. Data is given only where information was available. Where recent survey dates are given, these are also the first discovery dates.

Occurrence	Survey Date	Host	Number of thalli
Dipper Creek, Maces Bay	2005	Eastern cedar	3
Ten Mile Creek, Bains Corner	2006	Eastern cedar	31
Grand Manan Island	2008	Sugar maple	27

Table 3. Summary of the distribution details of *Degelia plumbea* occurrences discovered since 1999 in Newfoundland. Nine are in native trees and one in a park on non-native trees. Data is given only where information was available. Where recent survey dates are given, these are also the first discovery dates. Number of thalli marked with an asterisk(*) are confirmations of the species presence at that site; no thallus counts were made.

Occurrence	Survey Date	Host	Number of thalli
Bar Pond Fox Marsh	2006	yellow birch	1*
Avondale Waters	2005	yellow birch	1*
Fourth Pond	2005	yellow birch	1*
North of Fourth Pond		yellow birch	
Pratt		Norway maple	11
Argentia Access Road			
Halls Gullies Access Road		yellow birch	
Conne River		yellow birch	91+
Sir Robert Bond Park	2006	Norway maple and 4 other non-native species	821

Table 4. *Degelia plumbea* occurrences in Canada that were discovered before 1999.

Occurrence	Discovery Date	Phorophyte	Province
French Cove	1980	red maple	Nova Scotia
Gunn Ponds	1982	red maple	Nova Scotia
Lake Charlotte Rock	1980	red maple	Nova Scotia
Port Ban Cove			Nova Scotia
Four Mile Brook			Nova Scotia
Goose Harbour Lake			Nova Scotia
Little Southwest Brook			Nova Scotia
Long Duck Lake			Nova Scotia
Lucifer Lake			Nova Scotia
MacNabs Brook			Nova Scotia
Meadow Lily Lake			Nova Scotia
Point Aconi			Nova Scotia
Rafter Lake			Nova Scotia
Sandy Bay		red maple	Nova Scotia
Sandy Cove Round Lake		red maple	Nova Scotia
Second Grimm Lake			Nova Scotia
Cape Rouge			Nova Scotia
Campobello Island			New Brunswick
South Placentia	1997	white spruce	Newfoundland
Sir Robert Bond Park		Norway maple	Newfoundland

Figure 2. Current distribution of *Degelia plumbea* in Canada and adjacent Maine (U.S.).

New Brunswick

There are three extant occurrences in this province for *D. plumbea* (Figure 2). It was first collected from Grand Manan Island, New Brunswick, by Henry Willey in 1879. This was reported in 1882 in part one of Tuckerman's Synopsis of North American Lichens (Tuckerman 1882). The specimens collected by Willey from Grand Manan are lodged in the Farlow Herbarium in Boston but there are no detailed location notes. The occurrence of *D. plumbea* on Grand Manan, New Brunswick, was confirmed in 2002 by Maxwell (pers. comm., 2008) who reported an occurrence near the island airport. The lichen was still present at this location in 2003 (Clayden, pers. comm., 2008) but could not be found in 2008. However, another occurrence, with abundant healthy thalli some 3 km away was discovered by Richardson and Seaward in 2008.

Searches on Campobello Island by Richardson, Clayden and Seaward in 2008 failed to relocate *D. plumbea* in an area below Fox Hill where it was seen some 30 years previously (Maass 1997).

There are two extant occurrences for mainland New Brunswick along the Fundy coast. There is an occurrence at Maces Bay, Charlotte County, and one at Ten Mile Creek, Bains Corner, Saint John County. These coastal occurrences were discovered during recent research on cedar swamps carried out by the New Brunswick Museum. The Maces Bay occurrence was discovered in 2005 (Sabine, pers. comm., 2008) and the Ten Mile Creek occurrence (Clayden, pers. comm., 2008, specimens in NBM) was found in 2006. An expanded search of the latter area in 2008, revealed four new occurrences within the stand. Surveys of cedar swamps studied elsewhere in the province have not revealed further occurrences of *D. plumbea.* There are no historical records for mainland New Brunswick.

Newfoundland

Between 1885 and 1888, Ernest Delamare collected specimens of *D. plumbea* from Coal River (Coal Brook, near Port aux Basques) and Whitbourne (near St. John's) Newfoundland and at Langlade on the nearby French Islands (St. Pierre and Miquelon), where the lichen was reported to be very rare. These specimens are now in the herbarium in Munich (Beck, pers. comm., 2008). *D. plumbea* was listed by Macoun (1902) as occurring in Newfoundland, the record being from Waghorne. This probably relates to the specimen collected by Waghorne and dated 8/11/1895 from Whitbourne and deposited in the British Museum London in 1896 as part of a collection of Newfoundland lichens. A map based on 19th century records and on a specimen collected in 1961 by Damman (2407 CDFN) shows *D. plumbea* at Northwest River, Bay D'Espoir (Ahti 1983). A 1977 specimen was collected by John Pratt (CANL 67237) in woods near St. Catherines in the Salmonier River Valley at the head of St. Mary's Bay.

There are several extant occurrences for *D. plumbea* on the Avalon Peninsula, Newfoundland (Figure 2). Of the occurrences recorded before 1999 and since, *D. plumbea* is still present in five (Tables 3 & 4). These are Sir Robert Bond Park, Whitbourne; Hall's Gullies; rock cut on the Argentia Access Rd.; Murphy's Pond; and St. Catherines on St. Mary's Bay. *D. plumbea* has also been found, with the help of the Miawpukek First Nation, at three new occurrences in the Bay D'Espoir area, close to where it was recorded by Ahti (1983). No recent attempts to find *D. plumbea* on Saint-Pierre and Miquelon are known.

The extent of occurrence of the lichen *D. plumbea* in Canada is estimated to be 165,510 km^2 and the Index of Area of Occupancy is 384 km^2. The area occupied by the forest stands in which the lichen is found is less, about 110 km^2.

Search effort

Few searches in eastern Canada have focused solely on finding *D. plumbea.* Most of the recent discoveries in all three provinces have occurred during general or cyanolichen lichen surveys.

General lichen diversity surveys in Nova Scotia include Casselman and Hill (1995), Selva (1999), Sneddon (1998), Seaward *et al.* (1997) and Cameron *et al.* (2007). Fourteen protected areas in Nova Scotia were surveyed for cyanolichens (Cameron and Richardson 2006). Two Tuckerman workshops (1999 and 2004) examined lichens around White Point and Parrsboro areas and a single *Degelia* occurrence was found at the Terence Bay Wilderness Area. Data on lichens was also collected from southern Nova Scotia by McMullin *et al.* (2008).

Cyanolichen surveys that have contributed to the known occurrences for *D. plumbea* are those of Maass (1983, 1993, 1997, 2000) who surveyed large areas of the Atlantic Provinces. *Degelia* occurrences were also discovered by Wolfgang Maass and Tom Neily during searches for *Erioderma pedicellatum* and for *E. mollissimum* as part of the COSEWIC reports on those species (Cameron *et al.* 2009; Maass & Yetman 2002), and by Anderson (2007) during explorations for compiling a provincial macrolichen checklist (Anderson in prep.) and during field research in Cape Chignecto Provincial Park to rediscover rare lichens found there by Maass (1997). Reports to the Nova Scotia Department of Natural Resources (Anderson 2004-2007) document the results of this re-survey. Much of the search effort carried out by F. Anderson, R. Cameron, and T. McMullin over the past decade, but especially in 2008 with the help of T. Neily, S. Clayden, D. Richardson and M. Seaward, involved revisiting known occurrences to collect site and thallus data. Figure 3 shows, for the province of Nova Scotia, areas that have been formally searched for cyanolichens. Digital photographs and collections were taken wherever possible of *D. plumbea* thalli and GPS readings were taken to establish the distribution of this lichen (data reported in the Tables1-3).

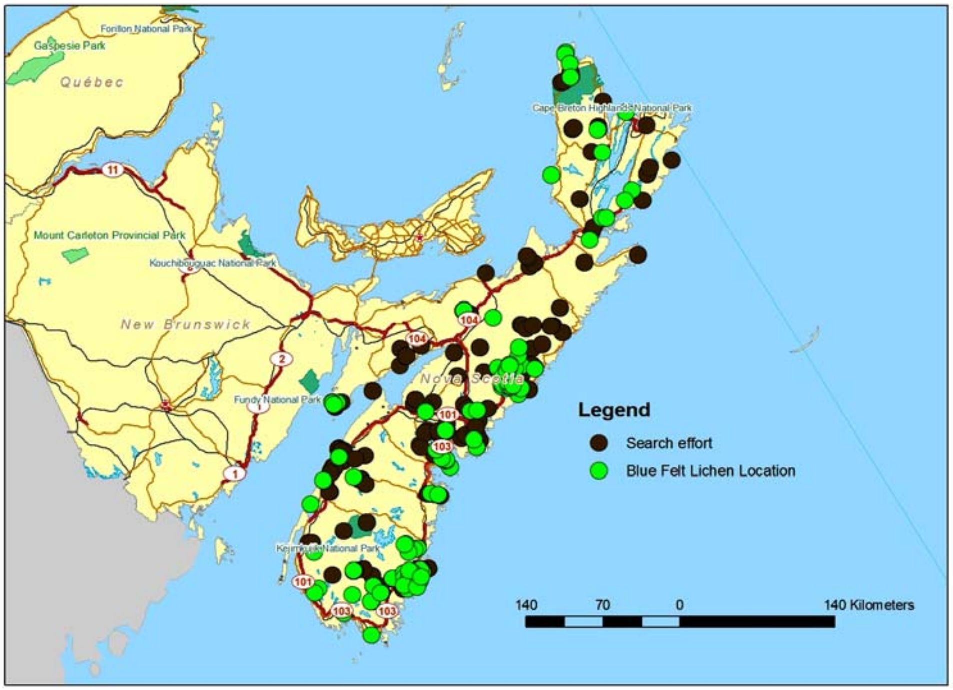

Figure 3. Areas of Nova Scotia that have been searched for lichens. The green spots indicate *Degelia plumbea* occurrences; the black spots represent areas that were searched for cyanolichens and those containing green algae but where no *Degelia* was found.

HABITAT

Habitat requirements

Degelia plumbea occurs in Atlantic Canada from sea level to just over 300m elevation (the highest elevation in the region is 820m, the peak of Mt. Carleton in New Brunswick). *D. plumbea* occurs most often in forests where the climate is cool and humid in summer but the winters are moderate and the rainfall throughout the year high. *Degelia* is especially common in low-lying areas where there is frequent fog or at higher elevations where there is cloud. It also occurs where there are topographic features that help to trap moisture, such as valleys, gullies, swamps, streams and lakes. These habitat characteristics indicate a requirement for high humidity levels. *Degelia plumbea* colonizes large mature or over-mature trees that grow in wet areas. This lichen is not restricted to a particular side of a tree but can be found at every cardinal point, suggesting its light requirements are not exacting. This lichen colonizes mature, coarse-barked trees in deciduous or mixed deciduous/coniferous forests where light levels increase during winter months but where there is protective shade in summer. It is most commonly found from 50cm above ground level up to about 2m. In some areas in Newfoundland, it occurs higher up its host trees.

Another important requirement for cyanolichens such as *D. plumbea* is a pollution-free environment. The sensitivity of lichens to air pollution and acid rain has been documented in many scientific papers (see Henderson 2000). Lichens accumulate pollutants from the air, precipitation and from particulates, a reflection of their efficient uptake systems. Lichens lack the protective cuticle found in vascular plants (Richardson 1992). Cyanolichens are particularly sensitive to sulphur dioxide and nitrogen oxides. Nitrogen fixation is essential for their survival and it is disrupted by the damaging effects of acid rain (Gilbert 1986; Cameron & Richardson 2006). Acid rain causes a reduction in the pH of substrata and depletes or inhibits the uptake of nutrients such as phosphate which are essential for nitrogen fixation.

North America

Maritime Canada and Maine mark the boundary between the deciduous-dominated Alleghenian forests of the south and the coniferous-dominated boreal forests of the north and Newfoundland. The Acadian forests are a mixture of deciduous and coniferous species (McMullin *et al.* 2008). *Degelia plumbea* thrives in such forests where there is a strong maritime influence, i.e. within 30 km of the coast, or when very near the coast, in forests that surround sheltered bays or inlets. Winters in areas where this lichen occurs are relatively warm with a mean January temperature around -8^{o}C while July temperatures are cool, ranging between 12 and 16^{o}C. Annual precipitation generally exceeds 1200mm and may be as much as 1600mm in some locations. Much of this falls as rain. Marine advection fog occurs up to 2,000 hours per year along the Atlantic and Fundy coasts (Clayden, 2009). Fog occurs most frequently from April to October and often late in the day during the highest temperatures. It is also frequent on the Avalon Peninsula in Newfoundland.

Nova Scotia

Degelia plumbea thrives in the Atlantic coastal forests of Nova Scotia. The *D. plumbea* locations in Nova Scotia are generally in mixed forests containing red maple (*Acer rubrum*) that are in wet depressions or adjacent to streams, rivers or lakes. These wet habitats are referred to as red maple swales (Golet *et al.* 1993). Red maple can make up 50% of the tree species composition while balsam fir (*Abies balsamea*) is also a common component, up to 30%. The age of red maples, in sites where *Degelia* ç frequent, can exceed 90-100 years, though the stem size may be as small as 10cm dbh (diameter at breast height). Despite the relatively young age of these trees, the woodlands may be very ancient due to wave/gap replacement occurring on a local and movable patch scale in the landscape (Mosseler *et al.* 2003). The poorly drained, moist depressions where these maples grow can occur in very narrow strips (100-150m) along stream edges, between ridges which scarcely register on topographic maps. The ridges provide protection from drying winds. Moss cover in the moist depressions is generally abundant and often includes a carpet of *Sphagnum.* The herb layer is usually dominated by cinnamon fern, but may include bunchberry, sarsaparilla, sedges, gold thread and false lily of the valley. Outside of these red maple swales, *D. plumbea* ç found on the Atlantic coast near rivers and streams or adjacent to wetlands. It also occurs less frequently in deciduous forests on rich soil on hillside slopes as in the Cape Breton Highlands, on the North Mountain on the Fundy coast, and in the Cobequid Hills. These forests are dominated by *Acer saccharum*, *Betula alleghaniensis* and *Fagus grandifolia*. *D. plumbea* is most often found in humid micro-climates near seeps, vernal ponds or steep sided gullies.

<u>New Brunswick</u>

Historical records of *D. plumbea* are from maple (*Acer spp.)*, yellow birch (*Betula alleghaniensis)*, and moss-covered rocks from Grand Manan and Campobello Islands (Tuckerman 1882; Maass, 1997). In 2002, this lichen was re-discovered on an old beech (*Fagus grandifolia)* on Grand Manan, and in 2008 on a large sugar maple (*Acer saccharum)* close to a small stream in an area of large mature yellow birch (*Betula alleghaniensis)* and Maple (*Acer* spp.) which was very rich in Lobarion species: *Lobaria pulmonaria, L. scrobiculata, Collema subflaccidum, Parmeliella triptophylla, Thelotrema lepadinum* and *Parmotrema crinitum*.

On the mainland in New Brunswick, both occurrences are within 5 km of the Bay of Fundy in the fog belt in low-lying, mossy forests dominated by eastern white cedar (*Thuja occidentalis).* The cedars in some stands have been dated to nearly 400 years old and the light levels in the stands are low (75-90% crown closure). They are generally humid, with deep moss cover on the ground and an open understory with scattered balsam fir (*Abies balsamea*), occasional red spruce (*Picea rubens*), and mountain paper birch (*Betula cordifolia)*. At Maces Bay, the cedar stand lies at an elevation of 15m on a west-facing slope above a small stream at the base of a 43m high north/south running ridge. Only one stem was found with *Degelia*. Nearby clear-cutting stopped about 40m from the *Degelia* location and the resulting blow-down included the lichen's 24cm dbh tree. The tree limbs were still intact when the lichen was discovered in 2005. In 2008, three thalli on the east face of the fallen and now moss-covered dead *Thuja* stem appeared healthy. Their sizes ranged from 1.2cm to 5cm. The second mainland occurrence is at Ten Mile Creek. This is a moderately open ca. 10-hectare *Thuja* stand which lies on the northwest side of a coastal domed bog at an elevation of approximately 45m. The normally low light levels in the stand were altered by a large blowdown which occurred since 1995 (Clayden, pers. comm., 2008). A small stream and several swampy areas enhance humidity levels in the stand, which receives frequent coastal fog. The 30 thalli in the stand are on stems of 13-29cm dbh. The U.S. occurrence near Cobscook Bay State Park, which is close to the Canadian border, is also on *Thuja*.

Newfoundland

The woodlands where *D. plumbea* occurs in this province are characterized by scattered mature yellow birch (*Betula alleghaniensis*) in coniferous forests that are dominated by balsam fir (*Abies balsamea*). Though trees are little more than a century old, such forests may be ancient (Thompson *et al.* 2003). On the Avalon Peninsula, *D. plumbea* usually grows on the trunks of old *Betula alleghaniensis* and most of the occurrences are within 25 km of the sea.

The Hall's Gullies area of the Avalon Peninsula consists of a series of connecting ribbed and end moraines (Damman 1983). The moraines can reach heights of 30m and are no farther apart than 200 to 300m. Between the moraines are peatlands consisting of bogs and fens. Density of peatlands in this area is very high, often occurring less than 100m apart. The topographic pattern creates a mosaic of interspersed wetlands and forests, resulting in a highly humid habitat. In the Hall's Gullies area, balsam fir (*Abies balsamea*) makes up at least 67% of all trees by basal area. *Picea mariana* is the next largest tree component. *Betula alleghaniensis* and *Betula papyrifera* are found occasionally. The proportion of dead trees in these forests ranges from 19% to 54%. Tree age from breast height cores averages 73 years and indicates habitats are even-aged but with variable diameters. Crown closure averages 55% or more. *D. plumbea* is found on the scattered yellow birch where the surrounding balsam fir has been wind-thrown (Hanel, pers. comm., 2008). The density of trees can vary a great deal from >17,000 stems/ha at one location to 3000 stems per ha at a second only 1 km away.

The Southeast Placentia area in the Maritime Barrens Eco-region is characterized by large areas of exposed bedrock and heath barrens. Forests are limited to sheltered valleys and coves and white spruce can be locally common due to historic coastal land-use patterns (cultivation, firewood-cutting, etc.). Slope bogs, basin bogs and fens are common. Southeast Placentia is comprised of an uneven-aged forest with tree ages that range from regeneration (only a few years old) to 180 years. Tree height and dbh are variable at Southeast Placentia because of the uneven-aged structure. Light levels on the tree boles at Southeast Placentia is greater as crown closure is very low (19%). This is the only occurrence where *D. plumbea* has been reported occasionally on *Picea marian*a and very rarely on *Picea mariana*. *Sphagnum* is abundant on the ground and there is usually little herb or shrub cover. The Southeast Placentia location is about 500m from a mapped wetland but small unmapped peatlands are found throughout this area.

At Lockyer's Waters and Fox Marsh, *D. plumbea* occurs in woodlands that are gently sloping and near small lakes or streams at elevations of about 200m. The forest floor where this lichen occurs is usually moss covered, the soil being moist to damp and the humidity high. Associated lichens belong to the Lobarion community and in order of frequency of co-occurrence are *Lobaria scrobiculata, L. pulmonaria, Thelotrema lepadinum, Nephroma helveticum, N. laevigatum, Leptogium cyanescens, Normandina pulchella and Pannaria rubiginosa.*

The Conne River occurrences are approximately 5 km from the head of Bay D'Espoir, some 150 km to the northwest of the Avalon Peninsula occurrences. The habitat of the Conne River occurrences, on the Mary Hawco Forest Access Road, is a moist balsam fir forest admixed with yellow birch, white birch and sometimes black spruce. One occurrence is on a toe slope transition to a wetland. The other cyanolichens present include *Parmeliella triptophylla and Fuscopannaria leucosticta*, along with the usual *Lobaria pulmonaria, L. quercizans* and *L. scrobiculata* (Hanel, pers. comm., 2008). In the Bay D'Espoir area, thalli are found on live, upright trees; and at the Lockyers Waters and Halls Gullies areas some 60% of *Degelia* thalli also occur on standing *Betula alleghaniensis* (Conway, pers. comm., 2008). Thalli of *D. plumbea* in these areas may be rather more common than indicated by the documented discoveries because they grow high up on the trees and are hard to find (Hanel, pers. comm., 2008).

The population of *D. plumbea* at Whitbourne and Salmonier River (St. Catherines), is unusual in that, at these locations, this lichen along with other members of the Lobarion community such as *Nephroma laevigatum, Lobaria quercizans*, and *Dendriscocaulon intriculatum* is found colonizing a range of non-native *Acer* species, including Norway maple (*Acer platanoides*). It seems that these lichens, growing nearby on old yellow birch were able to colonize and thrive on the old non-native trees whose bark has a suitable high pH. *D. plumbea* was found at Salmonier River in 1977 and it is still present there. This is interesting since it shows continuous occupancy by *D. plumbea* at this occurrence for 38 years (Pitcher, pers. comm., 2008

Habitat trends

Future changes to the habitats occupied by *D. plumbea* in Nova Scotia, New Brunswick and Newfoundland are expected to result from anthropogenic activity, especially, forestry, air pollution, industry and local development. These are dealt with under the threats section of this report. There are two additional factors affecting habitat trends in Newfoundland which relate to historical activities. These are firstly, the introduction of moose to the island. This has resulted in populations of moose which have increased to the point that they are preventing regeneration of yellow birch, the main host for *D. plumbea* (Mclaren *et al.*, 2004, Goudie, 2008). Secondly, past forestry activity is having an ongoing impact. At the present time, a high percentage of the *Degelia* discoveries on the Avalon Peninsula, in Newfoundland, have been in blow-down areas of the forest where the canopies are relatively open (Conway, Pitcher and Goudie, pers. comm., 2008). The *Betula alleghaniensis* in these areas are relicts left over from clear-cuts more than a decade ago. The loss of the wind-buffering conifers resulted in the mature *Betula alleghaniensis* being vulnerable to wind-throw. Most of the *Degelia* on the fallen trees has subsequently disappeared. This is likely a combination of desiccation following increased solar exposure as well as drying of the substrata as the birches die (Conway, Pitcher, pers. comm. 2008).

BIOLOGY

Life cycle and reproduction

Degelia plumbea is part of a group known as cyanolichens, so named because one partner of the symbiosis is the cyanobacterium, *Nostoc*. The cyanobacteria provide carbohydrates through photosynthesis to the fungal partner and also fix atmospheric nitrogen. Moisture is very important in the nitrogen fixation process (Nash 2008) and this is likely why many species of cyanolichens are found in very moist habitats such as coastal rain-forests and fog-forests. Phosphorus also plays a key role in the process and fertilization with this element can double the growth rate of cyanolichens (Nash 2008, McCune & Caldwell 2009). Phosphate uptake is inhibited by low pH precipitation, stem-flow or leachate that has passed over bark or through the canopy. Thus, these lichens are very sensitive to acidification of the substratum by air pollution or acid rain as well as by the direct effects of these pollutants.

Degelia plumbea, like other foliose lichens, obtains water and nutrients required for growth through interception of precipitation, fog or dew that contains dissolved ions, or particulates (Nash 2008).

Sexual reproductive structures (apothecia) are common in all but the small thalli of *D. plumbea*. The contained asci eject ascospores into the air. If these land on a suitable substratum, e.g., the bark of an old deciduous tree, they germinate and are attracted to grow toward any nearby cyanobacteria. If these are compatible, they become enveloped by the fungal strands and eventually grow to become a visible thallus (Honegger 2008). This must occur in every generation for lichens like *D. plumbea* which have no means of vegetative reproduction. Recent studies on some 80 lichen samples, about half of which were from Finland and seven from North America, have shown that lichen fungi are very selective with respect to the strains of cyanobacteria that successfully form their symbiotic associations (Myllys *et al.* 2007). *Degelia* has been found to associate with Clade II, the Nephroma guild, of *Nostoc*. None of these strains are free living. Clade II strains of *Nostoc* appear restricted to epiphytic lichen species of the lobarion community in old-growth forests. Epiphytic species, like *D. plumbea,* which disperse via ascospores might be expected to associated with a common free-living cyanobacterial genotype. As a consequence, *D. plumbea* spores have to encounter a vegetative reproductive unit (soredium or isidium) of a cyanolichen that cannot develop on that substratum, under the prevailing light and other environmental conditions (Richardson 1999, Ott *et al.* 2000). As these vegetative propagules disintegrate, the cyanobacteria are released. They are then available for being encircled by germinating spores of *D. plumbea*. The sporadic occurrence of this lichen on trees may be related to the presence of suitable strains of cyanobacteria on those tree trunks and favourable conditions of light, humidity and bark pH. Circumstantial evidence for this comes from the fact that several or many thalli of this lichen are often found when the lichen colonizes a particular tree. Although more research is needed on this aspect, strains of *Nostoc* from *Pseudocyphellaria* and *Nephroma* are the most likely candidates for capture by *D. plumbea* spores giving rise to the formation of a new thallus

(Myllys *et al.* 2007; Elvebakk *et al*. 2008). Reproduction and spread of *D. plumbea* may be limited by the requirement to have other cyanolichens present near trees where the spores land and this may contribute to the sporadic distribution and the rarity of this lichen in some areas.

There are probably four life stages for *D. plumbea* based on studies of other lichen species: (1) a very early pre-juvenile stage of thallus development which is invisible to the naked eye (Hilmo & Ott 2002); (2) a juvenile stage where thalli are visible but less than 0.5cm; (3) a pre-adult stage where thalli are between 0.6cm and 1.0cm. During this stage, thalli usually do not develop fruit bodies. This pre-adult stage has been observed in foliose lichens containing green algae (Hestmark *et al.* 2004) and in cyanolichens (Cameron & Garbary unpublished data); (4) an adult stage where thalli greater than 1cm diameter have developed fruit bodies. No measurement studies correlating size and maturity exist specifically *for D. plumbea.* Growth rates for foliose species vary over the lifespan of a thallus (Armstrong 1974; Hestmark *et al.* 2004). Growth is thought to be very slow during the pre-juvenile stage. The second growth phase is characterized by maximum growth and likely corresponds to the visible juvenile stage and may carry on through the pre-adult stage. During the fourth adult stage, growth slows down again and this typically corresponds with production of reproductive structures. There appear to be no data on growth rates of *D. plumbea* in either Europe or North America.

Herbivory and predation

A wide range of small invertebrates are known to be associated with and feed on lichens including Thysanurans, Collembolans, Psocopterans, Lepidopteran larvae, orbatid mites and gastropods (Seaward 2008). These provide valuable food for birds (Pettersson *et al.* 1995). In addition gastropods graze on thalli and three species have been found feeding on cyanolichens in Nova Scotia (Cameron unpublished data). *Pallifera dorsalis* is a small native slug, and *Arion subfuscus* and *Deroceras reticulatum* are larger aggressive species introduced from Europe (Davis 1992). Cameron found these species feeding on several rare cyanolichens including *Erioderma pedicellatum* and *Coccocarpia palmicola*. Recent studies suggest that mollusc grazing may play an important part in shaping the epiphytic vegetation of deciduous forests (Asplund & Gauslaa 2008) and that recently established juvenile thalli seem to be at particular risk (Asplund & Gauslaa 2008). Climate change has led to increased lichen grazing by molluscs that has contributed to reported extinctions of *Pseudocyphellaria crocata* in SW Norway (Gauslaa 2008). The importance of this is that the soredia of this lichen may be one source of compatible *Nostoc* strains for *D. plumbea*. The impact of grazing slugs on *D. plumbea* populations in Canada has yet to be studied, although observations to date suggest that grazing is less common than on *Erioderma* and *Coccocarpia* (Anderson, pers. comm., 2008). In Newfoundland, both introduced slugs and oribatid mites are known to forage on Lobarion communities (Pitcher, pers. comm., 2008; Thompson *et al.* 2003).

Physiology and adaptability

Like other cyanobacteria-containing lichens, *D. plumbea* needs to be wetted with liquid water after becoming dry in order to photosynthesize at normal rates (Lange *et al.* 1986). Thus the water economy of such lichens is the key to their growth and survival. Gauslaa & Solhaug (1998) showed that regardless of thallus size, circular rosettes of *D. plumbea* had an optimal quantum yield of photosystem II that remained at a high constant level during drying. There was also a highly significant positive relationship between thallus size and water-holding capacity and a strong negative correlation between size and water loss per thallus area. The improved water-holding capacity of larger thalli is mainly due to their thicker hypothallus, which acts as a substantial water reservoir. Water is absorbed by the hypothallus of *Degelia* faster than it is taken up by thalli of other associated lichens which grow in the same habitat and lack this structure (Degelius 1935). Thus the hypothallus of *D. plumbea* may reduce a dependency for frequent wetting events for thalli growing in open or semi-shaded habitats. Indeed, this species seems to be able to inhabit drier habitats than other species of *Degelia* (Jørgensen & James 1990). An increase of thallus size from one to $36cm^2$ led to a tenfold prolongation of the photosynthetically active period during a drying cycle at low radiation. The faster desiccation of smaller thalli indicated that they could be severely hampered by nearby logging operations (Gauslaa & Solhaug 1998). This experimental study confirmed earlier ecological observations that reported *D. plumbea* to be sensitive to increased desiccation from forestry operations. For example, Degelius (1935, p. 294) observed that all sun-exposed specimens of *D. plumbea* died after logging in a previously rich locality.

Degelia plumbea appears to have been affected by large-scale or even local level forest disturbances. It is especially sensitive to changes in forest structure that alter microclimates reducing local moisture regimes (see comments above under “Physiology and adaptability”). Logging in forests usually forms larger openings than caused by natural gaps, abruptly increasing radiation load and wind exposure causing enhanced evaporation rates. Small specimens of lichens, with size-dependent moisture reserves, tend to be more adversely affected than large well-established thalli of the same species (Gauslaa & Solhaug 1998).

Dispersal and migration

No vegetative propagules, such as isidia or soredia that can be dispersed by wind, water or animals, are produced by *D. plumbea.* While it is possible that fragmentation of thalli could lead to an increase in thallus numbers on a single tree trunk, thalli of this lichen are thick, relatively heavy and don’t fragment easily. Fragments would not be carried any distance by physical agents and hence be an effective means of dispersal to other trees. Thus, ascospores ejected from the fruit bodies and carried by wind to nearby tree branches and trunks appear to be the only means of initiating new thalli. Furthermore, this only happens if the germinating spores encounter a suitable strain of cyanobacterium upon germination. A study of the dispersal of *Lobaria pulmonaria* thalli growing in an old deciduous forest, and which propagates by both ascospores and vegetative propagules suggested that it disperses only about 230m from a previous location (Ockinger *et al.* 2005; Sillet *et al.* 2000; Walser 2004). The dispersal distance for *Degelia* thalli growing in a maple swale would unlikely to be greater.

Interspecific interactions

Lichens can be attacked by lichenicolous fungi which may reduce growth and reproduction. *D. plumbea* is colonized by *Stigmidium degelii* (Alstrup *et al.* 2004). This fungus forms many small, blackish perithecia on the surface of the thallus and the contained asci have colourless, 1-septate ascospores, 16 x 4.5μm. Two of 26 collections from a range of occurrences in Nova Scotia collected between 1977 and 1998 by Wolfgang Maass had the symptoms of attack, which upon sectioning revealed the colourless one-septate ascospores typical of this fungus. Specimens attacked by *Stigmidium degelii* have also been observed recently both in southern Nova Scotia and in coastal New Brunswick (Anderson, pers. comm., 2008). In Europe, *D. plumbea* is also known to be attacked by the parasitic lichenicolous fungus *Toninia plumbina* which lacks a thallus. The fruit bodies of this parasite contain asci, with ascospores that are usually three septate (Purvis *et al.* 1992). This parasite has not yet been recorded from North America but seems to prefer large healthy thalli of *D. plumbea* (Grube, pers. comm., 2008). It has been recorded from Scandinavia, Scotland, the Canary islands, Spain and Slovenia (Anon. 2008a).

Hypnum and *Zygodon* are two moss genera that have been recorded on tree boles colonized by *Degelia,* along with the liverwort *Frullania.* These bryophytes can overgrow *Degelia* but the circumstances which enable this are unclear. For example, in one New Brunswick occurrence, where *D. plumbea* grows on cedar, thalli had become overgrown by these mosses on two of the trees.

POPULATION SIZES AND TRENDS

Sampling effort and methods

It was not possible to revisit all sites where *D. plumbea* was known to have been collected (on the basis of literature records or herbarium specimens) to verify the lichen’s continued existence. Part of the reason was that prior to the present report, data on *D. plumbea* from Nova Scotia seldom included more than population size and approximate location or location and co-occurring lichens. The high concentration of *Degelia* occurrences along the Atlantic coast in red maple swales suggested that visiting similar sites in other geographic areas, and sites where *Degelia* occurred on substrata other than maple, might expand our knowledge about its habitat requirements. The search effort for this report was therefore directed toward data collection from occurrences where there was accurate location data rather than trying to relocate historic occurrences. Several typical sites on the Atlantic coast were, however, included to search for new occurrences. Finally, previous lichen surveys of the northern Nova Scotia coast (Northumberland Strait), done as part of the establishment of protected areas on the North Shore, had not discovered any *D. plumbea* occurrences. It was therefore decided not to search for new occurrences in this area, which is the driest part of the province and has the fewest fog days (Davis & Brown 1996).

In New Brunswick, the Fundy Coast is the only area with a suitable climate for *D. plumbea*. Again, prior to this report, general surveys (Gowan & Brodo 1988), studies of cedar (*Thuja*) stands and searches for *Erioderma pedicellatum* have examined the diversity of the lichen flora rather than searching specifically for *Degelia.* Stephen Clayden of the New Brunswick Museum has done extensive research on *Thuja* stands, which have yielded *Degelia* occurrences, and he assisted with searches for *D. plumbea* on Campobello Island.

The search effort in Newfoundland has involved inventories by W. Maass during the 1980s and 1990s. The eminent lichenologist, Teuvo Ahti, has also made several trips to Newfoundland and he included a distribution map of *D. plumbea* in his second paper on island lichens (Ahti 1974, 1983). Eugene Conway and Ian Goudie (The Newfoundland Lichen Education and Research Group) have conducted surveys for cyanolichens and found occurrences for *D. plumbea* on the Avalon Peninsula as have Mac Pitcher and Claudia Hanel. They also searched for and found the species near the occurrence in Bay D'Espoir where Ahti (1983) reported this lichen. John McCarthy has recently carried out lichen surveys in Newfoundland and discovered the location for *D. plumbea* at Murphys Pond. Overall, in Newfoundland, the potential habitat of *D. plumbea* remains largely under-surveyed (Hanel, pers. comm., 2008).

Abundance

Historical records of *D. plumbea* have not included thallus numbers at each site. In the past five years, data has yielded more than 771 thalli in 88 locations from Nova Scotia, 61 thalli in 3 locations from New Brunswick and more than 102 thalli from 8 natural habitat locations in Newfoundland. At the municipal Sir Robert Bond Park property in Newfoundland, 821 thalli were counted on five species of non-native deciduous trees (Pitcher & Chislett 2006). Differences in population sizes between NS, NB and NL are likely to reflect the proportional differences in the occurrence of *D. plumbea* among the provinces. The colour, size and shape of this lichen make it unlikely that it has been overlooked anywhere that lichens have been surveyed.

Abundance varies greatly within occurrences. In some occurrences there is one to a few thalli on just one tree, at others there may be more than 10 thalli on one to five trees. Some western Nova Scotia occurrences contain 12 or more thalli per tree.

Fluctuations and trends

The paucity of lichen research over the last fifty years in Nova Scotia means there is little documentary evidence to assess fluctuations in the population of *D. plumbea* in the province. The trend for *Degelia* populations in Nova Scotia will likely be downward as forestry activities selectively remove old *Acer* trees for firewood, biomass harvest or commercial smoke houses. Pannozzo and Colman (2008) document the fact that in 1958 one quarter of Nova Scotia's forests was over 80 years of age. In the last four decades this figure has dropped to 1%. Tree core data (D. Richardson and R. Cameron, unpubl.) shows that *Degelia* is most likely to be found on trees >80 years old. If this loss of old forest continues at a rate of 6% per decade, then the overall loss of forest habitat would lead to a reduction from about 90 occurrences to approximately 70 occurrences over the next 40 years in Nova Scotia.

In Newfoundland the decline in *D. plumbea* occurrences could also result from forestry if the known areas of *Degelia* occurrence which have been scheduled for cutting are actually logged over the next decade. As of 2009, this lichen still seems to occur in its former distribution area. However, in 1997 Wolfgang Maass documented a *Degelia* occurrence at southeast Placentia that had disappeared by 1999, but he found another *Degelia* occurrence nearby, on white spruce. The latter was still there although in poor condition in October 2007 (Conway, pers. comm., 2008). Another specimen of *D. plumbea* found at Golden Bay within the Cape St. Mary's Ecological Reserve appears to have been lost when the host tree was removed as part of trail-grooming. Thalli on a third tree located at Southern Head in 2007 could not be relocated in 2008, possibly because of collapse of the host tree (Goudie, pers. comm., 2008). Thus a downward trend is likely for Newfoundland in the future due to the progressive loss of old yellow birch and lack of replacement by younger trees due to browsing by the high populations of introduced moose (Mclaren *et al*, 2004, Goudie 2008).

In New Brunswick and Maine the number of occurrences has not changed, although in the case of the former, the current occurrences are in different locations. There were more historical collections from the 19th and early 20th century and specimens were sent to several herbaria. Today, the number of thalli of *D. plumbea* is very low and in New Brunswick, it is no longer found on Campobello Island.

Information from Europe indicates that the cause of the disappearance of *D. plumbea* is usually a combination of habitat destruction, air pollution from nearby urban areas or acid rain from trans-boundary pollution**.** These factors have resulted in the disappearance of *D. plumbea* from Belgium, Denmark, northern and western France and Luxemb*ourg* (Serusiaux 1984; Alstrup, pers. comm., 2008, Diederich *et al.* 2008 and pers. comm., 2008). On the Iberian Peninsula, it has been found that *D. plumbea* is especially sensitive to deforestation and atmospheric pollution and is classified as vulnerable (Carballal *et al.* 2007; Martinez *et al*. 2003). This lichen is also becoming rarer or vanishing in North Africa and Eastern Europe. Recent extensive field research in Sweden has shown that *D. plumbea* occurs in about 117 localities (same order of magnitude as Nova Scotia). However, the lichen has disappeared from sites where it once occurred, being found at only eight of sixty re-investigated localities. At 64% of the occurrences, losses were attributed to human activities, especially clear-cutting, and only 8% to natural succession (Hultengren & Norden 1996). The study suggested that the continued existence of *D. plumbea* is favoured by forest localities with several successional stages. This enables the lichen to disperse and colonize new trees when the shade in these mixed coniferous hardwood forests becomes too dense. Such research findings may be relevant to conservation efforts for *D. plumbea* being undertaken in Newfoundland, as well as to future efforts in New Brunswick or Nova Scotia.

Rescue effect

There is no possibility of rescue effect for *D. plumbea* from the United States since the species is very rare in Maine, which is the only possible source. Most of the North American population of *D. plumbea* is in Canada and so there is more likelihood that the population in Maine, U.S., will disappear before the Canadian populations.

THREATS AND LIMITING FACTORS

Changing climate

Preliminary analyses of fog frequency along the Atlantic coast of Nova Scotia and the Avalon Peninsula of southeastern Newfoundland suggest that a significant decline has occurred over the past several decades (Beauchamp *et al.* 1998, Muraca *et al.* 2001). *D. plumbea,* like several other cyanolichens occurring mainly in coastal fog forests, is a very drought-sensitive species (Gauslaa & Solhaug 1998). If the reported declines in fog frequency are ongoing and are confirmed by further research, these species could be negatively affected.

Pollution

Cyanolichens are extremely sensitive to air pollution and acid rain (Richardson & Cameron 2004; Cameron & Richardson 2006). Trans-boundary air pollution is still affecting Atlantic Canada and thus may continue to reduce habitat quality for *D. plumbea*. The 2004 Canadian Acid Deposition Science Assessment results indicate that even though total acid deposition has declined in eastern Canada, large areas in southern New Brunswick and southern Nova Scotia will continue to receive levels of acid deposition in excess of critical loads (Environment Canada 2004). A critical load can be defined as the deposition loading above which harmful effects to the ecosystem can be quantified. A critical level is the concentration in the atmosphere above which direct adverse effects may occur to receptors such as plants or ecosystems. It is difficult to establish critical loads and critical levels for lichens. However, Glavich & Geiser (2008) indicate that ongoing studies on U.S. federally managed lands should yield the data needed to narrow critical load ranges. The critical level for nitrogen deposition has been estimated as between 0.26-0.33 kg ha^{-1} yr^{-1} while that for ammonium ions, in wet deposition, has been estimated to be 0.044-0.055 mg L^{-1} for the coniferous forests in the western U.S. These levels led to a decline in the presence and abundance of sensitive lichen species (Glavich & Geiser 2008).

The Canadian Deposition Assessment presents a worst case and best case scenario which depends on how much NO_x deposition is counted as contributing to acid precipitation. Even in the best case scenario, southwestern Nova Scotia and the eastern shore of Nova Scotia and New Brunswick exceed estimated critical loads. These are areas where *D. plumbea* occurs, so that acid precipitation may in due course overcome the buffering capacity of the tree bark, making it unsuitable for the growth of this lichen**.** The upper Bay of Fundy and Avalon Peninsula are below critical loads in the best case scenario but exceed critical loads in worst case scenarios. Exceedances are occurring despite a 21% decline in SO_2 emissions and 17% decline in NO_X emissions in eastern Canada between 1985 and 2000. More than 50% of nitrogen and sulphur deposition in Nova Scotia and southern New Brunswick is from the eastern U.S. and southern Ontario and Quebec. Emissions of SO_2 in the U.S. have declined 40% between 1985 and 2000 but there has been little decline in NO_x. Predicted declines of SO_2 and NO_x in eastern Canada are 21% and 39% respectively by 2020 . In the U.S., predicted declines are 38% for SO_2 and 47% for NO_x by 2020 (Environment Canada 2004). There is no doubt that large areas of eastern Canada will continue to receive levels of acid deposition. Tree bark, like lakes, has an inherent buffering capacity, with maple having a greater buffering capacity than coniferous trees. Continued exposure to acid rain eventually results in the buffering capacity being exceeded and the substratum can quickly become too acid for sensitive cyanolichens to survive or more importantly for very young thalli to thrive (Nieboer *et al.* 1984).

Industry, mining and minerals

In Newfoundland, New Brunswick, and Nova Scotia, there are industrial developments that may, and could in future, affect air quality near *D. plumbea* locations.

In Newfoundland, the Come By Chance oil refinery is situated one km north of Southern Head on Placentia Bay. It has been producing 115,000 barrels per day for approximately 20 years with annual SO_2 emissions averaging 30,000 tons. The prevailing wind is westerly and in 2006 one *D. plumbea* thallus was found on *Picea glauca* (Figure 4), ten kilometres upwind of the refinery (Conway, pers. comm., 2008) This occurrence was revisited in October 2007 but the thallus could not be found. No other *D. plumbea* thalli have been located either on *Picea* or *Betula alleghaniensis* in the Southern Head area or near the Come By Chance oil refinery. A possible expansion of the Come by Chance oil refinery in Newfoundland could double processing of the current 115,000 barrels per day and could result in increased emissions (Morgan 2008).

Figure 4. *Degelia plumbea* growing on *Picea glauca* at Southern Head on Placentia Bay, Newfoundland (photo E. Conway).

The Newfoundland and Labrador Refining Corporation has proposed that an oil refinery be built on Southern Head, Placentia Bay. The project was approved through the environmental assessment stage and was expected to begin operation in 2011, but has been put on hold following the recent economic downturn (Anon. 2007b). The refinery was to process 300,000 barrels of crude oil per day with a possibility of expanding to 600,000. The refinery will be about 60 km north of *D. plumbea* locations in Southeast Placentia. Annual emissions for SO_2 and NO_x are expected to be 6589 and 3228 tonnes respectively when processing 300,000 barrels per day (Environmental Assessment Report (EAR) 2006a). Two thalli have been documented for Southeast Placentia, one by Christoph Scheidegger in 1997 and one by Wolfgang Maass in 2003 on *Picea glauca*. The first had disappeared and the second was in very poor condition in 2007 (Conway, pers. comm., 2008). Vale Inco Newfoundland and Labrador Ltd. is proposing a nickel processing plant in Long Harbour within about 50 km of *D. plumbea* locations. This project has also been approved through the environmental assessment stage. Expected emissions range from 201 to 212 tonnes of SO_2 and 57 to 94 tonnes of NO_x depending on the processing method (EAR 2006b, Anon. 2008c). The approved hydromet process is predicted to release relatively little air pollution and, because of the prevailing westerly winds, emissions are unlikely to affect the Southeast Placentia area (Goudie 2009).

Nova Scotia,, the province in which *D. plumbea* is most common, is rich in minerals such as zinc, lead and gold that have been exploited for decades. Only in recent years have environmental assessments become required that include studies on the fauna and flora, including lichens. A gold processing facility proposed for Moose River, Nova Scotia, is close to three *D. plumbea* locations (Anon. 2007a). The recent report on the Touquoy Gold project, Moose River Gold Mines, Nova Scotia, identified the presence of *D. plumbea nearby*. This lichen has until recently been given a general status ranking of yellow (sensitive) by the province (Draft Cyanolichen Status List NS DNR). It was found at two locations on the Touquoy project site and at a third just outside. At the first site, there has been a clear-cut near the tree on which *D. plumbea* was found but further development is not planned for the area (Anon. 2007a). The thalli of *D. plumbea* may be affected by a reduction in humidity as a result of the clear-cut and any pollution or particulates from the nearby mining activity. Elsewhere in Nova Scotia, particulates and pollution as well as tree removal in the vicinity of other industrial developments such as gas storage, transfer stations, etc. could pose a potential threat to populations of *D. plumbea*.

Forestry

In New Brunswick, the woodland of the occurrence on Grand Manan Island is owned by a forestry company. The two mainland occurrences in the province are on cedar swamps with no protection and so the threat of harvesting is present for all three.

In Nova Scotia, there is much forestry activity in areas that are nearby the locations where *D. plumbea* occurs. Harvest levels have exceeded or met sustainable harvest levels in the last 10 years, but to date clear-cuts have avoided wet habitats and focused on coniferous species. Currently, direct harvest is less of a threat to *D. plumbea* than edge effects. For example, at the Rickers Lake occurrence in Nova Scotia, *D. plumbea* was found in a buffer zone alongside a lake with an adjacent clear-cut. The thallus was on a red maple and was clearly in decline. The host tree had suffered from wind damage and had leaned over so that the lichen was on the under side. This would both reduce its ability to be wetted, a key to photosynthesis by cyanolichens, and lower the available light levels (Cameron pers. comm., 2008). Forestry activities can have a negative impact on lichens that extends up to 50m into the forest from a cut (Rheault *et al.* 2003; Esseen & Renhorn 1998). In 1958, 25% of Nova Scotia forests were over 80 years of age but now the figure is 1%, so that the province has lost almost all the old forest (Pannozzo & Coleman 2008). *D. plumbea* only colonizes large mature or over-mature *Acer, Fraxinus* and *Betula alleghaniensis* trees, so that the dwindling amount of old forest over the long term is a threat.

In Newfoundland, a large area with *D. plumbea occurrences was* scheduled for harvesting but has been given a reprieve. Buffer zones were proposed for protecting *Erioderma mollissimum* and *E. pedicellatum* populations, but these have been of mixed success in maintaining these species (Cameron & Neily 2007; Cameron *et al.* 2007). There is a view that considerable old growth habitat supporting rare cyanolichens has and is being destroyed by the lack of integration of ecological principles into forest management. Ecosystem-based guidelines, promised by the Government of Newfoundland and Labrador in its sustainable forest strategy policy document have not yet been delivered (Anon. 2006). Buffer requirements (~20m), even if they are followed, are unlikely to provide much help for *D. plumbea*, a species that is very susceptible to a reduction in humidity as a result of opening up of the forest. Furthermore, *D. plumbea* is most common on old *Betula alleghaniensis* that occurs sporadically in the *Abies* *balsamea* forests. In some areas where the balsam fir are cut in forestry operations, the *Betula alleghaniensis* are left as seed trees but they often do not adapt well to the open environment and die (Hanel, pers. comm., 2008). The current forest management system is not approached from an ecological perspective and as a result the old balsam fir forests are being rapidly lost. The likely rate of loss is probably about 20% per year as harvest operations are targeting these mature to over-mature stands (Goudie, pers. comm., 2008). These old balsam fir forests are the prime habitat for the Lobarion community in the Avalon Peninsula.

In the Conne River forest management area, within the forest management area of the Miawpukek First Nation of Newfoundland, no commercial pulpwood or sawlog cutting is currently taking place. However, yellow birch is a preferred species for firewood. With the increase in oil prices, the number of firewood permits issued by the First Nation has sharply increased (Hanel, pers. comm.). Due to manpower shortage, not all the blocks cut by the Miawpukek First Nation band members at Conne River for domestic purposes have been surveyed for *D. plumbea* prior to cutting. The harvesting threat to the lichen may apply to this area and to nearby non-First Nation communities as well. Unfortunately, the Newfoundland and Labrador Department of Natural Resources doesn't do pre-harvest rare lichen surveys in the area. Elsewhere, especially in Nova Scotia, selective cutting of maple to supply smokehouses to process the rapidly growing production of farmed Atlantic salmon is another trend that could reduce available habitat for *D. plumbea*.

Other developments

Other human activity within the landscape may also affect habitat quality for *D. plumbea*. Roads can affect hydrology by concentrating water flow and diverting natural water drainage systems (Cameron 2006). For example, the 2002 *D. plumbea* occurrence near the Grand Manan airport disappeared, probably due to the 1993 runway construction. The narrow 100m x 300m woodland where the lichen was found would have been unable to maintain the necessary moisture levels when a swath of tarmac 914m long by 23m wide was laid down close to it. High levels of harvesting in a landscape can increase wind and drying effects in adjacent forests (Hunter 1990). As mentioned earlier (see "Physiology and adaptability" section), young thalli of *Degelia plumbea are* particularly sensitive to this type of disturbance.

The Avalon Peninsula of Newfoundland is also under rapid development for cottages. Presently, there are only very limited guidelines for the preservation of forest cover on building lots. These lots average about 0.5 ha and the cumulative loss of Avalon boreal forest habitat, over the last few decades, is considerable and will likely continue into the future (Goudie, pers. comm., 2008). Coastal development in Nova Scotia and New Brunswick also continues at a significant rate but no data appears to be available on the rate of forest loss. However, the Halifax Regional Municipality is the fastest growing community in Nova Scotia, and the number of new subdivisions has more than doubled from 429 in 1998 to 883 in 2005. Fortunately, these are not near any known *Degelia* occurrences.

Biomass

In Nova Scotia, Proposals currently approved in principal will see the development of a 60MW biomass co-generating facility built by Newpage in collaboration with Nova Scotia Power for the production of electricity. This power station will use coniferous forest biomass as well as “low grade” hardwoods as a source of energy (Anon. 2009, Myrden 2010). The latter, valued because of its higher calorific value, will almost certainly include maple and yellow birch that are hosts for *D. plumbea*. This development could dramatically threaten *D. plumbea* populations in the medium to long term.

Browsing by moose

In Newfoundland, the progressive loss of old yellow birch as a result of old age, harvesting or blow-down, and the lack of replacement by younger trees due to browsing by the high populations of introduced moose is a threat (Mclaren *et al*., 2004, Goudie 2008). In Newfoundland, mature yellow birch is required by *D. plumbea* as a host so widespread browsing of young trees by moose that prevent survival is a serious cause for concern (Pitcher, pers. comm., 2008).

PROTECTION, STATUS, AND RANKS

Legal protection and status

Degelia plumbea is not legally protected in Canada under the *Species at Risk Act*, nor in Nova Scotia or Newfoundland and Labrador, both jurisdictions which have endangered species legislation.

Non-legal status and ranks

Degelia plumbea was until recently assigned a yellow (sensitive) status by the Province of Nova Scotia along with thirteen other lichens and a range of vascular plants and animals (Pannozo & Colman 2008). However, the status of *D. plumbea* is currently being reconsidered as surveys have revealed that it currently occurs more frequently than the status category definition allows. At a recent meeting it was proposed that it be given a green status. In New Brunswick, the species has a General Status of “May be at Risk,” and a NatureServe ranking of S1.

Habitat protection and ownership

The three New Brunswick occurrences are not protected by designation or by legislation.

Fifteen of the Nova Scotia occurrences for *D. plumbea* are in protected areas. Six are in two provincial parks, four in already-designated Wilderness Areas, two on conservation land owned by the Nature Conservancy of Canada, and one on federally owned Department of National Defence property near a transmission tower. Two are on land recently designated a provincial Wilderness Area (designation in 2009). Some of the remaining occurrences are on Crown land, which can be leased for forestry or mining activities or are owned by forestry companies who operate on the south and eastern shores. Other locations where *D. plumbea* occurs are owned by private landowners.

The verified locations for *D. plumbea* on the Avalon Peninsula, Newfoundland, on Crown land have no legal protection status and none are within the Avalon Wilderness Reserve (AWR). While commercial logging has been postponed in the area of Hall’s Gullies, the area remains an approved commercial cut in the 2006-2011 Sustainable Forest Management Plan (www. gov.nl.ca/dnr). The area where *D. plumbea* is found in Sir Robert Bond Park in Whitbourne, where the Newfoundland and Labrador Legacy Nature Trust has been active, has municipal protection through its designation as a park. The occurrence at St. Catherines, Salmonier River, is privately owned and the owner is aware of the importance of protecting this population of *D. plumbea.* The three occurrences known from the Miawpukek First Nation forest management area, Conne River, are not officially protected, but harvest practices are being modified in areas where *D. plumbea* has been discovered.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

David Richardson is Dean Emeritus at Saint Mary's University. He has studied lichens since 1963 and as sole author written two books on lichens: The Vanishing Lichens and Pollution Monitoring with Lichens. He has also completed over twenty book chapters and 100 research papers on various aspects of lichenology. He has studied lichens in Australia, Canada, Ireland and the United Kingdom.

Frances Anderson is a Research Associate at the Nova Scotia Museum of Natural History, Halifax. She has been carrying out field work on lichens in Nova Scotia for more than five years and has extensive experience in doing field inventories. She is currently working on a macrolichen checklist for the province.

Robert Cameron has been studying lichens for over ten years beginning with a Master's degree in Biology at Acadia University studying the effects of forestry practices on lichens. More recently, Mr. Cameron has been studying the effects of air pollution on lichens, coastal forest cyanolichens and more specifically boreal felt lichen. He is currently the ecologist with Protected Areas Branch of Nova Scotia Environment, responsible for the protected areas research program.

Troy McMullin recently completed a Master's degree on the relationships between lichens and old-growth forests in southern Nova Scotia. He is currently studying for a PhD at the University of Guelph, Ontario, on the effects of different silvicultural techniques on lichens in northern Ontario forests.

COLLECTIONS EXAMINED

The following herbaria were contacted with respect to *D. plumbea* specimens from North America. Specimens, when found, were either borrowed and examined by a COSWIC team member (DHSR, FA, RC or TM) or studied by the local lichenologist at the herbarium consulted. The Herbaria were:

- New York Botanical Garden Herbarium, New York
  Farlow Herbarium, Harvard University, Massachusetts
  University of British Columbia Herbarium, British Columbia
  Oregon State University Herbarium, Oregon
  Ontario Agricultural College Herbarium, University of Guelph, Ontario
- Herbier Louis-Marie, Laval University, Quebec
- Agnes Marion Ayre Herbarium, Memorial University of Newfoundland
- University of Prince Edward Island Herbarium, Prince Edward Island
- Natural Resources Canada - Ressources naturelles Canada, Canadian Forest Service
  - Service canadien des forêts, Atlantic Forestry Centre - Centre de foresterie de l'Atlantique, Corner Brook, Newfoundland.

- Gros Morne National Park Collection, Newfoundland
- Marie-Victorin Herbarium, University of Montreal, Quebec (lichen specimens now in New Brunswick Musuem)
- Sherbrooke University (lichen specimens now in Herbier Louis-Marie Herbarium)
- Herbier Louis-Marie Herbarium at Laval University. No Specimens were *D. plumbea*:
- University of Washington Herbarium
- The Natural History Museum London, United Kingdom
- The Botanische Staatssammlung München, Munich, Germany
- The New York Museum1
- The Royal Botanical Garden Herbarium, Edinburgh, Scotland.