COSEWIC
Assessment and Status Report

on the

Ghost Antler Lichen
Pseudevernia cladonia

in Canada

NOT AT RISK
2011

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 2011

Common name
Ghost Antler Lichen

Scientific name
Pseudevernia cladonia

Status
Not at Risk

Reason for designation
This lichen occurs predominantly in montane cloud forests in Quebec and in coastal fog forests in New Brunswick and Nova Scotia. In both the coastal and montane situations the species is found in humid spruce/fir forest where it reproduces by fragmentation and very seldom by sexual reproduction. Since the last status report, many new locations have been found in all three provinces, recent surveys estimate more than three million individuals, at 41 locations. However, in the long term, climate change and anthropogenic threats may reduce populations of this lichen.

Occurrence
Quebec, New Brunswick, Nova Scotia

Status history
Designated Special Concern in April 2006. Status re-examined and designated Not at Risk in November 2011.

COSEWIC
Executive Summary

Ghost Antler Lichen
Pseudevernia cladonia

Wildlife species description and significance

The Ghost Antler Lichen (*Pseudevernia cladonia*) is a chalky white, tree-inhabiting macrolichen with narrow bifurcating lobes. The thallus has a shrubby habit superficially resembling that of a reindeer lichen. It lacks vegetative propagules and only very rarely produces sexual reproductive structures (apothecia). It is restricted, globally, to montane and coastal cloud/fog forests in eastern North America and the Caribbean region. No other lichen is known to have this unusual distribution pattern. The coastal occurrences of Ghost Antler are largely within Canada. At montane locations, it may prove to be a sensitive indicator of climate and vegetation change

Distribution

Ghost Antler occurs mainly in high-elevation spruce-fir forests in the Appalachian Mountains of eastern North America, from the Great Smokies (35°N) to Mont St-Magloire in southeastern Quebec (46.6°N). In the northeastern portion of its range, it also occurs at low elevations along or near the Bay of Fundy and the Atlantic Coasts of Maine, New Brunswick, and Nova Scotia. A widely disjunct population in the Dominican Republic inhabits montane forests of Hispaniolan Pine. Before 2004, Ghost Antler had been found in Quebec only once, in 1959, on Mont Orford. Targeted searches since 2004 have shown that it occurs more widely at elevations >800 m in the area of southeastern Quebec adjoining the mountains of the northeastern United States. A population on Mont Tremblant in the southern Laurentian Mountains, discovered in 2009, is disjunct by about 200 km from those east of the St. Lawrence River.

Habitat

In North America, Ghost Antler occurs in cool, humid, montane or coastal coniferous forests dominated by Red Spruce and (or) Balsam Fir. A key feature shared by these coastal and high elevation stands is their frequent and often prolonged immersion in fog or cloud. In Canada, Ghost Antler has been found growing on Balsam Fir, Red Spruce, Black Spruce, and rarely White Spruce. It occurs mainly on twigs and branches, less frequently on the trunks of these tree species or on snags or woody debris on the forest floor.

Biology

Lacking specialized vegetative propagules, and only rarely forming apothecia and ascospores, Ghost Antler reproduces mainly by thallus fragmentation. However, its thallus is not particularly brittle, unlike those of many fruticose epiphytic lichens. It thus seems to have a limited capacity for long-distance dispersal. Often, few other lichens are present on the twigs it inhabits. This might indicate it is weak in competition, and excluded from branches with greater coverage of other species, or that it is tolerant of some characteristics of the twig microhabitat inhospitable to other lichens.

Population sizes and trends

Forty-one locations for Ghost Antler in Canada are known: 7 in Quebec, 16 in New Brunswick, and 18 in Nova Scotia. In Quebec, Ghost Antler was known from only one location prior to 2004 but subsequent searching of spruce-fir stands, e.g. at Mont Mégantic, Mont Tremblant, and above 800 m in the Eastern Township region resulted in the discovery of additional populations which together comprise more than 3,000,000 thalli. In the Maritime Provinces most populations consist of <50 thalli. A notable exception is a population discovered in 2006 in the Nerepis Hills, NB, where at least 100,000 thalli are present in humid, old-growth spruce-fir forests. It is likely that additional populations will be found in unexamined, high-elevation, mature, fir-dominated forests in southern Quebec, and in coastal or near-coastal humid spruce-fir forests in New Brunswick and Nova Scotia.

Trends in the Canadian populations of this lichen cannot be readily assessed, owing to the scarcity of historical data on its distribution and abundance. However, four small historically known populations in the Maritimes were not re-found in recent surveys.

Threats and limiting factors

The absence of Ghost Antler in many humid coastal forests in New Brunswick and Nova Scotia is probably a consequence of its limited dispersal capacity. Cutting of mature, coastal and montane spruce-fir forests can also alter or eliminate stands most likely to harbour populations. Buffer zones are unlikely to conserve the habitat or protect the Ghost Antler. The second-largest population known in the Maritimes is in an unprotected old-growth Red Spruce stand located near the city of Saint John. This could easily be eliminated by cutting and (or) housing development.

Montane populations of Ghost Antler in southern Quebec and in the Nerepis Hills of New Brunswick are potentially threatened by anthropogenic climate and vegetation change. Documented upward shifts in the mean elevation of the cloud base, and in the elevation of the ecotones between major vegetation types, could cause extensive reductions in the area of montane fir-dominated cloud-forest suitable for Ghost Antler. Also, an increased incidence of forest fires could pose a threat to this lichen and its host trees. A few of its montane populations in Quebec may have been reduced in extent and numbers by alpine-ski developments. Wind farm developments in high elevation spruce-fir forests could also be a potential threat.

Protection, status, and ranks

Eight of the 34 locations of Ghost Antler known in the Maritimes are in protected areas. However, these are all small populations, and two of them have not been relocated since 1980. The largest population in the Maritimes is informally protected by its location in part of a military base (CFB Gagetown) where there has been no forest harvesting for many decades. In Quebec, three of the seven locations documented to date are in Quebec national parks, and two others are partly or entirely in protected areas owned and managed by the Nature Conservancy of Canada. One of the Quebec locations currently has limited protection in a Zone d'exploitation contrôlée (ZEC) but an ecological reserve is proposed which will provide the highest level of protection.

In 2006, Ghost Antler was designated as a species of Special Concern by COSEWIC. Shortly afterward, a large, previously unknown population was discovered in New Brunswick (Nerepis Hills, CFB Gagetown), suggesting that further review of the status of this species was in order. As a result of this uncertainty, Ghost Antler was not listed under the *Species at Risk Act* (SARA). In the Assessment of the General Status of Species in Canada published in 2011, Ghost Antler is designated as “Undetermined” in New Brunswick and “Sensitive” in Nova Scotia and Quebec. Finally, it has been given an SNR rank, according to NatureServe, in North Carolina and Pennsylvania.

TECHNICAL SUMMARY

Pseudevernia cladonia
Ghost Antler Lichen — Pseudévernie fantôme
Range of occurrence in Canada: QC, NB, NS

Demographic Information

Generation time (average age of parents in the population)	Uncertain, but probably < 10 years
Is there an inferred continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within 2 generations	Unknown
Inferred percent reduction in total number of mature individuals over the last 3 generations	Unknown
Projected percent reduction in total number of mature individuals over the next 3 generations	Unknown
Inferred percent reduction in total number of mature individuals over any 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?	Unknown
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence	39,300 km²
Index of area of occupancy (IAO) *Based on 2 km × 2 km grid*	200 to 240 km²
Is the total population severely fragmented?	No
Number of locations	41
Is there an inferred continuing decline in extent of occurrence?	No
Is there an inferred continuing decline in index of area of occupancy?	No
Is there an inferred continuing decline in number of populations?	No
Is there an inferred continuing decline in number of locations?	No
Is there an inferred continuing decline in extent of habitat? Yes as a result of climate change affecting cloud elevation and fog frequency	yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
Canada (see Table 1 for breakdown of numbers among individual populations)	>3,250,000
Total	>3,250,000

Quantitative Analysis

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

Threats (actual or imminent, to populations or habitats)

Logging, and more human access leading to an increase in the incidence of forest fires. Suburban development, mountain-top developments (ski slopes, communication towers, wind farms, access roads). Climate change: increasing temperatures and increasing elevation of cloud-base is likely to cause an upward shift and loss of perhumid montane coniferous forest habitat. This occurs in a narrow band of elevation near the summits of the Appalachian range in southern Quebec. The population in the Nerepis Hills of New Brunswick, although at lower elevation, could face a similar threat. The reduced incidence of fog in coastal regions where the lichen occurs is also a threat to its existence which depends on the provided moisture.

Rescue Effect (immigration from outside Canada)

Status of outside population(s): Large populations in montane spruce-forests in Appalachian and Adirondack Mountains of eastern United States	
Is immigration known or possible?	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Yes

Current Status

COSEWIC: Not at Risk (2011)

Additional Sources of Information:

Status and Reasons for Designation

Status: Not At Risk	**Alpha-numeric code:**
Reasons for designation: This lichen occurs predominantly in montane cloud forests in Quebec and in coastal fog forests in New Brunswick and Nova Scotia. In both the coastal and montane situations, the species is found in humid spruce/fir forests where it reproduces by fragmentation and very seldom by sexual reproduction. Since the last status report, many new locations have been found in all three provinces; recent surveys estimate more than three million individuals at 41 locations. However, in the long term, climate change and anthropogenic threats may reduce the populations of this lichen.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable as there is no evidence of a decline in the number of mature individuals which are currently estimated to exceed three million.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable as the extent of occurrence exceeds 20,000 km², and while the IAO is <500 km², none of the subcriteria apply.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable as the number of individuals is estimated to exceed three million.
Criterion D (Very Small or Restricted Total Population): Not applicable as the population is neither small nor restricted.
Criterion E (Quantitative Analysis): Not applicable.

PREFACE

Since 2006, when the first assessment of *Pseudevernia cladonia* was completed, new fieldwork has yielded substantial new data on its distribution and abundance in Canada. Twenty-one previously unknown occurrences were discovered: four in Quebec, five in New Brunswick, and 12 in Nova Scotia, bringing the total number of occurrences known in Canada to 41.

Populations were discovered in montane Balsam Fir-dominated forests in the Appalachian region of southeastern Quebec that had not been searched previously. One of these, at Mont St-Magloire in the Massif du Sud, extends the known range of *P. cladonia* in Quebec by c. 140 km toward the northeast. A population on Mont Tremblant in the southern Laurentian Mountains, discovered in 2009, is the first non-Appalachian occurrence documented in Quebec. It is disjunct by c. 200 km from occurrences east of the St. Lawrence River, and by a similar distance from the nearest populations in the United States, in the Adirondack Mountains of upstate New York.

In New Brunswick, a population of *P. cladonia* numbering at least 100,000 thalli was discovered in humid, old-growth Red Spruce-dominated forest in the Nerepis Hills. About 30 km inland from the Bay of Fundy, this area has escaped intensive forest harvesting as it is part of the Canadian Forces Base Gagetown.

The range of *P. cladonia* in Nova Scotia was extended toward the northeast by c. 170 km, from the Halifax area to a locality in Guysborough County. Many small additional populations were discovered at scattered locations within 20 km of the Atlantic coast.

These discoveries increase the estimated extent of occurrence of *P. cladonia* in Canada from 7,510 km^2 (COSEWIC 2006) to 39,300 km^2, and the estimated area of occupancy from 3.6 km^2 to 11 km^2.

The overall population size can be estimated only to an order of magnitude (millions, 10^6), as in 2006.

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
(2011)

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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TABLE OF CONTENTS

List of Figures

List of Tables

WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and classification

Pseudevernia cladonia (Tuck.) Hale & W.L. Culb.
Bryologist 69: 165 (1966)

Basionym: *Evernia furfuracea* var. *cladonia* Tuck., *Proceedings of the American Academy of Arts and Sciences* 1: 204 (1847); type: United States, "firs and other trees, on the mountains of northern New England", *Tuckerman* (FH – holotype).

Additional synonyms: *Parmelia furfuracea* var. *cladonia* (Tuck.) Howe, *Bryologist* 16: 35 (1913); *Parmelia cladonia* (Tuck.) Du Rietz, *Svensk Botanisk Tidskrift* 18: 390 (1924); *Evernia ceratea* var. *cladonia* (Tuck.) Fink*, The Lichen Flora of the United States*, 340 (1935)

Classification: Following convention, the lichen *Pseudevernia cladonia* bears the name of its fungal component (mycobiont). The genus *Pseudevernia* is a member of the ascomycete family Parmeliaceae, in the order Lecanorales. The photosynthetic components (photobionts) of *Pseudevernia* thalli are coccoid green algae belonging to the genus *Trebouxia*. Analysis of the ITS region of nrDNA from a single thallus of *P. cladonia* collected in North Carolina (Kroken and Taylor 2000) places its photobiont in *T. simplex* Tschermak-Woess (Hauck *et al.* 2007; Piercey-Normore 2009). It is possible that studies of additional thalli will show that *P. cladonia* is lichenized with more than one *Trebouxia* species. However, *T. simplex* is the only photobiont detected to date in analyses of several thalli of the largely sympatric *P. consocians* (Vainio) Hale & W.L. Culb. (Piercey-Normore 2009).

Pseudevernia is a small genus, comprising four or five species worldwide. Hale (1968) recognized six species, but two of these, *P. olivetorina* (Zopf) Zopf and *P. soralifera* (Bitt.) Zopf, are now known to be nested within *P. furfuracea* (L.) Zopf (Ferencova *et al.* 2010). *Pseudevernia furfuracea* is widely distributed in temperate to boreal western Eurasia and northern Africa. The North American *Pseudevernia* species form a monophyletic sister group to *P. furfuracea*. They include *P. cladonia*, *P. consocians*, *P. intensa* (Nyl.) Hale & W.L. Culb., and an apparently undescribed species so far known only from Mexico (Ferencova *et al.* 2010).

No infraspecific taxa are recognized in *P. cladonia*.

Common name: Ghost Antler Lichen. The name Antler Lichen was introduced by Nearing (1947), the modifier, "ghost", by Brodo *et al.* (2001). Ghost Antler alludes to the form of the lichen and its pale, nearly white colour. The French name "Panache" is a word widely used in Quebec and the Maritime Provinces for the antlers of deer, moose and caribou. It was first proposed by Gilbert Lavoie of Edmundston, New Brunswick, in 2006. In the SARA Registry the name in French for *P. cladonia* is "Pseudévernie fantôme".

Morphological description

Pseudevernia cladonia is a conspicuous tree-inhabiting macrolichen. Its chalky white to pale grey, matte-textured thallus is repeatedly branched from the base in even dichotomies (Figure 1). The internal branch-angles are mostly 70° to 110°, each curving slightly inward past the branching point in the form of a wishbone. The newly formed and younger branches are round to slightly flattened in cross-section, and c. 0.2 mm in diameter. They gradually become more strap-shaped, with a channeled lower surface formed by down-turning and thickening of the lobe margins. Because the branching is in various planes, the thallus assumes a tufted (fruticose) growth-form somewhat resembling that of a caribou lichen. This character is alluded to in the species name, *cladonia*.

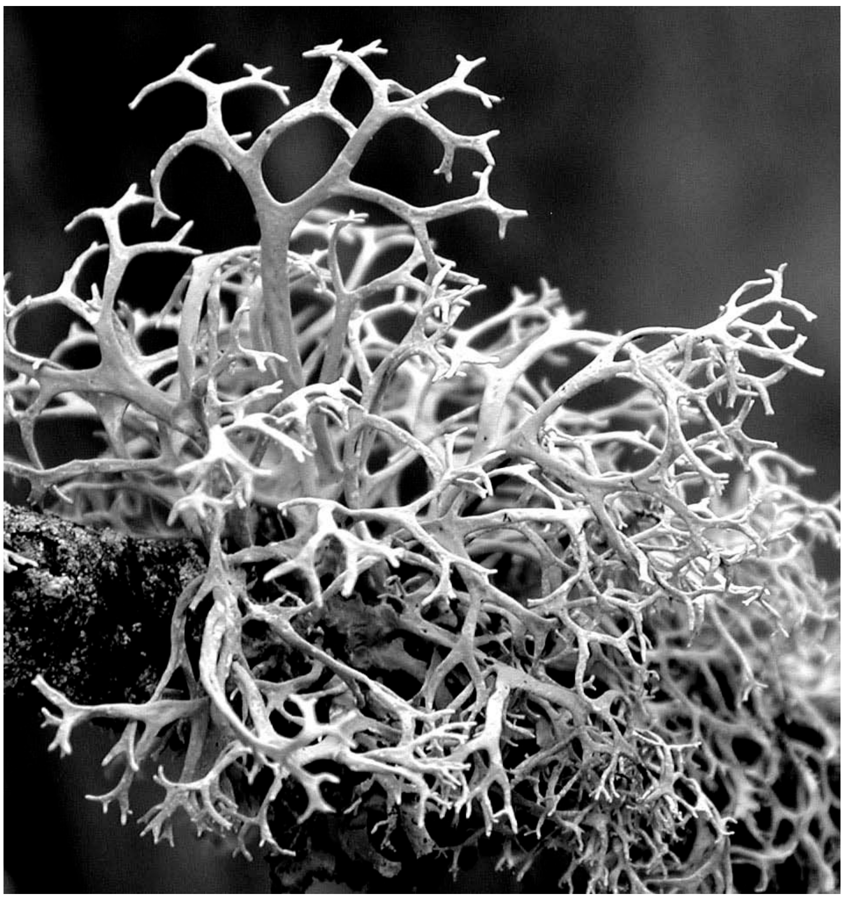

Figure 1. Thallus of *Pseudevernia cladonia*, on a twig of *Picea rubens*, at Wolsely Lake, New Brunswick (photo: S.R. Clayden).

Luxuriant thalli of *P. cladonia* can attain a diameter of 12 cm and a height (thickness) of 4 cm. In the older, basal parts of large thalli, the branches may be up to 3 mm in width. Their channeled lower surfaces become grey (or locally brown) to black-mottled to entirely black, though these dark-pigmented areas sometimes develop a thin, ash-white bloom. Over time, the changing orientation of some branches relative to the light induces irregular switching in the development of upper-surface and lower-surface characteristics. Such branches are more irregular (less flattened) in cross-section, and may have longitudinal ridges alternating with blackened grooves and pits.

Isidia, soredia, or other specialized vegetative propagules are lacking. Fine stress cracks orientated transversely to the branch axes are often present, but these extend inward only to the base of the cortex. The dense cottony medulla is resistant to tearing; thus, the thallus does not fragment readily. Pycnidia are infrequent on the upper sides of younger branches; they are visible externally as black spots measuring 0.05 to 0.08 mm in diameter. Apothecia are extremely rare, and have been observed in only one thallus in the Canadian populations of *P. cladonia* (Quebec: ZEC Louise Gosford, 1 km south of Trou du Diable, moderately open montane forest of *Abies balsamea* and *Picea rubens*, with scattered *Betula cordifolia*; on branch of *Abies*; Clayden 12699, NBM).

The cortex and medulla contain the secondary chemical products atranorin and lecanoric acid, respectively.

Population spatial structure and variability

The largest populations of *P. cladonia* in Canada are in island-like patches of humid, high-elevation coniferous forest. There are also gaps in its range near the Bay of Fundy and Atlantic coasts. Its sporadic distribution, together with its lack of readily dispersible propagules, could suggest a history of contraction and fragmentation of a formerly more continuous range. However, the occurrence of extensive, apparently suitable, but unoccupied habitat suggests, instead, that each population stems from a separate founder-event. The likelihood of such events (establishment in a patch of suitable, but previously unoccupied habitat) would increase with the passage of time. In general, founder events tend to contribute to genetic drift and differentiation between populations. However, relevant data on the genetic variability of *P. cladonia* mycobionts and photobionts are not yet available. The rarity of sexual reproduction in the mycobiont is not evidence, in itself, of a lack of potential avenues for differentiation among or within populations.

Designatable units

There is only one recognized DU. The montane populations of *P. cladonia* in southern Quebec and the low elevation coastal populations in the Maritime Provinces are separated by more than 300 km. Between these two regions, however, scattered populations are present in montane western and central Maine, and in Hancock and Washington counties in coastal eastern Maine. There is thus no major gap in the range between Quebec and the Maritimes. Despite the obvious differences in the topographic situations of the montane and coastal populations, the climate and vegetation of these areas share many features (Clayden 2010; Clayden *et al.* 2011). The Quebec Appalachians and the Maritimes both fall within the Atlantic Maritime Ecozone (Ecological Stratification Working Group 1995). Mont Tremblant can be considered as an outlier of this ecozone, with a toposequence of climate and vegetation similar to that in the Appalachian region east of the St. Lawrence valley.

Special significance

Pseudevernia cladonia is restricted, globally, to montane and coastal cloud/fog forests in eastern North America and the Caribbean region. No other lichen, or other organism, is known to share this specific distribution pattern. Other species that are characteristic of temperate to hemiboreal cloud forests in these regions also occur in montane and (or) coastal forests on other continents. The coastal and near-coastal occurrences of *P. cladonia* are largely within Canada. At its montane locations, it may prove to be a sensitive indicator of climate and vegetation change.

DISTRIBUTION

Global range

Pseudevernia cladonia occurs primarily in high-elevation forests dominated by Balsam Fir (*Abies balsamea*, including var. *fraseri* – see Potter *et al.* 2010) and (or) Red Spruce (*Picea rubens*) in the Appalachian Mountains of eastern North America, from 35°N to 46.6°N (Figure 2). In the United States, it is known from the Great Smoky Mountains (Tennessee, North Carolina), the Alleghenies (Virginia, West Virginia), the Catskills and Adirondacks (New York), the Green and White Mountains (Vermont, New Hampshire). It also occurs in Maine on the mountains of western and north-central Maine as well as at lower elevation near the coast in Hancock and Washington counties (Hale 1955, 1968; Hinds and Hinds 1998). Probably extirpated occurrences on Kittatinny Mountain and in the Watchung Mountains of New Jersey are documented by specimens collected in 1932 by Gladys P. Anderson (New York Botanical Garden, C. V. Starr Virtual Herbarium: http://sciweb.nybg.org/science2/VirtualHerbarium.asp). The montane occurrences in the northeastern United States are contiguous, or nearly so, with other high-elevation occurrences in the Appalachian region of southeastern Quebec, Canada. The only known occurrence in Quebec outside the Appalachian region is on Mont Tremblant, in the southern Laurentians. At the northeastern periphery of its range, *P. cladonia* occurs at low elevations along the eastern Gulf of Maine, Bay of Fundy and Atlantic coasts of Maine, New Brunswick, and Nova Scotia. A widely disjunct population occurs on Hispaniolan Pine (*Pinus occidentalis*) in the mountain forests of the Dominican Republic, at c. 19°N (Hale 1968).

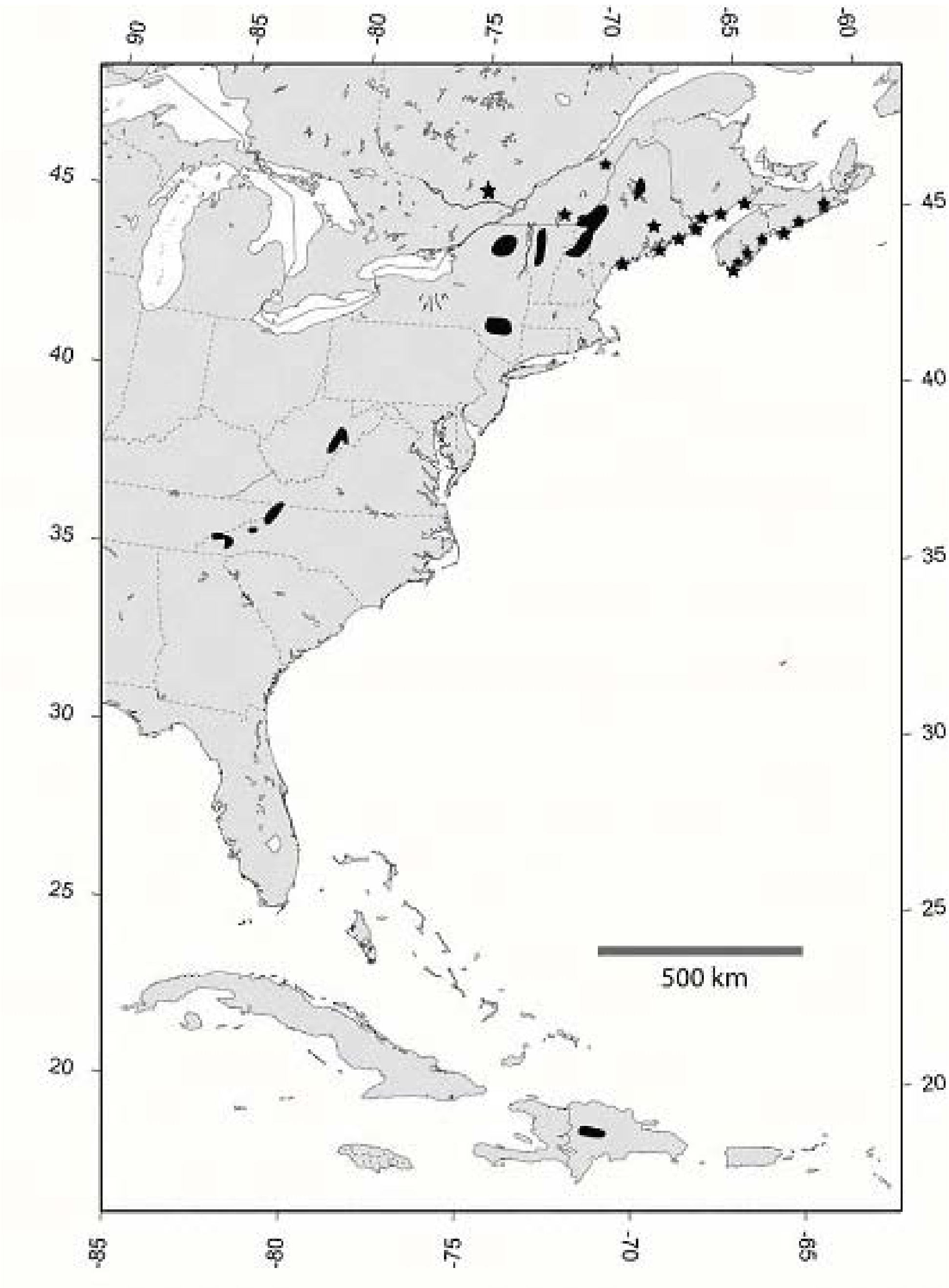

Figure 2. Global distribution of *Pseudevernia cladonia*. Stars indicate isolated occurrences, and in some cases represent two or more closely spaced locations.

From south to north in the Appalachians, the mean lower elevational limit of montane Red Spruce-fir forests decreases from about 1500 m in the Great Smokies to about 760 m in the mountainous boundary region between New Hampshire/Maine and southeastern Quebec (Marcotte and Grandtner 1974; Gauvin and Bouchard 1983; Cogbill and White 1991). At Mount Katahdin, Maine, the equivalent limit is at about 550 m (Cogbill and White 1991). The decrease between southeastern Quebec and Mount Katahdin in the elevation of the deciduous-coniferous forest ecotone appears to reflect a gradient of increasing oceanicity (decreasing continentality) from west to east (Cogbill and White 1991; Clayden 2010). The montane deciduous-coniferous ecotone is also correlated with a summer (July) mean temperature of c. 17°C (Cogbill and White 1991; White and Cogbill 1992). Along the Bay of Fundy, the transition from coastal spruce-fir forest to inland mixed and deciduous forests is likewise correlated with this isotherm (Clayden 2000).

The montane and coastal distribution of *P. cladonia* largely reflects these latitude-elevation, temperature, continentality, and forest vegetation gradients. In the Smokies, it is "common in the coniferous forest belt … from 1540 m upwards" (Degelius 1941). On mountain slopes in southern Quebec, its lowest known occurrences are at c. 790 m (observations by Stephen Clayden, Gabriel Lafontaine, and Clément Robidoux). The elevational range of *P. cladonia* on the slopes of Mount Katahdin has not been documented; the highest reported occurrence is at c. 1070 m (Hinds *et al.* 2009). Between Katahdin and the Maine coast, scattered populations are present in old-growth forests at intermediate to low elevations (Degelius 1940; Sullivan 1996; Hinds and Hinds 1998; J.W. Hinds, personal communication; S.B. Selva, personal communication; W.S.G. Maass collections at NBM): Somerset Co. (Sandy Bay Mountain), Piscataquis Co. (Big Squaw Mountain; Big Reed Pond), Penobscot Co. (Orono), Cumberland Co. (Prince Point), Hancock Co. (Lead Mountain; Black Mountain; Acadia National Park), and Washington Co. (Steuben; Quoddy Head State Park).

The upper elevational limit of *P. cladonia* along the Appalachians can be inferred to coincide with that of closed forests dominated by Balsam Fir. Fir extends to higher elevations than Red Spruce owing to its greater cold-hardiness (see Cogbill and White 1991, Clayden *et al.* 2011). The climatically determined treeline is exceeded only on scattered high summits, such as Mount Washington and Mount Katahdin.

Canadian range

From west to east, the known occurrences of *P. cladonia* in Canada cluster into five geographic groups: (1) Mont Tremblant in the southern Laurentian Mountains, Quebec; (2) the Appalachian region of southeastern Quebec, from Mont Sutton near the border with northern Vermont, to Mont St-Magloire in the Massif du Sud; (3) the Nerepis Hills of southern New Brunswick, c. 30 km inland from the Bay of Fundy; (4) the north coastal region of the Bay of Fundy in New Brunswick and Nova Scotia, to c. 10 km inland; (5) the Atlantic coastal region of Nova Scotia, to c. 20 km inland (Figure 3; Table 1).

Since 2006, the western, eastern and northern limits of the known range in Canada have been extended through discoveries of new populations (Figures 3, 4; Table 1). The occurrences in the Monts Sutton and Massif du Sud (Mont St-Magloire) areas were predicted in 2006 (COSEWIC 2006); an occurrence at Mont Tremblant was considered possible, but unlikely.

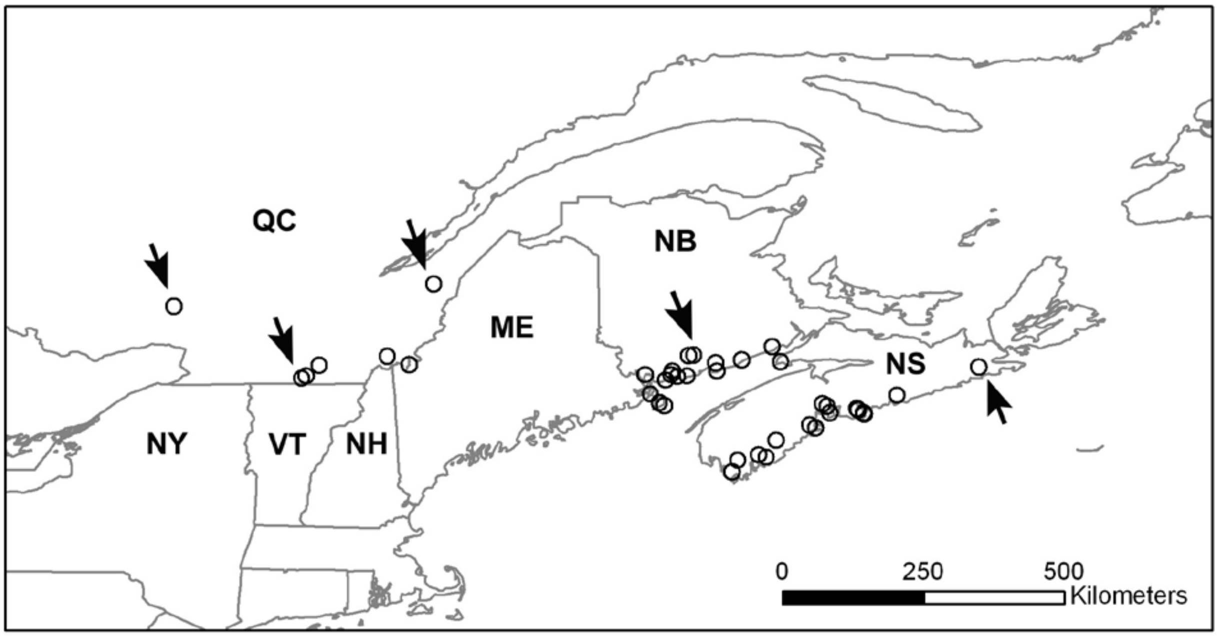

Figure 3. Distribution of *Pseudevernia cladonia* in Canada. From west to east, arrows designate several locations that were first discovered between 2006 and 2009: Mont Tremblant (QC), Monts Sutton and Mont Singer (QC), Mont St-Magloire (QC), Nerepis Hills (NB), and Forest Hill (NS).

Table 1. Canadian locations of *Pseudevernia cladonia*. Locations with the year of discovery underlined are additions to those documented in the 2006 status report. Parentheses around the year of the last search indicate that the lichen was not found. Herbarium acronyms are from Index Herbariorum (Holmgren *et al.* 1990).

Locality	Year discovered	Most recent survey	No. thalli	Discovered by	Collection(s)
NEW BRUNSWICK					
Albert Co.: Fundy National Park, Kinnie Brook	1980	[2005]	<10	S.P. Gowan	CANL
Charlotte Co.: Beaver Harbour	2003	2003	18	S.R. Clayden	NBM
Charlotte Co.: Campobello Island	<u>1980</u>	[2008]	<10	W.S.G. Maass	NBM
Charlotte Co.: Grand Manan	2001	2003	<10	M. Maxfield	NBM
Charlotte Co.: Knights Mill Brook	<u>2007</u>	2007	>200	S.R. Clayden, D.L. Sabine	NBM
Charlotte Co.: Lake Anthony	<u>2011</u>	2011	<10	S.R. Clayden	NBM
Charlotte Co.: Love Lake Brook	<u>2010</u>	2011	<10	S.R. Clayden, R.T. McMullin	NBM
Charlotte Co.: New River Beach Provincial Park	2004	2009	46	S.R. Clayden	NBM
Charlotte Co.: Ross Island	2002	2003	<10	M. Maxfield	NBM
Charlotte Co.: Sam Orrs Pond	<u>2008</u>	2011	>200	S.R. Clayden	NBM
Queens Co.: CFB Gagetown, Mount Douglas	1996	2010	<100	S.R. Clayden	NBM
Queens Co: CFB Gagetown, Nerepis Hills	<u>2006</u>	2010	>100,000	S.R. Clayden, J.P. Goltz, D. McCullum, D.L. Sabine	NBM
St. John Co.: Big Salmon River	<u>1980</u>	1980	<10	W.S.G. Maass	NBM
St. John Co.: Cape Spencer	1991	2003	5	S.R. Clayden	NBM
St. John Co.: Chance Harbour	1991	2005	>200	S.R. Clayden	NBM
St. John Co.: Saint John, Wolsely Lake	1996	2009	>2,000	S.R. Clayden	NBM
NOVA SCOTIA					
Cumberland Co.: Cape Chignecto Provincial Park	1983	2006	>300	W.S.G. Maass, S.R. Clayden, F. Anderson	NBM, NSPM
Guysborough Co.: Forest Hill	<u>2009</u>	2009	>20	F. Anderson	NSPM
Halifax Co.: Halibut Cove	1980s	[2004]	1	W.S.G. Maass	
Halifax Co.: Halifax, Leiblin Park	c. 1974	2004	10	W.S.G. Maass	NBM

Locality	Year discovered	Most recent survey	No. thalli	Discovered by	Collection(s)
Halifax Co.: Lake Charlotte	<u>2006</u>	2006	2	F. Anderson, T. Neily	NSPM
Halifax Co.: Long Lake Provincial Park	<u>2008</u>	2008	8	F. Anderson	
Halifax Co.: Portuguese Cove	1980s	[2004]	<10	W.S.G. Maass	
Lunenburg Co.: Big Whitford Lake	<u>2007</u>	2007	1	F. Anderson	
Lunenburg Co.: Blandford Nature Reserve	2005	2007	<20	F. Anderson, R.P. Cameron	NSPM
Lunenburg Co.: Crouses Settlement	<u>2007</u>	2007	<10	F. Anderson	NSPM
Lunenburg Co.: Indian Path Common	2006	2006	<10	F. Anderson	NSPM
Lunenburg Co.: Timber Lake	<u>2006</u>	2006	<10	F. Anderson	
Queens Co.: Eagle Lake	<u>2006</u>	2006	<10	F. Anderson	
Shelburne Co.: Clyde River	<u>2007</u>	2007	<10	F. Anderson	
Shelburne Co.: Jordan River	<u>2007</u>	2007	>500	F. Anderson, T. Neily	NSPM
Shelburne Co.: Misery Lake	<u>2007</u>	2007	<10	F. Anderson	
Shelburne Co.: Oak Park	1980s	1980s	<10	W.S.G. Maass	
Halifax Co: Abraham Lake	2011	2011	<10	F. Anderson R. Cameron	
QUEBEC					
Mont Singer	2008	2008	>10,000	G. Lafontaine, C. Robidoux	
Mont St-Magloire	2009	2009	>100	S. R. Clayden	NBM
Monts Sutton	2008	2009	>100,000	G. Lafontaine, C. Robidoux	NBM
Parc national du Mont Mégantic	2004	2004	>1,000,000	S. R. Clayden, M. Mildenberger	NBM
Parc national du Mont Orford, Mont Orford	1959	2004	>20,000	F. LeBlanc	QFA, NBM
Parc national du Mont Tremblant, Mont Tremblant	2009	2009	>10,000	S. R. Clayden, T. Spribille, V. Wagner	NBM
ZEC Louise-Gosford	2004	2004	>2,000,000	S. R. Clayden, M. Mildenberger	NBM

Figure 4. Selected locations of *Pseudevernia cladonia* populations discovered between 2006 and 2009. Top left, top right, middle left: montane Balsam Fir forest near summit of Mont St-Magloire, QC. Middle right: montane forest of Balsam Fir, Red Spruce, and Heartleaf Birch near summit of Mont Tremblant. Bottom: Old growth Red Spruce-dominated forest in Nerepis Hills, NB (photos: S.R. Clayden).

These range extensions increase the estimated “extent of occurrence” (EO) of *P. cladonia* in Canada to c. 39,300 km^2 from 7,510 km^2 (COSEWIC 2006). About 84% (33,000 km^2) of the currently estimated EO is in Quebec, 9% (3,500 km^2) in Nova Scotia, and 7% (2,800 km^2) in New Brunswick. These estimates were obtained by totalling the areas of three polygons encompassing the well-separated occurrences in each of the three provinces – see Figure 3. The occurrence near Cape Chignecto, NS, was included in the New Brunswick polygon.

The revised, estimated “area of occupancy” in Canada is c. 11 km^2: 10 km^2 in Quebec, 0.6 km^2 in New Brunswick, and 0.3 km^2 in Nova Scotia. In 2006, the “area of occupancy” was estimated to be c. 3.6 km^2 in Quebec and < 0.01 km^2 in the Maritime Provinces. The new estimate for Quebec is based on the approximate area of *mature* Balsam Fir-dominated forest occurring at elevations above 800 m within a rectangle defined by the coordinates 45°N, 47°N, 70°W, and 75°W. This encompasses the Appalachian region of southeastern Quebec and the southern Laurentian Mountains. (A GIS analysis carried out for the 2006 status report by geomatics staff at the Direction du patrimoine écologique et du développement durable, Ministère de l’Environnement, Quebec, indicated that the area of montane fir forests (all maturity classes) in this rectangle was c. 17.86 km^2.) For New Brunswick and Nova Scotia, each occurrence (locality) was assigned an arbitrary minimum area of occurrence (AOO) of 1 hectare. For locations comprising more than one sublocality, each of the latter was considered to occupy 1 hectare. The Nerepis Hills occurrences were assigned an AOO of 50 hectares, though there is considerable uncertainty in this estimate. (In the 2006 status report, each of the Maritimes locations was assigned an AOO of only 10 m^2 (0.001 ha).)

The index of area of occupancy (IAO) can be approximately estimated on the basis of the number of locations known for *P. cladonia* in Canada. With few exceptions, no superimposed 2 km × 2 km square would cover more than a single locality, and most locations could be encompassed by such a square. The exceptions are the large montane populations, for example, along the Quebec-Maine border near Mont Gosford. The population in the Nerepis Hills of New Brunswick is also scattered across several 2 km × 2 km squares. With allowance for these variations, the total Canadian population would occupy approximately 50 to 60 2 km × 2 km grid squares, or 200 to 240 km^2.

Reliable information on the occurrence of this lichen in Canada has been slow to emerge. Torrey (1935) reported it from the Chic-Choc Mountains, “at 2500–3000 ft,” in the Gaspé region of Quebec, but there are no relevant voucher specimens at NY, where R.H. Torrey’s collections are housed (R. C. Harris, personal communication). Nor are there subsequent reports from the Chic-Chocs, though a number of experienced lichenologists have visited the region. Lepage (1947-1949) reported *P. cladonia* for Quebec on the basis of a specimen from Cap-aux-Corbeaux, (*Lepage 1835* [QFA, NBM]). This material has been revised to *Anaptychia crinalis* (Schaerer) Vězda (S.R. Clayden, unpublished). Lepage (1947-1949) also recorded *P. cladonia* for Nova Scotia, but did not provide locality or specimen data; no earlier reports or collections from that province have been located. An erroneous report for Ontario (Yoshimura and Sharp 1968) resulted from misinterpretation of a specimen label.

The first collections of *P. cladonia* in Canada were apparently made by Fabius LeBlanc near the summit of Mont Orford, Quebec, in 1959 (*LeBlanc 11589*, *11622* [QFA]). LeBlanc (1960, 1963) considered this lichen to be part of a rarely occurring assemblage of species ("Union à *Parmelia furfuracea*") found "dans les montagnes où l'atmosphère est humide." No subsequent collections or observations of *P. cladonia* on Mont Orford or elsewhere in Quebec were made prior to a reconnaissance undertaken by S.R. Clayden in 2004.

In the 1970s and 1980s, while researching the distribution of *Erioderma* species and other rare epiphytic cyanolichens in Atlantic Canada, Wolfgang Maass discovered six small populations of *P. cladonia* in Nova Scotia and another in New Brunswick. Details of one of the Nova Scotia locations and a brief mention of the other sites were included in an unpublished report (Maass 1997). The New Brunswick locality, noted in the 2006 COSEWIC status report as Deer Island, is here corrected to Campobello Island, following the discovery of a voucher specimen in the herbarium of W.S.G. Maass (transferred to NBM in November 2009).

Search effort

Pseudevernia cladonia is a conspicuous, easily identified lichen. Thalli can occur above eye-level in some localities so during fieldwork for this report, the tree canopy was inspected with binoculars. Searches were also made on recently wind-thrown trees, and, where feasible, by climbing. It is unlikely to be overlooked by specialist or even general lichen collectors.

The recent discoveries of scattered large populations in southern Quebec may reflect the limited lichenological exploration of montane forests in that region. The three Quebec populations documented in the 2006 status report, and four others discovered subsequently (Table 1), were located and surveyed during a total of seven days of intensive searching. However, there are other montane areas between the Monts Sutton and Mont St-Magloire that have not yet been searched and where *P. cladonia* is very likely to be found. In the Parc national du Mont-Tremblant (1,510 km^2), there are other areas, in addition to the Tremblant massif itself, with elevations above 800 m.

Areas of potential occurrence in spruce-fir forests along or near the Bay of Fundy coasts in New Brunswick and Nova Scotia, as well as along or near the Nova Scotian Atlantic coast, have been explored over many years by S. Clayden, S. Gowan, W. Maass, F. Anderson, T. Neily, R. Cameron, D. Sabine, and others. The overall lichen collections base for these areas is at least 8,000 specimens, and there are no large areas in which no lichen collections have been made. Because of its very sporadic occurrence, however, it is highly probable that small, previously unknown populations of *P. cladonia* will continue to be discovered in wet coastal spruce-fir forests and in old and (or) humid upland spruce-fir forests within c. 30 km of the coast in these areas. This is clearly shown by the work of Nova Scotia lichenologist Frances Anderson (personal communications, 2006-2011). Since 2006, in the course of intensive fieldwork toward the preparation of a catalogue of Nova Scotia macrolichens, Ms. Anderson has more than doubled the number of known occurrences of *P. cladonia* in that province, from seven to 18 (Table 1) (Several of these recently discovered occurrences consist of a number of sites within a kilometre of one another.). Her search time in areas where *P. cladonia* potentially occurs in Nova Scotia is at least 200 field-hours. In New Brunswick, the most recently discovered population (see Table 1) is in a lakeshore spruce-fir forest at 170 m elevation (Lake Anthony), c. 20 km from the Bay of Fundy (S.R. Clayden, unpublished data).

HABITAT

Habitat requirements

Pseudevernia cladonia occurs primarily in humid montane and coastal forests dominated by Red Spruce and (or) Balsam Fir – see Clayden (2010) and Clayden *et al.* (2011) for an analysis of the bioclimatic context of these forests and their lichen biota. It is absent from boreal spruce-fir forests in which Red Spruce is replaced by Black Spruce (*P. mariana*) and/or White Spruce (*P. glauca*). However, Black Spruce is present in some of the poorly drained coastal hemiboreal forests in New Brunswick and Nova Scotia. In most of these stands, there are also scattered Heartleaf Birch (*Betula cordifolia*) and mountain-ash (*Sorbus americana, S. decora*). In the Dominican Republic, *P. cladonia* occurs in high elevation forests of Hispaniolan Pine (*Pinus occidentalis*).

Key features of these coastal and montane habitats are their cool temperatures and frequent, often prolonged, immersion in fog or cloud. The mean cloud base along the Appalachians in eastern North America is c. 800 m. Above this elevation, slopes and summits in the northern Appalachians are in cloud for 30% to 50% of the time (Mohnen 1992). The large population of *P. cladonia* discovered in the Nerepis Hills in southern New Brunswick in 2006 is in an area frequently immersed in low summer cloud (Clayden 2010).

Along the Bay of Fundy, marine advection fog formed by cooling of moist air masses passing over the cold ocean surface blankets the coastal region for 12% to upwards of 27% of the time from April to October (Cox *et al.* 1989). Fog frequency increases from west to east from the mid-Maine coast into the Bay of Fundy (Jagels *et al.* 1989), reaching its highest levels near Saint John, New Brunswick (Cox *et al.* 1996), and declining toward the head of the bay. Localized areas of higher fog incidence, including Cape Chignecto, Nova Scotia, may indicate the presence of colder surface waters near shore, in turn reflecting tidal currents and mixing patterns.

The south shore of the Bay of Fundy is less foggy than the north shore (Cox *et al.* 1996); this may account for the apparent absence there of *P. cladonia*. Fog frequency and duration along the Atlantic shore of Nova Scotia are comparable to or higher than those in the Bay of Fundy (Beauchamp *et al.* 1998; Muraca *et al.* 2001), but detailed data on fog occurrence on these coasts are not available.

Where it occurs near the coast, *P. cladonia* is a species of humid forest interiors, not wind-exposed headlands. The structure and topographic setting of its habitats in New Brunswick and Nova Scotia are otherwise quite variable. Some are mature to old growth Red Spruce-dominated forests with a high canopy and many trees >100 years old. Although these stands may be on poorly drained sites, others are on well-drained, west- or northwest-facing, cool slopes and adjoining low ridges, often near lakes or peatlands. With increasing distance from the coast, *P. cladonia* is increasingly confined to old growth stands, in which high relative humidity offsets the lower frequency of fog. It is significant in this regard that the rather isolated occurrence of *P. cladonia* at Big Reed Pond in northern Maine is in the largest tract of old growth Red Spruce forest remaining in the state (Selva 1994).

Although *P. cladonia* is a frequent epiphyte in montane fir forests in the Adirondacks (Schmull *et al.* 2002), the White Mountains (Lang *et al.* 1980), and nearby southern Quebec, at least in Quebec its presence/absence and relative abundance are clearly a function of stand age, continuity, and humidity. A stand age of c. 80 years is commonly considered to be the average interval at which Balsam Fir forests are recycled by epidemics of Spruce Budworm, senescence, and wind-throw (e.g. Lang *et al.* 1980). Such recycling (or harvesting for pulpwood) takes place at widely varying scales, giving rise to extensive areas of even-aged stands, as well as mosaics of much smaller forest patches, the ages uniform within, but variable between adjacent patches. Within this dynamic context, *P. cladonia* in Quebec is largely restricted to mature to over-mature stands, ranging from small patches < 0.1 ha in size to ± continuous areas perhaps approaching 50 ha. It is also more frequent on north-facing than other slope aspects. On level ground, it is more frequent in sites with impeded drainage. At the lowermost site (790 m) found in Quebec, it occurs on the north- (but not south-) facing slope of a small, steep-sided, forested ravine, still with extensive ice in its mossy, boulder-filled base when the area was examined in mid-June 2004.

At some of the New Brunswick and Nova Scotia coastal sites for *P. cladonia*, the forests are quite low in stature (maximum tree height 10-12 m). These stands may be rather open in structure as a result of wind-throw of dead or dying trees. However, relative humidity remains high owing to poor drainage and the presence of extensive, though thin, mats of *Sphagnum*.

Pseudevernia cladonia is a twig and branch specialist (Figure 5). It is less common on tree trunks, snags, and coarse woody debris on the forest floor. All of the epiphytic thalli observed in Canada have been on *Abies balsamea*, *Picea rubens*, *P. mariana* or *P. glauca* (on *P. glauca* at one site only, in coastal New Brunswick). LeBlanc (1960) recorded it on *Betula alleghaniensis* on Mont Orford, but there is no voucher specimen for this record. In the southern Appalachians, *P. cladonia* occurs mainly on *Abies balsamea* var. *fraseri* and *Picea rubens*, but infrequently also on hardwood trees, on the ericaceous shrub *Menziesia pilosa* and, rarely, on rock (Degelius 1941; Dey 1978).

Figure 5. Thalli of *Pseudevernia cladonia* on dead twigs of a live Balsam Fir tree, in old-growth Red Spruce-dominated forest in the Nerepis Hills, NB (photo: S.R. Clayden).

At most of the *P. cladonia* sites in New Brunswick and Nova Scotia, the thalli are mainly on fine, dead, often decorticate, twigs of fir (Figure 5), and less commonly Red or Black Spruce. In the coastal locations, it occurs especially on small, spindly, shade-suppressed trees that are generally only 1 to 3 m tall, and located beneath a canopy of trees 10 to 20 m in height. In the old-growth Red Spruce forests in the Nerepis Hills and at Wolsely Lake, New Brunswick, *P. cladonia* is present not only on small firs and woody debris, but also on the boles of large Red Spruces and on dead, spreading lower branches, c. 6 to 10 m above the ground, of some of these large trees. In its montane fir forest habitat in southern Quebec, *P. cladonia* regularly occurs from the lowest spreading fir branches upward nearly to the tops of the trees. It is probably most abundant from about 1.5 to 4 m above the ground, and again, is most common on dead branches and needle-free portions of live branches. However, it can also spread to a limited degree over live needles.

There are generally few other lichens present with *P. cladonia* on the branches and twigs it colonizes (Figure 5) – often only the crustose species *Fuscidea arboricola* and *Scoliciosporum chlorococcum*, and scattered small foliose thalli of *Hypogymnia* species and *Imshaugia aleurites*. This is an association of naturally acidic substrata. Although pH measurements of *Abies* or *Picea* twigs were not made, the bark pH of trunks of *P. rubens*, which can be colonized by *P. cladonia*, is often <3.5, and can be as low as 2.8 (S.R. Clayden, unpublished data).

It is unclear whether *P. cladonia* tends to be excluded by interspecific competition on branches with more abundant foliose and fruticose lichen cover. However, the common epiphytic macrolichens occurring with it at the stand level are perhaps less able to colonize or thrive, as it does, on fine dead twigs. The coverage and diversity of other lichens is often greater on neighbouring branches or trees, and includes an assemblage of common species typical of moist spruce-fir forests. It is also possible that *P. cladonia* thalli require good ventilation (promoting rapid drying?), in spite of the humidity of its spruce-fir habitats. If so, this requirement might be best met in the branch/twig microhabitat where it is commonly found.

Habitat trends

The overall area of known and potential (unexplored) habitat for *P. cladonia* in Canada appears to have been fairly stable in recent decades. Logging of montane fir-dominated forests has occurred at scattered locations in Quebec near the international boundary with the United States. There has also been extensive logging in the Massif du Sud, where the northernmost population of *P. cladonia* is located. Smaller losses of montane habitat due to ski-hill development have occurred at Mont Tremblant, Mont Sutton, Mont Orford, and in the Massif du Sud.

In the Maritime Provinces, logging of moist, mature, coastal or near-coastal spruce-fir forests over the past 150 years may have reduced the availability of suitable habitat. This cannot be known with certainty, as thorough inventories of the epiphytic lichens of such forests were initiated only in the 1970s and 1980s. It may be significant, as previously noted, that the largest (Nerepis Hills) population of *P. cladonia* known in this region is in old-growth Red Spruce, and that its northernmost occurrence in Maine is likewise in an exceptional remnant of old spruce forest. Local losses or alteration of habitats which formerly supported populations of *P. cladonia* in the Maritimes resulted either from natural disturbances or from human activity, including housing development.

High-elevation and coastal Red Spruce-dominated forests in northeastern North America have been under intense anthropogenic stress over the past half-century or more (Friedland *et al.* 1984; Johnson *et al.* 1988; Jagels *et al.* 1989; Eagar and Adams 1992; Cox *et al.* 1996; Lazarus *et al.* 2006; Mohan *et al.* 2009). The main stressors have been acid deposition from cloud water and coastal fog, and an increasing frequency of winter thaws linked to climate warming. These reduce the cold-hardiness of spruce and increase the incidence of freezing injuries, leading to increased mortality. Balsam Fir seems resistant to these stresses, and its montane populations have not experienced diebacks like those of Red Spruce (Johnson *et al.* 1988).

At two of the montane sites in Quebec with *P. cladonia* populations (Mont Tremblant, Mont Sutton), the mean pH of cloud water from 1985 to 1991 was 3.72 and 3.90, respectively (Schemenauer *et al.* 1995). Similar or more acidic values (as low as 3.0) have been recorded in coastal forests along the Gulf of Maine and Bay of Fundy (Cox *et al.* 1989; Jagels *et al.* 1989). Decline of Red Spruce has been more evident at high than low elevations (Lazarus 2006), but trees with symptoms of winter injury have also been observed in coastal Maine and New Brunswick (Jagels *et al.* 1989; additional references in Mohan *et al.* 2009).

Compounding these stresses are upward shifts of climate and vegetation zones on mountain slopes. In the Green Mountains of Vermont, the elevation of the ecotone between northern hardwoods and spruce-fir forests increased by c. 100 m between 1962 and 2005, consistent with an increase of 1.1°C in regional annual mean temperature (Beckage *et al.* 2008). The mean elevation of the cloud base in the northern Appalachians, which may be a more proximate influence on the position of the deciduous-coniferous ecotone, has also been increasing in recent decades (Richardson *et al.* 2003).

At higher elevations (> 800 m) in the Green Mountains, extensive die-back of Red Spruce has facilitated sharp increases in the abundance of Balsam Fir (Beckage *et al.* 2008). This increase may offset spruce habitat loss for *P. cladonia* because balsam fir is also a possible, though less common, host for this lichen. Climatic and vegetation changes are also probably occurring, or will occur, in the montane forests in the Appalachian and Laurentian regions of southern Quebec. An eventual consequence of the continued upward shift of vegetation zones could be the loss of perhumid high-elevation coniferous forests supporting *P. cladonia*.

The impacts of climate change on perhumid coastal spruce-fir forests in New Brunswick and Nova Scotia are difficult to predict. A range of climate models for Atlantic Canada (Vasseur and Catto 2008) forecast mean annual temperature increases of c. 2°C by 2050 and 4°C by 2080. Smaller increases are predicted for coastal areas where cold ocean temperatures provide more thermal buffering. Precipitation is expected to increase across the region, but these increases may be insufficient to offset increased evapotranspiration resulting from warmer temperatures (see Clayden *et al.* 2011).

BIOLOGY

Life cycle and reproduction

Apothecia and ascospores are formed only very rarely by *P. cladonia*. Sexual reproduction by the mycobiont is thus likely to be of minor importance in the reproduction of the *P. cladonia-Trebouxia* symbiosis. Conidia-bearing structures (pycnidia) are also rare in this lichen; this may partly account for the scarcity of apothecia, as in many lichens such conidia apparently function primarily as sexual gametes. However, there is no direct evidence indicating that conidia serve this function in *Pseudevernia* or other parmelioid lichens. Conidia of a few lichen fungi have been successfully germinated in culture, and it is conceivable that they might function in some cases as vegetative propagules of the mycobiont. It is interesting that the related *P. intensa*, an endemic of the southern Rocky Mountains, produces both pycnidia and apothecia frequently.

Soredia, isidia, or other specialized vegetative propagules are also lacking in *P. cladonia*. This lichen must therefore reproduce mainly through fragmentation of the thallus. The thallus is not particularly brittle, and although the cortex may have frequent cracks running transversely to the branch axes, the adjoining portions of the thallus are, for the most part, held closely together by the well-developed, cottony medulla. The generation time is the average time required for a new thallus fragment to attach to its substrate and grow to a size where it, in turn, becomes subject to fragmentation. The time involved is unknown, but is probably less than 10 years. It is unclear why the abundance of *P. cladonia* varies among locations by several orders of magnitude. There are stands where hundreds, thousands, or even greater numbers of thalli, of a full range of sizes, are present. In these instances, the cycle of establishment, fragmentation, and re-establishment is evidently very effective. In other locations, little within-stand recruitment occurs, even where well-developed thalli are present. This could reflect lower rates of fragmentation, or establishment, or both.

Physiology and adaptability

Little is known about the physiology of *P. cladonia* on the basis of experimental or quantitative studies. Its requirements and tolerances can be inferred to some extent from its overall geographic range and community-level occurrence. Its restriction to foggy coastal and montane cloud forests suggests a requirement for cool, humid climates. At low to intermediate elevations, and with increasing distance from moist coastal areas, it is increasingly restricted to humid old-growth stands. Its conifer twig, branch, and trunk substrata are moderately to strongly acidic. It is much less impacted by acidifying pollutants, particularly sulphur dioxide, than are epiphytic cyanolichens. This is consistent with its persistence within the city limits of Halifax and Saint John.

Dispersal and migration

Wind and animals, particularly birds, are the main potential vectors for the dispersal of *P. cladonia* within and between stands, and over longer distances. There are no reports of use of this lichen as nesting material by birds, but it is likely that they pick up fragments inadvertently while foraging for insects. It is an intriguing possibility that the widely disjunct population of *P. cladonia* on the island of Hispaniola originated from propagules dispersed by Bicknell's Thrushes. The specialized habitat and fragmented montane range of Bicknell's Thrush during the breeding season in northeastern North America are similar to those of a large part of the population of *P. cladonia*. Most of the global population of Bicknell's Thrush winters in montane forests on Hispaniola, following over-sea migration from areas north of the Carolinas (COSEWIC 2009).

Dispersal of *P. cladonia* is probably limited, nonetheless, by a very modest reproductive effort. In this respect, it somewhat resembles the boreal forest-inhabiting fruticose lichen *Alectoria sarmentosa*. It may also share some aspects of the population dynamics of that species. Dettki (1998) and Dettki *et al.* (2000) have shown that, in Scandinavia, *A. sarmentosa* has a very limited capacity to disperse from old-growth spruce forests, its optimal habitat, to adjoining clear-cuts and regenerating stands. This might partly reflect a requirement for the humid microclimatic conditions of old stands, but is also a function of the very limited production of propagules (thallus fragments). In contrast, some *Bryoria* and *Usnea* species fragment readily, and can therefore be efficient dispersers and colonizers of young forests. Overall, the sporadic distribution of *P. cladonia* in maritime eastern Canada, and its absence from extensive areas of apparently suitable habitat, are suggestive of rare instances of successful long-distance dispersal to humid, cool, spruce-fir stands.

Interspecific interactions

Often, few other lichens are present on the twigs colonized by *P. cladonia*. This might indicate it is weak in competition, and excluded from branches with greater coverage of other species, or that it is tolerant of some chemical or other characteristic(s) of the twig microhabitat that are inhospitable to other lichens

POPULATION SIZES AND TRENDS

Sampling effort and methods

See the above sections: **DISTRIBUTION**, **Search Effort**.

Abundance

Forty-one locations of *P. cladonia* in Canada have been documented (Table 1): 7 in Quebec, 16 in New Brunswick, and 18 in Nova Scotia. Five of the Nova Scotia locations (Cape Chignecto Provincial Park, Long Lake Provincial Park, Blandford Nature Reserve, Indian Path Common, Eagle Lake) comprise two or more sub-localities within 1 km of one another (F. Anderson, personal communication). In New Brunswick, the Nerepis Hills locality is a composite of *P. cladonia* occurrences in old spruce-fir forests clustered around several small lakes within an area of c. 10 km^2 at elevations of 250 m to 300 m. The Monts Sutton, Mont Mégantic, and ZEC Louise-Gosford locations in Quebec are all composites of two or more sub-localities. With only a few exceptions, the listed locations are separated from one another by at least 10 km.

Twenty-six of the 34 locations known in the Maritime Provinces were first found after 1990. Most of these comprise fewer than 50 thalli. A notable exception is a population discovered in 2006 at Trout Lake in the Nerepis Hills of New Brunswick, where at least 100,000 thalli are present in humid, old-growth spruce-fir forests. Recent surveys carried out in 2010, in the Range and Training area within the Canadian Forces Base, Gagetown, discovered new occurrences of *P. cladonia* at Little Trout Lake, Manks Lake, Mountain Lake, Parker Lake and Mountain Brook, but none with populations comparable to that at Trout Lake, so there is no basis for an upward revision of the overall population size of c. 100,000 thall in this area (Bell 2011). Even larger populations occur in scattered montane Balsam Fir-dominated forests in the Appalachian region of southeastern Quebec. Until 2004, the only population known in this area, and in all of Quebec, was at the summit of Mont Orford. Recent discoveries in several other montane areas increase the estimated population size in Quebec to more than 3,000,000 thalli. A disjunct population on the elongated summit of Mont-Tremblant, discovered in 2009, probably consists of at least 10,000, and possibly more than 100,000 thalli. It is likely that additional occurrences will be found in unexamined, high-elevation, mature, fir-dominated forests near Mont Tremblant, as well as within the area framed by the known occurrences east of the St. Lawrence River valley (Figure 3).

At the stand level, especially in the Maritime Provinces, the occurrence of *P. cladonia* is often highly clumped. A single or a few small trees may bear most (sometimes dozens or hundreds) of the thalli, with similar neighbouring trees having few or none. This pattern apparently results from the initial colonization of a tree near its apex, followed by downward dissemination and establishment of fragments, with little lateral dispersal from tree to tree.

Fluctuations and trends

Although the total population of *P. cladonia* in Canada is probably stable, trends cannot be readily assessed, given the scarcity of historical data on its distribution and abundance. There are four small historically known populations in the Maritimes that have not been re-found in recent surveys (Table 1). The recent increases in the number of locations known in each province are due to increased, targeted search efforts.

In the spruce-fir forests in the Adirondack Mountains, New York, which are affected by Red Spruce dieback, *P. cladonia* remains frequent (Schmull *et al.* 2002).

Rescue effect

The populations of *P. cladonia* in southeastern Quebec are, in part, continuous with populations in the montane coniferous forests of eastern Maine and northern New Hampshire. Immigration of individuals into Canada is possible and likely in this area. Populations in the Adirondack Mountains of upstate New York and the Green Mountains of Vermont may also provide a source of propagules dispersing to outliers of humid, montane fir forest in southern Quebec, including those on the summits of Mont Tremblant and the Monts Sutton. Immigration into the coastal regions of New Brunswick and Nova Scotia probably occurs sporadically from montane populations in the northeastern United States.

THREATS AND LIMITING FACTORS

With only a few exceptions, the listed locations for *P. cladonia* are separated from one another by at least 10 km and the most common single threatening event, identified in the 2006 status report, forest removal, would be unlikely to affect more than one location simultaneously (COSEWIC 2006). Cutting of mature, coastal and montane spruce-fir forests may alter or eliminate stands harbouring populations of *P. cladonia*. The standard 30 m buffer on water bodies and wetlands is unlikely to be sufficient to conserve habitat or protect *P. cladonia* populations. Logging is also occurring in other montane fir-dominated forests along portions of the Quebec-Maine border, but the extent and impacts of this activity have not been assessed. In addition, the second-largest population known in the Maritimes is in an unprotected old-growth Red Spruce stand located near the city of Saint John. This could easily be eliminated by cutting and (or) housing development.

Some of the montane populations in Quebec may have been affected in terms of extent and thallus numbers by alpine-ski developments. The most significant of these impacts is thought to have occurred near the summit of Mont Orford. At Mont Tremblant, the ski slopes and related infrastructure are currently limited to about 20% of the portion of the massif that potentially supports populations of *P. cladonia* (1.5 km of the c. 7.5 km northwest-to-southeast linear extent of elevations above 800 m.) The population at Mont St-Magloire is within the “Parc régional du Massif du Sud”. This includes a ski hill at Mont du Midi (summit, 915 m), about 5.5 km east of Mont St-Magloire. However, the impacts of the ski development are probably less than those of logging in adjoining portions of the Massif du Sud plateau with elevations >800 m.

Wind farm development in high elevation spruce-fir forests could also be a potential threat. The increased human activity could, like climate change, increase the incidence of forest fires

In the Fundy and Atlantic coastal regions of New Brunswick and Nova Scotia, the number of occurrences and population sizes of *P. cladonia* do not appear to be limited, at present, by the availability of humid coniferous forests. Its sporadic occurrence, and mostly small population sizes, seem instead to be attributable to its limited capacity for dispersal. Each of the known occurrences apparently stems from an isolated instance of establishment from propagules transported over long distances. Cutting of moist mature spruce-fir forests will, nonetheless, eliminate sites that are more likely to harbour populations than are young stands. The occurrence at Wolsely Lake, which is the second largest known in the Maritime Provinces, is at risk of being logged owing to its private ownership and proximity to a residential area in the city of Saint John.

The northern range limits of montane populations of *P. cladonia* appear to be determined by cold winter temperatures. Like Red Spruce, it is a species of Appalachian and hemiboreal, not boreal, forests (see Cogbill and White 1991; Clayden 2010; Clayden *et al.* 2011). Highly humid, but colder (boreal) bioclimates, such as the higher elevations of the Laurentian Mountains north of Quebec City, or portions of the highlands of northern New Brunswick and Gaspésie, are evidently outside the climatic tolerance ranges of these species. The western limits of *P. cladonia*, also with parallels to the limits of Red Spruce, are probably determined by climatic moisture availability. Although there are disjunct populations of Red Spruce as far west as the Algonquin Highlands and Lake Nipissing in Ontario (Mosseler *et al.* 2000), these are at low to intermediate elevations (<550 m) with lower precipitation and humidity than the mountain summits of southern Quebec where *P. cladonia* occurs.

The populations in montane southern Quebec and in the Nerepis Hills of New Brunswick are potentially threatened over a longer time-frame by anthropogenic climate and vegetation change. High-elevation and coastal Red Spruce-dominated forests in northeastern North America have been under intense stress from acid deposition via cloud water and coastal fog, and an increasing frequency of winter thaws linked to climate warming (Mohan *et al.* 2009). These reduce the cold-hardiness of spruce and increase mortality (see **Habitat Trends** section). A warming climate trend could increase the incidence of forest fires (Bell 2011). Upward shifts in the mean elevation of the cloud base have been documented as well as the elevation of the ecotones between major vegetation types (Richardson *et al.* 2003, Beckage *et al.* 2008). These could cause extensive reduction in the area of montane, fir-dominated cloud-forest suitable for *P. cladonia*. Similar concerns have been expressed about populations of other species dependent on montane spruce-fir forests in northeastern North America, particularly Bicknell's Thrush (Rodenhouse *et al.* 2008; COSEWIC 2009).

PROTECTION, STATUS, AND RANKS

Legal protection and status

None.

Non-legal status and ranks

NatureServe: G2G4 (distribution data incomplete; national, state and provincial ranks not assigned).

COSEWIC (2006): Special Concern

General Status in Canada (2011): Canada (3: sensitive), Quebec (3: sensitive), New Brunswick (5: undetermined), Nova Scotia (sensitive). Finally, it has been given an SNR rank, according to NatureServe in North Carolina and Pennsylvania.

Habitat protection and ownership

Eight of the 34 known occurrences in the Maritime Provinces are in protected areas. However, these are all small populations, and two of them have not been relocated since 1980. The largest population in the Maritimes is in part of the Range and Training area within the Canadian Forces Base, Gagetown, New Brunswick within the Nerepis Valley/Nerepis Hills Forest Management Zone. This area is not currently included in the 25 year harvest Operational Forest Management Plan of CFB and therefore temporarily protected from timber harvest activities (Bell 2011). There has been no forest harvesting in this area for many decades. In Quebec, three of the seven occurrences documented to date are in Quebec national parks, though mountain-top ski development has taken place in two of these. Two other occurrences (Sutton

Mountains, Mont Singer) are partly or entirely in protected areas owned and managed by the Nature Conservancy of Canada within the “Corridor Appalatien” (see http://www.apcor.ca). One of the Quebec occurrences on Mount Gosford is in a Zone d’exploitation contrôlée (ZEC), which does not guarantee protection from logging. However, the mountain down to 720 m in altitude is proposed as an ecological reserve which provides the highest level of protection, (http://www.mddep.gouv.qc.ca/biodiversite/airesprotegees/articles/090329/mont-gosford.pdf.) although climate change may, in the long term, affect organisms in the reserve.

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Authorities contacted for current and (or) 2006 status reports

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COLLECTIONS EXAMINED

The locations of all collections examined for this report are listed in Table 1.