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ERIODERMA PEDICELLATUM IN NORTH AMERICA: A CASE STUDY OF A RARE AND ENDANGERED LICHEN.*

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A single thallus of *Erioderma pedicellatum* has been found in Newfoundland near one of the 2 North American localities known thus far for this unusual lichen. Whereas almost all of the other species of the genus have tropical to subtropical affinities in their distribution and ecological adaptation, *E. pedicellatum* can tolerate winter temperatures down to near -30°C. The habitat of *E. pedicellatum* in Newfoundland has now been characterized in sufficient detail to allow the possible rediscovery of the lichen in its type locality on Campobello Island, N.B., where it was once found in association with *Erioderma mollissimum*. However, during the past 70 years, only small areas of Campobello Island have not been affected by either forest fires or logging. The fire histories in the North American localities of *E. pedicellatum* have been researched and documented, and all other obvious or possible environmental hazards to the survival of this rare and endangered lichen, including pollution and biological factors, are discussed.

Introduction

After a lapse of nearly twenty years the evasive lichen *Erioderma pedicellatum* (Hue) P.M. Jørg. has been found once again in North America. This lichen is the only exclusively boreal species of the predominantly tropical genus *Erioderma*, a member of the Pannariaceae containing the bluegreen alga *Scytonema* as a symbiont (Keuck 1977). The species occupies a rather narrow niche in some cool and highly humid parts of the boreal forest on both sides of the Atlantic Ocean. In Europe apparently all of the localities known thus far were originally discovered by Ahlner (1948) in North Trøndelag and Värmland but in spite of efforts to protect the species it has disappeared from all of these sites, the last sighting having been made in 1962 by Degelius (in schedulis). Jørgensen (1978) blamed the modern logging techniques and the deterioration of the required microclimatic conditions in the woodlands adjacent to clearcut areas for the disappearance of the species. The North American distribution is very skimpy. The type was collected by Farlow in July of 1902 on Campobello Island in New Brunswick (Jørgensen 1972), and additional material became known from the collections of Ahti made in 1956 near the base of Burin Peninsula in Newfoundland. Ahti's published *Erioderma* locality lies 13.5 km west of Swift Current near the northwestern shore of Long Pond (Ahti and Jørgensen 1971; at altitude 150 m, see loc. 25 a in Ahti 1974). It was based on several thalli collected "on thin twigs of *Abies balsamea*" (Ahti No. 9490). An as yet unpublished occurrence was communicated to me by Teuvo Ahti and is based on a single thallus collected about 3 km north-northwest of Long Pond (Ahti No. 6414, on dead fallen *Abies* in moist forest; at altitude 180-200 m, see loc. 25 b in Ahti 1974). The approximate origins of these collections have been included in figure 1 together with the newly found locality, to be described under "Ecological Observations".

In view of the established retreat of *E. pedicellatum* from Europe it became of great interest to assess the future of the species in North America.

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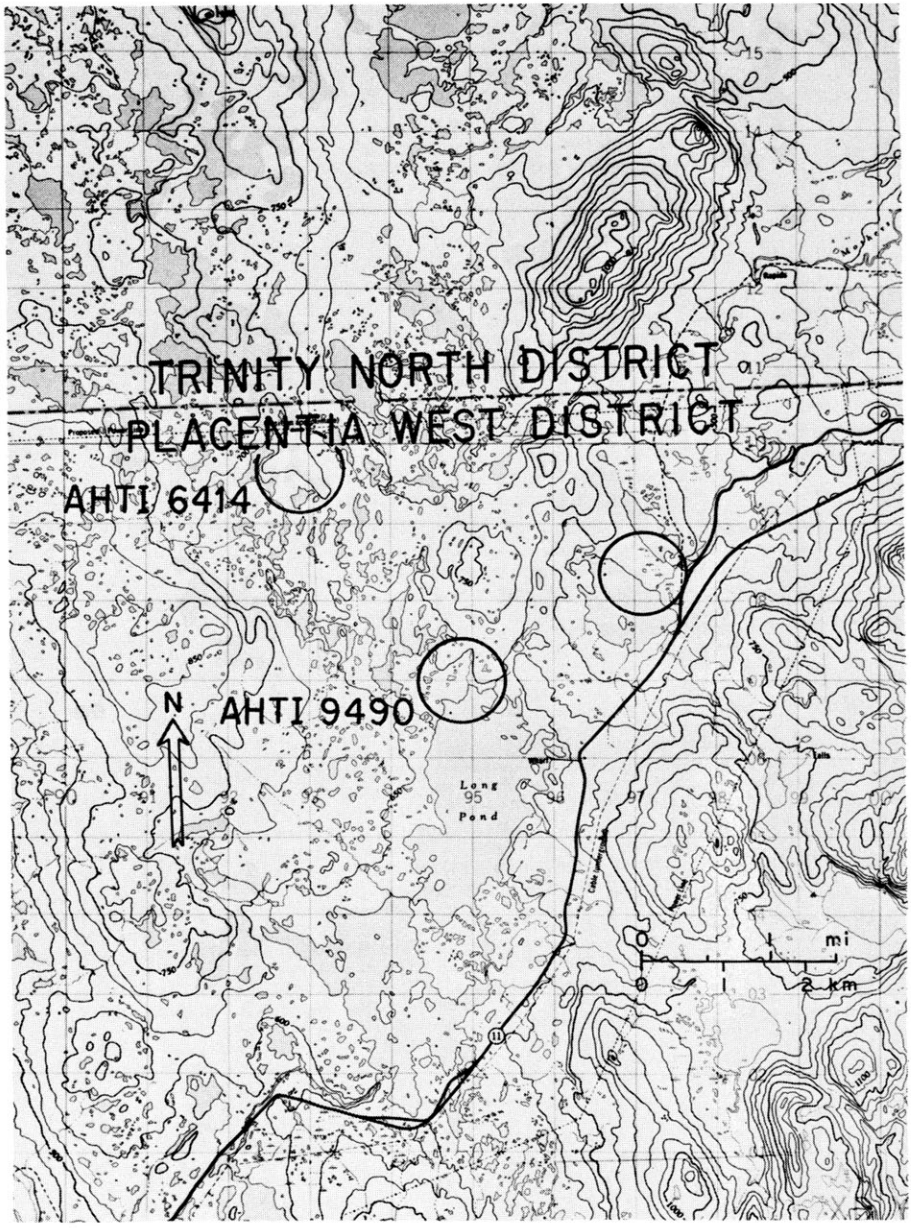


Fig. 1. Distribution of *Erioderma pedicellatum* in Newfoundland. The three localities (circled) are in close proximity to one another a little north from Long Pond and about 13 km west of Swift Current Village. The localities in which the lichen was collected by Teuvo Ahti have been placed on the map as accurately as possible by Dr. Ahti himself and are designated by his collection numbers (which do not reflect any chronological order of his collecting). The original dirt road has been straightened out and paved as inserted on the section of the map shown (reproduced from Sound Island, National Topographic Series, sheet 1 M/16, edition 2 MCE, series A 781, with permission of the Department of Energy, Mines and Resources, Ottawa). Note the great abundance of small ponds and pools in this highly humid district near the Atlantic Ocean.

Ecological Observations

During a recent exploratory trip to Newfoundland a single specimen of *E. pedicellatum* was finally located after a search for the species that had lasted several years. An old portion of the thallus has been deposited as a voucher in the Naturhistoriska Riksmuseet in Stockholm (W. Maass No. LP-18, collected 18 Sept. 1979). The remainder of the thallus has been used up for mass spectrometry, culture work and a transplant experiment to be described elsewhere.

The pocket of fir forest within which *E. pedicellatum* was discovered is seen in Figure 2. It is situated on the northeastern shore of an unnamed pond ca. 2.4 km northeast of Long Pond at 47°54'00"N and 54°21'49"W and an altitude of about 175 m (Fig. 1). The forest stand is only about 100 m wide and 300 m long, and occupies a small ridge between the lake and a bog pond surrounded by open bog. This bog showed evidence of a fire (Fig 2) which at this point must have come from an easterly direction. Within about 25 m from this affected area and behind a narrow zone of *Picea mariana* (Mill.) B.S.P. at the edge of the moat, a few of the specimens of *Abies balsamea* (L.) Mill. at the bottom of the slope showed a rich lichen vegetation closely resembling that described by Ahti and Jørgensen (1971). Several trees had *Lobaria scrobiculata* (Scop.) DC. and *Coccocarpia palmicola* (Spreng.) Arvidss. & D. Gall. on the trunks and one, with a diameter of 14 cm at breast height and rather smooth bark, contained a single thallus of *E. pedicellatum* (4.8 x 2.8 cm large) which from a

Fig 2. The locality of *Erioderma pedicellatum* 2.4 km northeast of Long Pond. The picture was taken in a north-northwesterly direction from near the southeastern corner of an unnamed pond ("Erioderma Pond") draining into the Pipers Hole River system. The pocket of mixed *Abies* forest is surrounded by a large burnt area. See text for details of the fire and habitat.

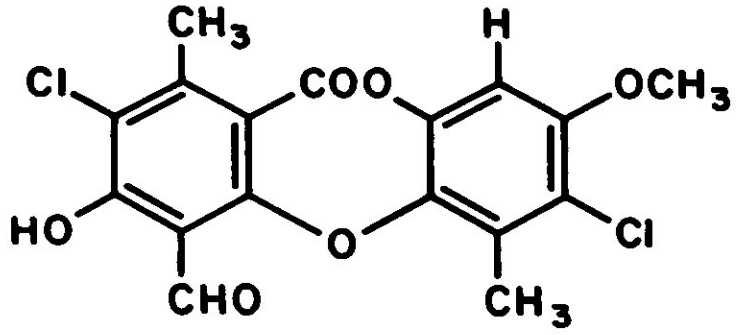
distance looked like a small version of a *Peltigera* (Fig 3). It grew on the northeastern side of the trunk at about 1.5 m from the ground (or 1.2 m as measured on the opposite side). The habitat was considerably less shaded than expected from the description by Ahti and Jørgensen. However, the lichen was moist although it had not rained for a couple of days, and in this state was dark gray to almost bluish or slate gray, which is in sharp contrast with the deep green color of the remotely related tropical species *E. physcioides* Vain. and with the grayish green color of the more closely related *E. wrightii* Tuck. The specimen displayed characteristically upturned margins showing the whitish underside with a dark hairy felt further below (Fig 4). This development of an eriostratum is much more pronounced than in material seen from Sweden and may be due to the appressed type of growth over bark. The Swedish material pictured by Keuck (1977, Fig. 204) and Ahlner (1948, Pl. 6 & 7) does not display upturned margins, which may be due to smaller thalli and their preparation as herbarium specimens. The upper side of our thallus contained the diagnostic hairs (Jørgensen 1972) and apothecia. Some of the apothecia were very

Fig 3. The thallus of *Erioderma pedicellatum* (x 2) in the moist condition. The lichen was moved into a sunny spot for the photograph. Note the upturned lobes with apothecia in all stages of development and the white marginal zone of the underside. The dark eriostratum is visible on a young lobe to the right. The old darkened portion of the thallus is at right center. The foliose *Hypogymnia vittata* and threads of the fruticose *Alectoria sarmentosa* subsp. *sarmentosa* are also seen in the picture.

Fig 4. Close-up of *Erioderma pedicellatum* (x 4). Note the upturned margins of the lobes displaying mature apothecia, from which spores have been obtained for the cultivation of the mycobiont, and the white marginal zone of the underside followed by a dark eriostratum. *Alectoria sarmentosa* subsp. *sarmentosa* is seen near the upper edge and the hepatic *Frullania asagrayana* is in the upper right hand corner of the picture.

young and undeveloped (barely emerging from the cortex); others, however, were fully mature with a strongly convex hymenial disk, making these fruiting bodies appear semiglobose. Furthermore, the presence of a metabolite characteristic of *E. pedicellatum* (Ahti & Jørgensen 1971; Jørgensen 1972) was indicated by mass spectrometry. This metabolite is identical with the chlorinated depsidone eriodermin (Fig 5) isolated from *E. sorediatum* D. Gall. & P. M. Jørg. (Maass 1980a) and is presently known only from members of the genus *Erioderma* (Maass 1980b).

The corticolous lichens found associated with *E. pedicellatum* have been included in Table I which summarizes the available information on this unusual lichen community. On the bark of the fir tree examined, the following bryophytes were present: *Blepharostoma trichophyllum* (L.) Dum., *Frullania asagrayana* Mont., *Lophozia ventricosa* (Dicks.) Dum., *Nowellia curvifolia* (Dicks.) Mitt. and *Ptilidium pulcherrimum* (Weber) Hampe. The ground cover of the forest was mossy and made up of the hepatic *Bazzania trilobata* (L.) Gray, the mosses *Dicranum majus* Turn., *Hylocomium splendens* (Hedw.) B.S.G., *Pleurozium schreberi* (Brid.) Mitt., *Ptilium crista-castrensis* (Hedw.) De Not., *Rhytidiadelphus triquetrus* (L.) Warnst., *Sphagnum nemoreum* Scop. and *S. quinquefarium* (Braithw.) Warnst., the fern *Osmunda cinnamomea* L. and the



$C_{17}H_{12}Cl_2O_6$

Fig 5. The chemical structure of the depsidone eriodermin.

Table I. Lichens found with *Erioderma pedicellatum*.

		1	2	3
A	*Coccocarpia palmicola* (Spreng.) Arvidss. & D. Gall. [= *C. cronia* (Tuck.) Vain.]	+	+	
B	*Lobaria pulmonaria* (L.) Hoffm.			+
	L. scrobiculata (Scop.) DC.	+		+
	Nephroma bellum (Spreng.) Tuck. [as *N. laevigatum auct.*]			+
	N. laevigatum Ach. [as *N. lusitanicum* Schaer.]			(+)
	N. parile (Ach.) Ach.			+
	Pannaria ahlneri P. M. Jørg.	(+)	(+)	(+)
	Peltigera aphthosa (L.) Willd.	+		
	P. collina (Ach.) Schrad. [as *P. scutata* (Dicks.) Duby]			(+)
	P. neopolydactyla (Gyeln.) Gyeln.	+		
	P. polydactyla (Neck.) Hoffm. s.lat. (close to *P. neckeri* Müll. Arg.)	+		
C	*Alectoria sarmentosa* (Ach.) Ach.	+	+	
	Bacidia chlorantha (Tuck.) Fink	+		
	Bryoria bicolor (Ehrh.) Brodo & D. Hawksw. [as *Alectoria bicolor* (Ehrh.) Nyl.]			+
	B. implexa (Hoffm.) Brodo & D. Hawksw. [as *Alectoria implexa* (Hoffm.) Nyl.]			+

B. nadvornikiana (Gyeln.) Brodo & D. Hawksw. [as *Alectoria altaica* (Gyeln.) Räs.]			+
B. trichodes (Michx.) Brodo & D. Hawksw. subsp. trichodes	+		
B. trichodes subsp. *trichodes*, sorediate morphotype	+		
B. trichodes subsp. *americana* (Mot.) Brodo & D. Hawksw.	+		
Cavernularia hultenii Degel.	(+)*	(+)	+
Cladonia cenotea (Ach.) Schaer.	+		
C. cf. *chlorophaea* (Flörke) Spreng.	+		
C. crispata (Ach.) Flot.	+		
C. cf. *ochrochlora* Flörke	+		
C. squamosa (Scop.) Hoffm.	+		
Graphis scripta (L.) Ach.	+		
Haematomma cismonicum Beltr.	+		
Haematomma sp. *sensu* Brodo 1968	+		
Hypogymnia physodes (L.) Nyl. [= *Parmelia physodes* (L.) Ach.]	+	+	+
H. tubulosa (Schaer.) Hav.	+		
H. vittata (Ach.) Gas. [= *Parmelia vittata* (Ach.) Nyl.]	+	+	
Lecidea albofuscescens Nyl.	+		
L. helvola (Koerb.) Th. Fr.	+		
Lopadium pezizoideum (Ach.) Koerb.	+		
Mycoblastus affinis (Schaer.) Schauer	+		
M. sanguinarius (L.) Th. Fr.	+		
Ochrolechia androgyna (Hoffm.) Arn. s.str.	+		
Parmelia squarrosa Hale [= *P. saxatilis* (L.) Ach. var. *divaricata sensu* Ahti]	+	+	
P. sulcata Tayl.	+	+	
Pertusaria sp.	+		
Platismatia glauca (L.) W. Culb. & C. Culb. [= *Cetraria glauca* (L.) Ach.]	+	+	+
P. norvegica (Lynge) W. Culb. & C. Culb.	+	+	
Protoblastenia cinnabarina (Somm.) Räs.	+		
Ramalina thrausta (Ach.) Nyl.	+		
Sphaerophorus globosus (Huds.) Vain.	+		
Thelotrema lepadinum (Ach.) Ach.		+	
Usnea longissima (L.) Ach.	+		
Usnea sp.			+

Column 1 - Lichens on *Abies* in the newly found Newfoundland locality. Three as yet unidentified crustose species were also present.
Column 2 - Previously reported as growing on *Abies* in Newfoundland by Ahti and Jørgensen (1971).
Column 3 - Lichens associated with *E. pedicellatum* in Europe according to Ahlner (1948), the community being restricted here to *Picea abies* as a host tree.

\+ Present.
(+) Present in similar habitats in the same general area.
* Found near the northeastern shore of Long Pond.

A Cyanophilic lichen with *Scytonema*.
B Cyanophilic lichens with *Nostoc*.
C Lichens containing only a green alga as a phycobiont.

flowering plants *Clintonia borealis* (Ait.) Raf., *Coptis trifolia* (L.) Salisb., *Cornus canadensis* L. and *Gaultheria hispidula* (L.) Muhl. The cyanophilic lichens *Peltigera aphthosa* (L.) Willd., *P. neopolydactyla* (Gyeln.) Gyeln. and *P. polydactyla* (Neck.) Hoffm. s.lat. together with *Cladonia* species (mostly *C. crispata* (Ach.) Flot., *C.* cf. *orchrochlora* Flörke and *C. squamosa* (Scop.) Hoffm.), *Dicranum* mosses (*D. scoparium* Hedw. and *D. fuscescens* Turn.) and *Bazzania trilobata* were forming sleeves around the bases of the trunks. Some of the differences in the composition of the lichen community described from Europe (Col. 3 of Table I) and Newfoundland (Cols. 1 & 2) may well be due to the specific environment induced by the respective host tree.

It is believed that the growth of *E. pedicellatum* on a tree trunk is exceptional since previously the species was found only on rather thin twigs (either dead or alive) on the lower branches of *Picea abies* (L.) Karst. (Ahlner 1948) and *Abies balsamea* (Ahti & Jørgensen 1971; Jørgensen 1972). Our failure to detect the lichen on branches in the newly found locality is interpreted as being due to a severe reduction of the original population by the fire, the exceptional specimen on live bark being better protected from desiccation than thalli growing on twigs. That this specimen did not arrive by a more recent colonization is deduced from the extraordinarily large size of the live thallus and the fact that the latter obviously regenerated from a very old portion still recognizable but darkened and decomposed. The survival of *E. pedicellatum* in a woodlot that had been so close to the fire attests to the ability of this lichen to withstand a few days of SO_2 pollution and smoke released by the fire although the dose appears to have been deleterious. Over 11 km away, the closest village to the east which was not reached by the blaze (Swift Current) had been evacuated during this event for three days because of the massive development of smoke.

Another ecological point of interest is that *E. pedicellatum* obviously does not require a snow cover to survive the winters, as shown by the height above ground at which it was found. According to the Monthly Meteorological Summaries issued by the Department of Environment Canada, winter temperatures at the Sunnyside weather station on the isthmus of Avalon Peninsula (only about 32 km east of Long Pond at 47°51'N and 53°57'W and 46 m above sea level) fall to between -15°C and -28°C during February, the coldest month, when a snow cover may be present or absent.

The lichen community with which *E. pedicellatum* is associated throughout its range (Table I) is a variant of the "Lobarion" growing on coniferous trees. The Lobarion as it occurs on both sides of the Atlantic Ocean outside of the tropics is characterized by the presence of numerous cyanophilic lichens including some of the larger foliose epiphytes found in these regions [*Lobaria scrobiculata, L. quercizans* Michx. or *L. amplissima* (Scop.) Forss., *L. pulmonaria* (L.) Hoffm. and *Pseudocyphellaria crocata* (L.) Vain.]. The typical Lobarion occurs on hardwood trees (*Acer, Betula* and *Populus*) and is usually well developed in the mature mixed forests of eastern Canada and the adjacent United States as far as it has not been eliminated by air pollution (see Maass 1980c with respect to the change in the distribution of *Lobaria pulmonaria*). The variant on coniferous trees (*Abies, Picea, Thuja*) is especially pronounced within the fog belt of Atlantic Canada and not uncommon in the coastal areas of Newfoundland and Nova Scotia. Perhaps the limitation of this variant to cool boreal sites is related to the decreased growth rates of the conifers here, which provide a more slowly expanding bark for the establishment of lichen holdfasts.

The frequent association between *Erioderma* and *Coccocarpia*, observed in the Newfoundland localities of *E. pedicellatum* (Table I), in a habitat of *E. mollissimum*

(Samp.) Du Rietz (visited in the Great Smoky Mountains together with Per Magnus Jørgensen in 1977), and in many tropical sites, is perhaps due to the fact that both of them contain species of the same bluegreen algal genus, *Scytonema,* as their phycobiont. For the de novo formation of thalli of *E. pedicellatum,* a species which lacks vegetative propagules but always produces an abundance of fungal spores, the presence of suitable algal cells in the environment seems necessary. In addition it is astonishing to observe that often several species of *Erioderma* occur together in the same locality (see also Jørgensen 1972; 1979) although most of them show a very sporadic distribution pattern. This indicates the possibility that all members of *Erioderma* as well as *Coccocarpia* may employ the same species of *Scytonema* as a phycobiont. On the basis of metabolic studies discussed by Feige (1978) it seems possible that lichen algae can revert to a free-living state when the lichen association disintegrates. This would make the algae available for incorporation into new lichen thalli. As *Coccocarpia palmicola* forms isidia which function as vegetative propagules, this lichen would seem to be a possible vehicle to spread or maintain a viable population of *Scytonema* for lichenization (e.g. by *E. pedicellatum* spores). It is hoped that this hypothesis of identical phycobionts for *Erioderma* and *Coccocarpia* can be tested by the cultivation of the respective symbionts and a series of recombination experiments.

The discovery that *E. pedicellatum* can also exist under more illuminated conditions might explain the presence of the somewhat photophilous *Erioderma mollissimum* in one of the five packets of *E. pedicellatum* from Campobello Island as identified by Jørgensen (1972). The preference of *E. pedicellatum* for cool, shaded habitats (Ahti & Jørgensen 1971) may simply be an expression of a demand for a high relative humidity. In general, the tropical species of *Erioderma* seem to prefer steep sunlit places in the mountains above 1000 m altitude, where a high relative humidity is maintained by fairly regular afternoon rains, by dew at night and a rather dense to half-open scrub vegetation which helps to keep down the evaporation. Perhaps the only exception to this rule is our recent discovery of a presumably new species of *Erioderma** in the Blue Mountains of Jamaica which occurs in very deep shade on the mossy trunks of the elfin forest above 2000 m altitude, preferably on extremely steep slopes with eastern to northeastern exposures where winter temperatures sometimes approach the freezing point. Thus *E. pedicellatum* does not stand alone with its reported ability to live in dark forests. Moreover, the new species may turn out to be an extreme exponent of such an adaptation, as it seems to be entirely dependent on extremely low light intensities for growth.

Observations in the Type Locality

A search for *E. pedicellatum* in the type locality during repeated visits to Campobello Island has been unsuccessful. An assessment of the continued presence of *E. pedicellatum* on this island is made difficult by the fact that no precise information was given except "Campobello". Other cryptogamic collections made by Farlow in July 1902 on the island (all at FH) include *Sphagnum wulfianum* Girg. and the lichens *Alectoria sarmentosa* (Ach.) Ach. subsp. *sarmentosa, Bryoria friabilis* Brodo & D. Hawksw. on fences in association with *B. fuscescens* (Gyeln.) Brodo & D. Hawksw. var. *positiva* (Gyeln.) Brodo & D. Hawksw. and *B. trichodes* (Michx.) Brodo & D. Hawksw. subsp. *americana* (Mot.) Brodo & D. Hawksw. (see Brodo & Hawksworth 1977, who refer to the collector of these lichens as unknown; the handwriting on the labels has now been identified as belonging to Farlow), *Catillaria* sp. (on the bark of

* to be described by Dan Nilson of the University of Göteborg.

Fagus, det. Imshaug 1951) and *Verrucaria ceuthocarpa* Wahlenb. ex Ach. A precise locality (Schooner Cove) has been given only for the *Verrucaria*. The collecting dates are not known although in Farlow's diary for July 1902 at least his visits to Bridgeport Harbor (20 July) and Middle Ground (28 July), both presumably in the U.S.A., have been mentioned. If *E. pedicellatum* was gathered near Schooner Cove, the chances are that its original habitat was destroyed by fires (Figs 6, 7). However, at least one of the more typical associates of *E. pedicellatum*, *Thelotrema lepadinum* (Ach.) Ach., was recently found in a *Thuja* swamp southwest of Schooner Cove (leg. W. Maass, 5 Nov. 1979, CANL). Other possible areas for the type locality are in the southern part of the island, namely between Ragged Point and Great Duck Pond (near the bog around Lost Pond), on the southeastern and northern slopes of Fox Hill (above the edges of the bogs there) and in swampy woodlands near Adam's Pond southeast of Friar Bay (Fig 7). Of these places, the only ones outside the established forest fire areas (Fig 6) and not surveyed as yet by the present author are those around Fox Hill. Perhaps here lies the hope for rediscovering both *E. pedicellatum* and *E. mollissimum*, the latter not yet having been found elsewhere in Canada or in the United States outside of the Great Smoky Mountains. In none of the locations recently studied on the island were any cyanophilic lichens seen on *Abies*, although *Lobaria scrobiculata* (very rare, near Schooner Cove and Herring Bay Head), *L. pulmonaria* (abundant only on poplar southwest of Little Whale Cove) and *L. quercizans* occasionally occur on hardwood trees. Nor was *Sphagnum wulfianum* relocated, despite a meticulous search for it. In eastern Canada this species is always found in mixed coniferous woods containing either *Abies* or *Thuja* or both, and it is quite possible that Farlow collected it in the same locality as the *Eriodermae*.

Factors Adversely Affecting the Distribution and Survival of E. pedicellatum in Newfoundland and New Brunswick

Biological factors, logging, forest fires, pollution and land development may be singled out as hazards that have been shown or are likely to affect the survival of *E. pedicellatum* in North America.

Diseases of the Host Tree and other Biological Factors

The fate of *E. pedicellatum* in Eastern North America will depend in part on the ability of its host species, the balsam fir (*Abies balsamea*), to withstand the 2-pronged attack by the spruce budworm (*Choristoneura fumiferana* Clem.) and wood-rotting fungi, most notably *Stereum sanguinolentum* (Fr.) Fr. (Basham et al. 1953). Already many of the mature stands of *Abies balsamea* have been severely decimated by these infestations. The damage along the Atlantic coast of Nova Scotia is not quite as devastating as in some of the more remote areas including parts of the Cape Breton Highlands and the isthmus connecting Nova Scotia with New Brunswick (Kettela et al. 1977). It may be assumed that this sensitivity of the host species to forest pathogens has brought about not only the deterioration of local habitats but also a change in the macrodistribution of *E. pedicellatum*.

Often in conjunction with the microclimatic habitat conditions, other biological factors such as competition by more vigorously spreading lichens and mosses as well as feeding by numerous invertebrate and vertebrate animals will also help to determine the limits within which a lichen can maintain its populations. Mites, insects (including their larvae, e.g. caterpillars) and snails may take a toll on particular lichens depending on their grazing habits and biology, even though in some cases they may contribute to the spreading of the lichen ascospores (Gerson & Seaward 1977). In the Atlantic Provinces of Canada, insects belonging to the genus *Epizeuxis*

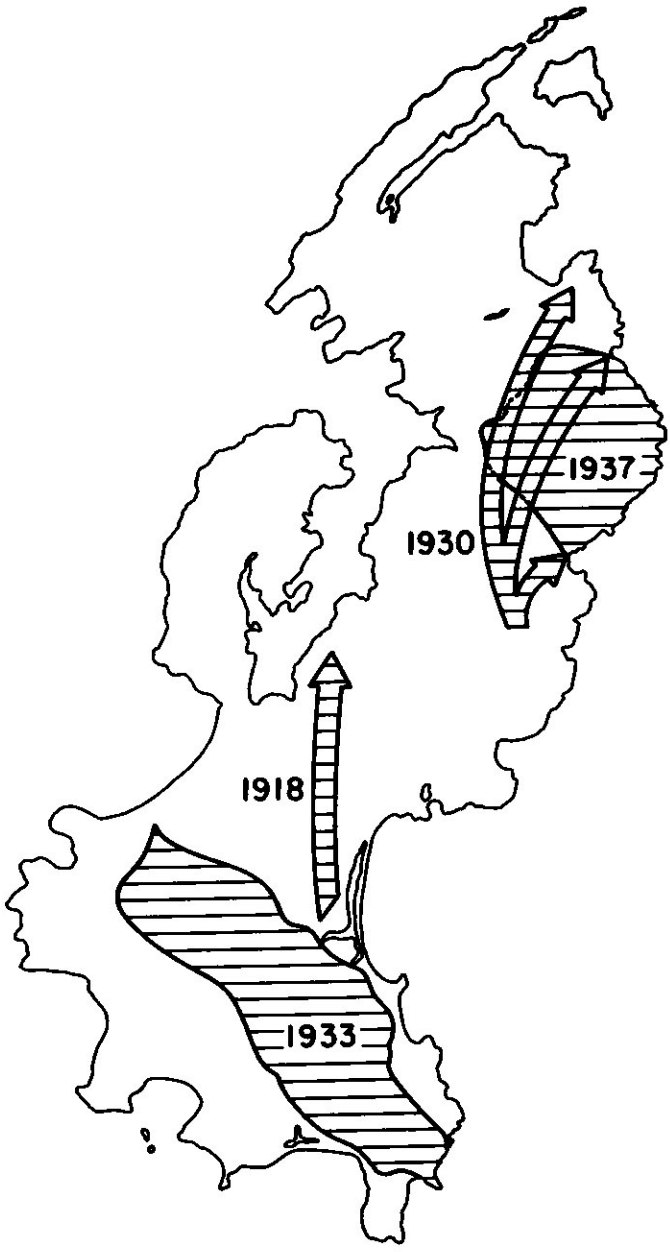


Fig 6. The larger fires on Campobello Island after 1905. The fires of 1933 and 1937 are documented by fire reports. The fire of 1918 started near the southern end of Lake Glensevern and jumped the old roads to Herring Cove and Wilson's Beach on its way to and along Harbour de Loutre. It is mentioned in a newspaper article published in the *St. John Globe* on June 6, 1918. The fire of 1930 started around May 6 near Pete's Hill and Pete's Meadow (Meadow Ice Pond), and burned through to Schooner Cove, White Rocks and Mill Cove. It was extinguished on May 10 as described in an excerpt from Deer Island dated May 12 and published in the *St. Croix Curier* of May 15, 1930.

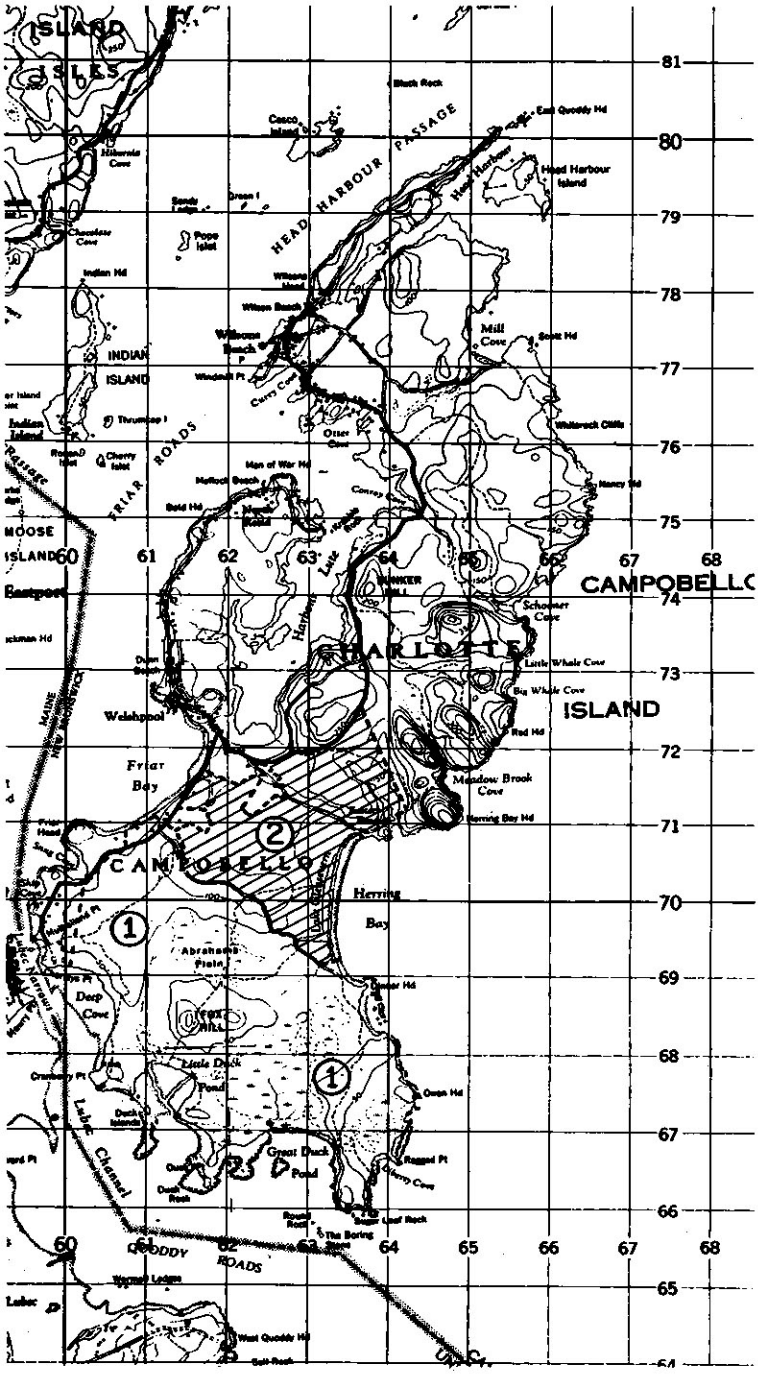


Fig 7. Topographic map of Campobello Island (reproduced from Campobello, National Topographic Series sheet 21 B/15 (west), edition 2 ASE, series A 791, with permission of the Department of Energy, Mines and Resources, Ottawa); the grid marks are 1-km^2 blocks. (1) Roosevelt Campobello International Park and Natural Area. (2) Campobello Provincial Park and Golf Lodge.

have been shown to be associated with foliose lichens on coniferous trees (Forbes 1954; Ferguson 1955). Other animals such as birds and porcupines, the latter specialized as bark eaters on coniferous trees, can damage lichens either mechanically or by their biological waste materials. Lichens in the breast-height community on the bark and twigs of fir trees may suffer also from the spring browsing of ruminant animals including moose and caribou (Peterson 1955; see also Brodo & Hawksworth 1977).

Logging

Extensive logging operations have been carried out on Campobello Island between about 1910 and 1970, first by the East Coast Lumber Company and then, after 1950, to some extent by the Dead River Company (with offices in Bangor, Me., and Fredericton, N.B.). Besides the removal of pulpwood (spruce and fir) from the land holdings of these companies (Fig 8), commercial wood has also been sold from the rest of the privately owned land, and traditionally the islanders have been cutting hardwood (birch, poplar and maple) as firewood for their own use.

Logging is also the way of life in many parts of Newfoundland although not conspicuously on or near the Burin Peninsula which largely consists of barren country. On the other hand, due to the strong winds that sometimes blow in this district, fires can become extremely serious. It may be assumed that fires have shaped the barrens which in prehistoric times must have been covered by coniferous forests surrounding all the peatlands and lakes.

Forest Fires

In the two North American stations from which *E. pedicellatum* is known, the incidence of fires has been high. The major fires on Campobello Island after 1905 have been plotted in Figure 6. It is not surprising that 1 or 2 of the large fires had started between Friar Bay and Lake Glensevern since, on this property (formerly belonging to the late Mrs. Adams), there used to be a large blueberry heath which was deliberately set afire from time to time to increase the yield of blueberries. These fires would sometimes burn out of control. Even though the exact damage from the fires of 1918 and 1930 is not on record it can be assumed that more than half of the island was struck by fire during the past 75 years. This is in sharp contrast with the mean annual burn rate of 0.13% reported by Wein and Moore (1977) for the entire southern coastal spruce-fir zone in New Brunswick within which Campobello Island lies. These authors believe that, prehistorically, this vegetation zone represents the area of lowest fire frequency in New Brunswick as it is associated with summer fog and low lightning frequency. Their data also show, however, that the more heavily populated areas in the western part of this zone are exceptional in this respect. The population of Campobello Island has been relatively constant during the past 100 years with between 1000 and 1250 inhabitants.

In Newfoundland, at least one enormous fire has swept across the area shown in Figure 1. It started on 1 Aug. 1961 near Dunn's River in the Terrenceville area and travelled in a northeasterly direction to and beyond the woodlands north of Long Pond. After reaching the Piper's Hole River Valley, the fire swung back and destroyed a significant portion of mature fir forest before it was extinguished (20 Sept. 1961). Fortunately, a few small pockets of this forest were left intact, particularly at the edges of larger bodies of water, such as on Long Pond and islands therein.

Pollution

Because *E.pedicellatum* contains a bluegreen alga as a symbiont and is thereby

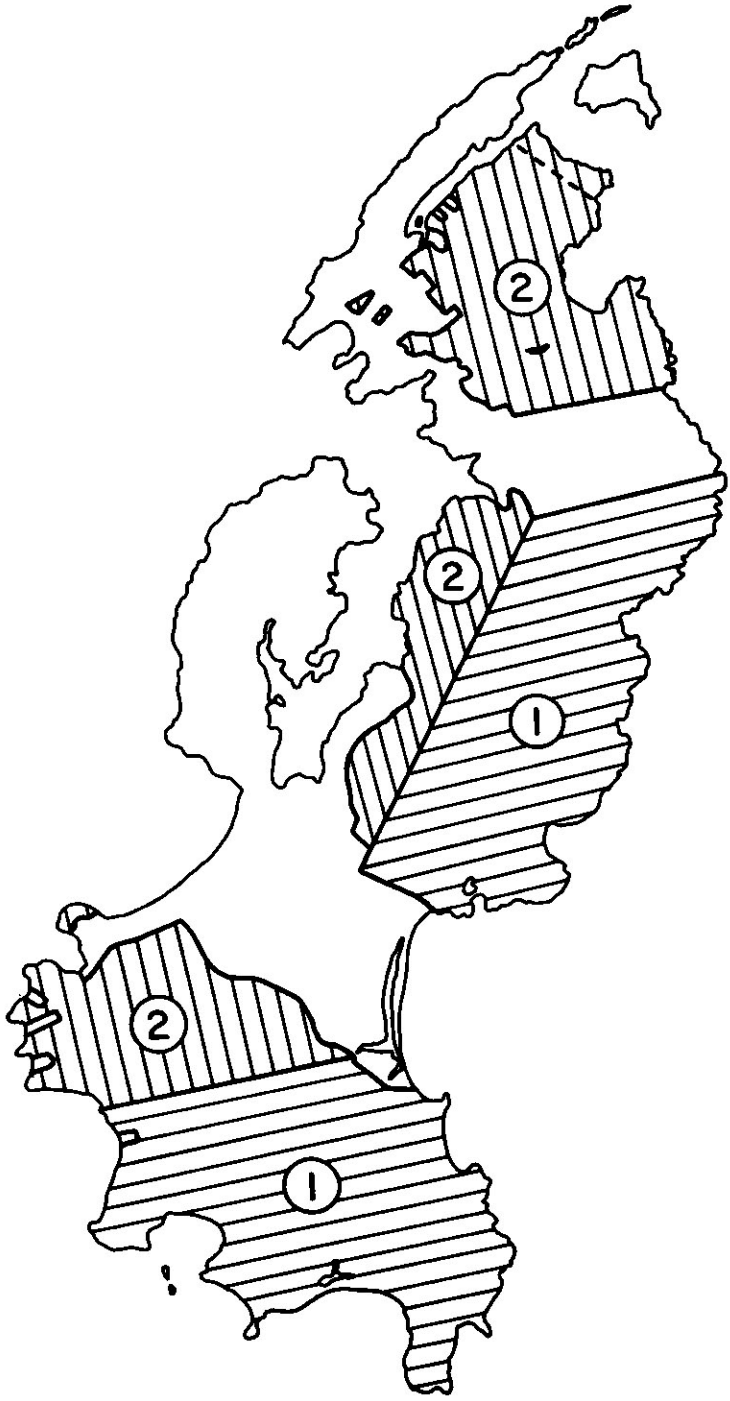


Fig 8. Campobello Island properties on which logging operations were carried out between about 1910 and 1970. Forested lands acquired by the Dead River Company soon after 1950 are shown by hatching. (1) Previously owned by the East Coast Lumber Company. (2) Previously owned by the Campobello Company.

capable of fixing atmospheric nitrogen, it may be assumed that it is highly sensitive to air pollution like other cyanophilic lichens. This predisposition is due to the inhibition of the nitrogenase activity of the phycobiont by SO_2 (Denison et al. 1976) combined with the preference of cyanophilic lichens for humid habitats. To illustrate this, none of the urban studies on air pollution and lichens that have been carried out in Halifax (Brawn & Ogden 1977), New York including Long Island (Brodo 1966), Montreal (LeBlanc & De Sloover 1970), Ottawa (Stephenson & Merriam 1975) and Winnipeg (Stringer & Stringer 1974) lists any cyanophilic lichens. In a taxonomic paper on Long Island, Brodo (1968) listed the following cyanophilic lichens as having occurred in the western half of Long Island adjacent to New York City : *Collema subfurvum* (Müll. Arg.) Degel., *Leptogium cyanescens* (Ach.) Körb., *Lobaria pulmonaria, L. quercizans, Peltigera aphthosa* var. *variolosa* (Mass.) Thoms., *P. canina* (L.) Willd. and *P. polydactyla*. However, *P. canina* was last seen in 1935 and all of the others were 19th century records (from 1866 or 1867). According to specimens at the Nova Scotia Museum of Science (NSPM) several cyanophilic lichens were collected along the Northwest Arm in Halifax in 1880 by A. H. MacKay (*Peltigera canina*, # 202; *Nephroma helveticum* Ach., # 203-B; *N. resupinatum* (L.) Ach., # 204-B; and *Leptogium cyanescens*, # 205-B) but none of these can now be found in the immediate vicinity of Halifax. Perhaps this "poliphobic"* behaviour of cyanophilic lichens can be blamed in part on the "desert effect" of cities (LeBlanc & Rao 1973), resulting in a slightly warmer and drier environment, but not in the cases of Halifax and New York where there is a strong sea climate. Similarly, in those few cases where cyanophilic lichens have been observed around mining areas (LeBlanc et al. 1974) or paper mills (Newberry 1974), they occurred only sporadically at great distances from the center of pollution (*Lobaria pulmonaria* 20 km and *L. quercizans* 13 km away, respectively). Cyanophiles are also suspected to be sensitive towards other types of pollution, since they were absent from an area of about 250 km^2 around the aluminum smelter at Arvida, Que., which emits hydrogen fluoride pollution (LeBlanc et al. 1972), and since Nash (1975) failed to report their presence in the mountainous woodlands near the zinc factory at Palmerston, Penn. Wielgolaski (1975) even reported on some experimental evidence according to which the cyanophilic lichens may be strongly reduced in those rural areas which suffer from strong, mostly global pollution, such as in southern Norway. In good agreement with this are the observations by Jørgensen (1978) on a general decline of members of Pannariaceae in Västergötland, Sweden, although changes of habitat conditions due to the partial removal of forests have been shown by him to be also very important. For these reasons it is not improbable that *E. pedicellatum* has already suffered from a similar deterioration of the air quality in North America.

Little is known of the chemical effect of the spraying of the woodlands against the spruce budworm upon the populations of lichens on balsam firs. In some forests of southern New Brunswick that have been treated with aerosol sprays containing pesticides a spotty discoloration of the foliose macrolichens can be observed. The harmful agents may be the pesticides themselves or the emulsifiers used for their dispersal in tiny droplets. The following pesticides have been applied to the forests of New Brunswick on a large scale: DDT (between 1952 and 1968), fenitrothion (from 1968 until now) and (in 1979) aminocarb (Matacil). On a more or less experimental scale, phosphamidone, carbaryl (Sevin) and *Bacillus thuringiensis* (BT) have also been tried. In Nova Scotia only BT has been used, in Cumberland County and the Cape Breton Highlands in 1979. Newfoundland has seen the application of

*Derived from the Greek words πόλις (polis = city) and φοβός (phobos = avoidance).

pesticides in 2 spray programs; one was directed against the hemlock looper (*Lambdina fiscellaria* Gn. f. *fiscellaria* Gn.) and employed fenitrothion (between 1968 and 1972), and a more recent one against the spruce budworm. In connection with the latter, the following compounds were tried in 1977 over a total of about 81,000 ha: fenitrothion, Matacil, acephate (Orthene) and BT. The following year saw the application of only Matacil over almost 810,000 ha, and in 1979 6000 ha were sprayed with BT. The relevance of these spray programs for the survival of *E. pedicellatum* is the possibility that this lichen is sensitive to some of the sprays and the fact that one of the sprayed areas (Bonavista Peninsula) was less than 65 km away from Long Pond. Sprays delivered from planes may be carried as far as that by winds. A general study of the effect of these biological control agents upon tree-dwelling lichens and their symbionts is needed, not only to establish any possible ranking in their sensitivities but also to investigate the potential of lichens in the biological degradation or inactivation of these pesticides which are often unpredictably harmful to both animals and man. So far, only the breakdown of a chlorinated biphenyl derivative has been investigated in lichens (Maass et al. 1976), and numerous parallel studies of the metabolism of this simple model of an industrial pollutant have shown that the pathways for the biological breakdown of this and similar compounds are probably no different in lichens than in other organisms. No information exists on the effect of BT upon lichens although much work has been carried out on the possible side effects of this bacterium in other living systems. In particular BT has been shown to have chitinolytic activity (Smirnoff & Valero 1977). This property of BT could result in the degradation of the cell walls of the mycobiont or at least interfere with its chitin metabolism. Such events might in turn upset the precarious balance of the symbionts and destroy the integrity of the lichen.

Land Development

Land development has not as yet been significant in the areas under discussion except for the building of roads and power lines and, on Campobello Island, the establishment of a golf course, campground, and a gravel field operation. In fact, the conversion of the southern part of Campobello Island into parks ("Roosevelt Campobello International Park and Natural Area" and "Campobello Provincial Park", Fig. 7) will protect these lands from commercial over-exploitation. However, the forested and rugged eastern coastal strip outside of these parklands is not presently being conserved although it is among the most spectacular in the Maritimes. According to a development plan of 1970 made for the Dead River Company it has been designated for possible future cottage lot development and a study of its lichen flora is a matter of urgency.

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Maps in Figures 1 and 7 Her Majesty the Queen in Right of Canada, 1971 and 1954 respectively. Reproduced from maps of the National Topographic System with permission of the Department of Energy, Mines and Resources, Ottawa.

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