C. Wetmore

LICHENS AND AIR QUALITY in ISLE ROYALE NATIONAL PARK

FINAL REPORT

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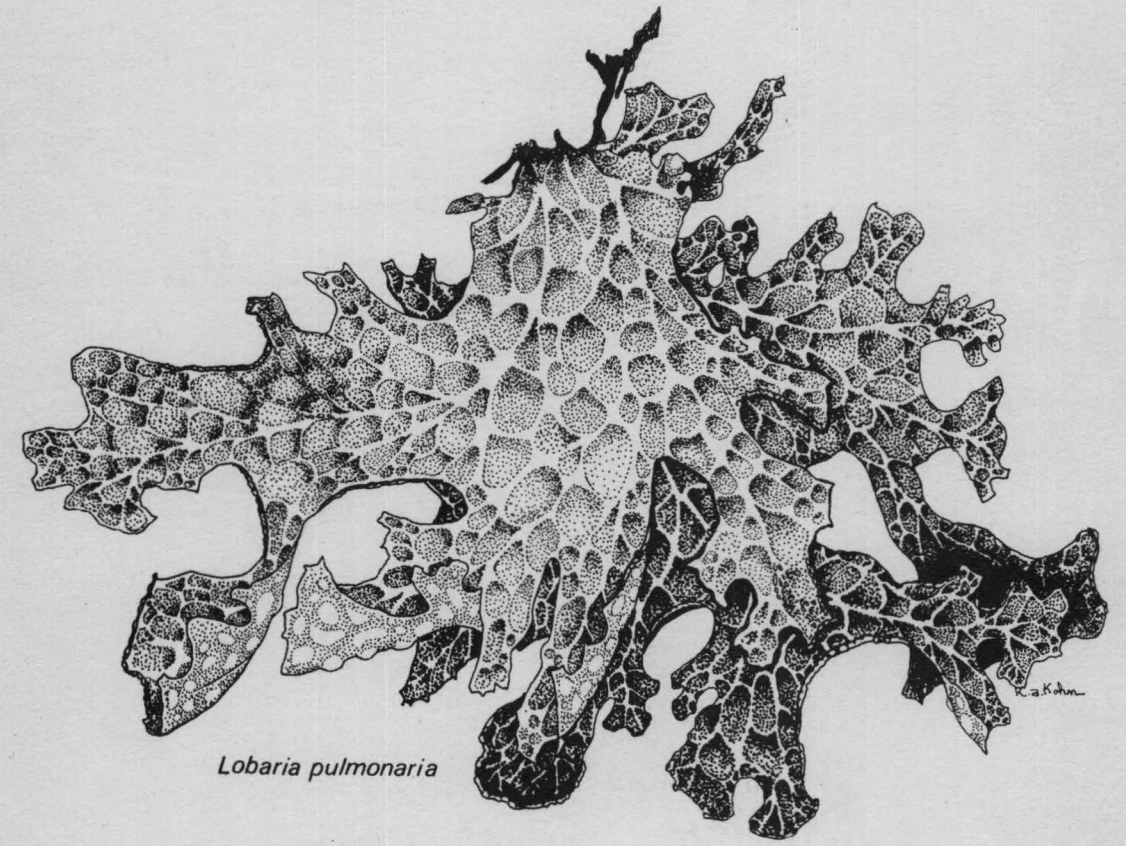

Lobaria pulmonaria

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LICHENS AND AIR QUALITY
IN
ISLE ROYALE NATIONAL PARK

Final Report

National Park Service
Contract CX 0001-2-0034

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LICHENS OF ISLE ROYALE NATIONAL PARK

PREFACE

Under a contract from the National Park Service (USDI CX 0001-2-0034) a lichen study was to be performed in Isle Royale National Park. This study was to survey the lichens of the park, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. This study is to establish baseline data for future restudy and determine the presence of any air quality problems as might be shown by the lichens at the time of the study. All work was done at the University of Minnesota with frequent consultation with Dr. James Bennett, NPS-AIR, Denver and with personnel in the park.

The park personnel have been very helpful during the field work which has contributed significantly to the success of the project. The study was made possible by funds from the National Park Service. The assistance of all of these are gratefully acknowledged. Martyn Dibben and Mason Hale helped with identifications of some problem specimens and their assistance is acknowledged.

INTRODUCTION

Lichens are composite plants composed of two different types of organisms. The lichen plant body (thallus) is made of fungi and algae living together in a symbiotic arrangement in which both partners are benefited and the composite plant body can grow in places where neither component could live alone. The thallus has no protective layer on the outside, such as the epidermis of a leaf, so the air in the thallus has free exchange with the atmosphere. Lichens are slow growing (a few millimeters per year) and remain alive for many years and so must have a habitat that is relatively undisturbed in order to survive. Lichens vary greatly in their ecological requirements but almost all of them can grow in places that only receive periodic moisture. When moisture is lacking they go dormant until the next rain or dew-fall. Some species can grow in habitats with very infrequent occurrences of moisture while others need high humidity and frequent wetting in order to survive. This difference in moisture requirements is very important in the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Some are damaged or killed by levels of sulfur dioxide as low as 13 ug/cubic meter (annual average) or by nitrogen oxides at 3834-7668 ug/cubic meter or by other strongly oxidizing compounds such as ozone. Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300 ug/cubic meter. The algae of the

thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae, which quickly leads to the death of the lichen. Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry. The nature of the substrate is also important in determining the sensitivity to sulfur dioxide since substrates with high pH seem to buffer the fallout and permit the persistence of more sensitive species than one would expect. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the levels in the substrate and the air and, since lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of the thallus of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of the sub-lethal but elevated levels in the air.

Isle Royale National Park has over 571,700 acres and includes many small islands and bays. The main island is about 45 miles long and 5 miles wide and has numerous lakes between the ridges that run parallel to the length of the island in a

northeast to southwest direction. The elevation ranges from 601 feet at the shore of Lake Superior to almost 1400 feet. Mean annual precipitation is about 25 inches but the lower elevations near Lake Superior are frequently enclosed in fog. The temperatures near Lake Superior are much cooler than on the ridges. Most of the rocks on Isle Royale are basaltic and conglomerate but in some locations they give a weak HCl+ reaction.

Most of the northeast end of the main island has been burned several times in recent history. The northwest end of the island from Lake Desor west probably was not burned during the early mining days around 1900. Large fires in 1936 burned most of the island from Lake Desor northeast to Rock Harbor. A portion of this near Siskiwit Lake was burned again in 1948.

Most of Isle Royale is coniferous forest in various stages of succession. The main exception is the unburned southwestern end which is old age sugar maple forest (Acer saccharum). The northeastern part of the island has white birch (Betula papyrifera) and quaking aspen (Populus tremuloides) on the ridges with some remaining rock outcrops and areas of young sugar maple. The valleys and lakeshores have balsam fir (Abies balsamea) and white or black spruce (Picea glauca and Picea mariana) with Thuja bogs (Thuja occidentalis) in the wetter areas. The off shore islands are mainly spruce and fir with mountain ash (Sorbus americana) and extensive rock shore communities.

The first lichens from Isle Royale were reported by Holt

(1908) but the University of Michigan Botanical Survey in 1930 produced the first complete list of lichens (Hedrick & Lowe, 1936) based on the collections of J. Lowe. Harris (1978) notes some lichens from the park based on reidentification of the Lowe collections in the University of Michigan herbarium. The present author has collected lichens on Isle Royale at various times since 1957 but few of these have been published. In the herbarium of the University of Minnesota are some lichens collected by W. S. Cooper during his ecological studies there but a complete list of his collections has never been published.

METHODS

Two months were spent in the park collecting for this project during the summers of 1983 and 1984. Seventy two localities were visited and 5246 collections were made (Fig. 1). A complete list of collection localities is given in Appendix I. Localities for collecting were selected first to give a general coverage of the park, second, to sample all vegetational types, third, to be in localities that should be rich in lichens. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens.

Identifications were carried out at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography for identification of the lichen substances where necessary. The original packet of each collection has been deposited in the University of Minnesota Herbarium and a representative set of duplicates will be sent to the park and to the Smithsonian Institution. All specimens deposited at the University of Minnesota are being entered into the computerized data base maintained there. Lists of species found at each locality are available from this data base at any time on request.

LICHEN FLORA

The following list of lichens is based on my collections for this project, my older collections now in the University of Minnesota herbarium and those reported in the literature. Because of the reliability of the identifications of Harris and the completeness of my collections the specimens in the University of Michigan have not been rechecked. This list includes 450 species collected for this study and 32 additional species not found in this study but previously reported and likely to occur in the park (enclosed in brackets). Species reported only by Hedrick & Lowe but not by Harris and not found in this study are probably misidentifications and are not listed. There are an additional 37 unidentified species. In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983).:

S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50ug per cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug per cubic meter.

X = new record

X Acarospora americana Magn.
Acarospora badiofusca (Nyl.) Th. Fr. Also reported by Harris, 1978.
X Acarospora fuscata (Nyl.) Arn.
Acarospora glaucocarpa (Wahlenb. in Ach.) Körb. Also reported by Hedrick & Lowe, 1936.
1 additional unidentified species of Acarospora
Acrocordia cavata (Ach.) Harris in Vezda Also reported by Harris, 1973.
X Anaptychia palmulata (Michx.) Vain.
S-I Anaptychia setifera Räs. Also reported by Hedrick & Lowe, 1936.
X Anisomeridium juistense (Erichs.) R. Harris
X Arthonia caesia (Flot.) Körb.
X Arthonia didyma Körb.
X Arthonia dispersa (Schrad.) Nyl.
X Arthonia fuliginosa (Schaer.) Flot.
X Arthonia intexta Almq.
X Arthonia patellulata Nyl.
X Arthonia punctiformis Ach.
I Arthonia radiata (Pers.) Ach. Also reported by Hedrick & Lowe, 1936.
1 additional unidentified species of Arthonia
[Arthopyrenia punctiformis Mass. Reported by Hedrick & Lowe, 1936,Harris, 1973.]
Aspicilia alphoplaca (Wahlenb. in Ach.) Poelt & Leuck. Also reported by Harris, 1978.
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
Aspicilia cinerea (L.) Körb. Also reported by Hedrick & Lowe, 1936.
X Aspicilia contorta (Hoffm.) Kremp.
1 additional unidentified species of Aspicilia
Bacidia bagliettoana (Mass. & DeNot. in Mass.) Jatta Also reported by Hedrick & Lowe, 1936, Thomson, 1951.
X I Bacidia chlorococca (Stenh.) Lett.
X Bacidia epixanthoides (Nyl.) Lett.
Bacidia laurocerasi (Del. ex Duby) Ozenda & Clauz. Also reported by Hedrick & Lowe, 1936.

x Bacidia obscurata (Sommerf.) Zahlbr.
[Bacidia rosella (Pers.) DeNot. Collected by Wetmore in 1980.
I Bacidia rubella (Hoffm.) Mass. Also reported by Hedrick & Lowe, 1936.
Bacidia sabuletorum (Schreb.) Lett. Also reported by Hedrick & Lowe, 1936.
Bacidia schweinitzii (Tuck.) Schneid. Also reported by Hedrick & Lowe, 1936.
Bacidia sphaeroides (Dicks.) Zahlbr. Also reported by Hedrick & Lowe, 1936.
x Bacidia umbrina (Ach.) Bausch
2 additional unidentified species of Bacidia
Baeomyces rufus (Huds.) Rebent. Also reported by Hedrick & Lowe, 1936, Thomson, 1967
I Bryoria capillaris (Ach.) Brodo & Hawksw. Also reported by Brodo & Hawksworth, 1977, Harris, 1978.
Bryoria chalybeiformis (L.) Brodo & Hawksw. Also reported by Brodo & Hawksworth, 1977, Harris, 1978.
S Bryoria furcellata (Fr.) Brodo & Hawksw. Also reported by Hedrick & Lowe, 1936.
I Bryoria fuscescens (Gyeln.) Brodo & Hawksw.
Bryoria nadvornikiana (Gyeln.) Brodo & Hawksw. Also reported by Harris, 1978.
S Bryoria trichodes (Michx.) Brodo & Hawksw. Also reported by Hedrick & Lowe, 1936, Brodo & Hawksworth, 1977.
I [Buellia alboatra (Hoffm.) Th. Fr. Reported by Imshaug, 1951, Harris, 1978.]
x Buellia arnoldii Serv.
Buellia disciformis (Fr.) Mudd Also reported by Hedrick & Lowe, 1936, Imshaug, 1951.
x Buellia nivalis (Bagl. & Car.) Hertel ex Hafel.
T Buellia punctata (Hoffm.) Mass. Also reported by Hedrick & Lowe, 1936, Imshaug, 1951.
Buellia schaereri DeNot.
I Buellia stillingiana J. Stein. Also reported by Imshaug, 1951.
x Buellia turgescens Tuck.
2 additional unidentified species of Buellia
x Calicium abietinum Pers.
[Calicium glaucellum Ach. Reported by Tibell, 1975, Harris, 1978.]
[Calicium parvum Tibell Reported by Tibell, 1975.]
Calicium salicinum Pers. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.
Calicium trabinellum (Ach.) Ach. Also reported by Tibell, 1975.
x Caloplaca arenaria (Pers.) Müll. Arg.
S-I Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr. Also reported by Hedrick & Lowe, 1936.
Caloplaca chrysophthalma Degel.
Caloplaca citrina (Hoffm.) Th. Fr. Also reported by Hedrick & Lowe, 1936.
[Caloplaca epithallina Lynge Collected by Wetmore,

1980.]

x S Caloplaca flavorubescens (Huds.) Laund.

x Caloplaca flavovirescens (Wulf.) Dalla Torre & Sarnth.

I Caloplaca holocarpa (Hoffm.) Wade Also reported by Hedrick & Lowe, 1936.

[Caloplaca obliterans (Nyl.) Blomb. & Forss. Reported by Harris, 1978.] ?

[Caloplaca sideritis (Tuck.) Zahlbr. Reported by Hedrick & Lowe, 1936, Harris, 1978.]

x Caloplaca sinapisperma (Lam. & DC.) Mah. & Gill.

Caloplaca ulmorum (Fink) Fink Also reported by Hedrick & Lowe, 1936, Rudolph, 1955.

x I-T Caloplaca vitellinula (Nyl.) Oliv.

2 additional unidentified species of Caloplaca

S-I Candelaria concolor (Dicks.) B. Stein Also reported by Hedrick & Lowe, 1936.

Candelariella aurella (Hoffm.) Zahlbr. Also reported by Hedrick & Lowe, 1936.

Candelariella efflorescens Harris & Buck Also reported by Harris & Buck, 1978.

I Candelariella vitellina (Hoffm.) Müll. Arg. Also reported by Hedrick & Lowe, 1936.

x S-I Candelariella xanthostigma (Ach.) Lett.

Catillaria atropurpurea (Schaer.) Th. Fr. Also reported by Hedrick & Lowe, 1936.

S Catillaria griffithii (Sm.) Malme Also reported by Harris, 1978.

Cetraria aurescens Tuck. Also reported by Hedrick & Lowe, 1936.

x Cetraria cucullata (Bell.) Ach.

Cetraria ericetorum Opiz. Also reported by Fink, 1919, Kärnefelt, 1979.

x Cetraria fendleri (Nyl.) Tuck.

x Cetraria halei W. Culb. & C. Culb.

Cetraria hepatizon (Ach.) Vain. Also reported by Hedrick & Lowe, 1936, Harris, 1978, Kärnefelt, 1979 (map).

Cetraria islandica (L.) Ach. Also reported by Harris, 1978.

x Cetraria oakesiana Tuck.

x I Cetraria orbata (Nyl.) Fink

I Cetraria pinastri (Scop.) S. Gray Also reported by Hedrick & Lowe, 1936.

I Cetraria sepincola (Ehrh.) Ach. Also reported by Hedrick & Lowe, 1936.

Cetrelia chicitae (W. Culb.) W. Culb. & C. Culb. Also reported by Culberson, 1965.

Cetrelia olivetorum (Nyl.) W. Culb. & C. Culb. Also reported by Culberson, 1962, Culberson & Culberson, 1968. 1958,

Chaenotheca brunneola (Ach.) Müll. Arg. Also reported by Tibell, 1975.

Chaenotheca chrysocephala (Turn. ex Ach.) Th. Fr. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.

[Chaenotheca cinerea (Pers.) Tibell Reported by Tibell,

1975, Harris, 1978.]

I Chaenotheca ferruginea (Turn. & Sm.) Mig. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.

Chaenotheca hispidula (Ach.) Zahlbr. Also reported by Tibell, 1975.

Chaenotheca laevigata Nadv. Also reported by Tibell, 1975.

Chaenotheca stemonea (Ach.) Müll. Arg. Also reported by Tibell, 1975.

Chaenotheca trichialis (Ach.) Th. Fr. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.

Chaenotheca xyloxena Nadv. Also reported by Tibell, 1975.

1 additional unidentified species of Chaenotheca

Chaenothecopsis consociata (Nädv.) A. Schmidt Also reported by Tibell, 1975, Harris, 1978.

Chaenothecopsis debilis (Turn. & Borr.) Tibell Also reported by Tibell, 1975, Harris, 1978.

Chaenothecopsis lignicola (Nadv.) A. Schmidt Also reported by Tibell, 1975, Harris, 1978.

Chaenothecopsis rubescens Vain. Also reported by Tibell, 1975, Harris, 1978.

Chaenothecopsis subpusilla (Kremp.) A. Schmidt Also reported by Tibell, 1975.

Chaenothecopsis viridialba (Kremp.) A. Schmidt Also reported by Tibell, 1975.

Chaenothecopsis viridireagens (Nadv.) Schmidt Also reported by Tibell, 1975, Harris, 1978.

✗ I Chrysothrix candelaris (L.) Laund.

Cladina arbuscula (Wallr.) Hale & W. Culb. Also reported by Hedrick & Lowe, 1936.

✗ Cladina mitis (Sandst.) Hustich

Cladina rangiferina (L.) Nyl. Also reported by Holt, 1908, Hedrick & Lowe, 1936.

Cladina stellaris (Opiz) Brodo Also reported by Holt, 1908, Hedrick & Lowe, 1936.

✗ Cladina stygia (Fr.) Ahti

✗ Cladonia acuminata (Ach.) Norrl.

Cladonia amaurocraea (Flörke) Schaer. Also reported by Holt, 1908, Hedrick & Lowe, 1936.

Cladonia bacillaris Nyl. Also reported by Hedrick & Lowe, 1936.

✗ Cladonia bacilliformis (Nyl.) Gluck

Cladonia botrytes (Hag.) Willd. Also reported by Hedrick & Lowe, 1936.

Cladonia cariosa (Ach.) Spreng. Also reported by Harris, 1975.

Cladonia cenotea (Ach.) Schaer. Also reported by Hedrick & Lowe, 1936.

Cladonia chlorophaea (Flörke ex Somm.) Spreng. Also reported by Hedrick & Lowe, 1936.

Cladonia coccifera (L.) Willd. Also reported by Hedrick & Lowe, 1936, Harris, 1978.

I Cladonia coniocraea (Flörke) Spreng. Also reported by Holt, 1908, Hedrick & Lowe, 1936.

Cladonia cornuta (L.) Hoffm. Also reported by Hedrick &

Lowe, 1936.
Cladonia crispata (Ach.) Flot. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
I Cladonia cristatella Tuck. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
[Cladonia cryptochlorophaea Asah. Collected by Wetmore in 1980].
Cladonia cyanipes Sommerf. Also reported by Harris, 1978.
Cladonia decorticata (Flörke) Spreng. Also reported by Hedrick & Lowe, 1936.
Cladonia deformis (L.) Hoffm. Also reported by Hedrick & Lowe, 1936.
Cladonia digitata (L.) Hoffm. Also reported by Hedrick & Lowe, 1936.
S-I Cladonia fimbriata (L.) Fr. Also reported by Hedrick & Lowe, 1936.
Cladonia floerkeana (Fr.) Flörke Also reported by Hedrick & Lowe, 1936.
Cladonia furcata (Huds.) Schrad. Also reported by Hedrick & Lowe, 1936.
Cladonia gracilis (L.) Willd. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
✗ Cladonia grayi Merr. & Sandst.
✗ Cladonia maxima (Asah.) Ahti
✗ Cladonia merochlorophaea Asah.
Cladonia multiformis Merr. Also reported by Hedrick & Lowe, 1936.
[Cladonia norrlinii Vain. Collected by Wetmore in 1980].
Cladonia parasitica (Hoffm.) Hoffm. Also reported by Hedrick & Lowe, 1936.
Cladonia phyllophora Ehrh. ex Hoffm. Also reported by Hedrick & Lowe, 1936.
Cladonia pleurota (Flörke) Schaer. Also reported by Hedrick & Lowe, 1936.
Cladonia pseudorangiformis Asah. Also reported by Harris, 1978., Evans 1955
Cladonia pyxidata (L.) Hoffm. Also reported by Hedrick & Lowe, 1936.
Cladonia rei Schaer. Also reported by Hedrick & Lowe, 1936.
Cladonia scabriuscula (Del. ex Duby) Nyl. Also reported by Hedrick & Lowe, 1936.
Cladonia squamosa (Scop.) Hoffm. Also reported by Hedrick & Lowe, 1936.
Cladonia subulata (L.) Web. in Wigg. Also reported by Hedrick & Lowe, 1936.
Cladonia sulphurina (Michx.) Fr. Also reported by Harris, 1978.
✗ Cladonia symphycarpa (Ach.) Fr.
Cladonia turgida (Ehrh.) Hoffm. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
Cladonia uncialis (L.) Wigg. Also reported by Hedrick & Lowe, 1936.

Cladonia verticillata (Hoffm.) Schaer. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
x Collema conglomeratum Hoffm.
x Collema furfuraceum (Arn.) DuRietz
[Collema glebulentum (Nyl. ex Cromb.) Degel. Reported by Degelius, 1974.]
x Collema nigrescens (Huds.) DC
x Collema polycarpon Hoffm.
x Collema pulcellum Ach.
x Collema subflaccidum Degel.
Collema tenax (Sw.) Ach. Also reported by Hedrick & Lowe, 1936.
x Collema undulatum Laur. ex Flot.
1 additional unidentified species of Collema
Coniocybe furfuracea (L.) Ach. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.
[Coniocybe sulphurea (Retz.) Nyl. Reported by Tibell, 1975, Harris, 1978.]
x Conotrema urceolatum (Ach.) Tuck.
[Cyphelium lucidum (Th. Fr.) Th. Fr. Reported by Hedrick & Lowe, 1936, Tibell, 1975.]
Cyphelium tigillare (Ach.) Ach. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.
x Dermatocarpon lachneum (Ach.) A. L. Sm.
Dermatocarpon luridum (With.) Laund. Also reported by Holt, 1908, Hedrick & Lowe, 1936. michelii. Thome. 87
Dermatocarpon miniatum (L.) Mann Also reported by Holt, 1908, Hedrick & Lowe, 1936.
x Dermatocarpon moulinsii (Mont.) Zahlbr.
x Dermatocarpon reticulatum Magn.
S Dimerella lutea (Dicks.) Trev. Also reported by Hedrick & Lowe, 1936.
* Dimerella pineti (Ach.) Vezda Hedrick & Lowe, 1936.
Diploschistes scruposus (Schreb.) Norm. Also reported by Hedrick & Lowe, 1936.
Endocarpon pulvinatum Th. Fr. Also reported by Harris, 1978.
x Endocarpon pusillum Hedw.
x Ephebe lanata (L.) Vain.
x Ephebe ocellata Henss.
I Evernia mesomorpha Nyl. Also reported by Hedrick & Lowe, 1936.
x I Evernia prunastri (L.) Ach.
I Graphis scripta (L.) Ach. Also reported by Hedrick & Lowe, 1936.
Gyalecta jenensis (Batsch) Zahlbr. Also reported by Hedrick & Lowe, 1936, Harris, 1978.
x Gyalecta truncigena (Ach.) Hepp
Haematomma elatinum (Ach.) Mass. Also reported by Hedrick & Lowe, 1936.
1 additional unidentified species of Haematomma
Heterodermia speciosa (Wulf.) Trev. Also reported by Hedrick & Lowe, 1936.
x Huilia crustulata (Ach.) Hert.

Huilia macrocarpa (DC. in Lam. & DC.) Hert.
Huilia panaeola (Ach.) Hert.
Huilia superba R. Anders., ined.
2 additional unidentified species of Huilia
Hypogymnia bitteri (Lynge) Ahti
I Hypogymnia physodes (L.) Nyl. Also reported by Hedrick & Lowe, 1936, Berry, 1941.
S Hypogymnia tubulosa (Schaer.) Hav.
Icmadophila ericetorum (L.) Zahlbr. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
Lecanactis chloroconia Tuck.
Lecania dubitans (Nyl.) A. L. Sm.
I Lecanora allophana Nyl. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
Lecanora argopholis (Ach.) Ach. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Harris, 1978.
Lecanora atra (Huds.) Ach. Hedrick & Lowe, 1936
Lecanora badia (Hoffm.) Ach.
Lecanora caesiorubella Ach. subsp. caesiorubella Also reported by Imshaug & Brodo, 1966.
Lecanora caesiorubella subsp. saximontana Imsh. & Brodo
I Lecanora carpinea (L.) Vain. Also reported by Hedrick & Lowe, 1936, Imshaug & Brodo, 1966, Harris, 1978.
Lecanora cateilea (Ach.) Mass. Also reported by Imshaug & Brodo, 1966, Harris, 1978.
Lecanora cenisia Ach. Also reported by Harris, 1978.
I Lecanora circumborealis Brodo & Vitik. Also reported by Hedrick & Lowe, 1936.
T Lecanora dispersa (Pers.) Somm.
T Lecanora hageni (Ach.) Ach. Also reported by Hedrick & Lowe, 1936, Harris, 1978.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora impudens Degel.
Lecanora meridionalis Magn.
T Lecanora muralis (Schreb.) Rabenh. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Harris, 1978.
Lecanora mutabilis Somm.
Lecanora opiniconensis Brodo, ined.
I Lecanora pallida (Schreb.) Rabenh. Also reported by Hedrick & Lowe, 1936.
Lecanora pallida var. pallida Also reported by Imshaug & Brodo, 1966, Harris, 1978.
Lecanora pallida var. rubescens Imsh. & Brodo Also reported by Imshaug & Brodo, 1966.
Lecanora piniperda Körb.
Lecanora polytropa (Hoffm.) Rabenh.
I Lecanora pulicaris (Pers.) Ach.
Lecanora rugosella Zahlbr. Also reported by Hedrick & Lowe, 1936.
Lecanora rupicola (L.) Zahlbr. Also reported by Hedrick & Lowe, 1936.
I Lecanora symmictera Nyl.
Lecanora thysanophora Harris ined.
Lecanora wisconsinensis Magn.

4 additional unidentified species of Lecanora
Lecidea aeruginosa Borr. in Hook. & Sowerb.
I [Lecidea albofuscescens Nyl. Reported by Harris, 1978, collected by Wetmore in 1980].
Lecidea anthracophila Nyl. Also reported by Hedrick & Lowe, 1936.
Lecidea atrobrunnea (DC. in Lam. & DC.) Schaer.
Lecidea berengeriana (Mass.) Th. Fr.
Lecidea elabens Fr. Also reported by Hedrick & Lowe, 1936.
Lecidea epixanthoidiza Nyl.
Lecidea erythrophaea Flörke
Lecidea friesii Ach. in Liljeb.
Lecidea fuscoatra Nyl. Also reported by Hedrick & Lowe, 1936, Harris, 1978.
Lecidea gelatinosa Flörke Also reported by Harris, 1978.
Lecidea globifera Ach. Also reported by Fink, 1919, Hedrick & Lowe, 1936, Harris, 1978.
Lecidea granulosa (Hoffm.) Ach. Also reported by Hedrick & Lowe, 1936.
Lecidea helvola (Körb. ex Hellb.) Oliv.
Lecidea hypnorum Libert
Lecidea insularis Nyl.
[Lecidea lithophila (Ach.) Ach. Reported by Harris, 1978.]
Lecidea lucida (Ach.) Ach. Also reported by Fink, 1919, Hedrick & Lowe, 1936.
Lecidea plana (Lahm ex Körb.) Nyl.
Lecidea plebeja Nyl.
Lecidea rufonigra (Tuck.) Nyl.
I Lecidea scalaris (Ach.) Ach.
Lecidea speirea (Ach.) Ach. Also reported by Harris, 1978.
Lecidea tessellata Flörke Also reported by Hedrick & Lowe, 1936, Harris, 1978.
S Lecidea vernalis (L.) Ach. Also reported by Hedrick & Lowe, 1936.
4 additional unidentified species of Lecidea
Lecidella carpathica Körb. Also reported by Harris, 1978.
I Lecidella elaeochroma (Ach.) Choisy Also reported by Hedrick & Lowe, 1936, Harris, 1978.
Lecidella euphorea (Flörke) Hert.
Lecidella stigmatea (Ach.) Hert. & Leuck. Also reported by Hedrick & Lowe, 1936.
Lepraria finkii (B. de Lesd. in Hue) R. Harris ined.
Lepraria lobificans (Hue) ined.
Lepraria neglecta Vain.
Leptogium arsenei Sierk
Leptogium burnetiae Dodge
Leptogium corticola (Tayl.) Tuck. Also reported by Hedrick & Lowe, 1936.
Leptogium cyanescens (Rabenh.) Körb. Also reported by Hedrick & Lowe, 1936.
Leptogium furfuraceum (Harm.) Sierk
Leptogium gelatinosum (With.) Laund. Also reported by Sierk, 1964, Harris, 1978.

Leptogium lichenoides (L.) Zahlbr. Also reported by Hedrick & Lowe, 1936.
Leptogium saturninum (Dicks.) Nyl. Also reported by Hedrick & Lowe, 1936.
✗ Leptogium tenuissimum (Dicks.) Körb.
2 additional unidentified species of Leptogium
[Letorhaphis atomaria (Ach.) Szat. Reported by Harris, 1973.
Leptorhaphis contorta Degel. Also reported by Harris, 1973.
Leptorhaphis epidermidis (Ach.) Th. Fr. Also reported by Hedrick & Lowe, 1936, Harris, 1973.
S Lobaria pulmonaria (L.) Hoffm. Also reported by Holt, 1908, Hedrick & Lowe, 1936.
Lobaria quercizans Michx. Also reported by Hedrick & Lowe, 1936, Jordan, 1973.
Lobaria scrobiculata (Scop.) DC. in Lam. & DC. Also reported by Harris, 1978.
I Lopadium pezizoideum (Ach.) Körb. Also reported by Lowe, 1935, Hedrick & Lowe, 1936.
Menegazzia terebrata (Hoffm.) Mass. Also reported by Hedrick & Lowe, 1936.
Micarea melaena (Nyl.) Hedl. Also reported by Hedrick & Lowe, 1936.
✗ Micarea peliocarpa (Anzi) Coppins & R. Sant.
✗ Micarea prasina Fr.
Micarea viridescens (Schrad.) Brodo Also reported by Hedrick & Lowe, 1936.
Microcalicium disseminatum (Ach.) Vain. Also reported by Tibell, 1975.
[Microthelia micula Körb. Reported by Harris, 1973.]
I Mycoblastus sanguinarius (L.) Norm. Also reported by Hedrick & Lowe, 1936.
Mycocalicium subtile (Pers.) Szat. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.
[Mycoglaena myricae (Nyl.) Harris Reported by Harris, 1973.]
1 additional unidentified species of Mycoglaena
Nephroma bellum (Spreng.) Tuck. Also reported by Hedrick & Lowe, 1936, Wetmore, 1960.
Nephroma helveticum Ach. Also reported by Hedrick & Lowe, 1936, Wetmore, 1960.
Nephroma parile (Ach.) Ach. Also reported by Hedrick & Lowe, 1936, Wetmore, 1960.
Nephroma resupinatum (L.) Ach. Also reported by Hedrick & Lowe, 1936, Wetmore, 1960.
✗ S-I Normandina pulchella (Borr.) Nyl.
✗ Ochrolechia arborea (Kreyer) Almb.
✗ S Ochrolechia rosella (Müll. Arg.) Vers.
1 additional unidentified species of Ochrolechia
Opegrapha niveoatra (Borr.) Laund. Also reported by Harris, 1978.
[Opegrapha prosodea Ach. Reported by Harris, 1978.]
I Opegrapha varia Pers. Also reported by Hedrick & Lowe,

1936.

Pachyospora verrucosa (Ach.) Mass. Also reported by Harris, 1978.

✗ Pachyphiale fagicola (Hepp ex Arn.) Zw.

Pannaria ahlneri Jørg. Also reported by Harris, 1978.

✗ Pannaria conoplea (Ach.) Bory

Pannaria leucophaea (Vahl.) Jørg. Also reported by Harris, 1978.

Pannaria pezizoides (G. Web.) Trev. Also reported by Hedrick & Lowe, 1936, Harris, 1978.

Pannaria praetermissa Nyl.in Chyd. & Furuhj. Also reported by Hedrick & Lowe, 1936, Harris, 1978.

Parmelia arnoldii Du Rietz Also reported by Hale, 1965.

I Parmelia caperata (L.) Ach. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Berry, 1941.

✗ Parmelia centrifuga (L.) Ach.

Parmelia conspersa (Ehrh. ex Ach.) Ach. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Berry, 1941.

✗ Parmelia crinita Ach.

✗ Parmelia cumberlandia (Gyeln.) Hale

✗ Parmelia disjuncta Erichs.

✗ I Parmelia exasperatula Nyl.

✗ Parmelia flaventior Stirt.

✗ Parmelia fraudans (Nyl.) Nyl.

✗ Parmelia galbina Ach.

✗ I Parmelia glabratula (Lamy) Nyl.

Parmelia hypopsila Müll. Arg. Also reported by Harris, 1978.

Parmelia infumata Nyl. Also reported by Esslinger, 1977.

✗ Parmelia mexicana Gyeln.

I Parmelia olivacea (L.) Ach. Also reported by Hedrick & Lowe, 1936, Berry, 1941, Ahti, 1966.

Parmelia omphalodes (L.) Ach. Also reported by Harris, 1978, collected by Wetmore in 1980.

[Parmelia panniformis (Nyl.) Vain. Also reported by Hedrick & Lowe, 1936.]

I Parmelia revoluta Flörke Also reported by Harris, 1978.

I Parmelia rudecta Ach. Also reported by Hedrick & Lowe, 1936.

I Parmelia saxatilis (L.) Ach. Also reported by Hedrick & Lowe, 1936, Berry, 1941.

I Parmelia septentrionalis (Lynge) Ahti Also reported by Ahti, 1966.

✗ Parmelia soredica Nyl.

✗ Parmelia sorediosa Almb.

✗ S Parmelia squarrosa Hale

✗ Parmelia stictica (Duby) Nyl.

I-T Parmelia subargentifera Nyl. Also reported by Hedrick & Lowe, 1936.

✗ S Parmelia subaurifera Nyl.

✗ Parmelia subcentrifuga Oxn.

✗ I Parmelia subrudecta Nyl.

✗ Parmelia substygia Räs.

I-T Parmelia sulcata Tayl. Also reported by Holt, 1908,

Hedrick & Lowe, 1936, Berry, 1941.

✗ Parmelia taractica Kremp.

Parmelia tasmanica Hook. f. & Tayl. Also reported by Harris, 1978.

I Parmelia trabeculata Ahti Also reported by Ahti, 1966, Esslinger, 1977.

✗ Parmeliella triptophylla (Ach.) Müll. Arg.

I Parmeliopsis aleurites (Ach.) Nyl. Also reported by Lowe, 1935, Hedrick & Lowe, 1936.

I Parmeliopsis ambigua (Wulf.) Nyl. Also reported by Hedrick & Lowe, 1936.

I Parmeliopsis hyperopta (Ach.) Arn. Also reported by Hedrick & Lowe, 1936.

✗ Parmeliopsis placorodia (Ach.) Nyl.

Peltigera aphthosa (L.) Willd. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Thomson, 1950, Harris, 1978.

Peltigera canina (L.) Willd. Also reported by Thomson, 1950.

Peltigera didactyla (With.) Laund. Also reported by Hedrick & Lowe, 1936, Thomson, 1950.

✗ Peltigera elisabethae Gyeln.

Peltigera evansiana Gyeln. Also reported by Thomson, 1950.

I Peltigera horizontalis (Huds.) Baumg. Also reported by Hedrick & Lowe, 1936, Thomson, 1950.

✗ Peltigera lepidophora (Nyl. ex Vain.) Bitter

✗ Peltigera leucophlebia (Nyl.) Gyeln.

Peltigera malacea (Ach.) Funck Also reported by Hedrick & Lowe, 1936, Thomson, 1950.

✗ Peltigera membranacea (Ach.) Nyl.

✗ Peltigera neckeri Müll. Arg.

Peltigera polydactyla (Neck.) Hoffm. Also reported by Hedrick & Lowe, 1936, Thomson, 1950.

Peltigera praetextata (Flörke ex Somm.) Zopf Also reported by Hedrick & Lowe, 1936.

Peltigera rufescens (Weis) Humb. Also reported by Hedrick & Lowe, 1936, Thomson, 1950.

Peltigera venosa (L.) Hoffm. Also reported by Hedrick & Lowe, 1936, Harris, 1978.

Pertusaria alpina Hepp ex Ahles Also reported by Dibben, 1980.

I Pertusaria amara (Ach.) Nyl. Also reported by Dibben, 1980.

Pertusaria consocians Dibb. Also reported by Dibben, 1980.

Pertusaria macounii (Lamb) Dibb. Also reported by Dibben, 1980.

I Pertusaria multipunctoides Dibb. Also reported by Dibben, 1980.

[Pertusaria neoscotica Lamb Reported by Dibben, 1980.]

Pertusaria ophthalmiza (Nyl.) Nyl. Also reported by Dibben, 1980.

[Pertusaria pustulata (Ach.) Duby Reported by Dibben, 1980.]

[Pertusaria sommerfeltii (Somm.) Fr. Reported by Dibben, 1980.]

Pertusaria trachythallina Erichs.
Pertusaria velata (Turn.) Nyl. Also reported by Hedrick & Lowe, 1936, Dibben, 1980.
3 additional unidentified species of Pertusaria
Phaeocalicium compressulum (Nyl. ex Vain.) Schmidt Also reported by Tibell, 1975, Harris, 1978.
[Phaeocalicium polyporaeum (Nyl.) Tibell Reported by Hedrick & Lowe, 1936, collected by Wetmore, 1972.]
Phaeocalicium populneum (Brond. ex Duby) A. Schmidt
Phaeophyscia adiastola (Essl.) Essl.
Phaeophyscia chloantha (Ach.) Moberg
Phaeophyscia ciliata (Hoffm.) Moberg Also reported by Hedrick & Lowe, 1936, Thomson, 1963.
Phaeophyscia constipata (Norrl. & Nyl.) Moberg
[Phaeophyscia decolor (Kashiw.) Essl. Reported by Harris, 1978 but included within P. endociccina in this list.
Phaeophyscia endococcina (Körb.) Moberg
Phaeophyscia endococcinodes (Poelt) Essl.
Phaeophyscia hirtella Essl.
Phaeophyscia hispidula (Ach.) Moberg Also reported by Hedrick & Lowe, 1936, Thomson, 1963.
I Phaeophyscia orbicularis (Neck.) Moberg Also reported by Thomson, 1963.
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Moberg
Phaeophyscia sciastra (Ach.) Moberg Also reported by Esslinger, 1978.
I Phlyctis argena (Spreng.) Flot.
I Physcia adscendens (Fr.) Oliv. Also reported by Thomson, 1963.
I Physcia aipolia (Ehrh. ex Humb.) Furnrohr Also reported by Hedrick & Lowe, 1936, Thomson, 1963.
Physcia caesia (Hoffm.) Furnrohr Also reported by Hedrick & Lowe, 1936.
T Physcia dubia (Hoffm.) Lett.
Physcia intermedia Vain.
I Physcia millegrana Degel. Thomson, 1963
Physcia phaea (Tuck.) Thoms.
I Physcia stellaris (L.) Nyl. Also reported by Hedrick & Lowe, 1936, Thomson, 1963.
Physcia subtilis Degel.
I Physcia tenella (Scop.) DC. in Lam & DC. Also reported by Hedrick & Lowe, 1936, Harris, 1978.
I Physconia detersa (Nyl.) Poelt Also reported by Hedrick & Lowe, 1936, Thomson, 1963.
Physconia muscigena (Ach.) Poelt Also reported by Thomson, 1963, Harris, 1978.
Placynthiella icmalea (Ach.) Coppins & James
Placynthiella oligotropha (Laund.) Coppins & James
Placynthium nigrum (Huds.) S. Gray
I Platismatia glauca (L.) W. Culb. & C. Culb. Also reported by Culberson & Culberson, 1968, Harris, 1978.
Platismatia tuckermanii (Oakes) W. Culb. & C. Culb. Also

reported by Holt, 1908, Hedrick & Lowe, 1936, Culberson & Culberson, 1968.

Polyblastia cupularis Mass.

Polyblastia theleodes (Sommerf.) Th. Fr.

Polyblastiopsis fallaciosa (Stizenb. ex Arn.) Zahlbr.

Protoblastenia rupestris (Scop.) J. Stein. Also reported by Hedrick & Lowe, 1936.

Protoblastenia siebenhaariana (Körb.) J. Stein.

Pseudevernia consocians (Vain.) Hale & W. Culb. Also reported by Hedrick & Lowe, 1936.

Pseudocyphellaria crocata (L.) Vain.

1 additional unidentified species of Psorotichia

1 additional unidentified species of Pyrenopsis

Pyxine sorediata (Ach.) Mont.

S Ramalina americana Hale

I Ramalina dilacerata (Hoffm.) Hoffm.

S Ramalina farinacea (L.) Ach. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Bowler & Rundel, 1978, Harris, 1978.

[Ramalina hypoprotocetrarica W. Culb. Reported by Harris, 1978, included in R. farinacea in this list.]

Ramalina intermedia (Del. ex Nyl.) Nyl.

S Ramalina obtusata (Arn.) Bitt.

S Ramalina pollinaria (Westr.) Ach. Also reported by Hedrick & Lowe, 1936.

Ramalina roesleri (Hochst. ex Schaer.) Hue Also reported by Harris, 1978.

Ramalina sinensis Jatta Also reported by Harris, 1978.

Ramalina thrausta (Ach.) Nyl. Also reported by Bowler, 1977.

1 additional unidentified species of Ramalina

Rhizocarpon badioatrum (Flörke ex Spreng.) Th. Fr. Also reported by Hedrick & Lowe, 1936.

Rhizocarpon cinereovirens (Müll. Arg.) Vain.

Rhizocarpon concentricum (Dav.) Beltr.

Rhizocarpon disporum (Naeg. ex Hepp) Müll. Arg. Also reported by Hedrick & Lowe, 1936.

Rhizocarpon distinctum Th. Fr.

Rhizocarpon geographicum (L.) DC. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Harris, 1978.

Rhizocarpon grande (Flörke ex Flot.) Arn. Also reported by Hedrick & Lowe, 1936.

Rhizocarpon hochstetteri (Körb.) Vain.

Rhizocarpon lecanorinum Anders

Rhizocarpon macrosporum Räs.

Rhizocarpon obscuratum (Ach.) Mass.

Rhizocarpon plicatile (Leight.) A. L. Sm.

Rhizocarpon polycarpum (Hepp) Th. Fr.

2 additional unidentified species of Rhizocarpon

Rhizoplaca chrysoleuca (Sm.) Zopf Also reported by Harris, 1978.

Rhizoplaca melanophthalma (DC. in Lam. & DC.) Leuck. & Poelt

x Rinodina colobina (Ach.) Th. Fr.
I Rinodina exigua (Ach.) S. Gray Also reported by Hedrick & Lowe, 1936.
x Rinodina metaboliza Vain.
x Rinodina populicola Magn.
x Rinodina subminuta Magn.
[Rinodina tephraspis (Tuck.) Herre Collected by Wetmore in 1972.]
x Rinodina trevisani Sheard, ined.
x Rinodina turfacea (Wahlenb.) Körb.
1 additional unidentified species of Rinodina
Schismatomma decolorans (Turn. & Borr. ex Sm.) Clauz. & Vezda
Solorina saccata (L.) Ach. Also reported by Hedrick & Lowe, 1936.
x Sphinctrina anglica Nyl.
Sphinctrina turbinata (Pers. ex Fr.) DeNot. Also reported by Hedrick & Lowe, 1936, Tibell, 1975.
x Spilonema revertens Nyl.
Staurothele fissa (Tayl.) Zw. Also reported by Hedrick & Lowe, 1936.
Staurothele fuscocuprea (Nyl.) Zsch. Also reported by Hedrick & Lowe, 1936.
I Stenocybe major Nyl. ex Körb. Also reported by Lowe, 1935, Hedrick & Lowe, 1936, Tibell, 1975
Stenocybe pullatula (Ach.) B. Stein Also reported by Tibell, 1975, Harris, 1978.
Stereocaulon dactylophyllum Flörke Also reported by Holt, 1908, Hedrick & Lowe. 1936, Harris, 1978.
Stereocaulon paschale (L.) Hoffm. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Harris, 1978.
x Stereocaulon pileatum Ach.
x Stereocaulon saxatile Magn.
Stereocaulon tomentosum Fr. Also reported by Hedrick & Lowe, 1936.
Sticta fuliginosa (Hoffm.) Ach. Also reported by Hedrick & Lowe, 1936.
x Strigula stigmatella (Ach.) R. Harris
Thelocarpon epibolum Nyl. Also reported by Harris, 1978.
x Thelocarpon laureri (Flot.) Nyl.
[Thelopsis melathelia Nyl. Reported by Harris, 1978.]
[Thermutis velutina (Ach.) Flot. Collected once by Wetmore in 1959]
x Thyrea nigritella Lett.
Toninia caeruleonigricans (Leightf.) Th. Fr. Also reported by Hedrick & Lowe, 1936, Harris, 1978.
1 additional unidentified species of Toninia
x Trapelia involuta (Tayl.) Hert.
x Trapelia placodioides Coppins & James
Umbilicaria deusta (L.) Baumg. Also reported by Hedrick & Lowe, 1936, Llano, 1950.
Umbilicaria hyperborea (Ach.) Hoffm. Also reported by Hedrick & Lowe, 1936, Harris, 1978.
Umbilicaria mammulata (Ach.) Tuck. Also reported by Llano,

1950.
Umbilicaria muehlenbergii (Ach.) Tuck. Also reported by Hedrick & Lowe, 1936, Llano, 1950, Harris, 1978.
✗ Umbilicaria phaea Tuck.
[Umbilicaria polyphylla (L.) Baumg. Reported by Harris, 1978.]
[Umbilicaria torrefacta (Lightf.) Schrad. Also reported by Harris, 1978, collected by Wetmore, 1958].
Umbilicaria vellea (L.) Ach. Also reported by Hedrick & Lowe, 1936, Llano, 1950.
Usnea cavernosa Tuck. Also reported by Hedrick & Lowe, 1936.
S Usnea ceratina Ach. Also reported by Hedrick & Lowe, 1936.
S Usnea filipendula Stirt. Also reported by Hedrick & Lowe, 1936.
S-I Usnea hirta (L.) Web. in Wigg. Also reported by Hedrick & Lowe, 1936.
✗ Usnea lapponica Vain.
Usnea longissima Ach. Also reported by Holt, 1908, Hedrick & Lowe, 1936, Harris, 1978.
✗ S-I Usnea subfloridana Stirt.
✗ Verrucaria aethiobola Wahlenb. in Ach.
Verrucaria elaeomelaena (Mass.) Arn. Also reported by Harris, 1978.
[Verrucaria margacea (Wahlenb. in Ach.) Wahlenb. Collected by Thomson in 1972].
2 additional unidentified species of Verrucaria
I [Xanthoria candelaria (L.) Th. Fr. Also reported by Hedrick & Lowe, 1936, collected by Cooper in 1909].
Xanthoria elegans (Link) Th. Fr. Also reported by Hedrick & Lowe, 1936.
✗ S-I Xanthoria fallax (Hepp in Arn.) Arn.
I Xanthoria polycarpa (Hoffm.) Rieber Also reported by Hedrick & Lowe, 1936.
✗ Xanthoria sorediata (Vain.) Poelt
Xylographa abietina (Pers.) Zahlbr. Also reported by Harris, 1978.
✗ Xylographa vitiligo (Ach.) Laund.

DISCUSSION OF FLORA

The lichen flora of Isle Royale is very diverse and there are many individuals of many species. Because of its location in Lake Superior there are more lichens in this park than in most other areas. Several species that only occur much further north have their southern limits here. Cetraria cucullata, Lobaria scrobiculata and Pseudocyphellaria crocata are examples of these. A few species are northern and western, such

as, Dermatocarpon moulinsii, Dermatocarpon reticulatum, Huilia superba, Parmelia substygia, Umbilicaria torrefacta and Umbilicaria phaea. Two species are new for North America: Protoblastenia siebenhaariana and Schismatomma decolorans. There are also numerous new park records in this list. The few species not yet identified may be undescribed species or new records for North America.

The most common species in the park are Bryoria trichodes, Cetraria pinastri, Cetraria halei, Cladina rangiferina, Cladonia cenotea, Lobaria pulmonaria, Physconia detersa, Usnea cavernosa and Usnea subfloridana. Especially on the small off-shore islands all the trees are completely covered with lichens.

The species reported by earlier studies but not found in this study are mostly very rare species that were missed in collecting or only occur in a few localities. With so many species present and many of them quite rare, it is not surprising that some of them were missed. The fact that Lobaria pulmonaria, one of the species most sensitive to sulfur dioxide, is so common in all parts of the park indicates that air quality is not damaging to the lichen flora and the species not found in this study were missed but may be found with further searching.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the park. These observations indicate that there is no visible damage to the

lichen flora of the park due to air quality degradation at this time. However, see below under Chemical Analysis.

Since lichens are not known to be sensitive to acid precipitation, no conclusions can be drawn about this environmental contaminant. However, preliminary reports indicate that some species of Umbilicaria do show damage from acid precipitation by dying at the margins. Some of these lichens were frequently seen in the park with dead margins, especially on Passage Island and the northeast end of the main island, and this may be due to acid rain.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive species within the park to look for voids in the distributions that might be caused by air pollution. Showman (1975) has described and used this technique in assessing sulfur dioxide levels around a power plant in Ohio. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors.

There are numerous lichens in the park that are very sensitive to sulfur dioxide according to the list presented in Wetmore, 1983 and several of these are very common. Species in the most sensitive category are usually absent when sulfur dioxide levels are above 50ug per cubic meter average annual concentrations. The species that occur in the park in this most sensitive category are as follows.

Bryoria furcellata (Fr.) Brodo & Hawksw.
Bryoria trichodes (Michx.) Brodo & Hawksw.
Caloplaca flavorubescens (Huds.) Laund.
Catillaria griffithii (Sm.) Malme
Dimerella lutea (Dicks.) Trev.
Hypogymnia tubulosa (Schaer.) Hav.
Lecidea vernalis (L.) Ach.
Lobaria pulmonaria (L.) Hoffm.
Ochrolechia rosella (Müll. Arg.) Vers.
Parmelia squarrosa Hale
Parmelia subaurifera Nyl.
Ramalina americana Hale
Ramalina farinacea (L.) Ach.
Ramalina obtusata (Arn.) Bitt.
Ramalina pollinaria (Westr.) Ach.
Usnea ceratina Ach.
Usnea filipendula Stirt.

The distributions of these species are mapped (Fig. 2-18). Although some of these species are not found at all localities, there is no indication that the voids in the distributions are due to poor air quality. Some of the localities where collections were made do not have suitable habitats for some of these species. Even the most sensitive species (Lobaria pulmonaria) occurs at localities where elemental analysis shows elevated sulfur levels (see below).

CHEMICAL ANALYSIS

An important method of assessing the effects of air quality is by examining the elemental content of the lichens (Nieboer et al, 1972, 1977, 1978; Erdman & Gough, 1977; Puckett & Finegan, 1980; Nash & Sommerfeld, 1981). Elevated but sublethal levels of sulfur or other elements might indicate incipient damaging conditions.

Lichens were collected for elemental analysis at several localities in the park. In some cases not all species were present in quantities needed for the analysis.

METHODS

Lichen samples of several species were collected in plastic bags at various localities in different parts of the park for laboratory analysis. Species collected and the substrates were Cladina rangiferina (soil), Evernia mesomorpha (trees), Hypogymnia physodes (trees), Parmelia sulcata (trees), and Umbilicaria muehlenbergii (rocks). These species were selected because they are relatively easy to clean and other authors have used them and so there is some information in the literature for comparison.

The 10 localities were selected to represent the geographical extremes of the park and to include lakeshore as well as ridgetop localities and are indicated on the map of collection localities (Fig. 1). One locality was on Passage Island at the far northeast end of the park. The rest were on the main island and are: Lookout Louise (NE ridgetop), Mt. Franklin (NE ridgetop), Ishpeming Point (ridgetop near middle of island), Huginnin Cove (SW end on ridgetop), Locke Point (NE lakeshore), Little Todd Harbor (northern lakeshore at middle of island), McGinty Cove (SW lakeshore), Long Point and Point Houghton (southern lakeshore). Ten to 20 grams of each species were collected at each locality. Because collections for analysis were made two different years the Locke Point locality was included each year for comparison.

Lichens were air dried and cleaned of all bark and soil under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for analysis.

Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and boron were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Centigrade for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. In cases when values were obtained at or below the detection limits these values have been adjusted before statistical analysis. If only one value is below the detection limit the value is included at 0.7 of the detection limit. If more than one reading is below the detection limit no statistical analysis has been done on that element at that locality.

All of the levels found in the Isle Royale lichens are

Table 1. Analysis of Isle Royale lichens
Values on ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
1983																	
C. rangiferina	553	1461	678	352	320	345	24.9	39.9	14.2	2.1	0.4	8.3	0.6	0.5	<.1	270	Passage Isl.
C. rangiferina	640	1745	759	378	296	313	28.3	38.3	14.4	2.2	0.5	7.4	0.5	0.5	0.1	220	Passage Isl.
C. rangiferina	554	1449	745	361	312	336	26.8	50.7	16.0	2.1	0.4	7.8	1.1	0.5	0.1	280	Passage Isl.
C. rangiferina	443	1419	1733	503	417	460	37.6	23.9	13.8	2.2	0.5	9.8	0.7	0.5	0.1	230	Locke Point
C. rangiferina	434	1313	1446	443	376	400	38.9	20.6	12.5	2.1	0.3	7.9	0.8	0.5	0.1	210	Locke Point
C. rangiferina	359	1137	1440	420	365	396	37.2	19.7	11.5	2.0	0.3	9.3	0.4	0.5	0.1	180	Locke Point
C. rangiferina	511	1612	791	295	391	399	48.7	26.6	26.3	2.4	0.4	9.1	0.8	0.6	0.2	400	Lookout Louise
C. rangiferina	541	1603	824	292	378	377	48.0	29.2	25.1	2.4	0.4	8.9	1.2	0.6	0.1	400	Lookout Louise
C. rangiferina	542	1590	825	291	363	362	48.0	29.2	24.6	2.4	0.4	9.0	0.5	0.5	0.1	420	Lookout Louise
C. rangiferina	482	1653	617	230	251	239	26.2	37.2	18.3	2.0	0.3	7.4	0.8	0.4	<.1	200	Point Houghton
C. rangiferina	391	1440	507	215	271	268	25.6	32.5	16.4	1.9	0.2	10.0	1.4	0.4	<.1	210	Point Houghton
C. rangiferina	513	1552	637	232	262	247	26.4	38.7	19.1	2.0	0.3	7.7	1.1	0.4	<.1	380	Point Houghton
C. rangiferina	1009	2960	1560	556	471	566	34.1	37.5	29.6	3.4	0.5	10.5	0.5	0.6	0.1	410	Ishpeming Pt.
C. rangiferina	917	2830	1643	582	502	621	35.0	37.2	31.5	3.3	0.5	11.0	0.5	0.6	0.2	580	Ishpeming Pt.
C. rangiferina	933	2776	1571	528	425	505	29.3	35.8	27.9	3.0	0.5	9.0	0.4	0.6	0.2	460	Ishpeming Pt.
1984																	
C. rangiferina	417	1230	712	234	236	204	25.4	15.4	11.7	1.4	1.6	6.0	0.7	0.3	0.1	380	Locke Point
C. rangiferina	448	1202	721	245	268	241	32.3	26.4	12.0	1.4	1.0	6.9	0.4	0.3	0.2	340	Locke Point
C. rangiferina	412	1134	643	225	264	234	30.0	10.5	10.7	1.3	1.2	7.1	0.7	0.3	<.1	320	Locke Point
C. rangiferina	503	1575	1139	474	696	930	31.6	15.1	19.0	2.5	1.0	5.1	1.1	0.8	0.1	560	Mt. Franklin
C. rangiferina	521	1459	1222	491	738	946	31.2	16.2	19.5	2.6	1.1	5.4	1.3	0.9	<.1	540	Mt. Franklin
C. rangiferina	594	1717	1296	516	710	919	29.5	17.2	20.3	2.8	0.9	5.8	1.1	0.9	<.1	590	Mt. Franklin
C. rangiferina	327	1247	515	232	297	273	37.4	11.1	13.4	1.8	1.8	7.8	0.9	0.3	0.2	390	Little Todd
C. rangiferina	356	1343	480	244	282	260	39.4	11.3	14.5	1.9	1.9	6.4	0.7	0.3	<.1	370	Little Todd
C. rangiferina	265	1031	480	216	307	297	31.2	11.0	12.8	1.8	1.3	7.3	1.0	0.3	<.1	430	Little Todd
C. rangiferina	367	1242	343	193	325	300	26.7	14.8	15.1	1.8	1.6	8.2	0.4	0.5	0.8	510	Huginnin Cove
C. rangiferina	379	1286	339	199	355	318	25.7	18.4	17.1	1.9	2.0	8.7	0.9	0.5	0.6	480	Huginnin Cove
C. rangiferina	390	1294	338	193	330	294	25.5	17.7	16.2	1.8	2.0	8.2	0.7	0.4	0.7	420	Huginnin Cove
C. rangiferina	439	1325	483	247	359	314	28.2	36.5	14.8	2.0	1.9	8.4	0.7	0.5	0.3	420	McGinty Cove
C. rangiferina	502	1472	502	250	341	298	29.4	36.6	15.6	2.1	2.1	7.7	0.6	0.5	0.5	410	McGinty Cove
C. rangiferina	456	1358	502	234	360	314	26.1	37.4	17.0	2.0	2.5	8.2	0.6	0.5	0.6	440	McGinty Cove
C. rangiferina	283	1078	515	193	349	295	24.5	21.2	14.6	1.9	1.7	8.9	0.8	0.5	0.4	400	Long Point
C. rangiferina	315	1191	516	197	333	281	22.6	23.4	15.0	1.9	1.7	8.3	0.8	0.4	0.5	320	Long Point
C. rangiferina	356	1364	658	215	271	214	22.1	32.9	16.3	1.8	1.9	6.0	0.6	0.5	0.5	340	Long Point
1983																	
E. mesomorpha	329	1454	431	227	247	276	16.1	23.2	24.4	2.0	0.3	14.7	<.3	0.5	0.3	650	Passage Isl.
E. mesomorpha	343	1405	368	201	211	239	13.1	19.1	24.7	1.7	0.2	16.4	<.3	0.4	0.4	560	Passage Isl.
E. mesomorpha	346	1463	345	207	255	305	18.1	19.5	23.1	2.1	0.3	17.4	0.4	0.5	0.4	620	Passage Isl.
E. mesomorpha	739	2199	1459	376	277	315	23.5	70.8	27.9	2.1	0.5	8.3	0.3	0.8	0.3	730	Locke Point
E. mesomorpha	609	2027	1275	358	251	305	21.9	66.0	25.8	2.0	0.5	7.7	<.3	0.7	0.3	600	Locke Point
E. mesomorpha	736	2230	1689	424	202	236	26.8	84.0	25.3	2.3	1.0	6.7	0.5	0.8	0.1	760	Locke Point
E. mesomorpha	579	2218	725	264	257	277	24.4	36.9	29.1	2.9	0.5	11.0	<.3	0.5	0.4	830	Lookout Louise
E. mesomorpha	594	2312	1304	291	272	297	25.5	49.9	30.4	2.9	0.7	12.2	<.3	0.8	0.3	840	Lookout Louise
E. mesomorpha	589	2297	774	277	266	298	25.2	32.5	30.1	2.7	0.6	11.4	<.3	0.6	0.2	910	Lookout Louise
E. mesomorpha	402	1732	410	213	305	358	28.6	20.6	24.0	3.0	0.7	20.1	<.3	0.7	0.2	740	Point Houghton
E. mesomorpha	461	1830	356	233	367	466	49.8	20.5	27.2	3.8	1.1	26.1	0.5	1.0	0.4	880	Point Houghton
E. mesomorpha	429	1745	389	198	253	259	29.8	19.6	22.3	2.5	0.6	16.5	<.3	0.6	0.3	700	Point Houghton
E. mesomorpha	504	2034	916	281	361	418	50.3	18.2	39.3	3.3	2.2	17.2	<.3	0.8	0.2	950	Ishpeming Pt.
E. mesomorpha	514	1919	716	284	384	453	50.5	17.5	40.9	3.2	2.0	18.2	<.3	0.8	0.1	960	Ishpeming Pt.
E. mesomorpha	556	2115	783	293	399	475	55.9	18.4	42.1	3.3	2.1	18.4	<.3	0.9	0.2	1120	Ishpeming Pt.

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
1984																	
E. mesomorpha	538	2158	781	335	400	465	32.0	45.6	29.7	2.9	3.1	10.3	0.8	0.7	0.4	790	Locke Point
E. mesomorpha	477	2020	603	290	366	397	33.3	29.9	28.4	2.9	3.2	10.5	1.0	0.7	1.0	840	Locke Point
E. mesomorpha	525	2158	784	331	352	362	29.3	42.6	27.8	2.7	2.7	10.2	0.8	0.7	0.7	570	Locke Point
E. mesomorpha	568	2532	809	354	460	469	31.9	21.6	33.3	3.8	2.8	17.6	0.9	0.8	1.4	1050	Mt. Franklin
E. mesomorpha	562	2565	909	370	511	537	32.5	20.0	37.8	3.7	3.2	18.1	1.0	0.9	0.7	1240	Mt. Franklin
E. mesomorpha	555	2499	925	350	447	480	31.1	23.3	32.5	3.6	3.6	18.8	1.0	0.8	0.5	1150	Mt. Franklin
E. mesomorpha	626	2652	730	385	396	465	36.0	20.6	35.0	3.8	4.5	12.6	0.9	0.8	0.5	1200	Little Todd
E. mesomorpha	628	2677	699	391	410	478	35.6	20.6	38.3	3.7	4.4	12.3	0.9	0.8	0.4	1140	Little Todd
E. mesomorpha	654	2786	744	397	400	470	35.0	21.0	39.9	3.8	4.4	12.8	1.0	0.7	0.4	1100	Little Todd
E. mesomorpha	447	2037	348	284	396	436	38.4	14.4	32.5	3.4	3.8	18.2	1.0	0.8	0.9	1130	Huginnin Cove
E. mesomorpha	486	2296	385	306	395	414	42.3	15.6	35.3	3.6	3.8	18.8	0.6	0.7	1.1	1050	Huginnin Cove
E. mesomorpha	474	2174	363	302	412	463	41.0	15.4	34.7	3.7	4.5	21.2	1.1	0.9	1.0	1100	Huginnin Cove
E. mesomorpha	412	1807	485	281	419	439	32.3	15.6	28.1	3.6	3.1	20.2	0.7	0.7	0.6	830	McGinty Cove
E. mesomorpha	404	1806	521	266	373	375	29.6	15.4	29.9	3.6	3.4	18.8	0.9	0.7	0.5	840	McGinty Cove
E. mesomorpha	452	1898	535	281	365	373	30.8	17.7	29.2	3.4	3.8	16.3	0.9	0.7	0.4	780	McGinty Cove
E. mesomorpha	953	3391	953	440	487	538	33.4	51.8	48.2	5.0	3.1	19.7	1.3	0.9	0.4	1070	Long Point
E. mesomorpha	917	3361	918	423	448	480	28.6	47.5	46.9	4.8	2.9	19.6	1.1	0.8	0.3	1010	Long Point
E. mesomorpha	854	3180	874	417	464	494	31.7	50.0	45.4	4.7	2.3	20.1	1.4	0.9	0.4	1150	Long Point
1983																	
H. physodes	611	2453	15512	762	326	440	9.3	174.7	80.6	4.6	0.4	38.6	1.2	0.5	1.1	670	Passage Isl.
H. physodes	597	2488	14496	727	315	420	11.5	169.2	78.1	4.6	0.4	37.1	1.2	0.5	1.0	710	Passage Isl.
H. physodes	655	2518	12298	716	298	390	10.5	178.8	77.2	4.5	0.4	33.8	1.3	0.5	0.9	700	Passage Isl.
H. physodes	689	3037	20335	804	354	565	19.8	127.8	79.8	4.8	0.3	49.5	1.1	0.6	1.1	800	Locke Point
H. physodes	659	2909	23316	789	303	504	18.6	131.7	81.7	4.3	0.2	45.7	1.3	0.5	1.1	840	Locke Point
H. physodes	699	3077	21004	782	312	491	20.4	134.3	84.8	4.6	0.3	44.4	1.3	0.5	1.6	800	Locke Point
H. physodes	641	3070	14971	1004	397	525	14.8	414.9	87.9	4.6	0.5	40.0	1.2	0.9	1.2	770	Lookout Louise
H. physodes	599	3055	14903	960	398	544	15.5	420.4	93.6	4.7	0.5	40.2	1.4	1.0	1.2	810	Lookout Louise
H. physodes	579	2959	14630	957	419	568	28.1	392.0	88.6	4.9	0.4	44.8	1.4	1.0	1.2	820	Lookout Louise
H. physodes	574	2586	14053	657	270	372	20.8	104.5	67.3	5.3	0.6	35.2	0.6	0.5	0.7	890	Point Houghton
H. physodes	558	2542	15135	662	302	423	20.4	108.0	68.5	5.6	0.7	37.4	0.6	0.6	0.7	800	Point Houghton
H. physodes	558	2535	13592	628	296	412	19.9	92.9	64.3	5.4	0.6	35.7	0.6	0.5	0.7	720	Point Houghton
H. physodes	668	3410	22631	493	306	478	15.1	67.8	101.0	5.6	1.4	41.6	0.9	0.4	0.9	1030	Ishpeming Pt.
H. physodes	670	3414	18022	491	328	497	19.1	63.6	96.6	5.7	1.5	39.8	0.8	0.5	0.8	1100	Ishpeming Pt.
H. physodes	671	3375	20843	499	338	514	16.2	68.0	98.6	5.6	1.4	42.1	1.0	0.6	0.9	1130	Ishpeming Pt.
1984																	
H. physodes	1206	3583	19379	1348	393	442	18.7	539.9	81.5	3.7	0.8	31.1	1.0	0.8	1.4	740	Locke Point
H. physodes	1082	3521	19326	1208	434	475	21.7	406.7	76.8	3.8	0.6	33.3	1.0	0.8	1.3	680	Locke Point
H. physodes	1266	3825	19814	1474	401	444	24.2	519.9	87.6	4.0	0.7	32.4	1.0	0.8	1.4	790	Locke Point
H. physodes	756	3958	22047	845	494	562	20.1	103.1	98.7	6.3	0.8	62.6	1.8	0.7	1.4	1050	Mt. Franklin
H. physodes	792	4000	18554	864	491	563	20.2	103.7	97.1	6.3	0.8	53.0	2.1	1.6	1.1	1000	Mt. Franklin
H. physodes	782	3883	18279	868	487	549	23.2	108.3	101.9	6.5	0.7	55.3	1.7	0.6	1.1	970	Mt. Franklin
H. physodes	588	2851	14541	809	445	519	20.2	73.3	70.7	4.9	1.0	32.5	1.0	0.5	0.7	765	Little Todd
H. physodes	694	3123	14366	835	411	474	23.2	70.5	77.8	4.8	0.9	32.8	1.3	0.5	0.7	950	Little Todd
H. physodes	650	2928	17071	843	413	480	23.3	72.7	72.8	5.0	1.1	34.7	1.2	0.6	0.8	860	Little Todd
H. physodes	663	2953	14432	592	465	511	23.0	74.2	102.7	5.7	1.3	40.7	0.6	0.5	0.9	860	Huginnin Cove
H. physodes	689	3192	15282	613	458	528	21.8	87.7	112.8	5.2	1.0	37.1	0.9	0.5	0.9	1030	Huginnin Cove
H. physodes	685	3112	15121	603	438	500	22.3	77.9	112.8	5.6	1.1	36.1	0.7	0.5	0.9	980	Huginnin Cove
H. physodes	757	2778	23222	829	387	423	14.2	156.9	105.6	5.9	0.7	34.2	0.7	0.4	1.0	630	McGinty Cove
H. physodes	719	2679	26646	839	419	458	17.3	155.1	121.0	6.1	0.9	34.4	0.6	0.6	0.9	860	McGinty Cove
H. physodes	701	2765	22759	820	519	587	19.3	150.9	107.4	6.7	0.9	42.1	0.9	0.7	1.0	810	McGinty Cove
H. physodes	1187	3953	22989	921	368	402	14.7	609.8	133.6	5.5	1.1	41.5	0.6	0.9	1.3	680	Long Point
H. physodes	1189	3888	21612	934	344	362	12.9	639.4	135.4	5.5	1.0	38.8	0.8	0.9	1.2	690	Long Point
H. physodes	1144	3819	22814	855	356	376	13.5	544.0	132.9	5.2	0.8	41.7	0.7	0.8	1.2	720	Long Point

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
1983																	
P. sulcata	1123	2968	2307	556	400	396	20.5	108.3	86.0	6.4	2.7	27.2	1.0	0.6	0.4	880	Passage Isl.
P. sulcata	1156	2921	2273	567	383	364	24.1	115.3	85.1	6.5	2.6	27.2	0.8	0.6	0.3	1010	Passage Isl.
P. sulcata	1203	3049	2299	574	357	349	18.3	113.4	85.1	6.2	2.6	25.0	1.0	0.6	0.3	920	Passage Isl.
P. sulcata	1724	3837	2594	639	488	456	33.3	185.6	80.7	7.3	2.4	34.1	1.7	1.0	0.8	970	Locke Point
P. sulcata	1697	3768	2526	641	510	493	34.5	188.9	80.4	7.2	2.4	34.9	1.5	1.1	0.4	920	Locke Point
P. sulcata	1528	3647	2786	656	566	556	35.1	188.2	76.6	7.8	2.5	37.3	1.6	1.0	0.4	930	Locke Point
P. sulcata	1236	3896	2808	474	470	470	21.6	89.1	105.4	9.4	2.8	25.6	1.3	0.6	0.3	1010	Lookout Louise
P. sulcata	1340	3998	2739	492	477	491	22.2	87.7	103.3	9.7	2.7	25.5	1.0	0.7	0.3	1020	Lookout Louise
P. sulcata	1219	3853	2676	484	564	574	28.8	83.9	109.3	10.5	2.8	26.9	1.4	0.7	0.4	1050	Lookout Louise
P. sulcata	1040	3143	2049	346	268	265	24.1	116.0	86.4	6.8	2.1	20.2	0.7	0.6	0.2	860	Point Houghton
P. sulcata	1103	3310	2178	360	249	247	25.3	136.1	89.5	6.8	2.1	19.4	0.4	0.6	0.3	860	Point Houghton
P. sulcata	1108	3185	2164	345	278	277	27.2	118.8	86.4	6.8	1.9	20.4	0.7	0.6	0.2	860	Point Houghton
P. sulcata	1855	4661	2418	433	342	353	25.5	57.7	121.9	10.8	3.5	44.8	0.8	0.6	0.4	1140	Ishpeming Pt.
P. sulcata	1767	4825	2359	452	366	404	33.4	55.0	124.1	10.9	3.4	37.2	1.1	0.7	0.5	1120	Ishpeming Pt.
P. sulcata	1731	4687	2389	438	337	359	28.7	55.9	115.8	10.5	3.3	39.0	1.0	0.6	0.4	1120	Ishpeming Pt.
1984																	
P. sulcata	1412	3501	2891	681	426	399	19.2	173.6	92.6	6.4	3.7	29.7	0.8	0.7	0.5	1110	Locke Point
P. sulcata	1340	3793	3113	696	418	350	16.7	170.0	95.9	6.6	4.4	30.2	0.9	0.5	0.5	1110	Locke Point
P. sulcata	1499	3850	2907	718	434	364	16.9	184.2	91.6	6.6	3.9	31.2	1.0	0.5	0.4	1140	Locke Point
P. sulcata	1582	4130	3034	537	425	387	16.2	83.3	146.6	7.4	4.0	36.6	1.0	0.5	0.5	1010	Mt. Franklin
P. sulcata	1620	4147	2871	525	393	362	14.4	83.9	150.1	7.7	3.9	35.7	1.0	0.5	0.5	1220	Mt. Franklin
P. sulcata	1457	3937	2945	519	368	332	17.5	80.0	128.5	7.0	3.8	32.2	0.8	0.5	0.4	1130	Mt. Franklin
P. sulcata	1045	3435	2507	473	526	442	25.9	48.0	97.7	8.3	4.9	28.7	1.2	0.6	0.3	1050	Little Todd
P. sulcata	1147	3526	2461	476	456	389	23.4	45.9	96.9	7.9	4.7	26.9	1.3	0.4	0.3	1210	Little Todd
P. sulcata	1096	3518	2803	505	510	444	25.6	48.8	104.5	8.4	5.3	28.6	1.5	0.6	0.5	1140	Little Todd
P. sulcata	1326	3696	2557	441	487	410	28.3	61.7	214.2	9.5	3.8	30.0	1.1	0.5	0.3	1040	Huginnin Cove
P. sulcata	1320	3617	2503	431	463	388	25.9	59.4	197.5	9.2	3.9	27.8	1.0	0.5	0.3	1100	Huginnin Cove
P. sulcata	1260	3736	2381	415	435	356	23.5	58.0	193.9	9.0	3.8	26.9	1.1	0.4	0.4	1130	Huginnin Cove
P. sulcata	1484	3346	3115	533	540	433	19.1	109.3	174.4	11.2	4.4	31.5	1.2	0.5	0.3	1025	McGinty Cove
P. sulcata	1461	3391	3123	520	558	459	21.3	96.2	166.2	11.4	4.0	32.0	1.1	0.6	0.4	1030	McGinty Cove
P. sulcata	1547	3406	3143	557	551	445	33.7	101.1	193.6	12.0	4.6	33.9	1.6	0.8	0.6	1040	McGinty Cove
P. sulcata	2324	4834	2820	577	357	281	27.1	212.8	151.6	9.8	5.2	29.6	0.8	0.5	0.3	1130	Long Point
P. sulcata	2302	4941	2862	601	450	366	16.1	217.1	152.5	11.0	5.4	33.9	1.0	0.6	0.4	1140	Long Point
P. sulcata	2555	5159	2828	622	359	288	14.9	225.9	148.7	9.9	4.9	28.7	0.8	0.5	0.4	1220	Long Point
1983																	
U. muehlenbergii	637	1926	396	467	1232	1696	73.9	18.3	27.2	9.8	0.2	28.1	2.9	1.1	0.1	1720	Passage Isl.
U. muehlenbergii	592	1607	410	500	1227	1709	92.3	16.9	29.1	7.6	0.1	23.5	3.0	1.0	0.1	1740	Passage Isl.
U. muehlenbergii	626	1825	475	520	1287	1789	89.0	21.6	30.7	9.9	0.2	30.2	3.5	1.1	0.1	1690	Passage Isl.
U. muehlenbergii	632	2241	663	308	901	1092	47.9	14.4	33.5	6.5	0.4	37.4	1.1	1.1	0.4	1520	Locke Point
U. muehlenbergii	658	1940	380	246	787	897	59.4	10.2	27.2	5.5	0.3	41.8	1.0	1.0	0.5	1640	Locke Point
U. muehlenbergii	979	2528	703	362	1021	1232	59.3	15.1	34.1	6.6	0.3	42.3	1.2	1.2	0.7	1840	Locke Point
U. muehlenbergii	603	2649	306	476	734	987	56.4	14.1	23.2	8.3	0.6	13.5	2.4	0.8	0.4	1450	Lookout Louise
U. muehlenbergii	555	2486	258	423	711	964	62.2	13.6	21.5	8.5	0.5	13.2	2.1	0.7	0.1	1360	Lookout Louise
U. muehlenbergii	627	2635	311	523	869	1201	58.3	15.7	24.6	9.2	0.4	11.5	2.6	0.8	0.2	1410	Lookout Louise

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
1984																	
U. muehlenbergii	626	2200	772	354	756	858	51.7	12.7	30.9	5.2	1.7	28.6	1.5	1.0	0.4	1510	Locke Point
U. muehlenbergii	867	2362	574	385	793	893	72.1	12.1	33.3	6.2	1.8	32.8	1.8	1.0	0.5	1190	Locke Point
U. muehlenbergii	475	1791	579	294	626	734	63.7	10.6	27.5	4.6	1.5	24.5	1.3	0.9	0.4	1395	Locke Point
U. muehlenbergii	597	2496	334	333	889	939	42.2	12.1	31.0	7.1	1.9	30.5	2.0	1.0	0.4	1830	Mt. Franklin
U. muehlenbergii	654	2613	365	347	717	807	39.9	11.0	32.8	6.3	1.8	28.8	1.4	0.8	0.5	1280	Mt. Franklin
U. muehlenbergii	638	2592	303	356	875	983	46.2	12.1	33.3	6.7	1.7	27.4	2.0	1.1	0.5	1660	Mt. Franklin
U. muehlenbergii	603	3086	347	373	559	620	36.6	11.3	23.6	4.6	1.8	16.1	1.4	0.6	0.7	2190	Little Todd
U. muehlenbergii	730	2449	269	386	644	868	35.8	13.4	26.0	4.9	1.5	16.3	1.6	0.7	0.5	2100	Little Todd
U. muehlenbergii	602	2546	270	305	487	564	30.9	9.9	22.7	3.9	1.6	13.5	1.1	0.6	0.4	1730	Little Todd
U. muehlenbergii	532	2409	278	355	721	815	42.9	11.0	32.5	7.9	2.9	19.0	1.5	0.9	0.4	1570	Huginnin Cove
U. muehlenbergii	672	2486	332	323	686	774	37.9	12.7	38.3	7.7	2.4	20.3	1.6	0.9	0.5	1510	Huginnin Cove
U. muehlenbergii	558	2510	294	305	658	729	41.0	11.2	38.6	7.3	2.0	18.8	1.4	0.9	0.4	1630	Huginnin Cove
U. muehlenbergii	598	1969	301	277	525	545	63.6	8.3	31.3	5.4	1.6	18.8	1.1	0.8	0.4	1580	McGinty Cove
U. muehlenbergii	585	1904	345	274	580	608	57.9	9.0	32.6	5.6	1.7	22.0	1.2	0.8	0.7	1840	McGinty Cove
U. muehlenbergii	625	1899	390	291	613	654	70.1	9.5	32.2	6.1	1.7	24.1	1.1	0.9	0.5	2000	McGinty Cove

Table 2. Summary of analysis of Isle Royale lichens
Values in ppm of thallus

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Cladina rangiferina 1983																	
Mean	582	1552	727	364	309	331	26.6	43.0	14.9	2.2	0.4	7.8	0.7	0.5	0.1*	257	Passage Isl.
Std. dev.	50	167	43	13	12	16	1.7	6.8	1.0	<.1	0.1	0.4	0.3	<.1	<.1*	32	Passage Isl.
Mean	412	1290	1540	455	386	419	37.9	21.4	12.6	2.1	0.4	9.0	0.6	0.5	0.1	207	Locke Point
Std. dev.	46	142	167	43	28	36	0.9	2.2	1.1	0.1	0.1	1.0	0.2	<.1	<.1	25	Locke Point
Mean	531	1602	813	293	378	379	48.2	28.3	25.3	2.4	0.4	9.0	0.8	0.6	0.1	407	Lookout Louise
Std. dev.	17	11	19	2	14	19	0.4	1.5	0.9	<.1	<.1	0.1	0.4	0.1	<.1	12	Lookout Louise
Mean	462	1548	587	225	261	251	26.1	36.1	17.9	2.0	0.3	8.4	1.1	0.4	#	263	Point Houghton
Std. dev.	64	107	70	9	10	15	0.4	3.2	1.4	0.1	<.1	1.4	0.3	<.1	#	101	Point Houghton
Mean	953	2856	1591	556	466	564	32.8	36.8	29.7	3.2	0.5	10.2	0.5	0.6	0.1	483	Ishpeming Pt.
Std. dev.	49	95	45	27	39	58	3.1	0.9	1.8	0.2	<.1	1.0	0.1	<.1	<.1	87	Ishpeming Pt.
Cladina rangiferina 1984																	
Mean	426	1189	692	235	256	227	29.2	17.4	11.5	1.4	1.3	6.7	0.6	0.3	0.1*	347	Locke Point
Std. dev.	20	49	43	10	18	20	3.5	8.1	0.7	0.1	0.3	0.6	0.2	<.1	0.1*	31	Locke Point
Mean	539	1584	1219	494	714	932	30.8	16.2	19.6	2.6	1.0	5.5	1.1	0.9	#	563	Mt. Franklin
Std. dev.	48	129	79	21	21	14	1.1	1.1	0.7	0.1	0.1	0.3	0.1	0.1	#	25	Mt. Franklin
Mean	316	1207	492	231	295	276	36.0	11.1	13.6	1.8	1.7	7.2	0.8	0.3	#	397	Little Todd
Std. dev.	46	160	20	14	13	19	4.3	0.2	0.9	0.1	0.3	0.7	0.1	<.1	#	31	Little Todd
Mean	316	1207	492	231	295	276	36.0	11.1	13.6	1.8	1.7	7.2	0.8	0.3	<.7	397	Huginnin Cove
Std. dev.	46	160	20	14	13	19	4.3	0.2	0.9	0.1	0.3	0.7	0.1	<.1	0.1	31	Huginnin Cove
Mean	466	1385	496	244	353	309	27.9	36.8	15.8	2.0	2.2	8.1	0.7	0.5	0.5	423	McGinty Cove
Std. dev.	32	77	11	8	11	9	1.7	0.5	1.1	<.1	0.3	0.3	0.1	<.1	0.1	15	McGinty Cove
Mean	318	1211	563	202	318	263	23.0	25.8	15.3	1.9	1.8	7.7	0.7	0.5	0.5	353	Long Point
Std. dev.	36	144	82	12	41	43	1.3	6.2	0.9	0.1	0.1	1.5	0.1	<.1	0.1	42	Long Point
Evernia mesomorpha 1983																	
Mean	340	1441	381	211	238	273	15.8	20.6	24.0	1.9	0.3	16.2	#	0.5	0.4	610	Passage Isl.
Std. dev.	9	31	45	13	23	33	2.5	2.3	0.8	0.2	0.1	1.3	#	0.1	<.1	46	Passage Isl.
Mean	694	2152	1474	386	243	285	24.1	73.6	26.3	2.2	0.7	7.6	0.3*	0.8	0.2	697	Locke Point
Std. dev.	74	109	207	34	38	43	2.5	9.3	1.4	0.2	0.3	0.8	0.2*	0.1	0.1	85	Locke Point
Mean	587	2276	935	277	265	291	25.0	39.8	29.9	2.8	0.6	11.5	#	0.6	0.3	860	Lookout Louise
Std. dev.	8	51	321	14	7	12	0.6	9.0	0.7	0.1	0.1	0.6	#	0.1	0.1	44	Lookout Louise
Mean	431	1769	385	215	308	361	36.0	20.2	24.5	3.1	0.8	20.9	#	0.7	0.3	773	Point Houghton
Std. dev.	29	53	27	18	57	104	11.9	0.6	2.5	0.6	0.2	4.8	#	0.2	0.1	95	Point Houghton
Mean	525	2023	805	286	381	449	52.2	18.0	40.7	3.2	2.1	17.9	#	0.9	0.2	1010	Ishpeming Pt.
Std. dev.	28	99	102	7	19	29	3.2	0.4	1.4	0.1	0.1	0.6	#	0.1	<.1	95	Ishpeming Pt.
Evernia mesomorpha 1984																	
Mean	513	2112	723	319	373	408	31.5	39.4	28.6	2.8	3.0	10.3	0.9	0.7	0.7	733	Locke Point
Std. dev.	32	80	103	25	25	52	2.0	8.3	0.9	0.1	0.3	0.2	0.1	<.1	0.3	144	Locke Point
Mean	562	2532	881	358	472	496	31.8	21.6	34.5	3.7	3.2	18.2	0.9	0.9	0.9	1147	Mt. Franklin
Std. dev.	7	33	63	11	34	36	0.7	1.7	2.8	0.1	0.4	0.6	0.1	0.1	0.5	95	Mt. Franklin
Mean	636	2705	724	391	402	471	35.6	20.7	37.7	3.7	4.4	12.6	0.9	0.8	0.4	1147	Little Todd
Std. dev.	15	71	23	6	7	6	0.5	0.3	2.5	<.1	0.1	0.3	0.1	<.1	0.1	50	Little Todd
Mean	469	2169	365	297	401	438	40.6	15.1	34.2	3.6	4.0	19.4	0.9	0.8	1.0	1093	Huginnin Cove
Std. dev.	20	130	19	12	9	25	2.0	0.7	1.5	0.2	0.4	1.6	0.2	0.1	0.1	40	Huginnin Cove
Mean	423	1837	514	276	386	396	30.9	16.2	29.1	3.6	3.4	18.4	0.8	0.7	0.5	817	McGinty Cove
Std. dev.	26	53	26	9	29	37	1.3	1.2	0.9	0.1	0.3	2.0	0.1	<.1	0.1	32	McGinty Cove
Mean	423	1837	514	276	386	396	30.9	16.2	29.1	3.6	3.4	18.4	0.8	0.7	0.5	817	Long Point
Std. dev.	26	53	26	9	29	37	1.3	1.2	0.9	0.1	0.3	2.0	0.1	<.1	0.1	32	Long Point

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Hypogymnia physodes 1983																	
Mean	621	2486	14102	735	313	417	10.4	174.3	78.6	4.6	0.4	36.5	1.2	0.5	1.0	693	Passage Isl.
Std. dev.	30	32	1643	24	14	25	1.1	4.8	1.8	0.1	<.1	2.5	0.1	<.1	0.1	21	Passage Isl.
Mean	682	3007	21552	792	323	520	19.6	131.3	82.1	4.6	0.3	46.5	1.2	0.5	1.3	813	Locke Point
Std. dev.	21	88	1564	11	27	40	0.9	3.3	2.5	0.3	0.1	2.7	0.1	<.1	0.3	23	Locke Point
Mean	606	3028	14835	974	405	546	19.5	409.1	90.0	4.7	0.5	41.6	1.3	0.9	1.2	800	Lookout Louise
Std. dev.	32	60	180	26	13	21	7.4	15.0	3.1	0.1	0.1	2.7	0.1	0.1	<.1	26	Lookout Louise
Mean	563	2554	14260	649	289	403	20.4	101.8	66.7	5.4	0.6	36.1	0.6	0.5	0.7	803	Point Houghton
Std. dev.	10	27	792	18	17	27	0.4	7.9	2.2	0.2	<.1	1.2	<.1	0.1	<.1	85	Point Houghton
Mean	669	3400	20499	494	324	497	16.8	66.5	98.7	5.6	1.5	41.2	0.9	0.5	0.8	1087	Ishpeming Pt.
Std. dev.	2	21	2324	4	16	18	2.1	2.5	2.2	0.1	0.1	1.2	0.1	0.1	0.1	51	Ishpeming Pt.
Hypogymnia physodes 1984																	
Mean	1185	3643	19506	1343	409	454	21.5	488.8	82.0	3.8	0.7	32.3	1.0	0.8	1.4	737	Locke Point
Std. dev.	94	161	268	133	22	19	2.7	71.8	5.4	0.2	0.1	1.1	<.1	<.1	0.1	55	Locke Point
Mean	777	3947	19627	859	491	558	21.2	105.0	99.2	6.4	0.7	57.0	1.9	1.0	1.2	1007	Mt. Franklin
Std. dev.	18	60	2101	12	3	8	1.8	2.8	2.5	0.1	0.1	5.0	0.2	0.6	0.2	40	Mt. Franklin
Mean	644	2967	15326	829	423	491	22.3	72.2	73.8	4.9	1.0	33.3	1.2	0.5	0.8	858	Little Todd
Std. dev.	53	140	1514	18	19	25	1.8	1.5	3.6	0.1	0.1	1.2	0.2	<.1	0.1	93	Little Todd
Mean	679	3086	14945	603	454	513	22.4	79.9	109.4	5.5	1.1	38.0	0.7	0.5	0.9	957	Huginnin Cove
Std. dev.	14	122	452	11	14	14	0.6	7.0	5.8	0.3	0.1	2.4	0.1	<.1	<.1	87	Huginnin Cove
Mean	726	2741	24209	830	442	489	16.9	154.3	111.3	6.2	0.8	36.9	0.8	0.6	1.0	767	McGinty Cove
Std. dev.	29	54	2123	10	69	87	2.6	3.0	8.5	0.4	0.1	4.5	0.2	0.2	<.1	121	McGinty Cove
Mean	1173	3887	22472	903	356	380	13.7	597.7	133.9	5.4	1.0	40.6	0.7	0.9	1.2	697	Long Point
Std. dev.	25	67	750	42	12	20	0.9	48.8	1.3	0.2	0.1	1.6	0.1	0.1	<.1	21	Long Point
Parmelia sulcata 1983																	
Mean	1161	2979	2293	566	380	370	21.0	112.3	85.4	6.4	2.6	26.5	0.9	0.6	0.3	937	Passage Isl.
Std. dev.	41	65	18	9	21	24	2.9	3.6	0.5	0.2	0.1	1.3	0.1	<.1	<.1	67	Passage Isl.
Mean	1650	3751	2635	645	521	502	34.3	187.6	79.2	7.4	2.4	35.4	1.6	1.0	0.5	940	Locke Point
Std. dev.	106	96	135	9	40	51	0.9	1.8	2.3	0.3	0.1	1.7	0.1	<.1	0.2	26	Locke Point
Mean	1265	3916	2741	483	504	512	24.2	86.9	106.0	9.8	2.8	26.0	1.2	0.7	0.3	1027	Lookout Louise
Std. dev.	65	75	66	9	52	55	4.0	2.7	3.0	0.6	<.1	0.8	0.2	0.1	0.1	21	Lookout Louise
Mean	1084	3213	2130	350	265	263	25.5	123.6	87.4	6.8	2.1	20.0	0.6	0.6	0.2	860	Point Houghton
Std. dev.	38	87	71	8	15	15	1.6	10.9	1.8	<.1	0.1	0.6	0.2	<.1	<.1	0	Point Houghton
Mean	1785	4724	2389	441	348	372	29.2	56.2	120.6	10.7	3.4	40.3	1.0	0.7	0.4	1127	Ishpeming Pt.
Std. dev.	64	88	29	10	16	28	4.0	1.3	4.3	0.2	0.1	3.9	0.2	0.1	0.1	12	Ishpeming Pt.
Parmelia sulcata 1984																	
Mean	1417	3715	2971	698	426	371	17.6	175.9	93.4	6.5	4.0	30.3	0.9	0.6	0.5	1120	Locke Point
Std. dev.	80	187	124	19	8	26	1.4	7.4	2.2	0.1	0.4	0.8	0.1	0.1	<.1	17	Locke Point
Mean	1553	4071	2950	527	395	360	16.0	82.4	141.7	7.4	3.9	34.8	1.0	0.5	0.5	1120	Mt. Franklin
Std. dev.	85	116	82	9	29	28	1.6	2.1	11.6	0.4	0.1	2.3	0.1	<.1	<.1	105	Mt. Franklin
Mean	1096	3493	2591	485	498	425	25.0	47.6	99.7	8.2	5.0	28.1	1.3	0.5	0.4	1133	Little Todd
Std. dev.	51	50	186	17	37	31	1.4	1.5	4.2	0.3	0.3	1.0	0.2	0.1	0.1	80	Little Todd
Mean	1302	3683	2480	429	462	385	25.9	59.7	201.9	9.2	3.8	28.2	1.1	0.5	0.3	1090	Huginnin Cove
Std. dev.	36	61	90	13	26	27	2.4	1.9	10.8	0.3	0.1	1.6	<.1	0.1	<.1	46	Huginnin Cove
Mean	1497	3381	3127	536	550	446	24.7	102.2	178.1	11.5	4.3	32.5	1.3	0.6	0.4	1032	McGinty Cove
Std. dev.	44	31	14	19	9	13	7.8	6.6	14.1	0.4	0.3	1.2	0.3	0.1	0.2	8	McGinty Cove
Mean	2394	4978	2837	600	389	312	19.4	218.6	151.0	10.2	5.2	30.7	0.8	0.5	0.4	1163	Long Point
Std. dev.	140	166	22	23	53	47	6.8	6.7	2.0	0.7	0.2	2.8	0.1	0.1	<.1	49	Long Point

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Umbilicaria muehlenbergii 1983																	
Mean	618	1786	427	496	1248	1731	85.0	18.9	29.0	9.1	0.2	27.3	3.1	1.1	0.1*	1717	Passage Isl.
Std. dev.	23	163	42	27	33	50	9.8	2.4	1.7	1.3	0.1	3.4	0.3	0.1	<.1*	25	Passage Isl.
Mean	756	2236	582	306	903	1074	55.5	13.3	31.6	6.2	0.3	40.5	1.1	1.1	0.5	1667	Locke Point
Std. dev.	194	294	176	58	117	168	6.6	2.7	3.8	0.6	0.1	2.7	0.1	0.1	0.2	162	Locke Point
Mean	595	2590	292	474	771	1051	59.0	14.5	23.1	8.7	0.5	12.7	2.4	0.8	0.2	1407	Lookout Louise
Std. dev.	36	90	29	50	85	130	3.0	1.1	1.6	0.5	0.1	1.0	0.3	<.1	0.1	45	Lookout Louise
Umbilicaria muehlenbergii 1984																	
Mean	656	2118	642	345	725	829	62.5	11.8	30.6	5.3	1.7	28.6	1.5	0.9	0.4	1365	Locke Point
Std. dev.	198	294	113	46	87	84	10.2	1.1	2.9	0.8	0.2	4.2	0.3	0.1	0.1	162	Locke Point
Mean	630	2567	334	345	827	910	42.8	11.7	32.4	6.7	1.8	28.9	1.8	1.0	0.4	1590	Mt. Franklin
Std. dev.	29	63	31	12	95	92	3.2	0.6	1.2	0.4	0.1	1.5	0.4	0.1	0.1	282	Mt. Franklin
Mean	645	2694	295	355	563	684	34.4	11.5	24.1	4.4	1.7	15.3	1.4	0.7	0.5	2007	Little Todd
Std. dev.	74	343	45	44	78	162	3.1	1.8	1.7	0.5	0.1	1.6	0.3	<.1	0.2	244	Little Todd
Mean	588	2468	301	328	688	773	40.6	11.7	36.5	7.6	2.4	19.4	1.5	0.9	0.4	1570	Huginnin Cove
Std. dev.	75	53	28	26	32	43	2.5	0.9	3.5	0.3	0.5	0.8	0.1	<.1	0.1	60	Huginnin Cove
Mean	603	1924	346	281	573	603	63.9	8.9	32.0	5.7	1.6	21.6	1.1	0.8	0.5	1807	McGinty Cove
Std. dev.	20	39	45	9	45	54	6.1	0.6	0.7	0.3	0.1	2.7	0.1	<.1	0.1	212	McGinty Cove

*= one value at or below detection limit; included as 0.7 of detection limit
#= two or more values at or below detection limit; not included in calculations

within typical limits. The highest levels of sulfur are on the ridgetops from the center of the island northeast but not at Passage Island. Lookout Louise has one species with highest level, Mt. Franklin has three species with highest or next to highest level and Ishpeming Point has four species in these categories. The lakeshore localities on the north side of the island have only one or two species in the top two positions. None of the species show highest levels at Passage Island or any of the south shore localities. Zinc also shows a similar pattern. This seems to indicate that there is air pollution coming from north or northwest of the park which is rising as the air flows over the island. There are known pollution sources in Thunder Bay, Ontario that is only 30 miles directly northwest of the center of the park. The sulfur levels in lichens tested range from 180 to 2190 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980). Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of the different species. Cladina rangiferina has the lowest levels and Umbilicaria muehlenbergii has the highest levels. The levels at Locke Point are about the same for the two years but most species show slightly higher levels in 1984. This may be due to weather conditions since 1983 was a dry year and 1984 was

normally wet. This points out the need for more sampling at different months of the year to determine the cause of this variation.

Although some localities show elevated sulfur levels by elemental analysis, the lichens most sensitive to sulfur dioxide are still present at these localities. This means that levels are not high enough to visibly damage or eliminates the lichens but there is sublethal pollution in the park that bears monitoring.

CONCLUSIONS

There is no indication that the lichens of Isle Royale National Park are being damaged by air quality. The lichen flora is diverse with many species present in all areas of the park. Many species in the group most sensitive to sulfur dioxide are present and their distribution in the park does not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area. However, the elemental analyses do show abnormal accumulations of polluting elements at some localities, especially on the ridgetops on the northeastern half of the island.

RECOMMENDATIONS

Because of the detection of elevated sulfur levels in the park it is recommended that frequent (annual?) checking of sulfur levels be made, especially at the ridgetop localities of Mt. Franklin and Ishpeming Point and perhaps at a north shore locality. This would also provide information on annual

fluctuations due to other causes. A survey for the most sensitive species should also be made every two to three years to detect the first cases of possible extinction of the most sensitive species due to air pollution if the present pollution increases. It would be desirable to set up a sulfur dioxide monitor in the park to corroborate the results of this lichen study.

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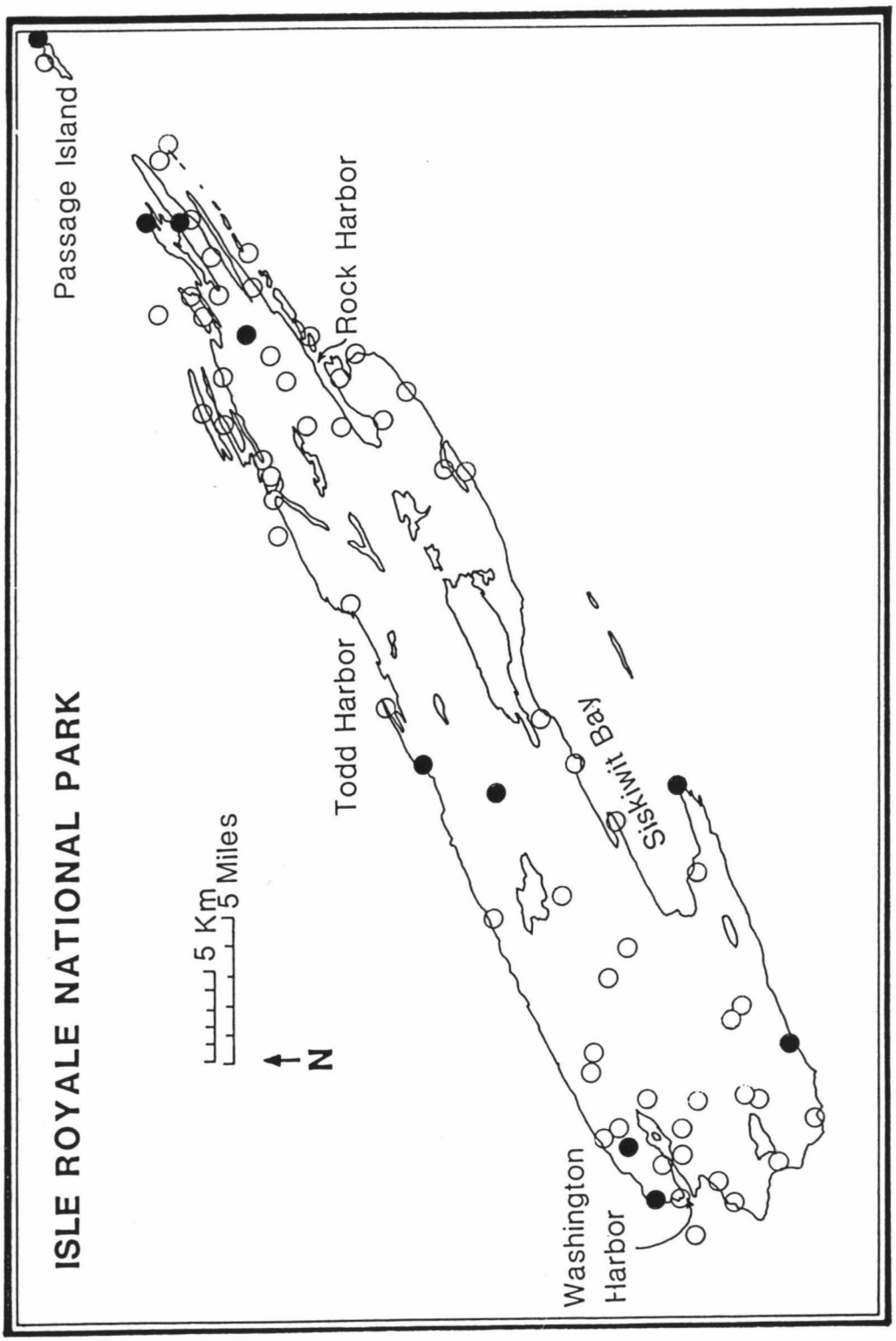

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.

APPENDIX I

Collection Localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by collection number and date of collection.

Keweenaw County, Michigan

46565-46673 West Caribou Island in Rock Harbor. In spruce - balsam fir forest near shore and in interior of island. 2 July 1983.

46674-46725 West Caribou Island in Rock Harbor. Along shore on rocks on outside of island. 2 July 1983.

46726-46793 Northeast end of Lane Cove. In old Thuja forest near shore with some balsam fir. 3 July 1983.

46794-46900 Around Lookout Louise. On ridge with balsam fir, white spruce and some old quaking aspen and white birch. 5 July 1983.

46902-46939 Ridge SE of Lookout Louise. Some rock outcrops, young balsam fir and old quaking aspen. 5 July 1983.

46940-47019 Southwest of Saginaw Point 1.5 miles. On rock outcrops with scattered jack pine, white birch, spruce and balsam fir. 6 July 1983.

47020-47115 At W end of Chippewa Harbor on S side below cliffs. In balsam fir forest with some birch and few mountain maples. 6 July 1983.

47116-47202 Inside Chippewa Harbor on N side of inner narrows. On rock outcrops with jack pine and aspen - birch in low areas between ridges. 6 July 1983.

47203-47282 Rock Harbor on main island W of Davidson Island just E of 3 mile campground. Around rock outcrops with some spruce and balsam fir. 7 July 1983.

47283-47357 At head of Duncan Bay. In Thuja swamp along stream in area of old trees and some spruce and balsam fir. 8 July 1983.

47358-47444 Rocky point outside of Locke Point. On rock shore with some small balsam fir and spruce. 8 July 1983.

47445- Passage Island near middle of island on N shore and in

47506 low center area. Thick forest with balsam fir, mountain ash and devils club. 9 July 1983.

47507-47584 Passage Island at NE tip on rock shore and in spruce - balsam fir woods with mountain ash and devils club in low areas. 9 July 1983.

47585-47690 Wallace Lake S of Rock Harbor. On ~~S~~ N side of lake in white birch -quaking aspen forest with some Thuja and balsam fir. 10 July 1983.

47691-47756 On main island across from Clay Isl. (S of Belle Isle). In cove in area of Thuja near shore and small stream. 11 July 1983.

47757-47815 W end of Pickerel Cove. In old white birch stand with few quaking aspen and some Thuja and balsam fir along shore. 11 July 1983.

47816-47887 At junction of west Daisy Farm trail and Greenstone Ridge trail. Around ridgetop in quaking aspen - white birch forest and open areas with scattered sugar maple. 12 July 1983.

47888-47917 West of Mt. Ojibway on steep north facing rock cliffs, deeply shaded. 12 July 1983.

47918 Daisy Farm in Rock Harbor. 12 July 1983.

47919-47981 Brady Cove off McCargo Cove. On N side in mixed forest near shore and swamp. 13 July 1983.

47982-48064 McCargo Cove, on point on W side of mouth. Rocky point with few trees. 13 July 1983.

48065-48151 Wilson Point in Todd Harbor. In mixed woods on narrow point of land with Thuja near shore. 14 July 1983.

48152-48223 Bog behind Green Isle in NE Todd Harbor. In narrow Thuja bog at end of bay. 14 July 1983.

48224-48310 South of Brady Cove off McCargo Cove. In Thuja swamp on S side of small bay. 15 July 1983.

48311-48394 Northeast side of Moskey Basin in Rock Harbor. In Thuja swamp extending back from shore. 16 July 1983.

48395-48506 Edwards Island at NE end of Tobin Harbor. In balsam fir woods along rock cliffs and on upper shore at SE tip of island. 17 July 1983.

48507-48580 Around old Feldtmann lookout tower. Open ridgetop with birch, aspen and brush burned in 1936. 18 July 1983.

48581- On N slope below new Feldtmann lookout tower. In mixed
48648 forest along ledges with birch, aspen, balsam fir and Thuja. 19 July 1983.

48649- South slope of ridge below new Feldtmann lookout tower.
48726 Near ridgetop in rock openings and low areas with aspen and ash. 19 July 1983.

48727- Bog behind Checker Point on S shore of Siskiwit Bay.
48800 Thuja bog with alder and brush SW of Francis Point. 20 July 1983.

48801- Point Houghton in Siskiwit Bay. In mixed forest along
48892 inner shore with balsam fir, birch and aspen. 20 July 1983.

48893- Ishpeming Point on Greenstone Ridge. Around ridgetop
48949 and on upper N facing slope in mixed young woods. 21 July 1983.

48950- Between Crow Point and Siskiwit Lake along old trail
49024 in mixed forest with low rock ledges. 21 July 1983.

49025- Bog behind Spruce Point in Siskiwit Bay. Thuja bog
49102 with area in center of black spruce. 22 July 1983.

49103- Point Hay in Siskiwit Bay. Mixed forest on point with
49175 balsam fir, birch, aspen and Thuja along shore. 22 July 1983.

49176- Swamp SW of Hidden Lake in Tobin Harbor. Thuja swamp
49263 with lots of alder and some spruce and balsam fir. 24 July 1983.

49264- On point N of Tallman Isl. in Tobin Harbor. On low
49351 ridge in mixed forest of balsam fir, old white birch and some quaking aspen. 24 July 1983.

49352- Mine Point S of Conglomerate Bay. On rocky point with
49427- jack pines. 25 July 1983.

49428- North of Conglomerate Bay. On ridge around ledges in
49526 mixed forest of birch, aspen, spruce and balsam fir. 25 July 1983.

49527- Heron Island in Rock Harbor outside of Tookers Isl.
49677 Rocky narrow island with spruce, balsam fir and some white birch and mountain ash. 26 July 1983.

49678- North of Robinson Bay. In mixed forest on hillside
49762 with some old quaking aspen. 27 July 1983.

49763- Small bay N of Stockly Bay off Five Finger Bay. At end
49338 of bay in Thuja swamp near stream. 27 July 1983.

51336- Mt. Franklin, on steep N facing cliffs with some white
51376 spruce, balsam fir and white birch. Sec. 12, T66N, R34W. 30 June 1984.

51377- Greenstone Ridge 1 mile SW of Mt. Franklin. On S facing
51423 slope in rock openings and in scattered clumps of old quaking aspen. Sec. 14, T66N, R34W. 30 June 1984.

51424- Net Island NE of Amygdaloid Isl. On NE half of island,
51468 mainly on rocky shore. Inland with spruce, balsam fir and mountain ash. Sec. 25 & 26, T76N, R34W. 1 July 1984.

51469- Amygdaloid Isl. In center of island on ridges and in
51554 valleys with birch, aspen, spruce and balsam fir. Sec. 33, T67N, R34W. 1 July 1984.

51555 Menangerie Island in Siskiwit Bay. 4 July 1984.

51556- Main island NE of Thompson Isl. In open, old white
51635 birch, aspen stand on north facing slope. Sec. 35, T64N, T39W. 4 July 1984.

51636- Johns Isl. in Washington Harbor. Along N shore on rocks
51691 and nearby trees. Sec. 3, T63N, R39W. 4 July 1984.

51692- Cove behind Middle Point SE of Washington Island. In
51756 Thuja bog near shore with stream. Sec. 11 & 14, T63N, R39W. 5 July 1984.

51757- Along S shore of Grace Harbor. In mixed forest with
51828 white spruce, yellow birch and Thuja. Sec. 12, T63N, R39W. 5 July 1984.

51829- Half mile E of Windigo along Greenstone Ridge Trail. In
51895 Thuja swamp with few yellow birch. Sec. 28, T64N, R38W. 6 July 1984.

51896- Half mile E of Rainbow Cove N of trail to Feldtmann
51953 Lake. Black spruce swamp with some Thuja. Sec. 19, T63N, R38W. 7 July 1984.

51954- Southwest of McGinty Cove on rocky point. Along shore
52076 and on top of point with some Thuja and white spruce. Sec. 35, T64N, R39W. 9 July 1984.

52077- SE of Grace Creek bog along Feldtmann Trail. In Thuja
52144 bog with birch, spruce and alder. Sec. 5, T63N, R38W. 10 July 1984.

52145- 1.5 miles SE of Washington Harbor on Feldtmann Trail.
52199 On hill with sugar maple and some old yellow birch. Sec. 5, T63N, R38W. 10 July 1984.

52200- One mile S of Huginnin Cove. In black spruce swamp on
52249 ridgetop E of trail. Some Thuja along margins. Sec. 20, T64N, R38W. 11 July 1984.

52250- Huginnin Cove. Along cliffs near shore NE of cove with
52342 some white birch and spruce and Thuja. Sec. 19 & 20, T64N, R38W. 12 July 1984.

52343- West end of Minong Ridge Trail. On rocky ridgetop with
52427 white pine, rocks and some Thuja. Sec. 15, T64N, R38W. 14 July 1984.

52428- South of Minong Ridge E of Huginnin Cove. In sugar
52470 maple and yellow birch area on ridge. Sec. 15, T64N, R38W. 14 July 1984.

52471- South of Lake Desor on Greenstone Ridge. Ridgetop in
52528 old burn around small rock outcrops with white birch and young sugar maple. Sec. 10, T64N, R37W. 15 July 1984.

52529- One mile N of Island Mine. On north facing ridge and in
52606 valley with Thuja, birch and some aspen and white pine. Sec. 20, T64N, R37W. 16 July 1984.

52607- Sugar Mountain on Greenstone Ridge. In old sugar maple
52649 forest with some yellow birch. Sec. 19, T64N, R37W. 16 July 1984.

52650- Half mile E of Long Point. In swamp W of small lake
52709 near shore with alder and Thuja. Sec. 27, T63N, R38W. 18 July 1984.

52710- The Head, W of Long Point. In low area behind point
52758 with old beach ridges with open spruce and birch. Sec. 29, T63N, R38W. 18 July 1984.

52759- One mile S of Huginnin Cove. On and around cliff on W
52864 side of fault with some Thuja, white pine and white spruce. Sec. 19, T64N, R38W. 19 July 1984.

52865- Swamp E of Feldtmann Lake. Alder swamp along trail with
52904 some black spruce and Thuja. Sec. 16, T63N, R38W. 20 July 1984.

52905- Cliff on Feldtmann Ridge SE of Feldtmann Lake. On top
52945 of cliff with few spruce and small Thuja and open grassy area. Sec. 16, T63N, R38W. 20 July 1984.

52946- North side of Washington Harbor just W of Beaver
53015 Island. Wet drainage to shore with Thuja, spruce and birch. Sec. 31, T64N, R38W. 21 July 1984.

53016- Ridge S of Washington Harbor, W of Beaver Island. On
53070 north facing slope with yellow birch, Thuja, some spruce and balsam fir. Sec. 31, T64N, R38W. 21 July 1984.

53071- North of Lake Desor at shore of Lake Superior. On shore
53141 rocks and in trees near shore. Sec. 28, T65N, R37W. 24 July 1984.

53142- NE point of Little Todd Harbor. In mixed forest on
53195 point with balsam fir, spruce, white birch and some Thuja. Sec. 17, T65N, R38W. 24 July 1984.

53196- Hawk Island near McCargo Cove. On NE end of island on
53254 rock shores and on ridgetop. Sec. 23, T66N, R35W. 25 July 1984.

53255- South Government Island in Rock Harbor. At NE end of
53357 narrow island with ledges on N side and balsam fir and mountain ash. 27 July 1984.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in Isle Royale National Park fall within the Sensitive category as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50ug sulfur dioxide per cubic meter (average annual).

Note: Refer to text for interpretation of these maps and precautions concerning absence in parts of the park.

Fig. 2 Bryoria furcellata (Fr.) Brodo & Hawksw.
Fig. 3 Bryoria trichodes (Michx.) Brodo & Hawksw.
Fig. 4 Caloplaca flavorubescens (Huds.) Laund.
Fig. 5 Catillaria griffithii (Sm.) Malme
Fig. 6 Dimerella lutea (Dicks.) Trev.
Fig. 7 Hypogymnia tubulosa (Schaer.) Hav.
Fig. 8 Lecidea vernalis (L.) Ach.
Fig. 9 Lobaria pulmonaria (L.) Hoffm.
Fig. 10 Ochrolechia rosella (Müll. Arg.) Vers.
Fig. 11 Parmelia squarrosa Hale
Fig. 12 Parmelia subaurifera Nyl.
Fig. 13 Ramalina americana Hale
Fig. 14 Ramalina farinacea (L.) Ach.
Fig. 15 Ramalina obtusata (Arn.) Bitt.
Fig. 16 Ramalina pollinaria (Westr.) Ach.
Fig. 17 Usnea ceratina Ach.
Fig. 18 Usnea filipendula Stirt.

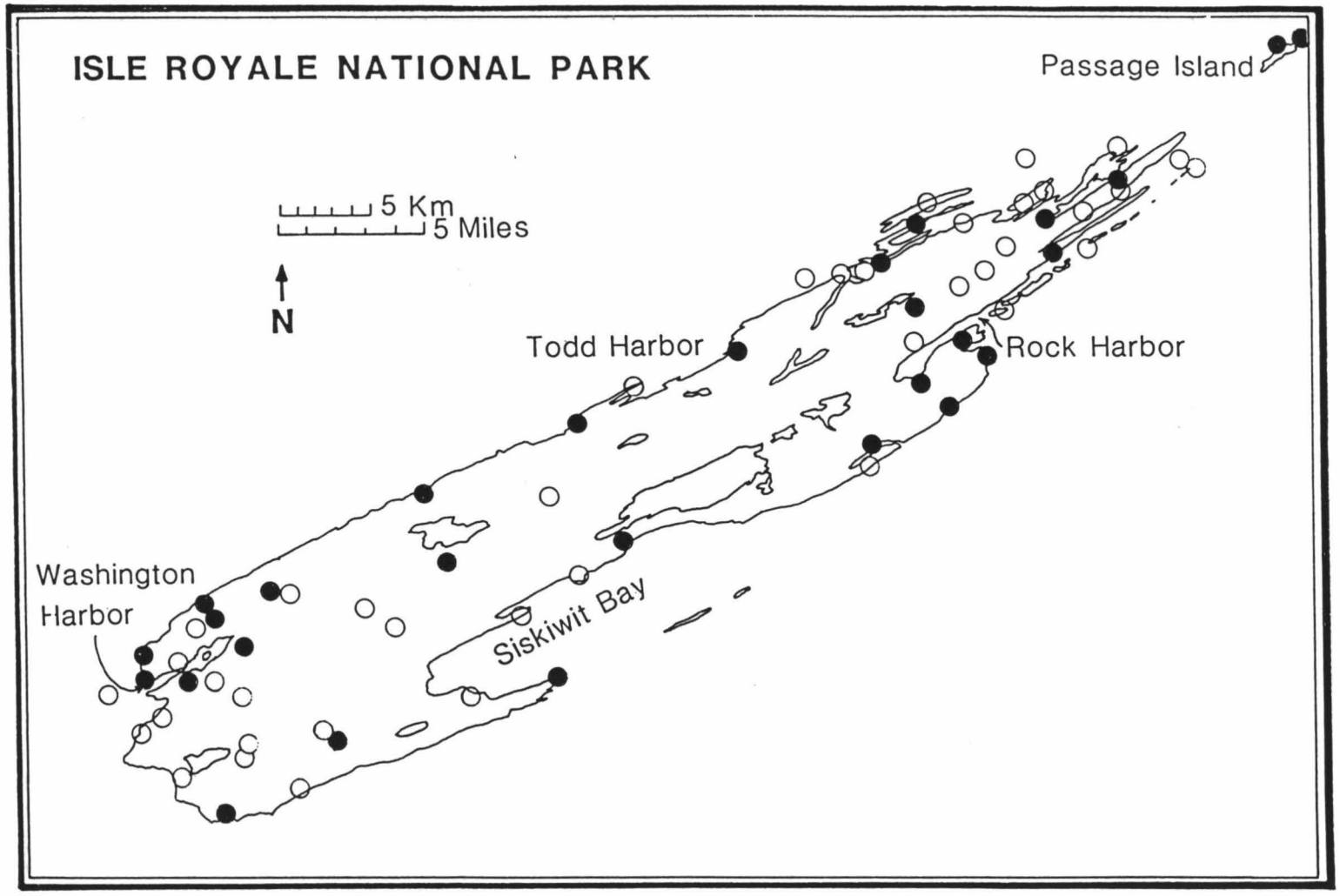

Fig. 2. Bryoria furcellata

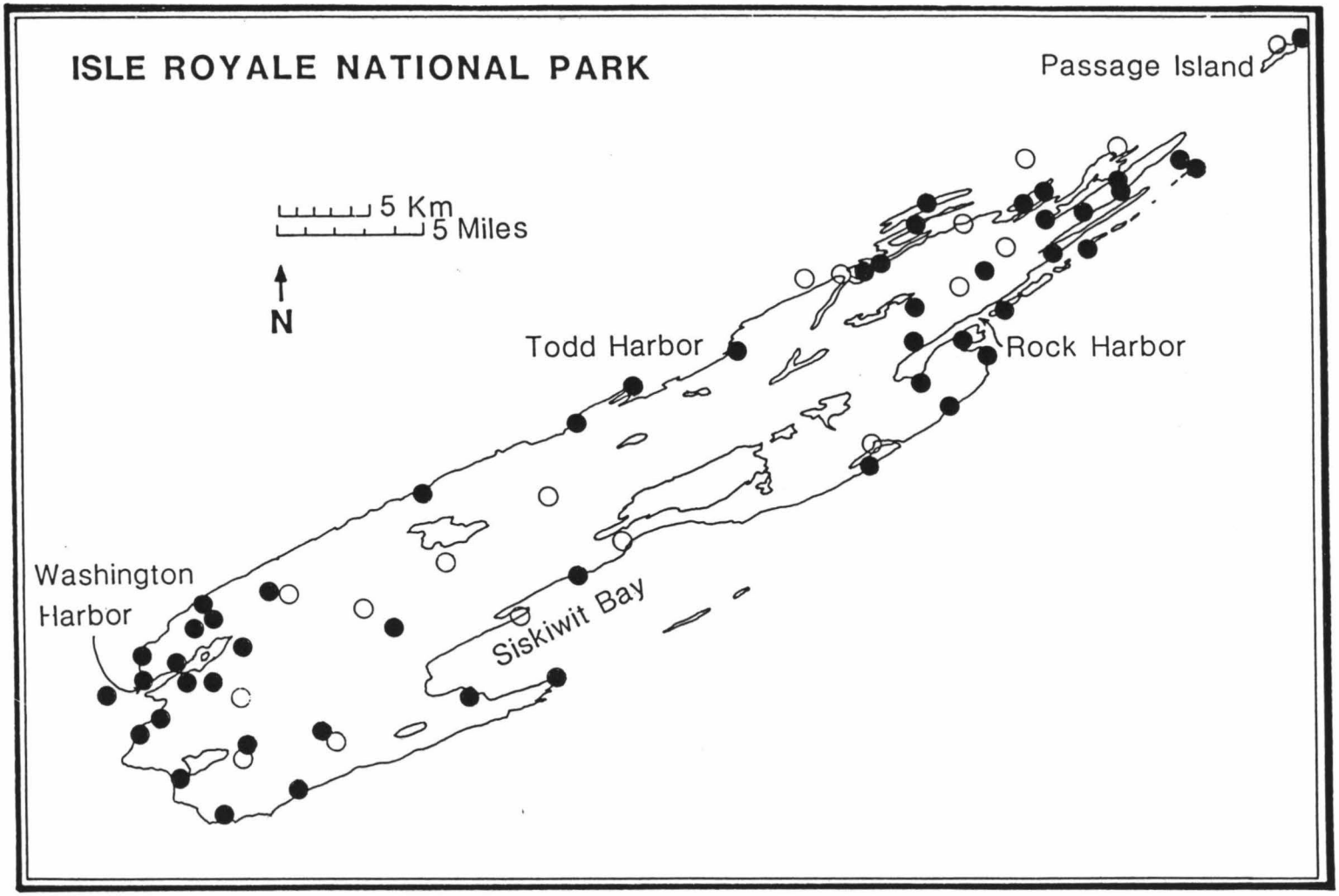

Fig. 3. Bryoria trichodes

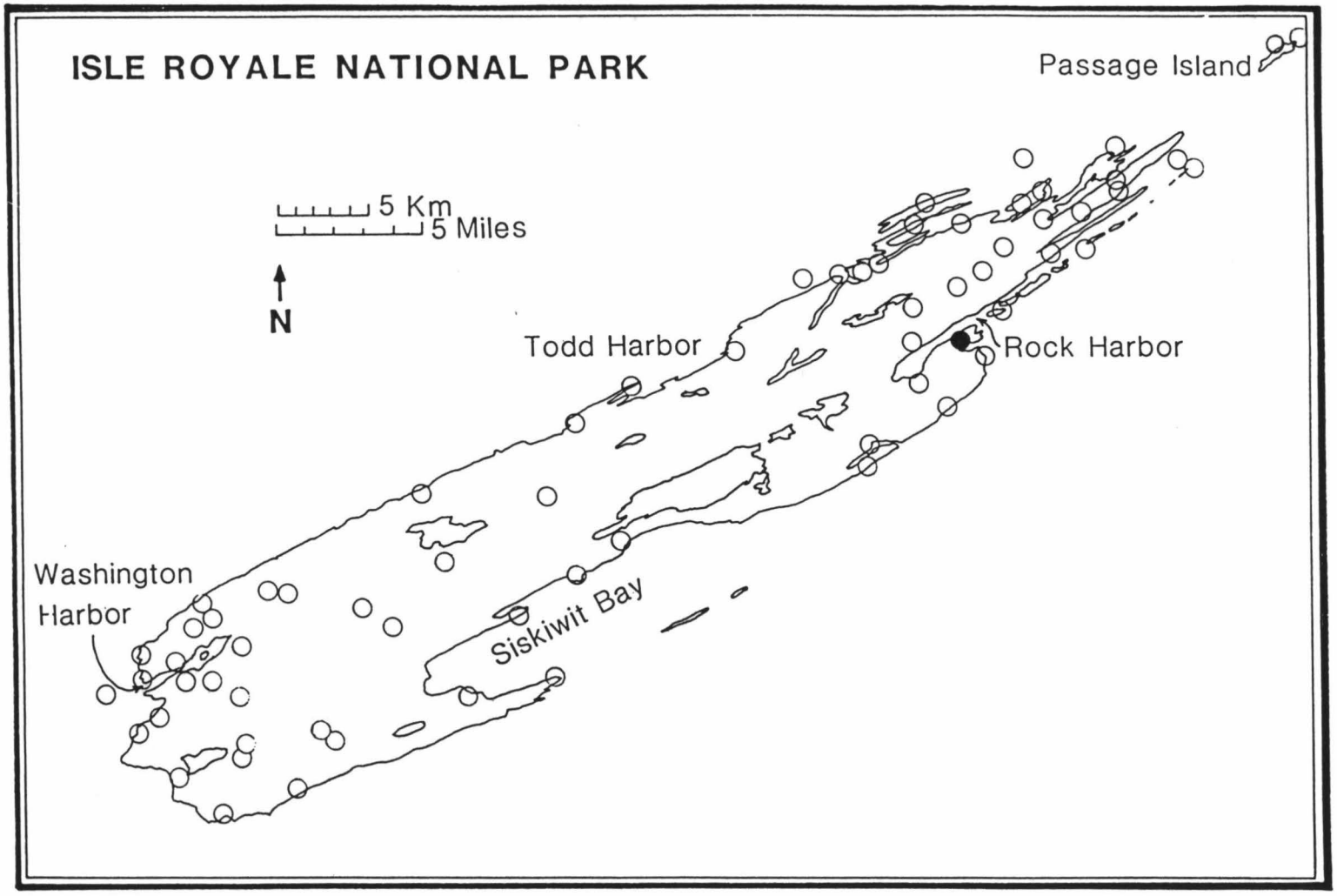

Fig. 4. Caloplaca flavorubescens

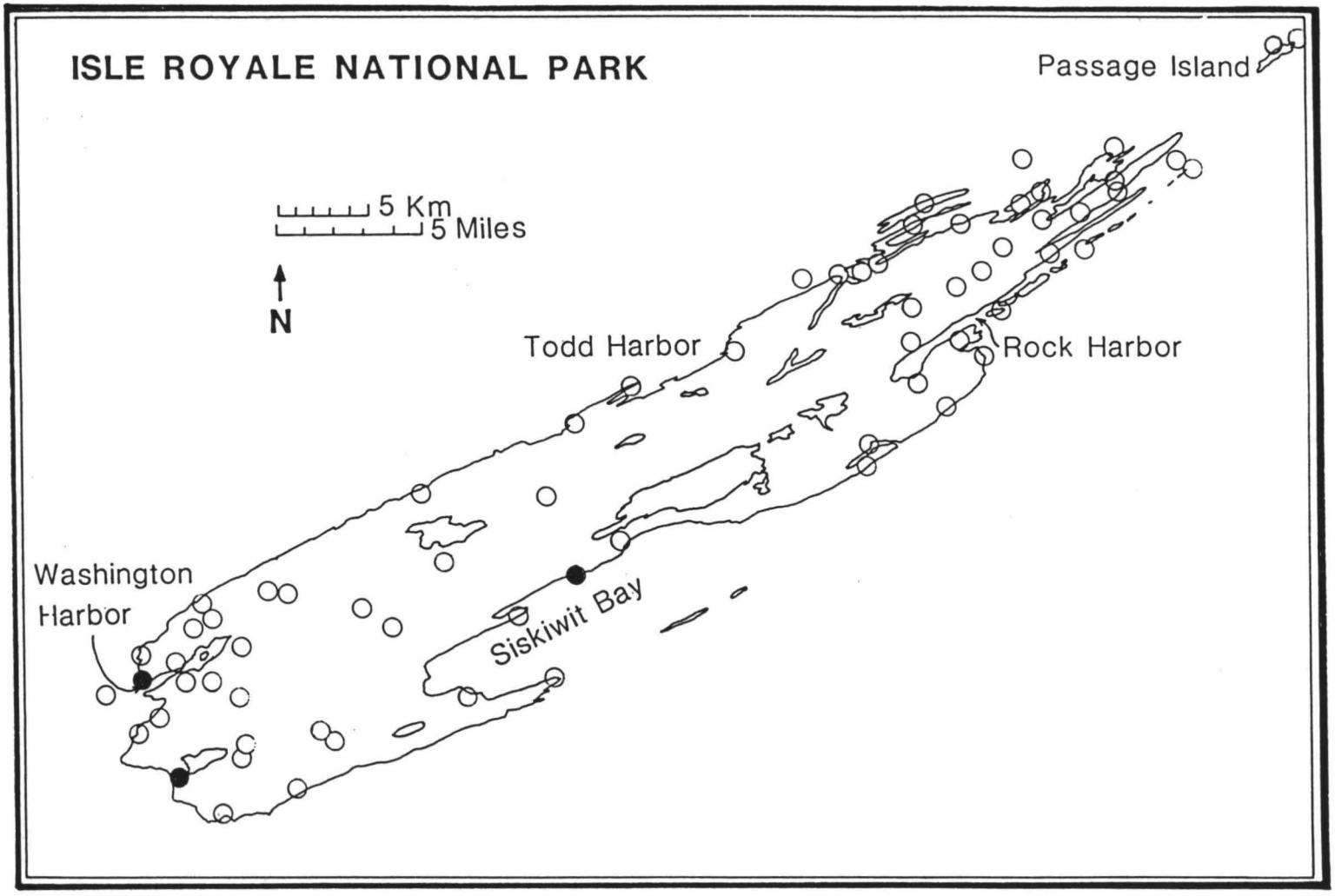

Fig. 5. Catillaria griffithii

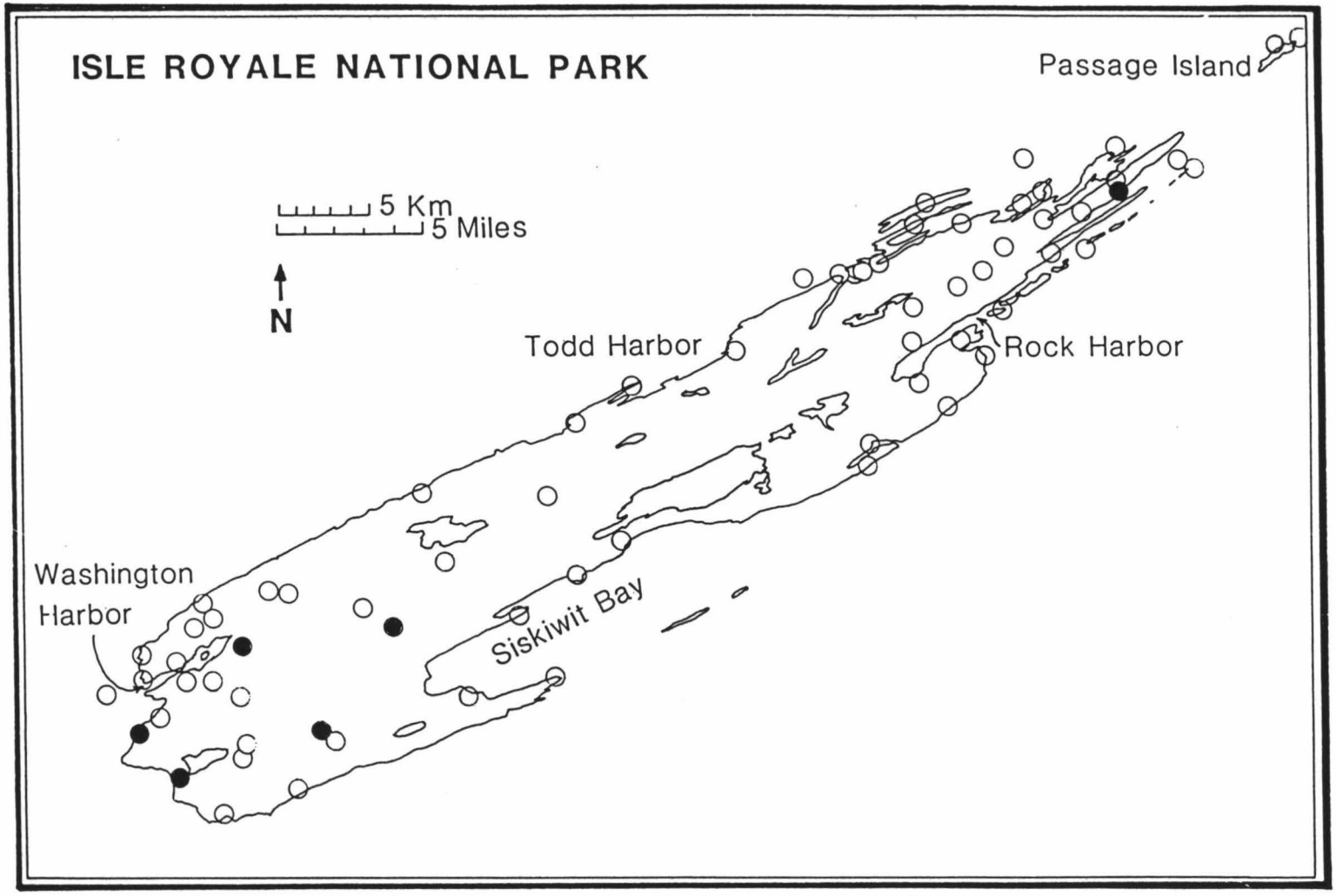

Fig. 6. Dimerella lutea

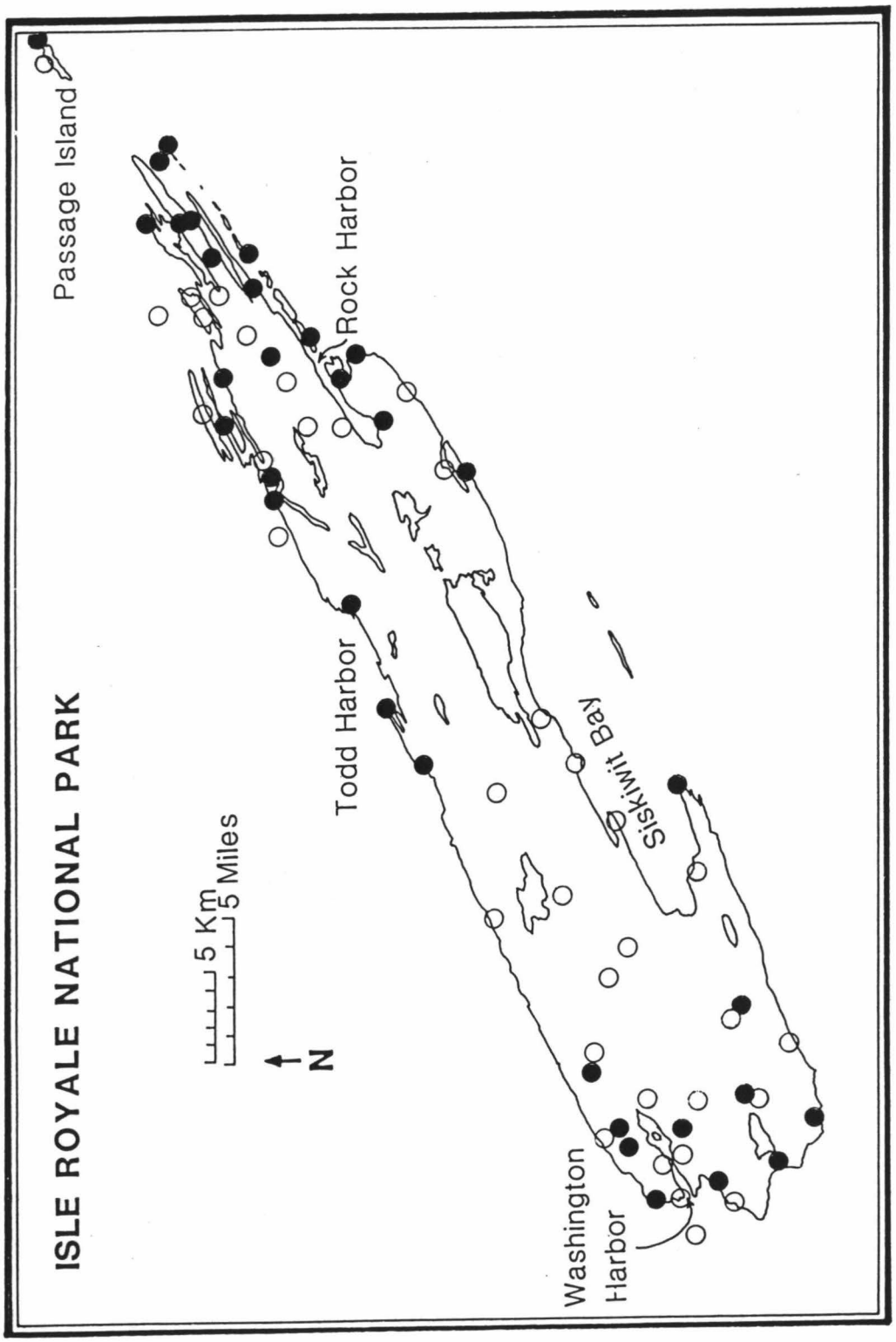

Fig. 7. Hypogymnia tubulosa

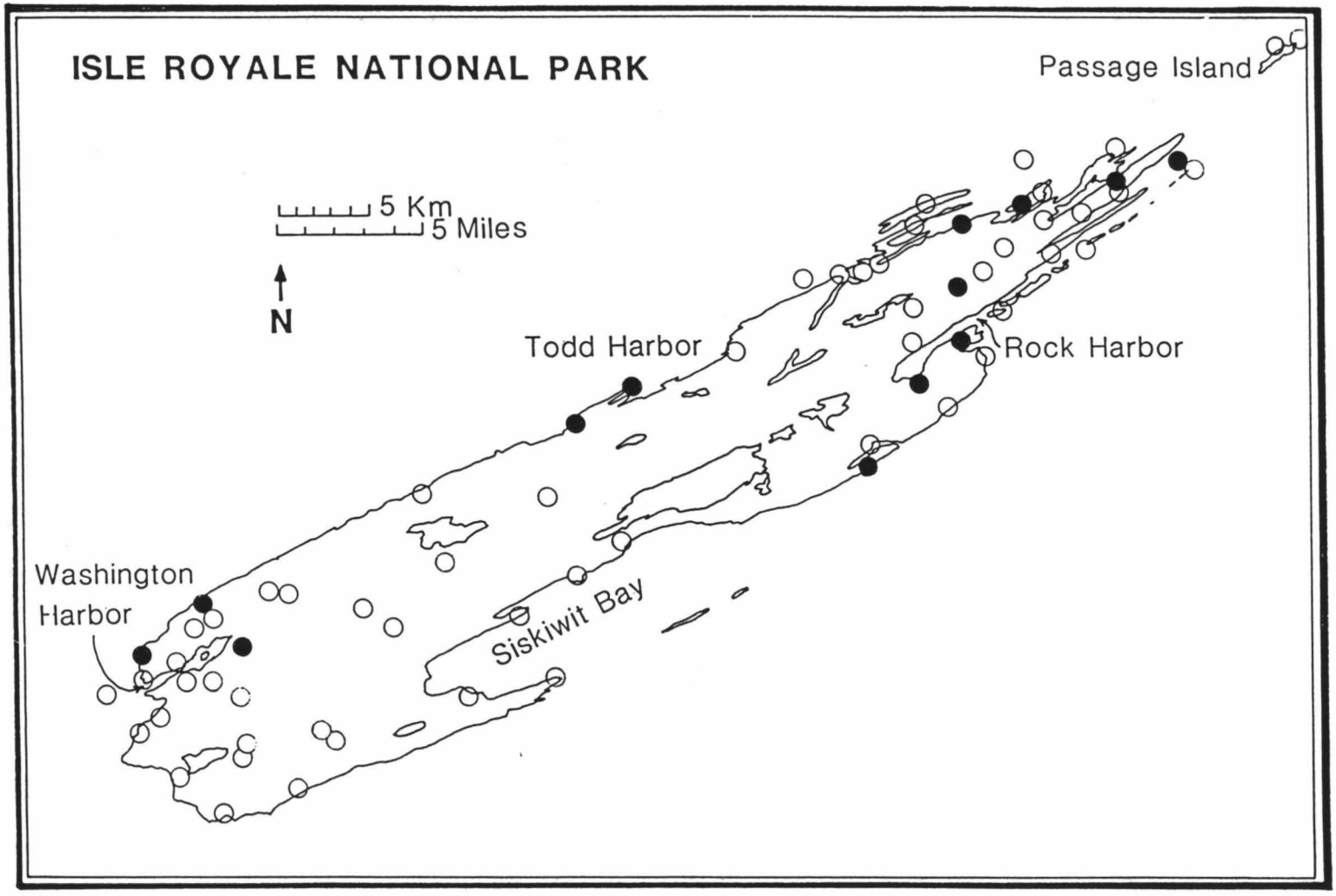

Fig. 8. Lecidea vernalis

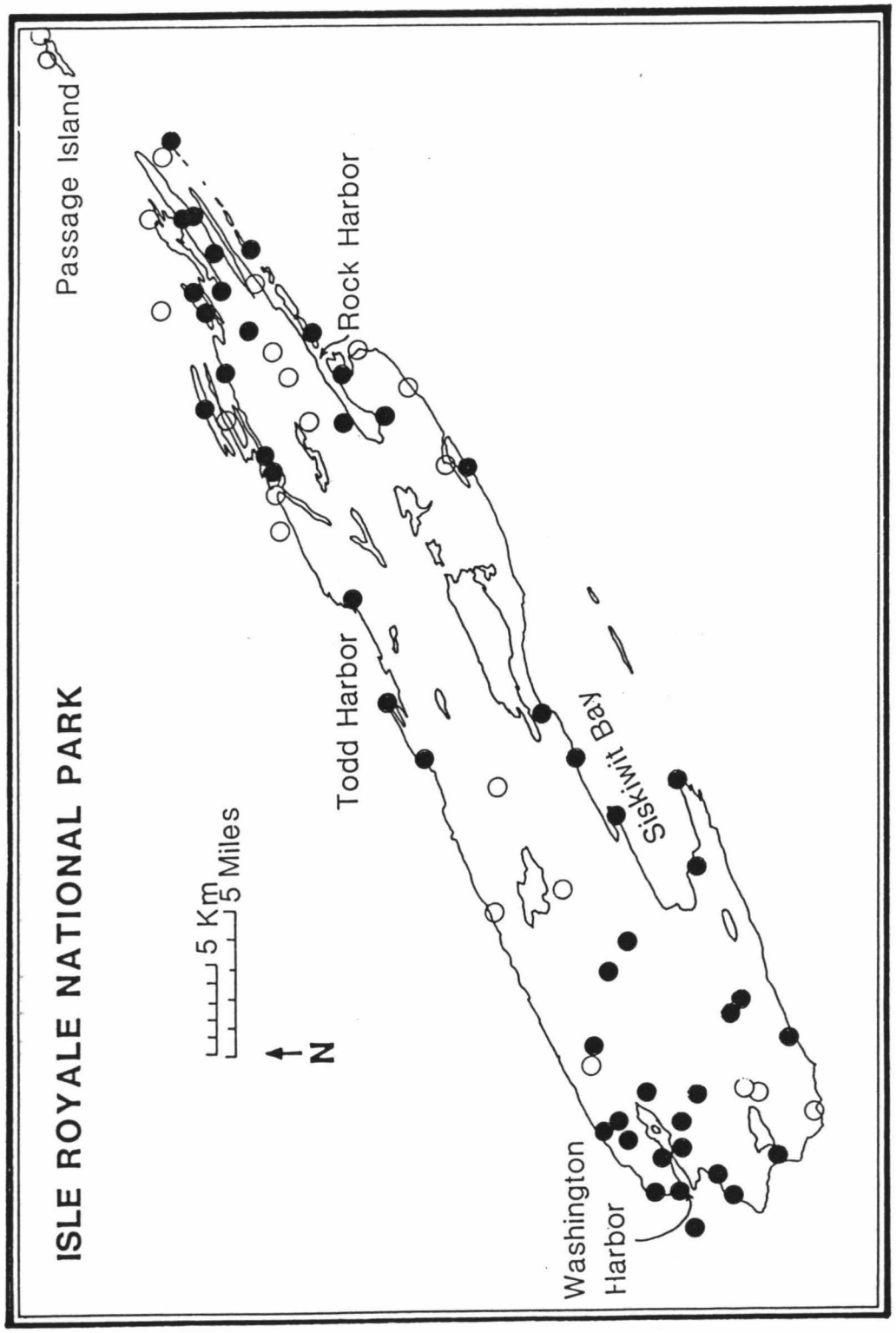

Fig. 9. Lobaria pulmonaria

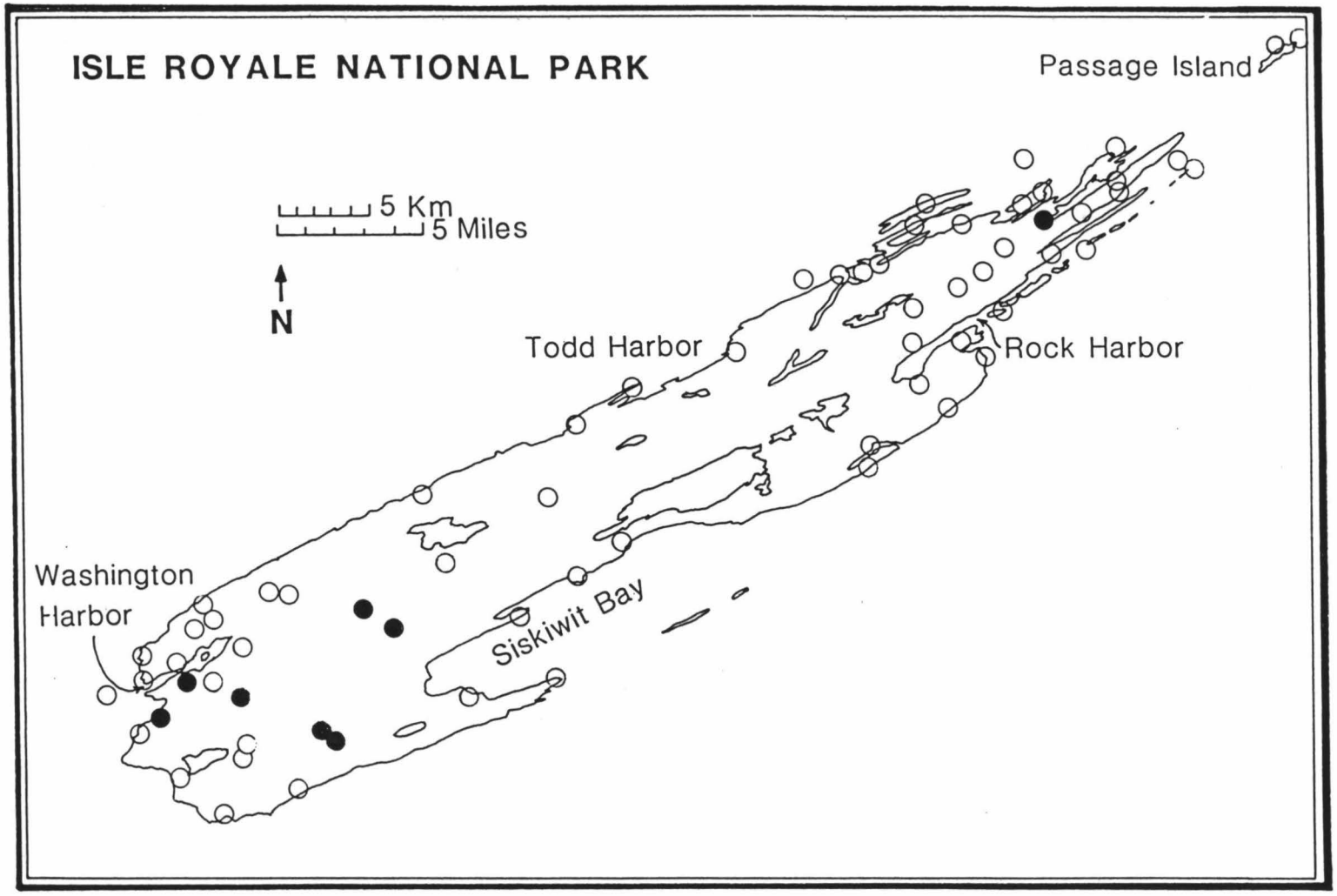

Fig. 10. Ochrolechia rosella

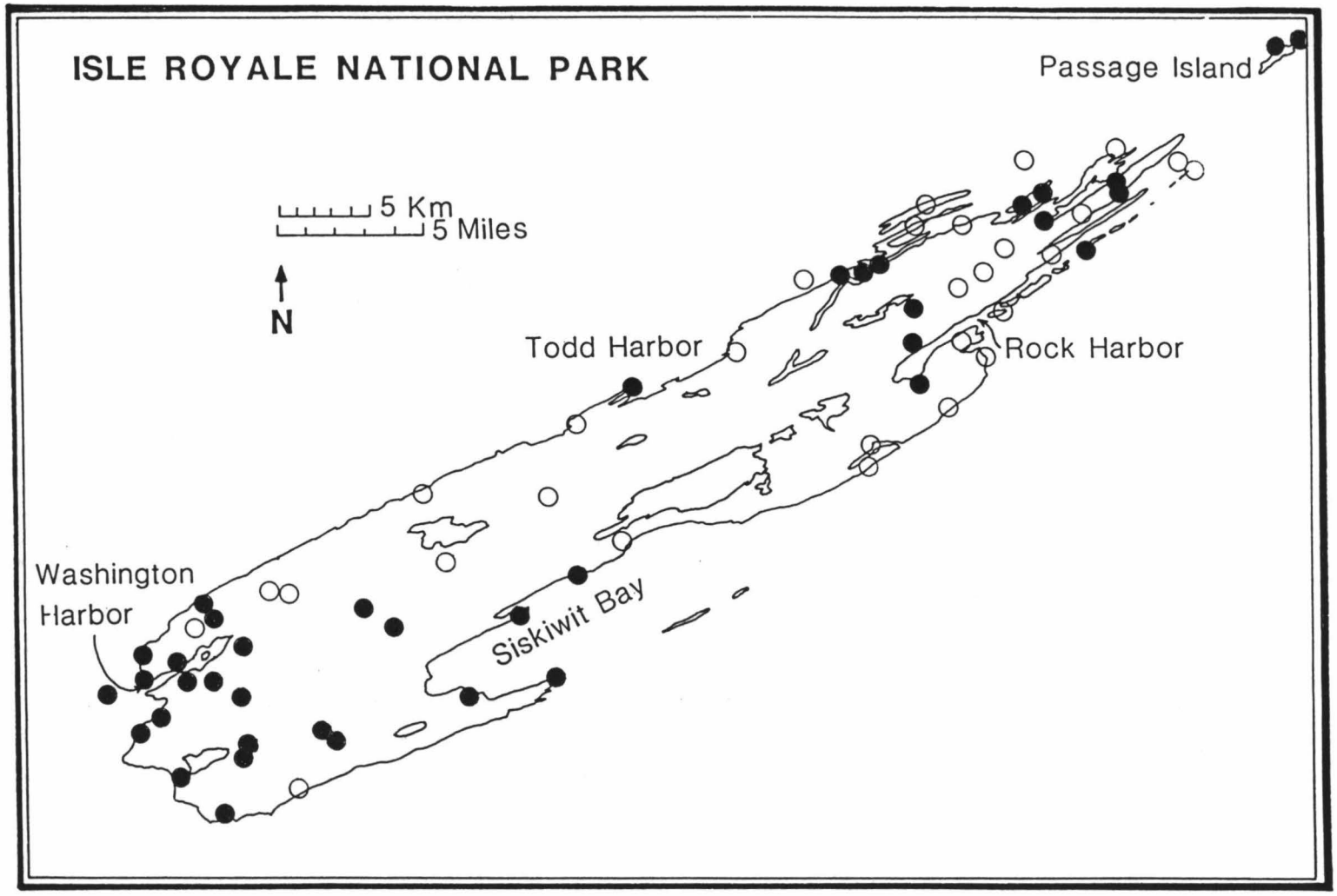

Fig. 11. Parmelia squarrosa

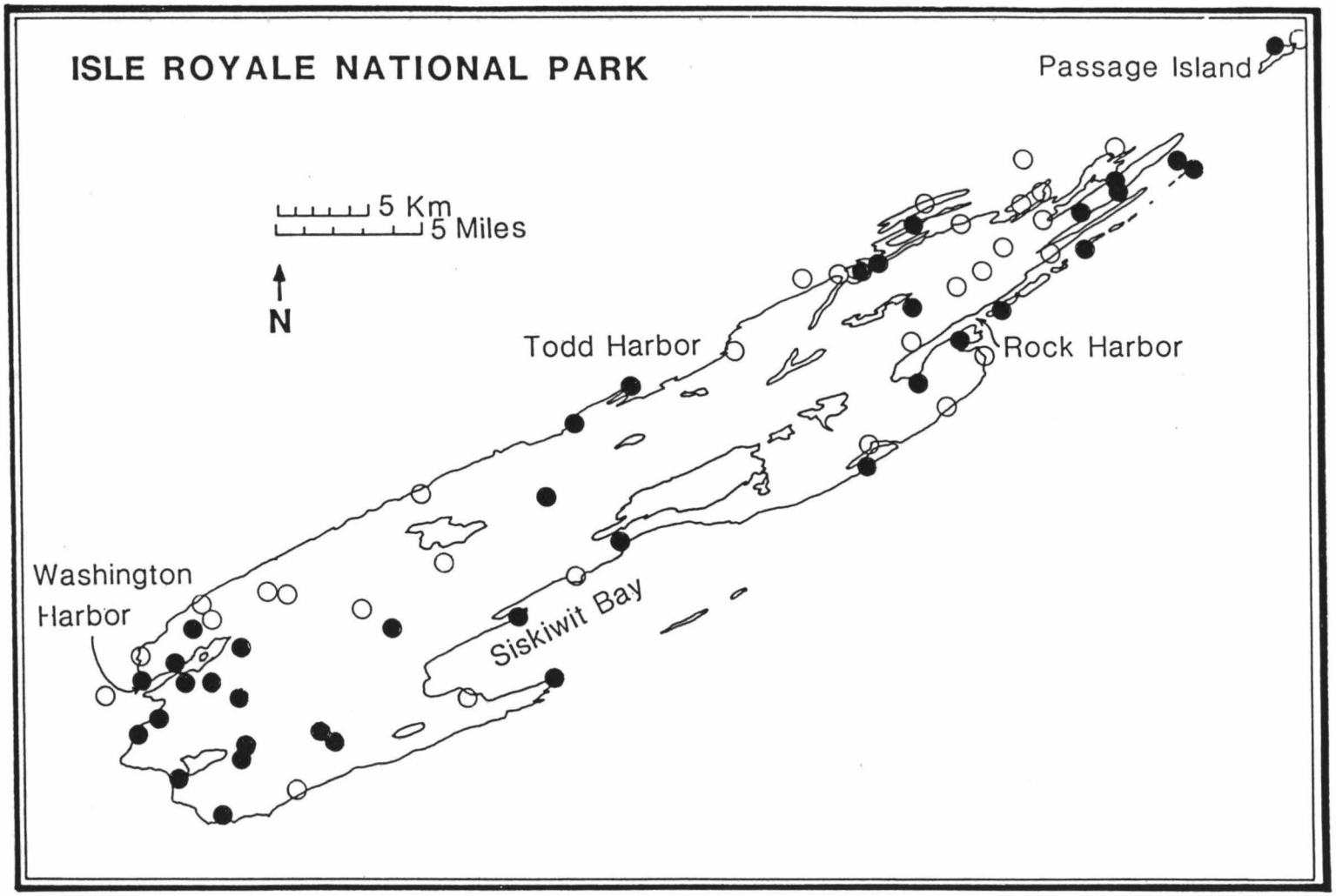

Fig. 12. Parmelia subaurifera

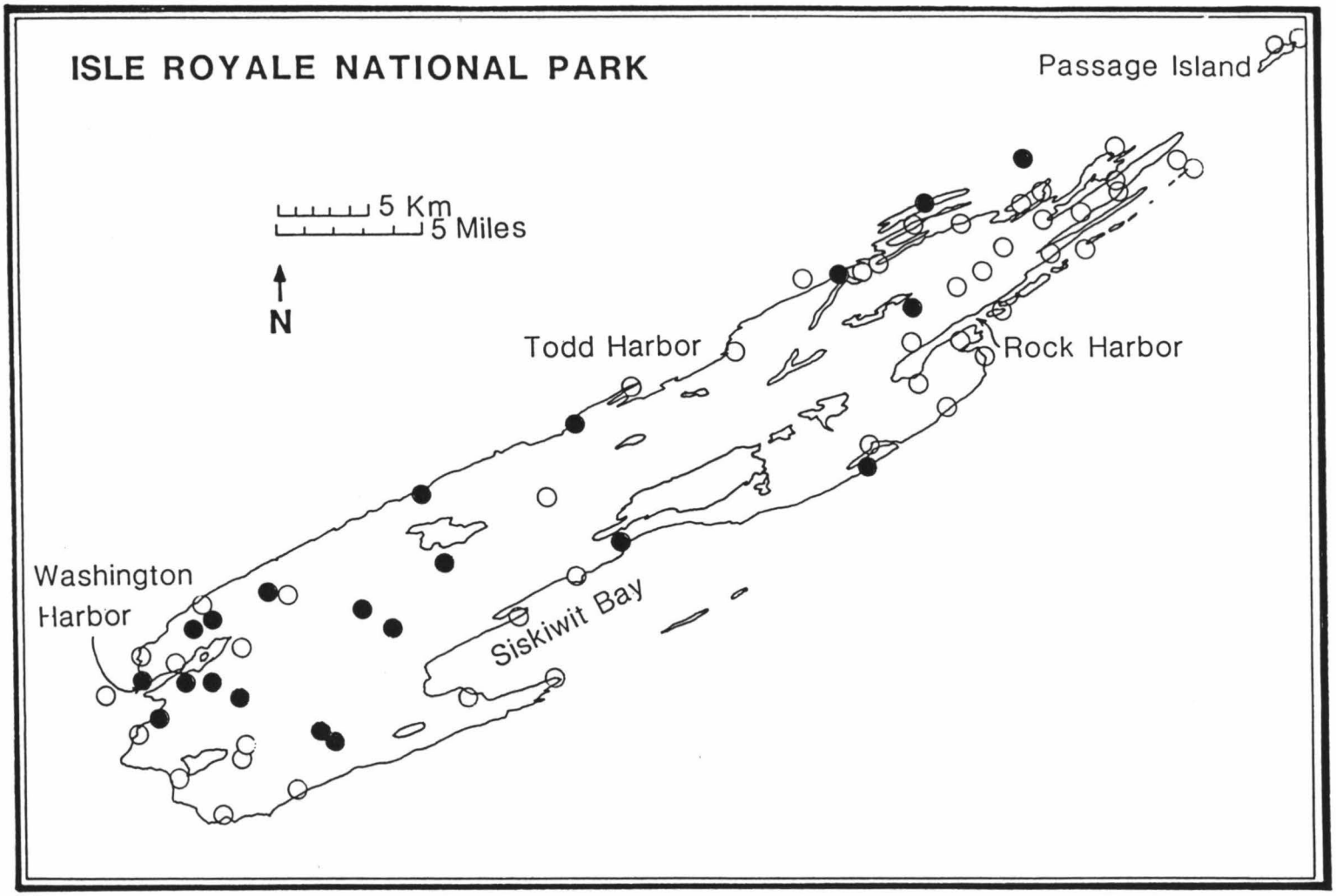

Fig. 13. Ramalina americana

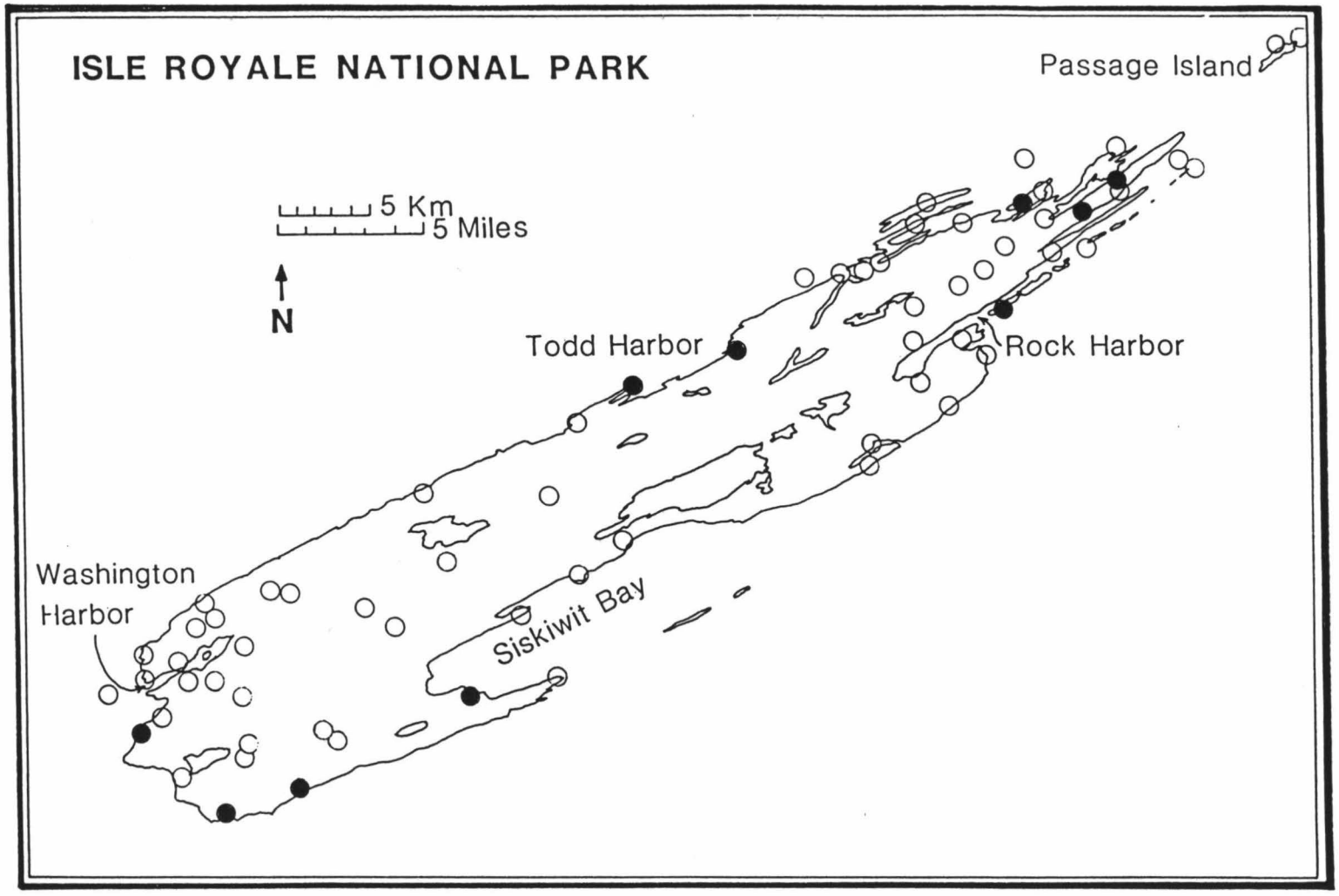

Fig. 14. Ramalina farinacea

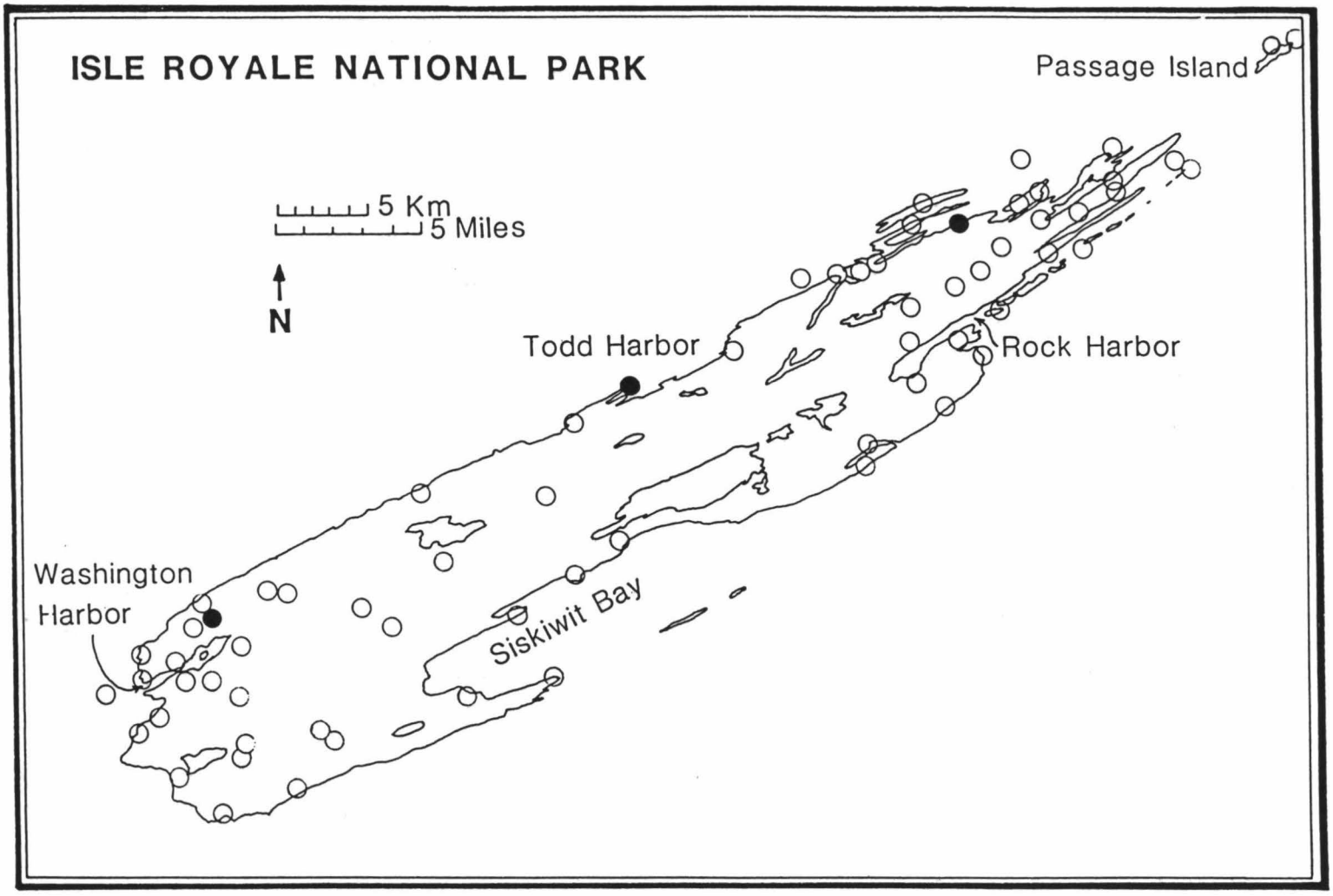

Fig. 15. Ramalina obtusata

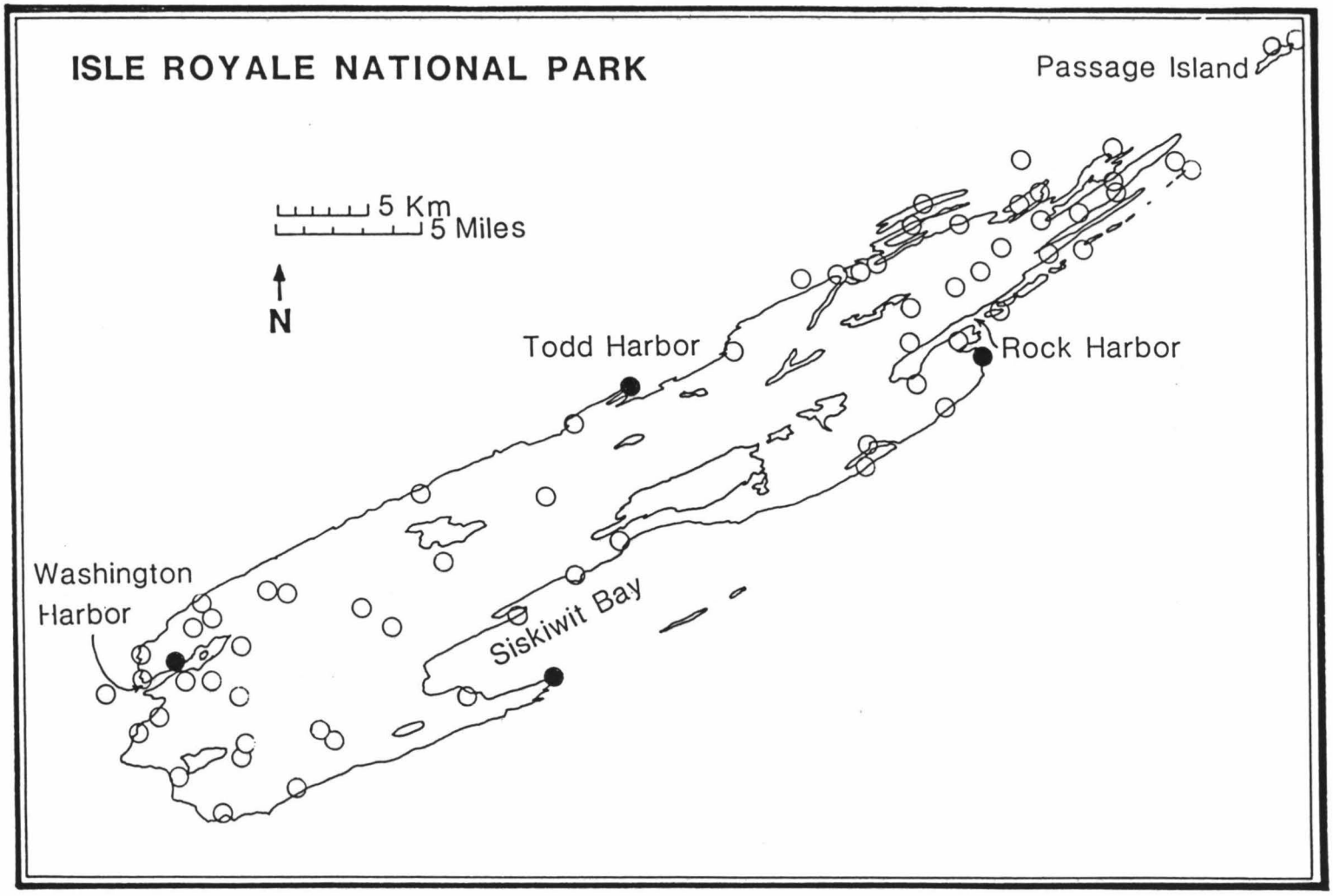

Fig. 16. Ramalina pollinaria

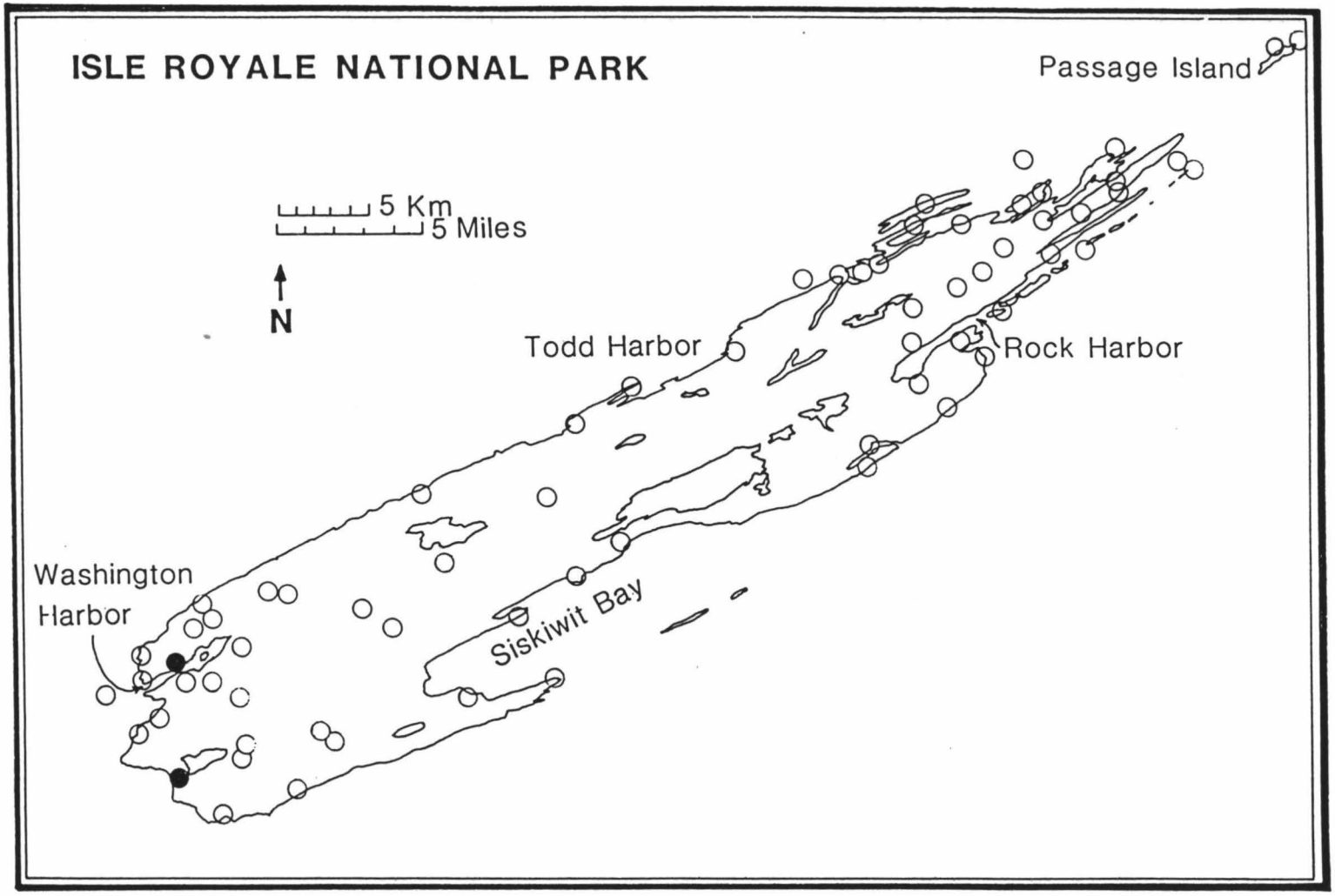

Fig. 17. Usnea ceratina

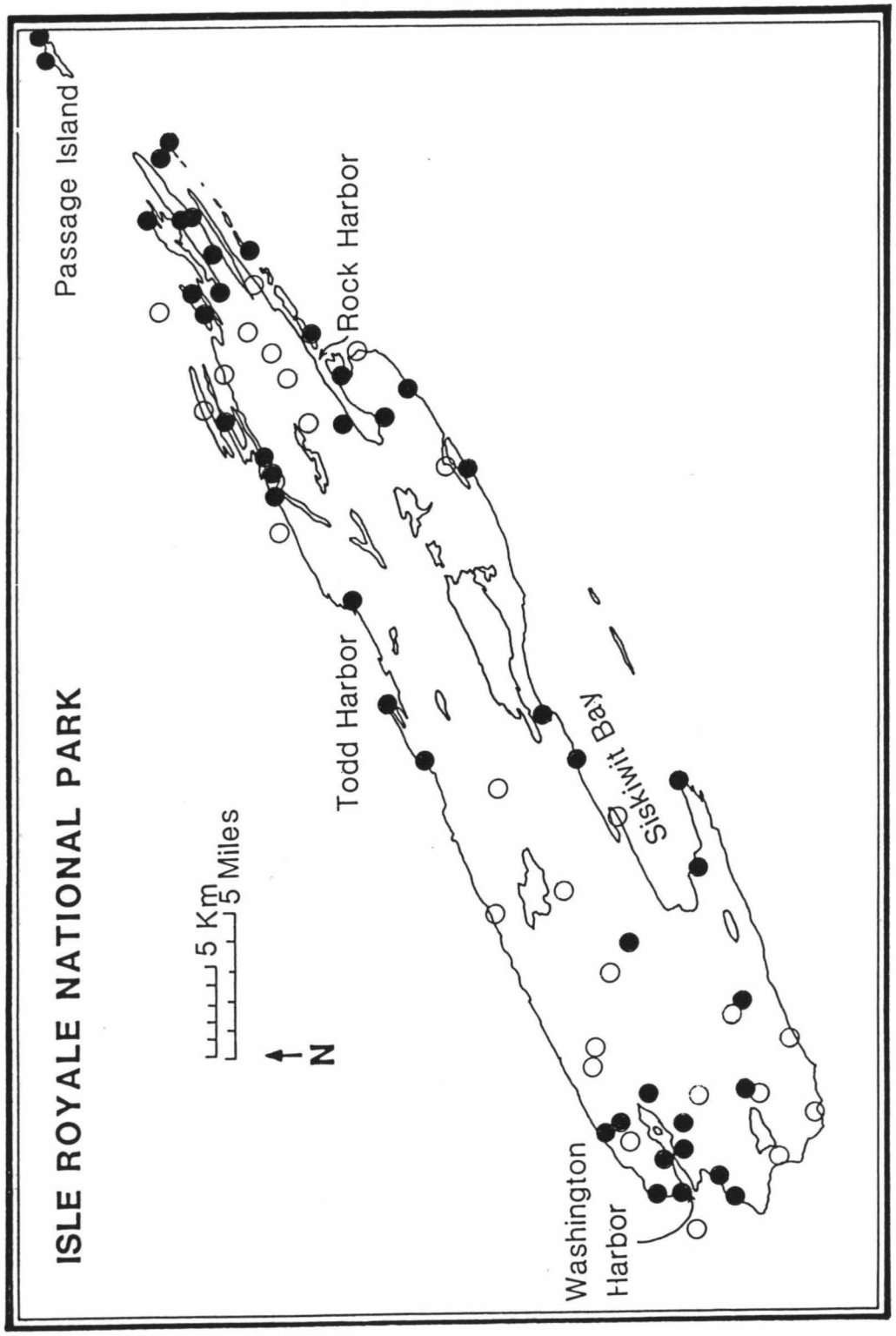

Fig. 18. Usnea filipendula