Working

LICHENS AND AIR QUALITY

IN

APOSTLE ISLANDS NATIONAL LAKESHORE

FINAL REPORT

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AND
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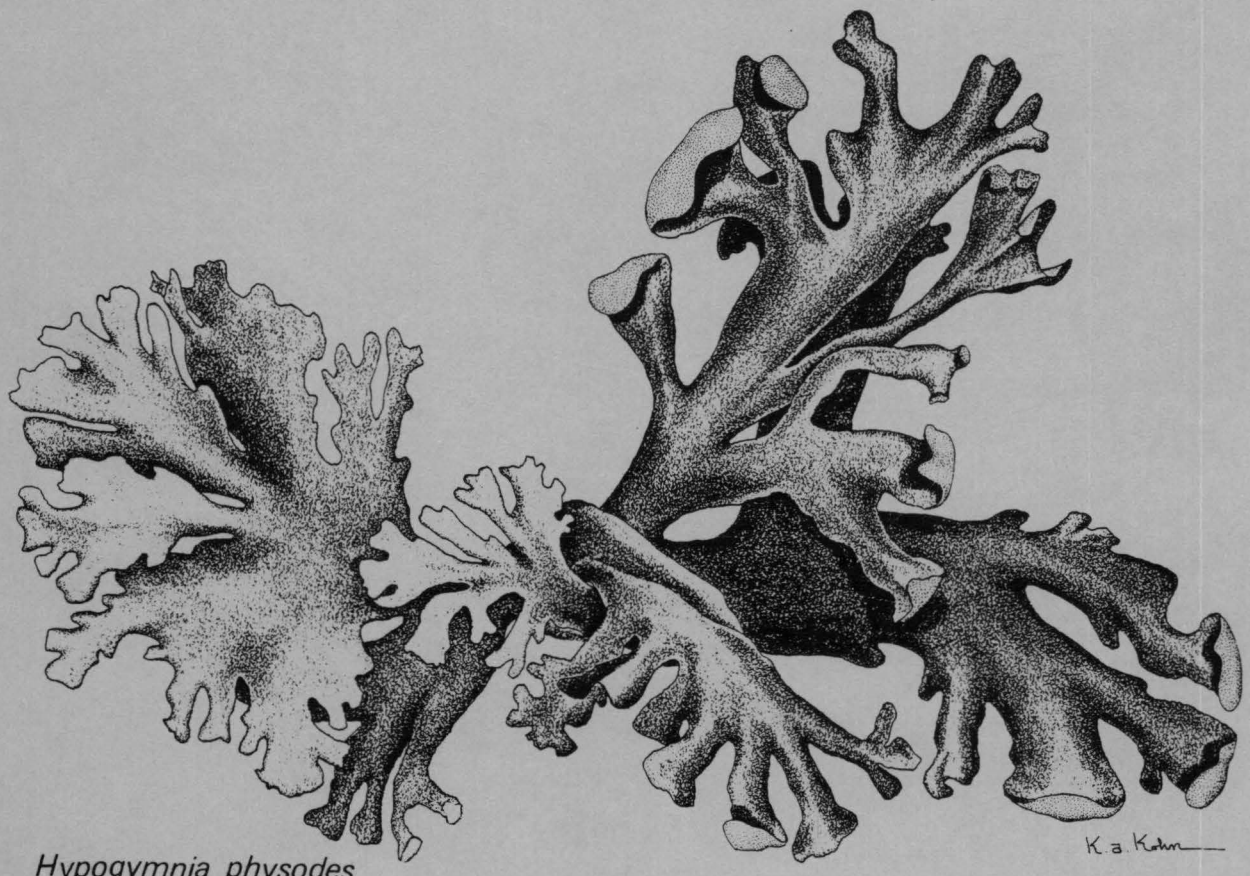

Hypogymnia physodes

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LICHENS AND AIR QUALITY
IN
APOSTLE ISLANDS NATIONAL LAKESHORE

Final Report

National Park Service
Contract CX 0001-2-0034
and USDI-PX6000-7-0731

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TABLE OF CONTENTS

LICHENS OF APOSTLE ISLANDS NATIONAL LAKESHORE

PREFACE

Under grants from the National Park Service (USDI CX 0001-2-0034 and USDI-PX6000-7-0731) a lichen study was to be performed in Apostle Islands National Lakeshore. 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, Mike Ruggiero, NPS Omaha 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 is gratefully 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. Many are damaged or killed by sulfur dioxide, nitrogen oxides, fluorides or ozone alone or in various combinations. Levels of sulfur dioxide as low as 13ug/cubic meter (annual average) will cause the death of some lichens (LeBlanc et al., 1972). Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300ug/cubic meter (Laundon, 1967, Trass, 1973). The algae of

the thallus are the first to be damaged and the first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. Dead lichens disappear from the substrate within a few months to a year as they disintegrate and decompose (Wetmore, 1982).

Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry (Nash, 1973, Marsh & Nash, 1979) and are more sensitive when growing on acid substrates.

Contrary to some published reports (Medlin, 1985) there is little evidence that most lichens are good indicators of acid precipitation. However, Sigal & Johnston (1986) have reported that one species of Umbilicaria shows visible damage due to artificial acid rain. They also report that similar symptoms were found in collections from various localities in North America. Lechowicz (1987) reported that acid rain only slightly reduced growth of Cladina stellaris but Hutchinson et al. (1986) reported that extremely acid precipitation killed or damaged some mosses and lichens. Scott & Hutchinson (1987) showed temporary reduction of photosynthesis in Cladina stellaris and C. rangiferina after artificial acid rain.

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.

Apostle Islands NL is a group of islands in the western end of Lake Superior around the Bayfield Peninsula which extends out from the south shore of the lake. The park was established in 1970 with 42,000 acres and includes 21 of the 22 islands in the archipelago. The largest island, Madeline Isl., is not included in the park. Most of the islands have been logged or burned and some have had land cleared for resorts, fishing camps, lighthouses or other activities. Now most of the developments are gone and the forest is returning to its natural state.

The islands are at the border of the deciduous forest and the northern Great Lakes conifer forest. Most of the forest is maple (Acer saccharum and A. rubrum) with birch (Betula papyrifera and B. alleghaniensis) and basswood (Tilia americana) and areas of hemlock (Tsuga canadensis). In wetter localities there are balsam fir (Abies balsamea), eastern white cedar (Thuja occidentalis), white and black spruce (Picea glauca and P. mariana). Pines are in rockier or drier areas and some large white pine (Pinus strobus) or smaller red pines (Pinus resinosa) but jack pines (P. banksiana) are quite rare. In areas of disturbance there are quaking aspens (Populus

tremuloides) are abundant. There are few areas with rock outcrops except along the shores of some islands or around old quarries.

There are few published reports on the lichens of the Apostle Islands. In 1965 a field trip by the American Bryological and Lichenological Society collected lichens at three localities in Bayfield County between Bayfield and Cornucopia (Brodo, 1967). Although none of these localities is within the park, the lichens collected may also be found within the park boundaries. Botanists from Wisconsin have collected a few lichens in recent years and some specimens may be found in the herbaria of the state but were not available for this study. A few of these collections have appeared in monographs but no lichen flora of the Apostle Islands has been published.

METHODS

Field work was done during August, 1987 and 1330 lichen collections were made at 24 localities on 12 islands and on the mainland. A complete list of collection localities is given in Appendix I and are indicated on Fig. 1. Localities for collecting were selected first to give a general coverage of the park, second, to sample all vegetational and substrate types, and third, to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats were studied. 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 have been entered into the herbarium 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 includes the taxa collected for this study and the taxa reported in the literature. The nomenclature for the literature reports has been brought up to date wherever possible but some of the generic segregates in the Fifth Lichen Checklist (Egan, 1987) are not accepted here. A list of probable misidentifications in the literature is in a separate list at the end. Species previously reported by Brodo for the area but not found during this study are enclosed in brackets. Species found only once are indicated by "Rare". 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.

SPECIES LIST

Acarospora americana Magn.
Acarospora fuscata (Nyl.) Arn.
Anaptychia palmulata (Michx.) Vain.
I Anisomeridium biforme (Borr.) R. Harris Rare
Arthonia byssacea (Weigel) Almq.
Arthonia caesia (Flot.) Körb. (Brodo, 1967)
[Arthonia dispersa (Schrad.) Nyl.(Brodo, 1967)]
Arthonia patellulata Nyl.
Arthonia punctiformis Ach. Rare
I Arthonia radiata (Pers.) Ach. Rare
Arthonia spadicea Leight. Rare
1 unidentified species of Arthonia
Arthopyrenia punctiformis Mass. Rare
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
Aspicilia cinerea (L.) Körb. Rare
Bacidia bagliettoana (Mass. & De Not.) Jatta Rare
Bacidia epixanthoides (Nyl.) Lett.
[Bacidia inundata (Fr.) Körb. (Brodo, 1967)]
Bacidia laurocerasi (Del. ex Duby) Ozenda & Clauz. Rare
Bacidia naegelii (Hepp) Zahlbr.
Bacidia populorum (Mass.) Trev. Rare
I Bacidia rubella (Hoffm.) Mass. Rare
Bacidia schweinitzii (Tuck.) Schneid. (Brodo, 1967)
Bacidia suffusa (Fr.) Schneid.
1 unidentified species of Bacidia
[Baeomyces rufus (Huds.) Rebent. (Brodo, 1967)]
I Bryoria capillaris (Ach.) Brodo & Hawksw.
S Bryoria furcellata (Fr.) Brodo & Hawksw. (Brodo, 1967, Brodo & Hawksworth, 1977)
Bryoria nadvornikiana (Gyeln.) Brodo & Hawksw. (Brodo, 1967)
S Bryoria trichodes (Michx.) Brodo & Hawksw.
Buellia arnoldii Serv.

Buellia disciformis (Fr.) Mudd (Brodo, 1967)
T Buellia punctata (Hoffm.) Mass.
Buellia schaereri De Not.
I Buellia stillingiana Steiner (Brodo, 1967)
Calicium abietinum Pers.
Calicium salicinum Pers.
Calicium trabinellum (Ach.) Ach.
Caloplaca arenaria (Pers.) Müll. Arg.
S-I Caloplaca cerina (Ehrh. ex Hedw.) Th. Fr. (Brodo, 1967)
Caloplaca flavovirescens (Wulf.) Dalla Torre & Sarnth. Rare
I Caloplaca holocarpa (Hoffm.) Wade (Brodo, 1967)
S-I Candelaria concolor (Dicks.) B. Stein (Brodo, 1967)
Candelaria fibrosa (Fr.) Müll. Arg.
Candelariella efflorescens R. Harris & Buck
I Candelariella vitellina (Hoffm.) Müll. Arg.
Cetraria halei W. & C. Culb.
I Cetraria orbata (Nyl.) Fink
I Cetraria pinastri (Scop.) Gray (Brodo, 1967)
I Cetraria sepincola (Ehrh.) Ach.
Cetrelia chicitae (W. Culb.) W. & C. Culb. (Brodo, 1967)
Cetrelia olivetorum (Nyl.) W. & C. Culb. (Brodo, 1967)
Chaenotheca brunneola (Ach.) Müll. Arg.
Chaenotheca chrysocephala (Turn. ex Ach.) Th. Fr.
I Chaenotheca ferruginea (Turn. ex Sm.) Mig.
Chaenotheca furfuracea (L.) Tibell (Brodo, 1967) Rare
Chaenotheca laevigata Nadv. Rare
Chaenotheca stemonea (Ach.) Zw. Rare
Chaenotheca trichialis (Ach.) Th. Fr.
Chaenotheca xyloxena Nadv.
Chaenothecopsis debilis (Turn. & Borr. ex Sm.) Tibell Rare
Chaenothecopsis pusilla (Flörke) Schmidt (Brodo, 1967) Rare
Chaenothecopsis rubescens Vain. Rare
Chaenothecopsis savonica (Räs.) Tibell
1 unidentified species of Chaenothecopsis
I Chrysothrix candelaris (L.) Laund.
Cladina arbuscula (Wallr.) Hale & W. Culb. Rare
Cladina mitis (Sandst.) Hustich (Brodo, 1967)
Cladina rangiferina (L.) Nyl. (Brodo, 1967)
Cladina stellaris (Opiz) Brodo
Cladina stygia (Fr.) Ahti
Cladonia amaurocraea (Flörke) Schaer.
Cladonia bacillaris Nyl. (Brodo, 1967)
Cladonia botrytes (Hagen) Willd.
Cladonia caespiticia (Pers.) Flörke (Brodo, 1967)
[Cladonia cariosa (Ach.) Spreng. (Brodo, 1967)]
Cladonia cenotea (Ach.) Schaer.
Cladonia chlorophaea (Flörke ex Somm.) Spreng. (Brodo, 1967)
I Cladonia coniocraea (Flörke) Spreng. (Brodo, 1967)
Cladonia cornuta (L.) Hoffm. Rare
Cladonia crispata (Ach.) Flot.
I Cladonia cristatella Tuck. (Brodo, 1967)

Cladonia cryptochlorophaea Asah.
Cladonia decorticata (Flörke) Spreng.
Cladonia deformis (L.) Hoffm. (Brodo, 1967)
Cladonia digitata (L.) Hoffm. Rare
Cladonia farinacea (Vain.) Evans Rare
S-I Cladonia fimbriata (L.) Fr.
Cladonia furcata (Huds.) Schrad. Rare
Cladonia gracilis (L.) Willd. (Brodo, 1967)
Cladonia grayi G. K. Merr. ex Sandst. Rare
Cladonia humilis (With.) Laundon Rare
Cladonia incrassata Flörke Rare
Cladonia macilenta Hoffm. Rare
Cladonia merochlorophaea Asah.
Cladonia multiformis G. K. Merr.
Cladonia phyllophora Ehrh. ex Hoffm.
Cladonia pleurota (Flörke) Schaer.
Cladonia pyxidata (L.) Hoffm. (Brodo, 1967) Rare
Cladonia ramulosa (With.) Laundon
Cladonia rei Schaer. (Brodo, 1967)
Cladonia scabriuscula (Del.in Duby) Leight. (Brodo, 1967)
Cladonia squamosa (Scop.) Hoffm. (Brodo, 1967)
Cladonia subulata (L.) Web. ex Wigg.
Cladonia sulphurina (Michx.) Fr. Rare
Cladonia turgida Ehrh. ex Hoffm. Rare
Cladonia uncialis (L.) Web. ex Wigg.
Cladonia verticillata (Hoffm.) Schaer. (Brodo, 1967)
Collema subflaccidum Degel.
Conotrema urceolatum (Ach.) Tuck. (Brodo, 1967)
Cyphelium lucidum (Th. Fr.) Th. Fr. Rare
Cyphelium tigillare (Ach.) Ach.
Dermatocarpon miniatum (L.) Mann Rare
S Dimerella lutea (Dicks.) Trev.
Dimerella pineti (Schrad. ex Ach.) Vezda (Brodo, 1967) Rare
Endocarpon pusillum Hedw. Rare
I Evernia mesomorpha Nyl. (Brodo, 1967)
I Graphis scripta (L.) Ach. (Brodo, 1967)
Haematomma pustulatum Brodo & W. Culb.
Heterodermia hypoleuca (Muhl.) Trev.
Heterodermia speciosa (Wulf.) Trev.
Hypocenomyce anthracophila (Nyl.) James & G. Schneid.
Hypocenomyce friesii (Ach. in Lilj.) James & G. Schneid.
I Hypocenomyce scalaris (Ach. ex Lilj.) Choisy (Brodo, 1967)
I Hypogymnia physodes (L.) Nyl. (Brodo, 1967)
S Hypogymnia tubulosa (Schaer.) Hav.
Icmadophila ericetorum (L.) Zahlbr. (Brodo, 1967)
I Imshaugia aleurites (Ach.) S. F. Meyer
Julella fallaciosa (Stizenb. ex Arn.) R. Harris (Brodo, 1967)
Kirschsteiniothelia aethiops (Berk. & Curtis) Hawksw. Rare
Lecanactis chloroconia Tuck.
I Lecanora allophana Nyl. (Brodo, 1967)
Lecanora caesiorubella Ach. subsp. caesiorubella (Brodo, 1967)

I Lecanora carpinea (L.) Vain. (Brodo, 1967)
Lecanora cenisia Ach. Rare
I Lecanora circumborealis Brodo & Vitik.
T Lecanora dispersa (Pers.) Somm.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora impudens Degel.
T Lecanora muralis (Schreb.) Rabenh.
I Lecanora pallida (Schreb.) Rabenh. var. rubescens Imsh. & Brodo (Brodo, 1967)
Lecanora piniperda Körb. Rare
Lecanora polytropa (Hoffm.) Rabenh. Rare
I Lecanora pulicaris (Pers.) Ach. (Brodo, 1967)
Lecanora rugosella Zahlbr.
I Lecanora saligna (Schrad.) Zahlbr. Rare
Lecanora strobilina (Spreng.) Kieff.
I Lecanora symmicta (Ach.) Ach. (Brodo, 1967)
Lecanora thysanophora Harris ined.
Lecanora wisconsinensis Magn.
1 unidentified species of Lecanora
Lecidea albohyalina (Nyl.) Th. Fr. Rare
Lecidea berengeriana (Mass.) Nyl. (Brodo, 1967)
[Lecidea delincta Nyl. (Brodo, 1967)]
Lecidea elabens Fr. Rare
Lecidea helvola (Körb. ex Hellb.) Oliv. (Brodo, 1967)
[Lecidea myriocarpoides Nyl. (Brodo, 1967)]
Lecidea plebeja Nyl.
S Lecidea vernalis (L.) Ach. Rare
2 unidentified species of Lecidea
Lecidella carpathica Körb. Rare
Lecidella stigmatea (Ach.) Hert. & Leuck.
Lepraria finkii (B. de Lesd. in Hue) R. Harris
1 unidentified species of Lepraria
Leptogium cyanescens (Rabenh.) Körb. (Brodo, 1967)
Leptogium lichenoides (L.) Zahlbr. Rare
Leptogium saturninum (Dicks.) Nyl. Rare
Leptorhaphis epidermidis (Ach.) Th. Fr. (Brodo, 1967)
S Lobaria pulmonaria (L.) Hoffm. (Brodo, 1967)
Lobaria quercizans Michx.
I Lopadium pezizoideum (Ach.) Körb.
Micarea melaena (Nyl.) Hedl.
2 unidentified species of Micarea
I Mycoblastus sanguinarius (L.) Norm.
Mycocalicium subtile (Pers.) Szat. (Brodo, 1967)
Nephroma helveticum Ach. Rare
Nephroma parile (Ach.) Ach.
Ochrolechia arborea (Kreyer) Almb.
S Ochrolechia rosella (Müll. Arg.) Vers. (Brodo, 1967)
Opegrapha prosodea Ach.
S-I Opegrapha varia Pers.
Pachyphiale fagicola (Hepp ex Arn.) Zw.
Parmelia albertana Ahti Rare
Parmelia aurulenta Tuck. (Brodo, 1967)
I Parmelia caperata (L.) Ach. (Brodo, 1967)
Parmelia crinita Ach. (Brodo, 1967) Rare

Parmelia cumberlandia (Gyeln.) Hale
Parmelia exasperata De Not. Rare
I Parmelia exasperatula Nyl.
Parmelia flaventior Stirt. (Brodo, 1967)
Parmelia galbina Ach. (Brodo, 1967)
Parmelia hypoleucites Nyl. Rare
I Parmelia olivacea (L.) Ach. (Brodo, 1967)
I Parmelia rudecta Ach. (Brodo, 1967)
I Parmelia septentrionalis (Lynge) Ahti
Parmelia soredica Nyl. (Brodo, 1967) Rare
S Parmelia squarrosa Hale
I-T Parmelia subargentifera Nyl.
(S) Parmelia subaurifera Nyl. (Brodo, 1967)
Parmelia subolivacea Nyl. in Hasse Rare
I Parmelia subrudecta Nyl. (Brodo, 1967)
I-T Parmelia sulcata Tayl. (Brodo, 1967)
I Parmeliopsis ambigua (Wulf. in Jacq.) Nyl. (Brodo, 1967)
I Parmeliopsis hyperopta (Ach.) Arn.
Peltigera canina (L.) Willd. (Brodo, 1967)
Peltigera didactyla (With.) Laundon (Thomson, 1946)
Peltigera elisabethae Gyeln.
Peltigera evansiana Gyeln. (Brodo, 1967)
I Peltigera horizontalis (Huds.) Baumg. (Brodo, 1967) Rare
Peltigera lepidophora (Nyl. ex Vain.) Bitter
Peltigera malacea (Ach.) Funck Rare
Peltigera membranacea (Ach.) Nyl.
Peltigera polydactyla (Neck.) Hoffm. (Thomson, 1946)
Peltigera praetextata (Flörke ex Somm.) Zopf
Peltigera rufescens (Weis.) Humb. (Thomson, 1946) Rare
Peltigera scabrosa Th. Fr. Rare
Pertusaria alpina Hepp ex Ahles
I Pertusaria amara (Ach.) Nyl. (Brodo, 1967)
Pertusaria consocians Dibb.
Pertusaria macounii (Lamb) Dibb. (Dibben, 1980)
Pertusaria ophthalmiza (Nyl.) Nyl. (Dibben, 1980)
[Pertusaria pustulata (Ach.) Duby (Brodo, 1967)]
Pertusaria rubefacta Erichs. Rare
[Pertusaria stenhammari Hellb. (Dibben, 1980)]
[Pertusaria trachythallina Erichs. (Brodo, 1967, Dibben, 1980)]
Pertusaria velata (Turn.) Nyl. (Dibben, 1980)
2 unidentified species of Pertusaria
Phaeophyscia ciliata (Hoffm.) Moberg (Brodo, 1967)
I Phaeophyscia orbicularis (Neck.) Moberg (Thomson, 1963, Brodo, 1967) Rare
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Moberg
Phaeophyscia sciastra (Ach.) Moberg (Brodo, 1967)
I Phlyctis argena (Spreng.) Flot. (Brodo, 1967)
I Physcia adscendens (Th. Fr.) Oliv. (Brodo, 1967)
I Physcia aipolia (Ehrh. ex Humb.) Fürnr. (Brodo, 1967)
Physcia caesia (Hoffm.) Fürnr. Rare
T Physcia dubia (Hoffm.) Lett. Rare
I Physcia millegrana Degel.

Physcia phaea (Tuck.) Thoms. Rare
I Physcia stellaris (L.) Nyl. (Brodo, 1967)
I Physconia detersa (Nyl.) Poelt (Thomson, 1963, Brodo, 1967)
Placynthiella icmalea (Ach.) Coppins & James
Placynthiella oligotropha (Laund.) Coppins & James Rare
Placynthium nigrum (Huds.) Gray Rare
Platismatia tuckermanii (Oakes) W. & C. Culb.
Porpidia macrocarpa (DC. in Lam. & DC.) Hert. & Schwab (Brodo, 1967)
Protoblastenia rupestris (Scop.) Steiner Rare
Pseudevernia consocians (Vain.) Hale & W. Culb. Rare
Pseudocyphellaria crocata (L.) Vain. Rare
Pyxine sorediata (Ach.) Mont.
S Ramalina americana Hale (Brodo, 1967)
I Ramalina dilacerata (Hoffm.) Hoffm.
Ramalina intermedia (Del. ex Nyl.) Nyl.
Rhizocarpon concentricum (Dav.) Beltram. (Brodo, 1967) Rare
Rhizocarpon grande (Flörke ex Flot.) Arn. Rare
1 unidentified species of Rhizocarpon
[Rinodina archaea (Ach.) Arn. (Brodo, 1967)]
Rinodina ascociscana Tuck.
Rinodina milliaria Tuck.
[Rinodina populicola Magn. (Brodo, 1967)]
Rinodina subminuta Magn. Rare
Rinodina turfacea (Wahlenb.) Körb. Rare
[Sarcogyne privigna (Ach.) Mass. (Brodo, 1967)]
I Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda (Brodo, 1967)
Scoliciosporum umbrinum (Ach.) Arn.
Sphinctrina anglica Nyl. Rare
Sphinctrina turbinata (Pers.) De Not.
Staurothele fuscocuprea (Nyl.) Zsch. Rare
I Stenocybe major Nyl. ex Körb. (Brodo, 1967)
Stenocybe pullatula (Ach.) B. Stein. Rare
Stereocaulon paschale (L.) Hoffm. Rare
Stereocaulon saxatile Magn.
Strigula stigmatella (Ach.) R. Harris
Thelocarpon laureri (Flot.) Nyl. Rare
[Thrombium epigaeum (Pers.) Wallr. (Brodo, 1967)]
Trapelia involuta (Tayl.) Hert. Rare
Trapelia placodioides Coppins & James
Trapeliopsis flexuosa (Fr.) Coppins & James Rare
Trapeliopsis granulosa (Hoffm.) Lumbsch. (Brodo, 1967)
Trapeliopsis viridescens (Schrad.) Coppins & James (Brodo, 1967)
Umbilicaria mammulata (Ach.) Tuck. Rare
Usnea cavernosa Tuck. (Brodo, 1967)
S Usnea ceratina Ach.
S Usnea filipendula Stirt.
S-I Usnea hirta (L.) Weber ex Wigg. (Brodo, 1967)
Usnea lapponica Vain. (Brodo, 1967) Rare
S-I Usnea subfloridana Stirt. (Brodo, 1967)

[Verrucaria aethiobola Wahlenb. in Ach. (Brodo, 1967)]
[Verrucaria margacea (Wahlenb. in Ach.) Wahlenb. (Brodo, 1967)]
Verrucaria muralis Ach.
Verrucaria nigrescentoidea Fink Rare
Xanthoria elegans (Link) Th. Fr.
S-I Xanthoria fallax (Hepp in Arn.) Arn. (Brodo, 1967)
I Xanthoria polycarpa (Hoffm.) Rieber (Brodo, 1967)
Xylographa opegraphella Will. in Rothr. Rare

The following species were reported by Brodo (1967) but are probable or certain misidentifications:

Bryoria glabra (Mot.) Brodo & Hawksw. = B. trichodes
Caloplaca durietzii Magn.
S-I Cetraria ciliaris Ach. = C. halei
I Lecanora subrugosa Nyl.
Lecidea conferenda Nyl.
Lecidea dicksonii auct.
S Ochrolechia androgyna (Hoffm.) Arn. = O. arborea
I Parmelia saxatilis (L.) Ach. = P. squarrosa
Pertusaria multipuncta (Turn.) Nyl. = P. ophthalmiza
Pertusaria pertusa (L.) Tuck.
Sarcogyne clavus (DC. in Lam & DC.) Kremp. = S. privigna
Trapelia coarctata (Sm.) Choisy in Wern. = T. involuta

DISCUSSION OF FLORA

This list includes 271 species collected for this study and 114 species previously reported by Brodo (1967). The most common species are Cladonia coniocraea, Hypogymnia physodes, Lacanora symmicta, Lobaria pulmonaria, Parmelia caperata, Parmelia rudecta, Parmelia subaurifera, Parmelia sulaca, and Physconia detersa.

There are some vouchers from the ABLS Foray in the University of Minnesota herbarium and, on checking, some of the species reported by Brodo were found to be misidentifications. Some of the species reported from the ABLS Foray are not known from North America and others do not occur in the Great Lakes Region. Of the 29 species reported by Brodo

but not found by me, 12 are either certain or probable misidentifications leaving 17 species not found. These 17 are either rare or require rare substrates not found in the park or were missed in my collecting. Some of these may also be misidentifications. There are an additional 12 unidentified species, some of which are undescribed.

The lichen flora of the Apostles is quite variable. On some islands with dense hardwood forests the lichen flora is not diverse but on other islands (especially Devils Isl.) there are many lichens. The lack of abundant rock outcrops limits the lichen flora significantly. Most of the rock that is available, as on the northern shore of Devils Isl., is soft sandstone with only a limited lichen flora. Most of the lichens in the hardwood forests are the common ones further south but on Devils Isl. numerous northern species occur.

This list of species presents the first listing of lichens for islands of the park and includes some species rare in the Great Lakes Region. The occurrence of Pseudocyphellaria crocata on Devils Isl. is especially noteworthy since it probably represents a new southern record for the Great Lakes Region. It formerly was found at several localities along the north shore of Lake Superior (prior to 1920) but has been collected in recent times only on Isle Royale (Michigan) and Voyageurs National Park and reported from the Susie Islands (Minnesota) by Thomson (1954).

An interesting tabulation indicates the uniqueness of different localities in the park. In the following list the

number in the first column indicates the number of species that were only found once in the park at that particular locality (these are the species that are indicated by "Rare" in the species list). The number in the second column is the locality number The localities are listed in the same order as in the locality list in Appendix I.

#	Loc#	
14	1	Basswood Isl., S end
3	2	Basswood Isl., center
4	3	Hermit Isl., S side
3	4	Stockton Isl., W side of tombolo
2	5	Stockton Isl., N edge Presque Isle
2	6	Manitou Isl., S tip
2	7	Stockton Isl., 1 mile E of Quarry Bay
3	8	Stockton Isl., Julian Bay
5	9	South Twin Isl., near airstrip
0	10	Cat Isl., S tip
0	11	Otter Isl., SE tip
1	12	Rocky Isl., inland
2	13	Devils Isl., highland S middle
4	14	Devils Isl., bog
7	15	Devils Isl., N shore
1	16	Outer Isl., W of lighthouse
4	17	Outer Isl., 1 mi S lighthouse
5	18	Outer Isl., S tip
4	19	Raspberry Isl., W side
1	20	Raspberry Isl., sand spit
3	21	Sand Isl., E side bog
0	22	Mainland, Little Sand Bay
0	23	Mainland, Sand Point
4	24	Mainland, Squaw Bay

The locality with the highest number is the southern end of Basswood Isl. around the shore and quarry. This locality is special partly because of the numerous shore rocks and also the shady rocks inland. The second highest number was the northern end of Devils Isl. Again, this locality has abundant rocks near the lakeshore but also a good balsam fir forest and has an aspect of more northern localities found on Isle Royale.

Some of the species found only once are rare wherever they are found throughout their distributional range and might be found at other localities with further searching and others may require special substrates that are rare in the park, but until additional collecting proves otherwise, the localities with the highest number of unique finds deserves special protection.

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. The lichen flora is very diverse and in many localities lichens cover the trees. These observations indicate that there is no air quality degradation in the park due to sulfur dioxide that causes observable damage to the lichen flora.

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 many lichens in the park with known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983) and most of these are fairly 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.
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
Usnea ceratina Ach.
Usnea filipendula Stirt.

The distributions of these species are mapped (Fig. 2-13). Although these species are not found at all localities and some are not common, 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 or substrates for some of these species.

ELEMENTAL 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.

METHODS

Samples of three lichen species were collected in spunbound olefin bags at various localities in different parts of the park for laboratory analysis. Species collected and the substrates were: Cladina rangiferina on soil, Hypogymnia physodes and Evernia mesomorpha on conifer tree branches.

These species were selected because they are present in abundance and relatively easy to clean.

Three localities were selected for elemental analysis and are indicated on the map of collection localities. These localities are: Stockton Isl. on west side of the tombolo north of Presque Isle, Outer Isl. at southern tip on the sand spit, and Raspberry Isl. around the sand spit at the southeastern end. Ten to 20 grams of each species were collected at each locality.

Lichens were air dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for analysis. Some of the replicates were ground before being divided and are so indicated in the tables. 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 B 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 Celsius 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 three replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. Some of the reported values are below the lower detection limits of the instruments and are indicated in the tables.

All of the levels found in the Apostle lichens are within typical limits for similar lichens From these tables it can be seen that there is no consistent correlation between element levels and location in the park. Although one species may have somewhat higher levels of an element at one locality, the other species may have higher levels at another locality so there is no overall correlation between high element levels and any one locality. The sulfur levels in lichens tested range from 460 to 1520 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) for other species of lichens. 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 two species. Cladina ranghiferina has lower levels than the other species. Even when taking these differences into account there

Table 1. Analysis of Apostle Isl. Lichens
Values in ppm of thallus

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
C. rangiferina	420	1737	513	303	201	219	25.8	33.0	13.0	3.5	5.3	1.2	#	0.4	0.2	500	Outer Isl.
C. rangiferina	482	1980	418	238	175	174	17.5	22.3	11.9	3.2	4.3	1.7	#	0.2	0.2	580	Outer Isl.
C. rangiferina	437	1750	523	293	183	179	18.9	34.9	12.9	3.3	6.1	*0.8	#	0.3	0.1	520	Outer Isl.
C. rangiferina	349	1367	452	252	202	193	17.8	54.2	13.0	2.8	5.5	2.3	#	0.3	0.2	475	Stockton Isl.
C. rangiferina	339	1418	420	227	194	195	22.2	39.3	11.9	3.6	5.3	3.2	#	0.3	0.2	480	Stockton Isl.
C. rangiferina	344	1347	491	256	189	178	19.1	60.1	12.9	3.0	6.4	2.4	#	0.3	0.2	460	Stockton Isl.
C. rangiferina	476	1765	613	311	249	261	29.0	34.6	16.5	3.8	6.2	2.8	#	0.4	0.2	650	Raspberry Isl.
C. rangiferina	468	1800	643	316	235	247	27.9	33.6	17.2	3.9	5.5	1.5	#	0.3	0.2	780	Raspberry Isl.
C. rangiferina	510	1885	653	329	219	270	28.8	34.4	16.8	3.9	5.9	1.9	#	0.4	0.2	640	Raspberry Isl.
E. mesomorpha	604	2560	658	363	491	610	46.9	32.1	27.7	12.1	6.5	5.2	0.8	1.0	0.4	1090	Outer Isl. @
E. mesomorpha	639	2586	689	367	493	632	45.4	32.9	28.1	11.8	5.7	6.5	0.9	1.1	0.4	1250	Outer Isl. @
E. mesomorpha	628	2603	702	367	482	605	44.3	33.1	28.6	12.0	6.3	5.0	0.8	1.0	0.4	1150	Outer Isl. @
E. mesomorpha	545	2323	478	373	596	675	36.4	60.9	39.1	6.6	8.4	10.2	0.8	1.0	0.2	1250	Stockton Isl.
E. mesomorpha	493	2122	424	341	579	638	33.9	55.6	37.8	5.9	8.1	9.2	0.8	0.9	0.1	1180	Stockton Isl.
E. mesomorpha	476	2132	453	337	594	706	30.9	54.4	35.8	6.7	7.5	8.9	0.7	0.9	0.2	1320	Stockton Isl.
E. mesomorpha	744	2961	999	418	594	900	41.0	44.9	28.3	5.8	6.5	6.2	1.0	1.0	0.3	1360	Raspberry Isl.
E. mesomorpha	755	2867	910	396	584	901	41.6	42.6	29.1	6.4	7.4	7.8	0.8	0.9	0.4	1220	Raspberry Isl.
E. mesomorpha	717	2769	1055	394	561	876	40.9	54.2	27.4	6.3	7.2	6.7	1.1	0.9	0.4	1350	Raspberry Isl.
H. physodes	655	3128	10790	637	440	533	29.5	119.4	52.6	7.7	6.2	16.2	0.8	0.8	1.2	1260	Outer Isl.
H. physodes	727	3284	11488	680	477	643	30.3	138.7	57.0	8.9	5.9	14.9	1.0	1.0	1.5	1250	Outer Isl.
H. physodes	654	3027	12638	655	487	637	28.9	137.0	56.7	8.6	5.7	14.8	1.2	0.9	1.5	1520	Outer Isl.
H. physodes	592	2797	9979	631	463	545	18.4	423.9	85.4	6.2	6.9	18.2	0.8	1.0	0.7	720	Stockton Isl.
H. physodes	608	2988	10642	644	489	560	17.3	426.2	91.6	6.6	6.8	16.2	1.5	0.9	0.6	640	Stockton Isl.
H. physodes	635	3028	11182	632	498	579	18.1	418.3	90.6	6.6	6.8	16.0	1.0	1.0	0.7	765	Stockton Isl.
H. physodes	907	3869	20344	1061	802	874	44.9	161.4	53.9	16.2	6.8	16.5	1.6	1.2	0.9	990	Raspberry Isl.
H. physodes	1001	4044	19771	1216	943	1026	55.4	153.9	51.0	16.4	7.1	14.9	2.0	1.7	0.8	990	Raspberry Isl.
H. physodes	1015	4038	19151	1263	921	961	59.1	183.3	51.2	17.1	7.4	14.6	2.1	1.3	0.8	1050	Raspberry Isl.

*= one value at or below detection limit; included as 0.7 of detection limit
#= two values at or below detection limit; not included in calculations
@= ground before dividing into replicates

Table 2. Summary of Analysis of Apostle Isl. Lichens
Values in ppm of thallus

Cladina rangiferina	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	446	1822	485	278	186	191	20.7	30.1	12.6	3.3	5.2	*1.2	#	0.3	0.1	533	Outer Isl.
Std. dev.	32	137	58	35	14	25	4.5	6.8	0.6	0.2	0.9	0.4	#	0.1	<.1	42	Outer Isl.
Mean	344	1377	454	245	195	189	19.7	51.2	12.6	3.1	5.7	2.6	#	0.3	0.2	472	Stockton Isl.
Std. dev.	5	37	36	16	6	9	2.2	10.7	0.6	0.4	0.6	0.5	#	<.1	<.1	10	Stockton Isl.
Mean	484	1817	636	319	234	259	28.5	34.2	16.9	3.8	5.8	2.0	#	0.4	0.2	690	Raspberry Isl.
Std. dev.	22	62	20	9	15	11	0.6	0.5	0.4	0.1	0.3	0.7	#	<.1	<.1	78	Raspberry Isl.

Evernia mesomorpha	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	624	2583	683	366	489	616	45.5	32.7	28.1	12.0	6.2	5.5	0.8	1.0	0.4	1163	Outer Isl. @
Std. dev.	18	21	23	2	6	15	1.3	0.5	0.5	0.1	0.4	0.8	<.1	0.1	<.1	81	Outer Isl. @
Mean	505	2193	452	350	590	673	33.7	57.0	37.6	6.4	8.0	9.5	0.8	0.9	0.2	1250	Stockton Isl.
Std. dev.	36	113	27	20	9	34	2.7	3.5	1.7	0.4	0.5	0.7	0.1	<.1	<.1	70	Stockton Isl.
Mean	739	2866	988	403	580	892	41.2	47.3	28.2	6.2	7.0	6.9	1.0	0.9	0.3	1310	Raspberry Isl.
Std. dev.	20	96	74	14	17	14	0.4	6.1	0.9	0.3	0.5	0.8	0.1	0.1	0.1	78	Raspberry Isl.

Hypogymnia physodes	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	678	3146	11639	657	468	604	29.6	131.7	55.5	8.4	5.9	15.3	1.0	0.9	1.4	1343	Outer Isl.
Std. dev.	42	130	933	22	25	62	0.7	10.7	2.4	0.7	0.2	0.8	0.2	0.1	0.1	153	Outer Isl.
Mean	612	2938	10601	636	483	562	17.9	422.8	89.2	6.5	6.8	16.8	1.1	1.0	0.7	708	Stockton Isl.
Std. dev.	22	123	603	7	18	17	0.5	4.1	3.3	0.3	0.1	1.2	0.4	0.1	<.1	63	Stockton Isl.
Mean	974	3984	19755	1180	889	953	53.1	166.2	52.1	16.6	7.1	15.4	1.9	1.4	0.8	1010	Raspberry Isl.
Std. dev.	59	99	597	106	76	76	7.4	15.3	1.6	0.4	0.3	1.0	0.3	0.3	0.1	35	Raspberry Isl.

*= one value at or below detection limit; included as 0.7 of detection limit
#= two values at or below detection limit; not included in calculations
@= ground before dividing into replicates

is no clear trend in accumulated levels of sulfur.

None of the other elements show elevated levels or gradients in concentrations.

These tables indicate that there are no air pollution problems that can be detected with these methods.

CONCLUSIONS

There is no indication that the lichens of Apostle Islands NL are being damaged by air quality. The lichen flora is quite diverse and the areas with greater diversity are more due to vegetation and substrate that air patterns. There is no impoverishment of the lichen flora in any part of the the park. The maps of the distributions of the more sensitive species do 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 where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at any locality.

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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.

Ashland County

59942-60012 South end of Basswood Island. Along shore around old quarry and campground in hardwood forest with some balsam fir and pines. Sec. 4, T50N, R3W. 1 August 1987.

60013-60062 In center of Basswood Island around clearing of old farm (McCloud). Openings with quaking aspen at edge and scattered oaks and maples. Sec. 27, T51N, R3W. 2 August 1987.

60063-60117 Hermit Island. On south side near western end near shore in hardwood forest with oak and maple and birch. Sec. 13, T51N, R3W. 2 August 1987.

60118-60179 Stockton Island. Along west side of tombolo north of Presque Isle near stream and bog with black spruce, red pine and white birch. Sec. 36, T52N, R2W. 4 August 1987. Chemical analysis.

60180-60250 Stockton Island at north edge of Presque Isle. In mixed conifer forest and along bog with Thuja, birch and balsam fir. Sec. 1 & 6, T51N, R1W. 5 August 1987.

60251-60312 Manitou Island. On southern tip from shore up to ridge in hardwood forest with maples, birch and balsam fir near shore. Sec. 24, T52N, R3W. 6 August 1987.

60313-60369 Stockton Island one mile east of Quarry Bay. In mixed forest of hardwoods with maples and birch and in low areas with balsam fir and Thuja. Sec. 35, T52N, R2W. 6 August 1987.

60370-60409 Stockton Island at shore of Julian Bay (north of Presque Isle). In pine stand back from shore with red pines and white pines and juniper. Sec. 6, T51N, R1W. 7 August 1987.

60410-60479 South Twin Island between airstrip clearing and ranger station. In mixed forest with birch, maple, Thuja and balsam fir. Sec. 29, T53N, R2W. 8 August 1987.

60480- Cat Island at southern tip. From shore back into wet

60532 area with Thuja, birch, yew and balsam fir and red pines on shore.. Sec. 12, T52N, R2W. 8 August 1987.

60533-60569 Otter Island at southeastern tip northeast of dock and sand spit. Near shore in mixed hardwood forest and balsam fir and Thuja. Sec. 11, T52N, R3W. 8 August 1987.

60570-60612 Rocky Island. Inland from dock area on main ridge. In mixed forest of maples, Thuja, balsam fir and birch. Sec. 25, T53N, R3W. 9 August 1987.

60613-60661 Devils Island. On high land near southern middle of island east of road. In mixed forest with big old white pines, birch and yew. Sec. 10, T53N, R3W. 10 August 1987.

60662-60698 Devils Island. On north end of bog near center of island with balsam fir, black spruce and dead snags and young birch. Sec. 10, T53N, R3W. 10 August 1987.

60699-60777 Devils Island. At north end along shore near lighthouse station on rocks and with balsam fir, mountain ash and white birch. Sec. 10, T53N, R3W. 11 August 1987.

60778-60849 Outer Island west of lighthouse. In virgin hemlock stand near shore with hemloch, birch, Thuja and sugar maple. Sec. 13, T53N, R1W. 13 August 1987.

60850-60908 Outer Island 1 mile south of lighthouse. In hardwood forest and wet areas with sugar maple, hemlock, yellow birch and some Thuja. Sec. 18, T53N, R1E. 13 August 1987.

60909-60961 Outer Island at southern tip on sand spit. Along shore with jack pines, white pine and red pine and some maples and birch. Sec. 10, T52N, R1W. 13 August 1987. Chemical analysis.

Bayfield County

60962-61043 Raspberry Island. On west side of island near shore with balsam fir, Thuja and birch. Sec. 19, T52N, R3W. 14 August 1987.

61044 Raspberry Island. On building at lighthouse station at southern end of island. Sec. 24, T52N, R4W. 15 August 1987.

61045-61068 Raspberry Island. Around sand spit and along shore at southeastern part of island with alder, pines and balsam fir. Sec. 19, T52N, R3W. 15 August 1987. Chemical analysis.

61069- Sand Island. On east side back from shore north of
61113 East Bay. At edge of swamp with alder, balsam fir and birch. Sec. 13, T52N, R5W. 16 August 1987.

61114- Mainland 0.5 miles west of Little Sand Bay Ranger
61169 Station. Along shore of Lake Superior with balsam fir, white birch and hemlock. Sec. 32, T52N, R4W. 18 August 1987.

61170- Mainland at Sand Point on shore of Lake Superior. Low
61227 area along shore with Thuja, white birch and balsam fir. Sec. 35, T52N, R5W. 18 August 1987.

61228- Mainland at Squaw Bay of Lake Superior at western end of
61271 park east of Meyers Road. Steep shore and gullies with alder, white birch and quaking aspen. Sec. 19, T51N, R5W. 18 August 1987.

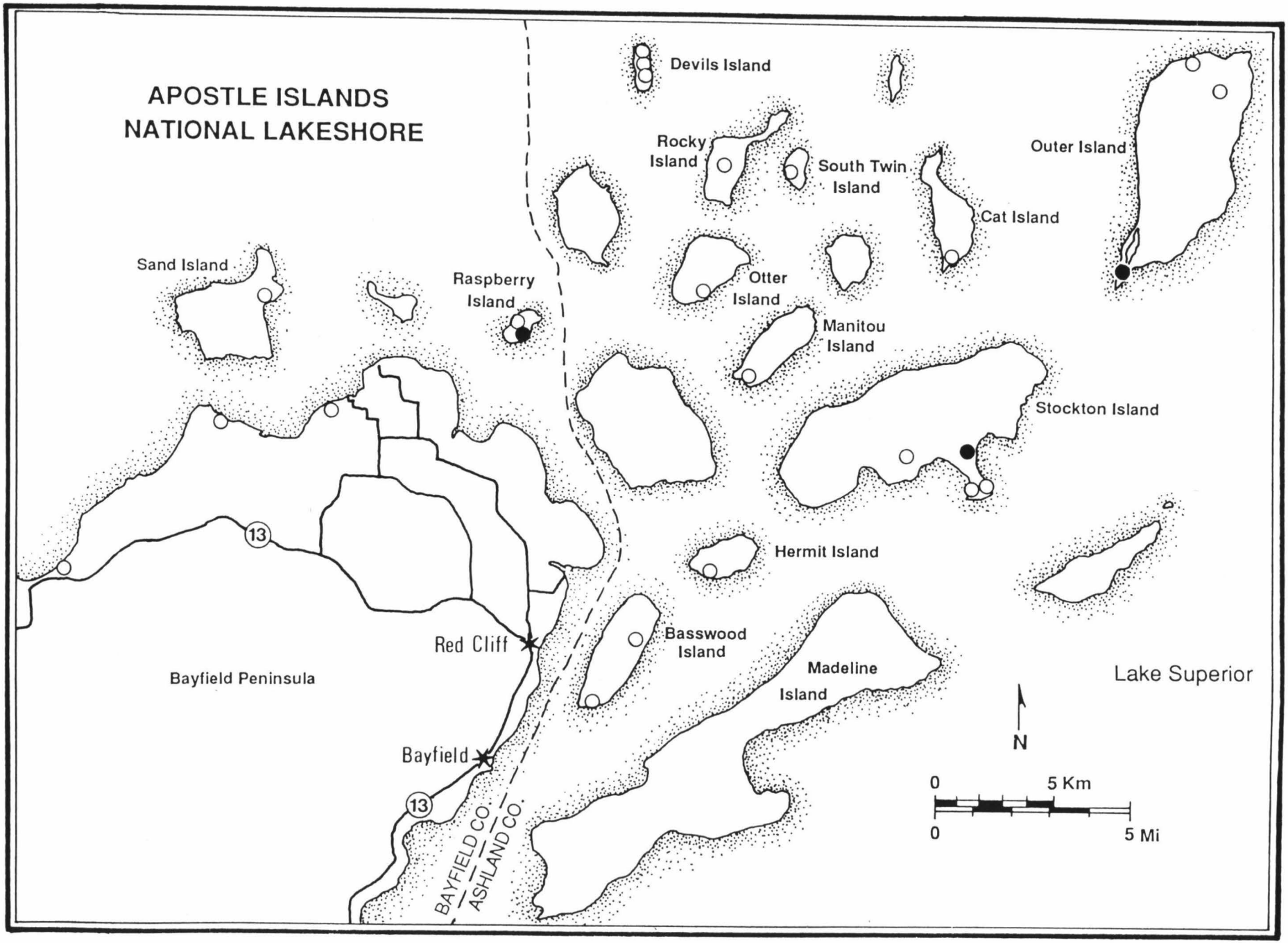


Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.

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 Apostle Islands NL 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). The intermediate category includes species present between 50ug and 100ug. The S-I group falls between the Sensitive and Intermediate categories. Open circles on the maps are localities where the species was not found and solid circles are where it was found.

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 Dimerella lutea (Dicks.) Trev.
Fig. 5 Hypogymnia tubulosa (Schaer.) Hav.
Fig. 6 Lecidea vernalis (L.) Ach.
Fig. 7 Lobaria pulmonaria (L.) Hoffm.
Fig. 8 Ochrolechia rosella (Müll. Arg.) Vers.
Fig. 9 Parmelia squarrosa Hale
Fig. 10 Parmelia subaurifera Nyl.
Fig. 11 Ramalina americana Hale
Fig. 12 Usnea ceratina Ach.
Fig. 13 Usnea filipendula Stirt.

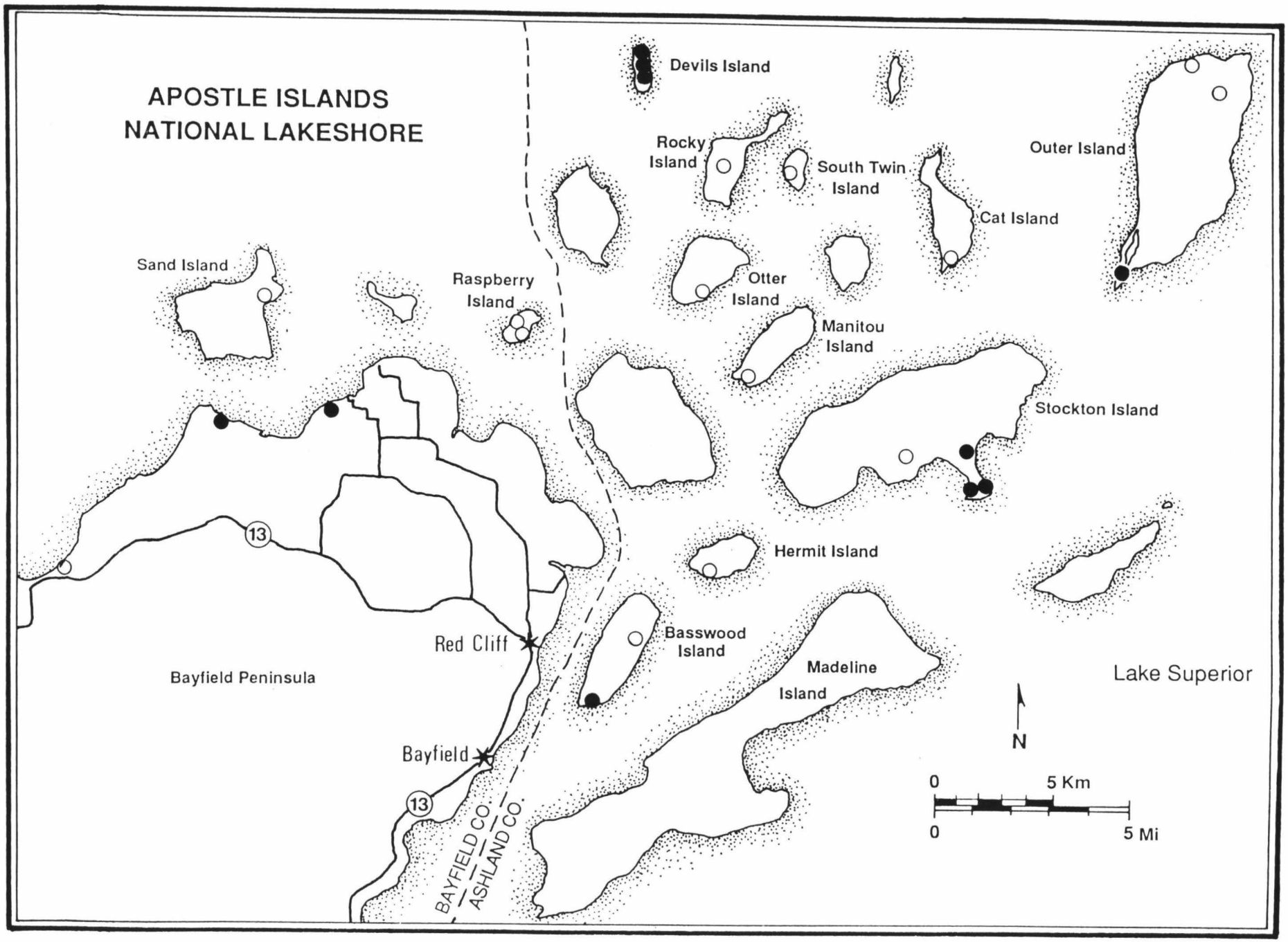


Fig. 2. Distribution of Bryoria furcellata

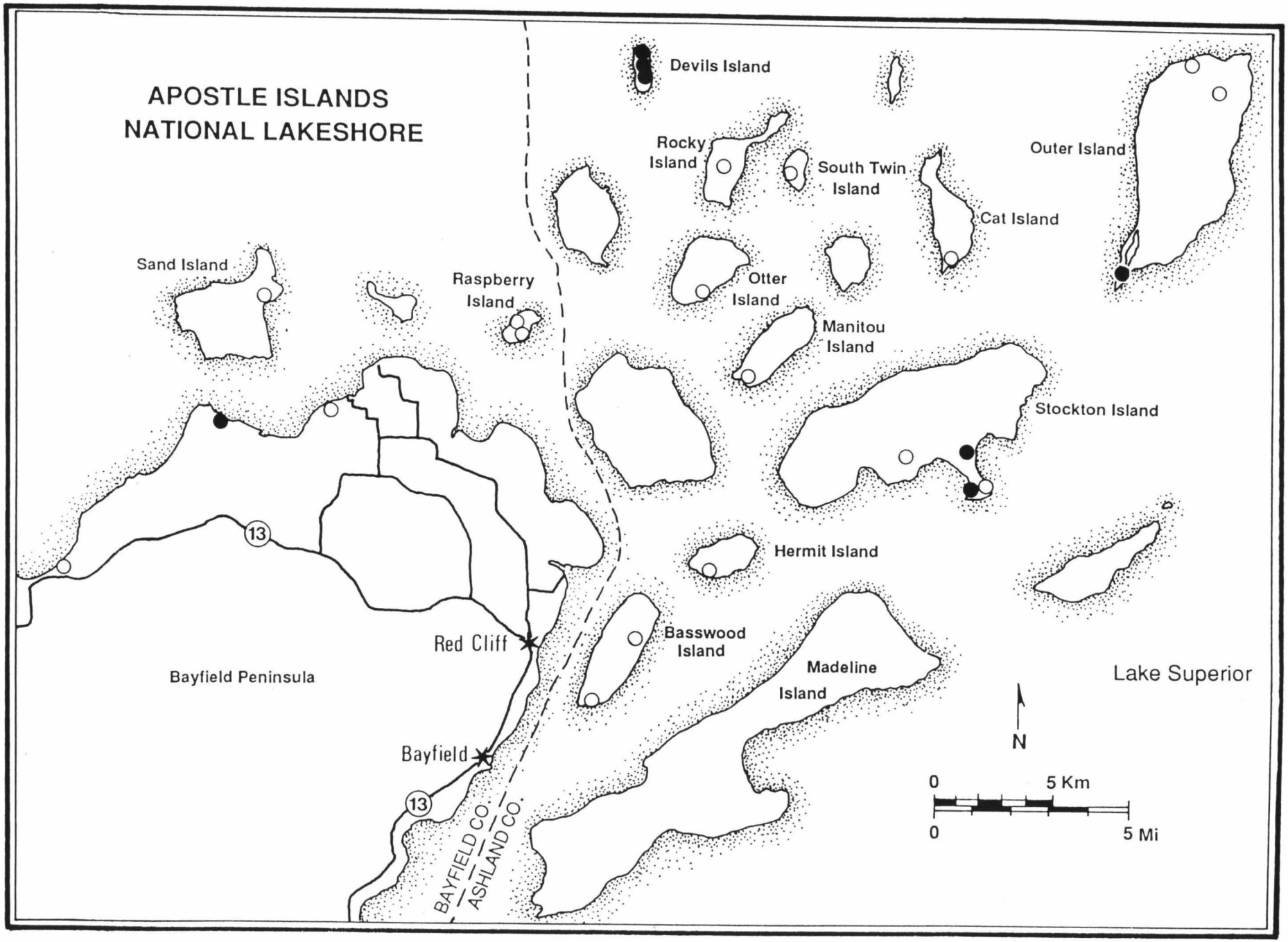


Fig. 3. Distribution of Bryoria trichodes

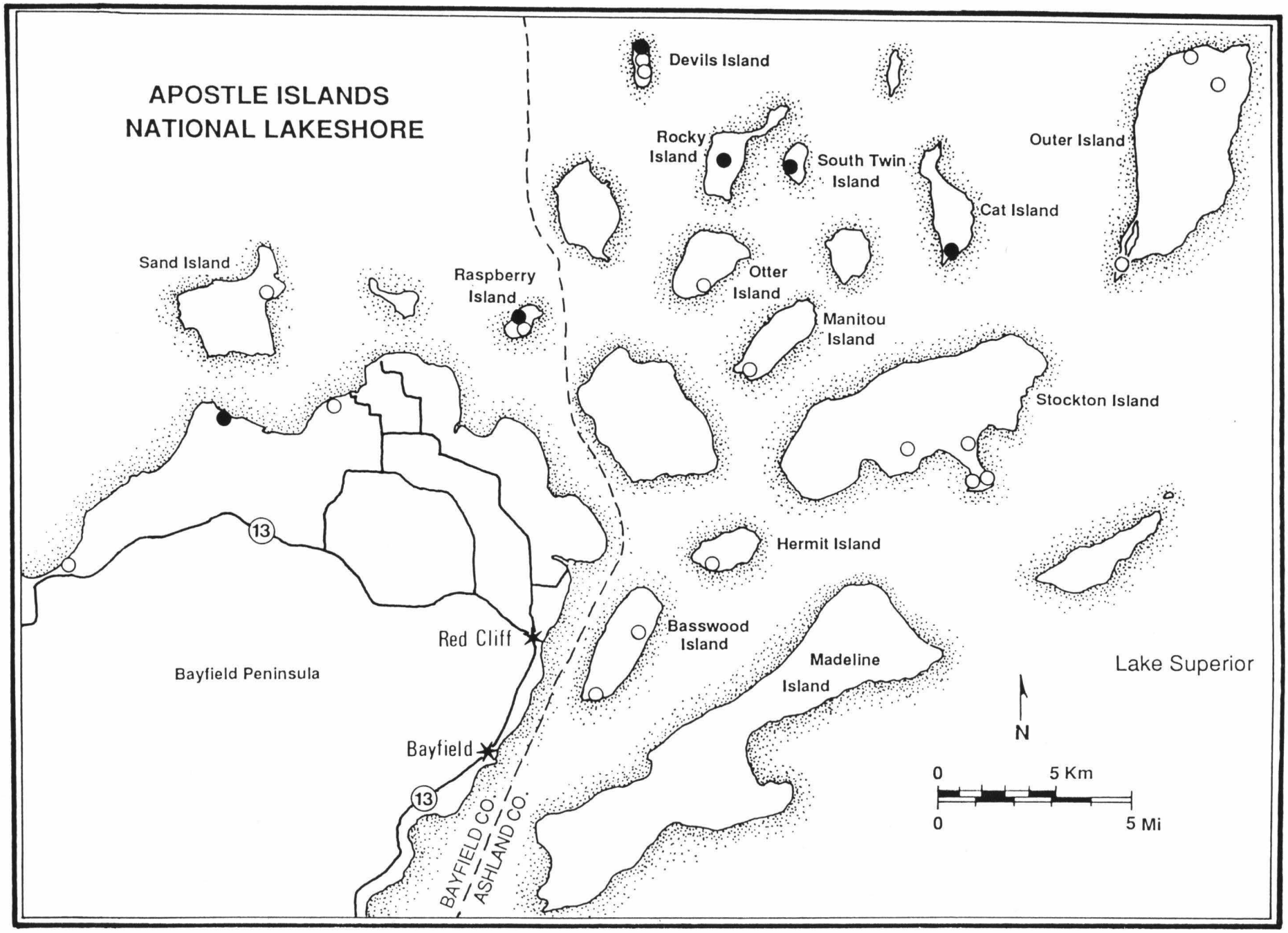


Fig. 4. Distribution of Dimerella lutea

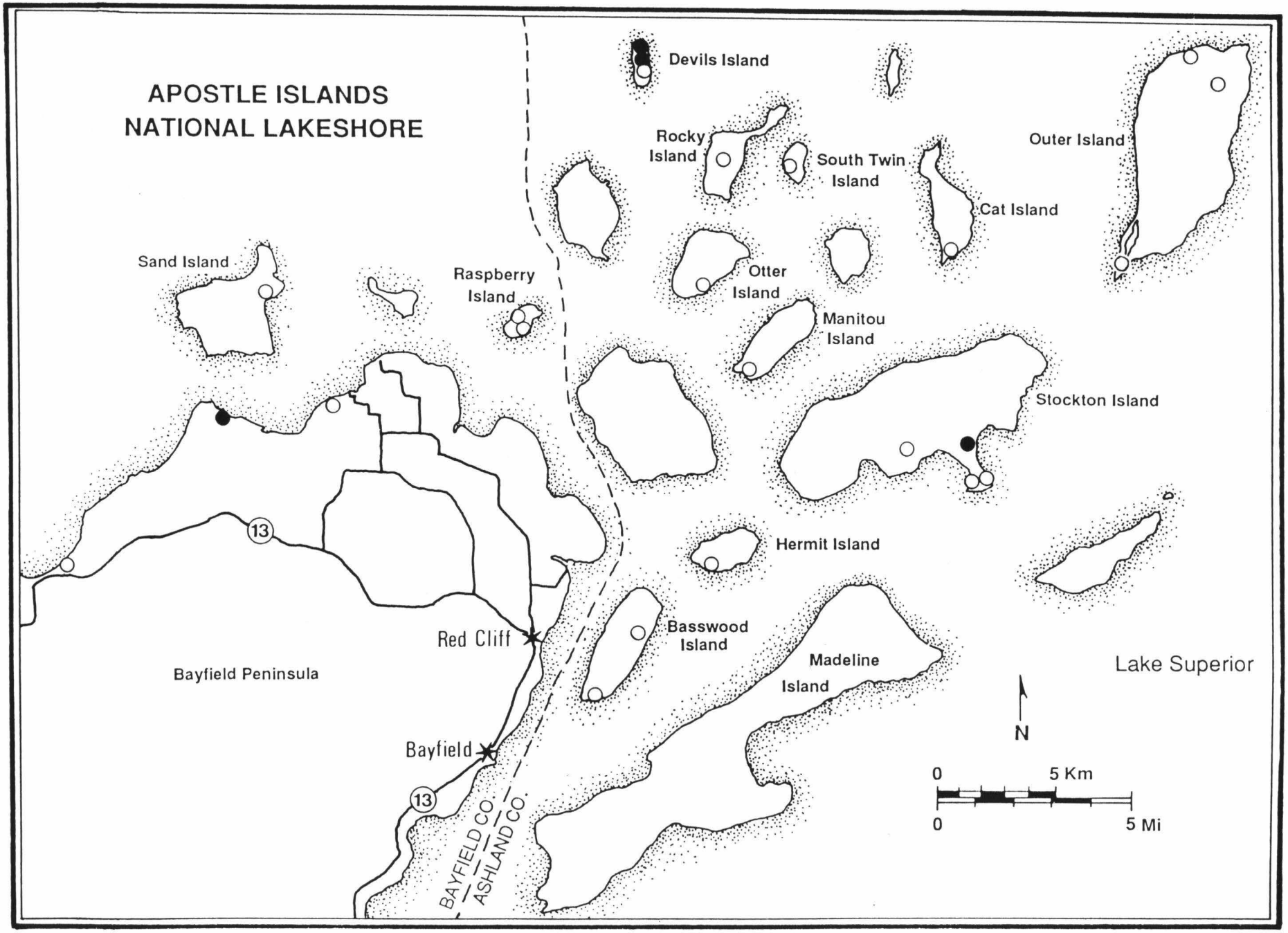


Fig. 5. Distrubution of Hypogymnia tubulosa

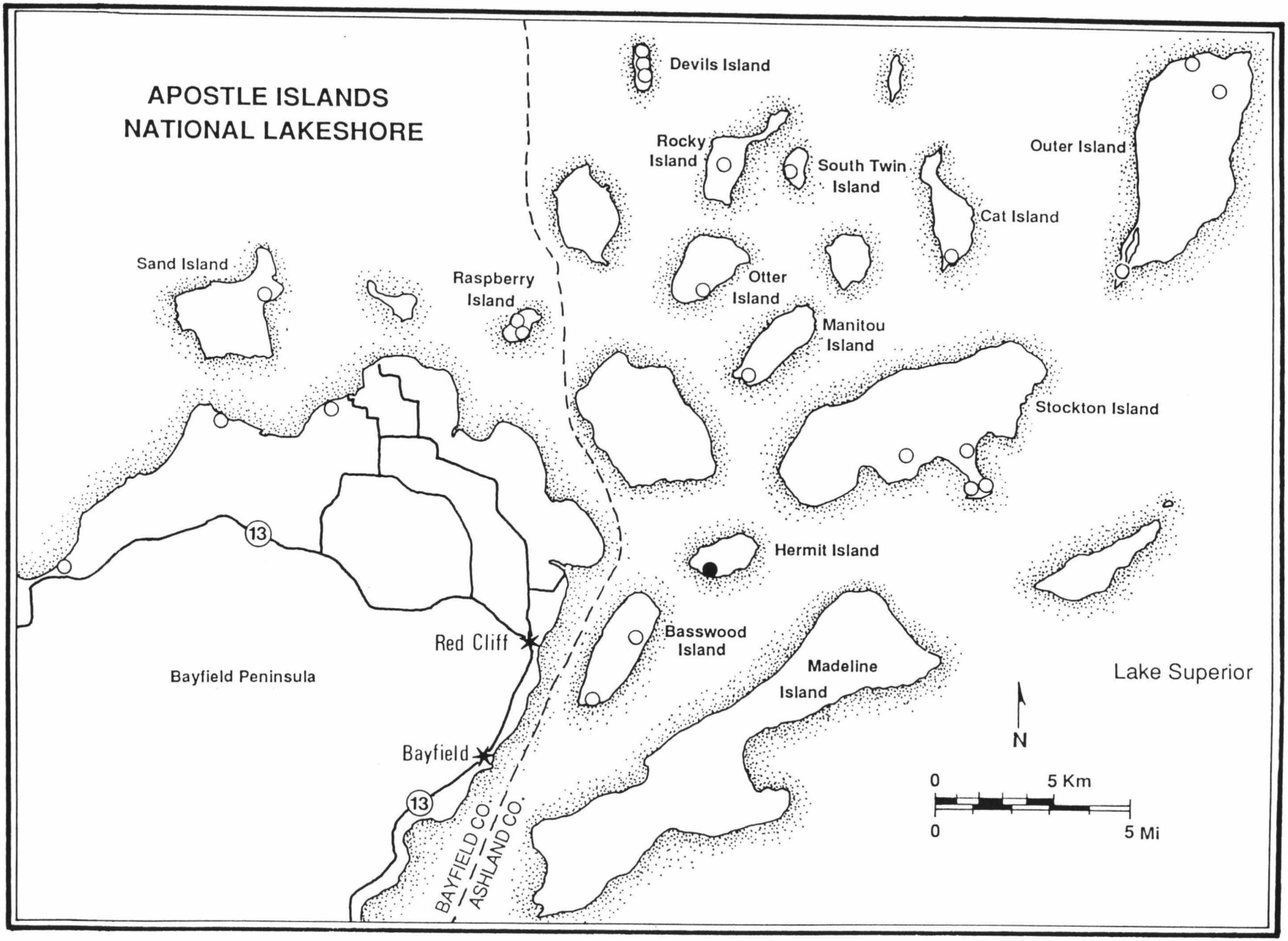


Fig. 6. Distribution of Lecidea vernalis

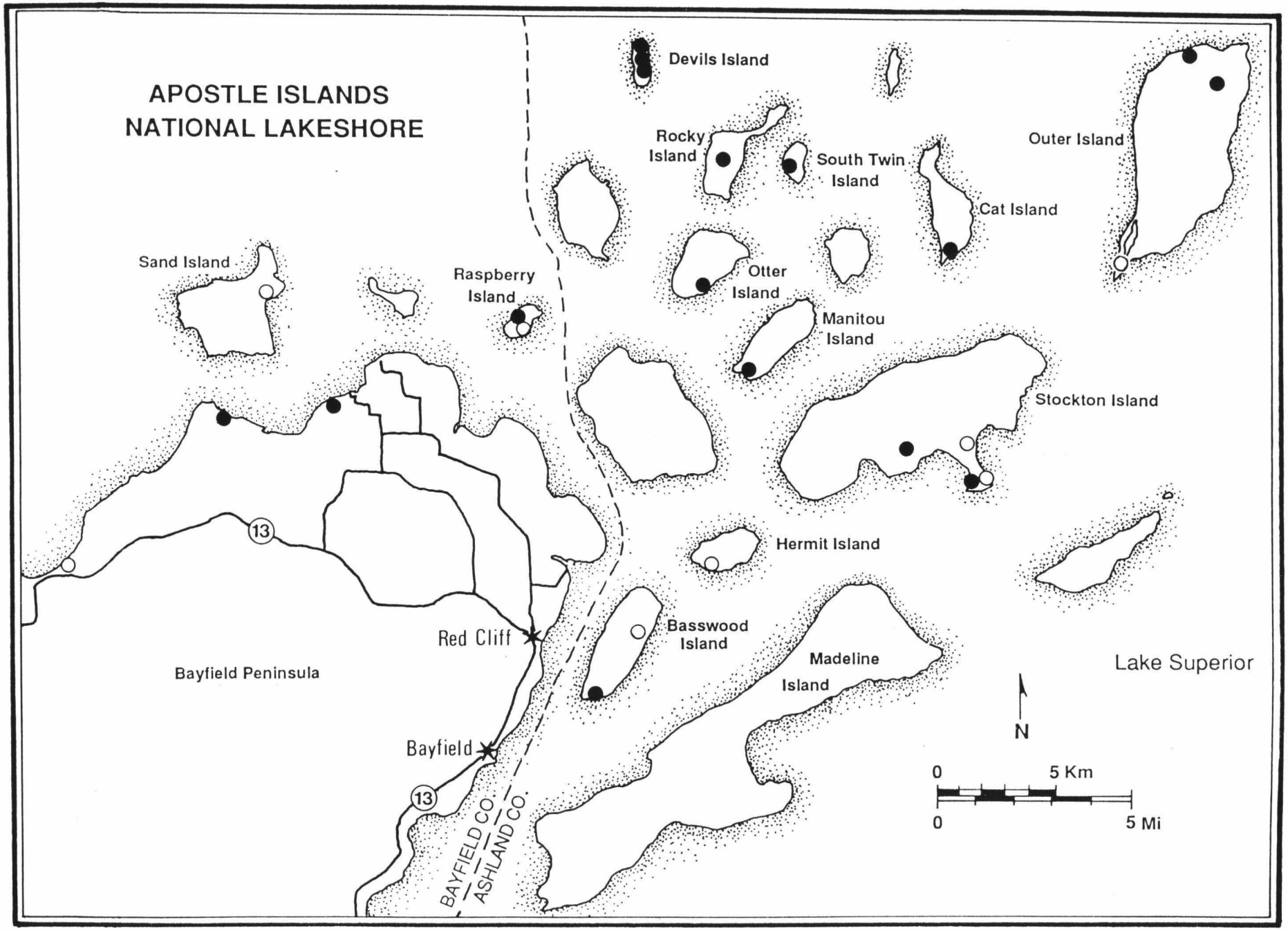


Fig. 7. Distrubution of Lobaria pulmonaria

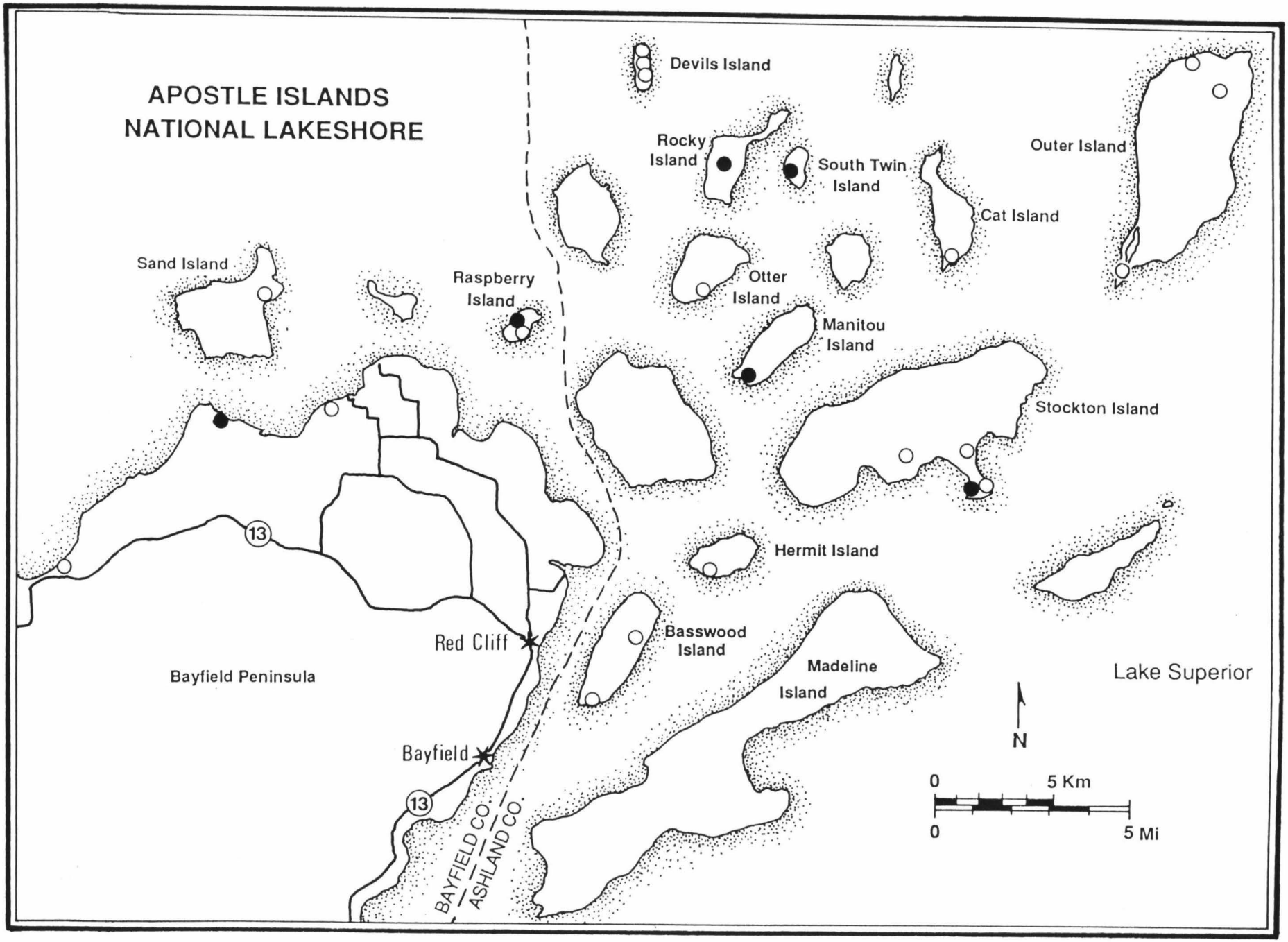


Fig. 8. Distribution of Ochrolechia rosella

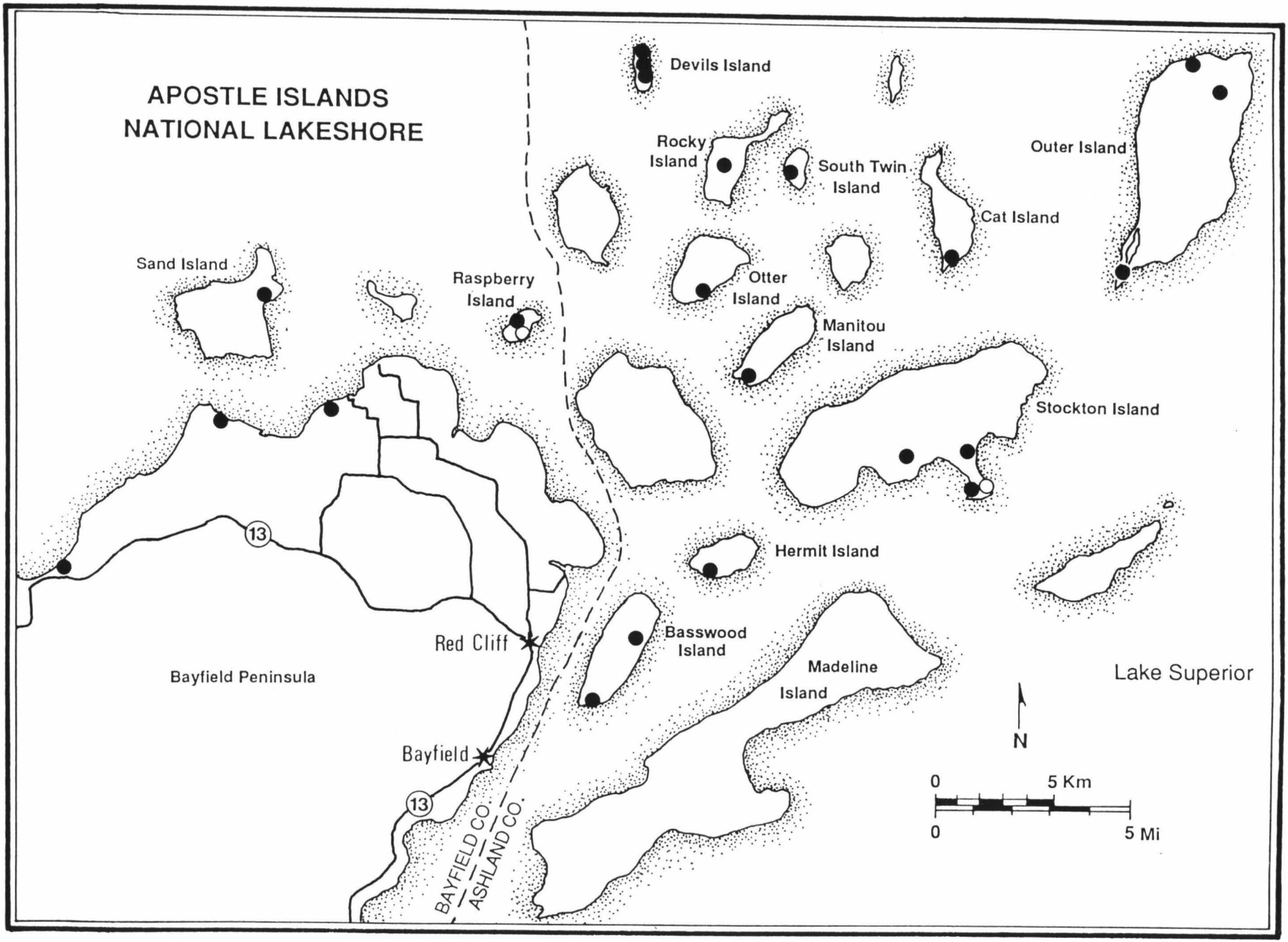


Fig. 9. Distribution of Parmelia squarrosa

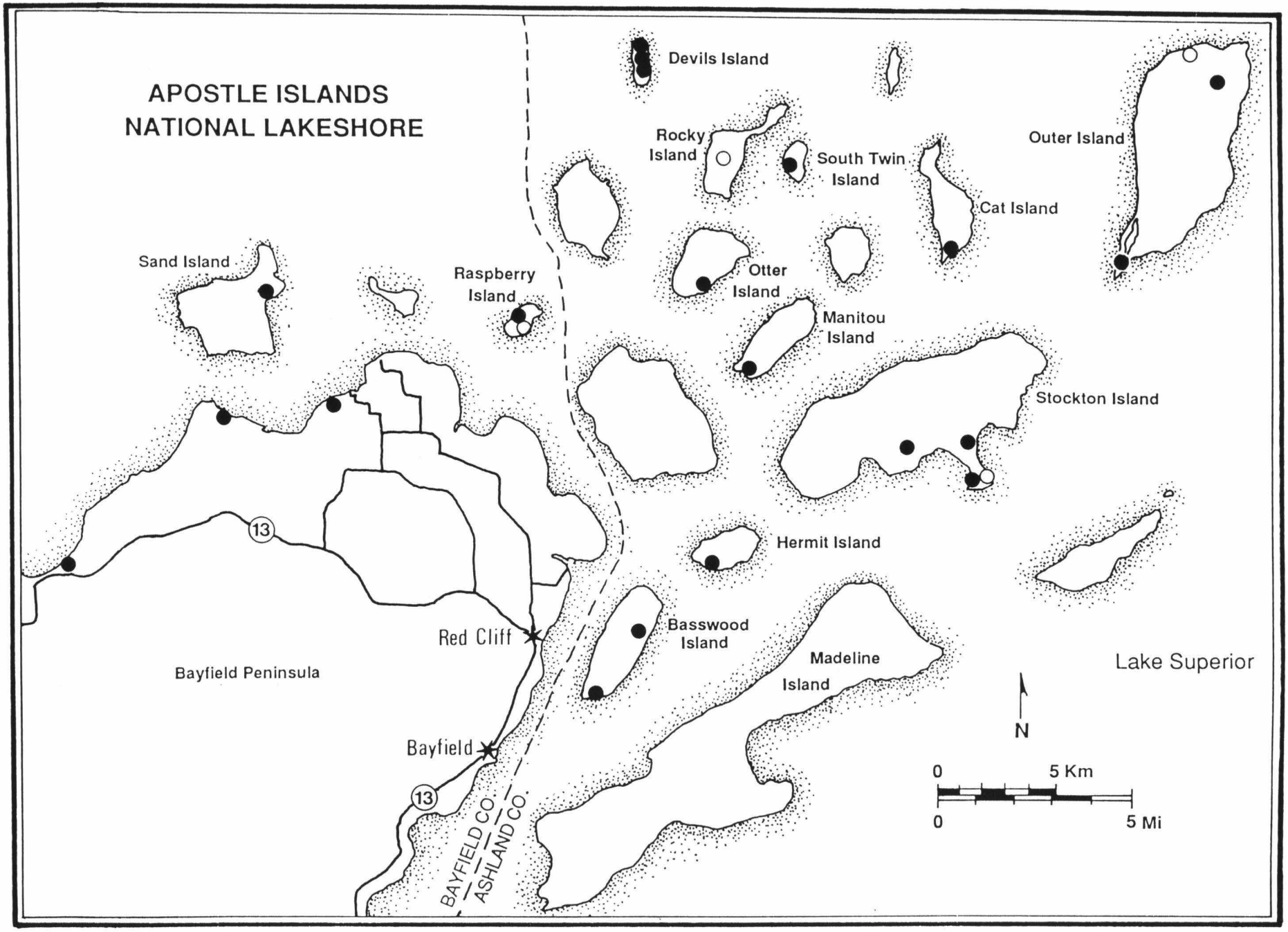


Fig. 10. Distribution of Parmelia subaurifera

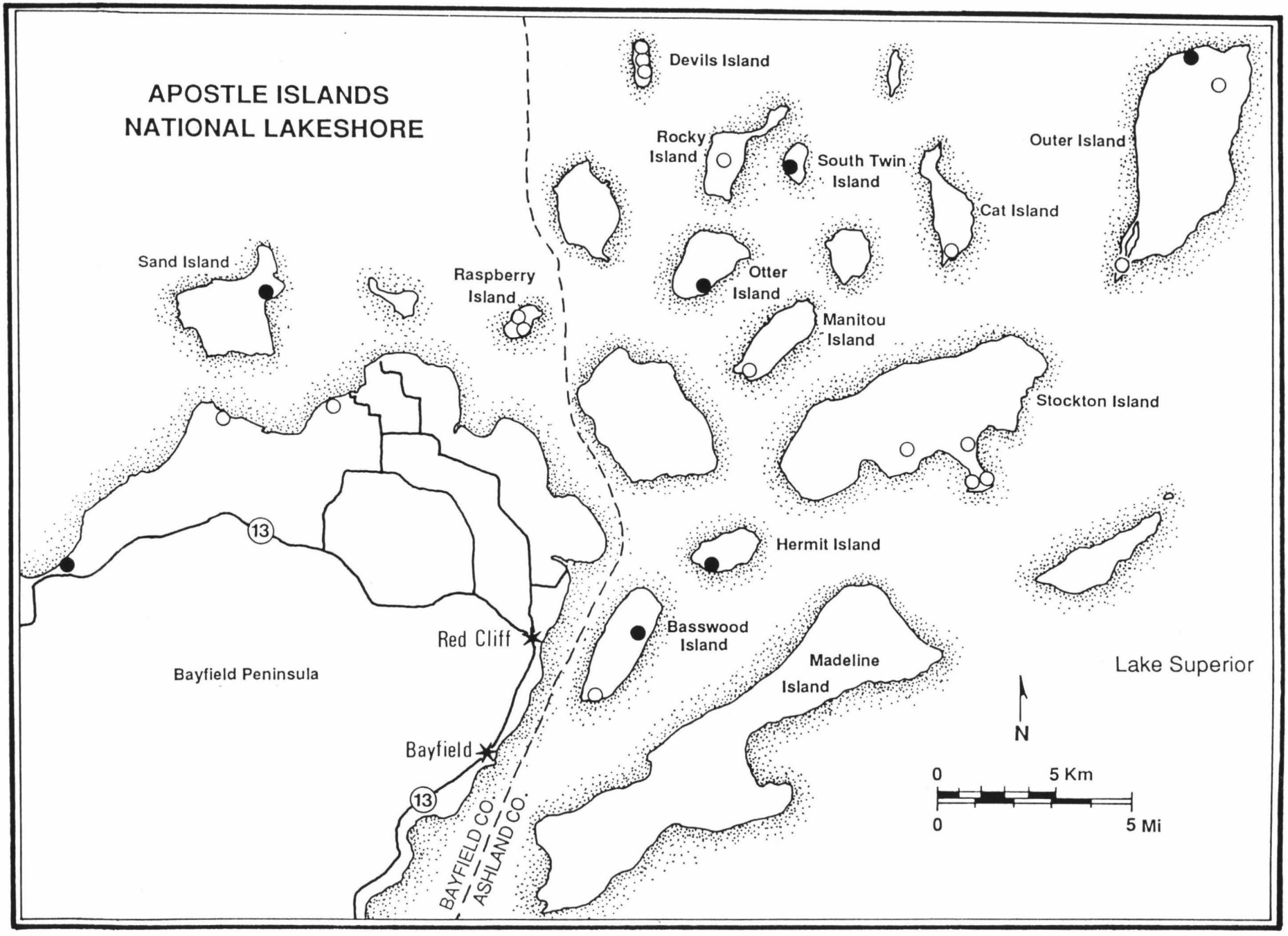
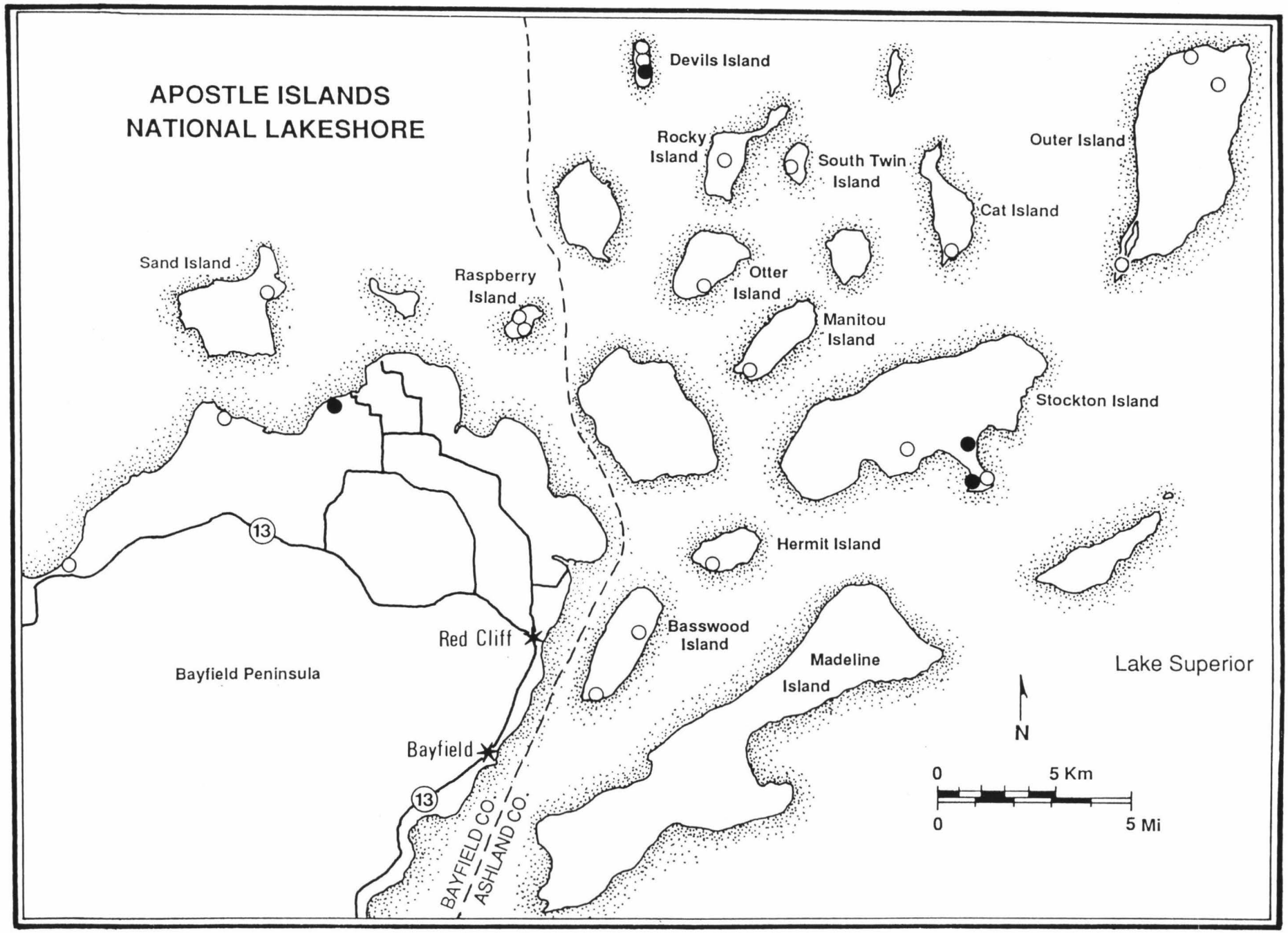


Fig. 11. Distribution of Ramalina americana



Fif. 12. Distribution of Usnea ceratina

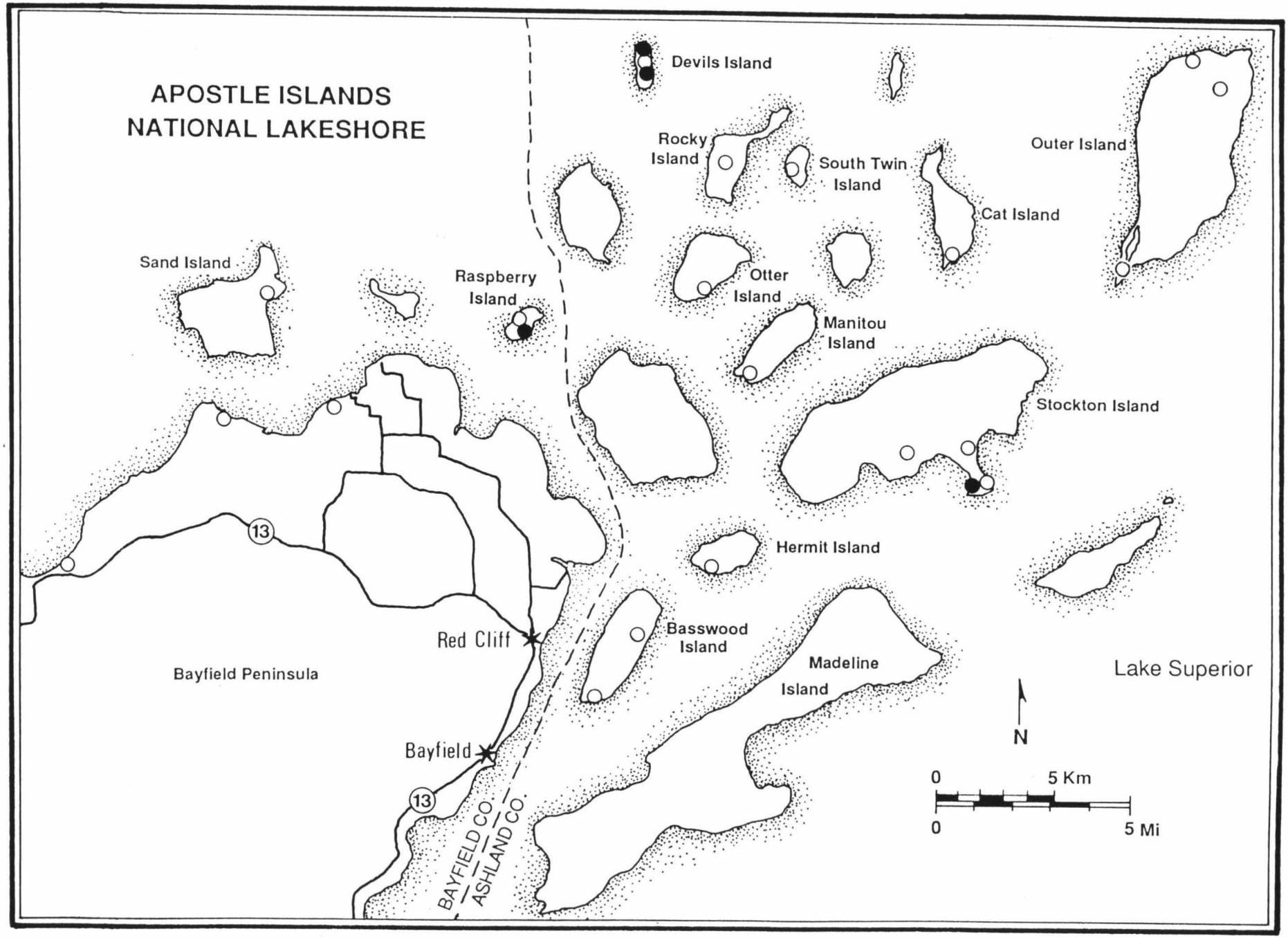


Fig. 13. Distribution of Usnea filipendula