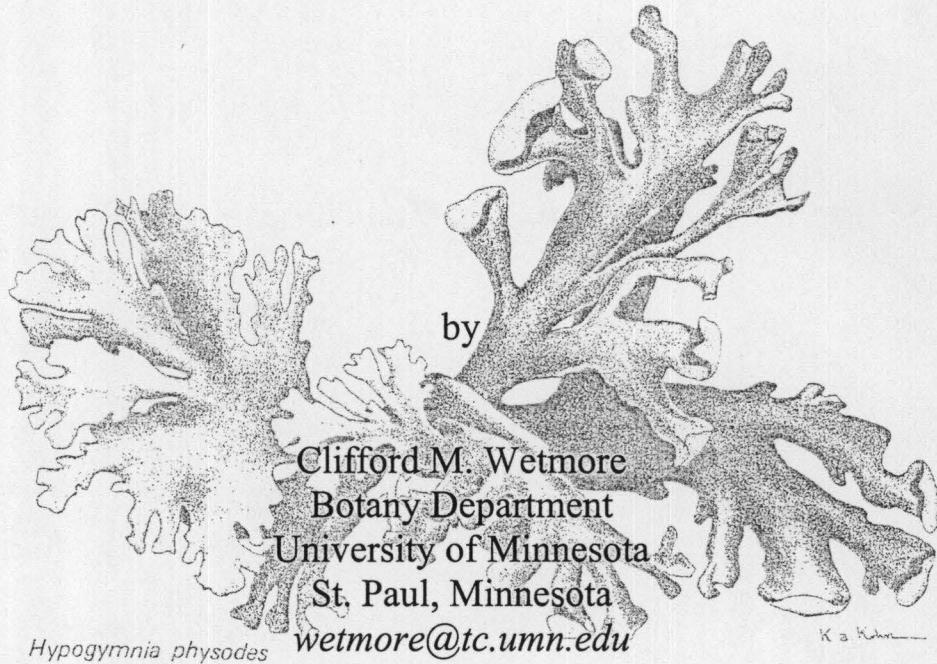


Working

2001 LICHEN STUDIES
IN
APOSTLE ISLANDS NATIONAL LAKESHORE

Final Report



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ABSTRACT

This study of the lichens of the Apostle Islands is in two separate parts. Part one is a survey of the lichens on eight islands not previously studied. The second is a restudy of the elemental analysis on Long Island and at the three localities sampled in 1987 and a comparison with the results of elemental analysis in 1987 and 1995.

Collections were made on Bear, Eagle, Gull, Ironwood, Michigan, North Twin, Oak, and York Isl. to complete the collecting on all islands of the Apostle Island National Lakeshore. There were 143 species collected including 21 new lichen records for the park. A total species list for the park is appended and lists 310 species.

Elemental analyses of lichens showed most elements decreasing but S and Cr are increasing.

A recommendation is made for additional collecting at inland localities with rock ledges or cliffs, in moist habitats with white cedar, black ash, and streams or springs.

A recommendation is made for periodic (5 years) restudy of the lichens by elemental analysis.

It is also recommended that a more detailed study of elemental analysis of some islands be done at a more frequent interval.

PREFACE

This report covers two projects on the lichens of Apostle Islands National Lakeshore. Under a purchase order from the National Park Service a restudy of lichen elemental analysis was to be done and a lichen study was to be performed on eight previously unstudied islands: Bear Isl., Eagle Isl., Gull Isl., Ironwood Isl., Michigan Isl., North Twin Isl., Oak Isl., and York Isl.

The elemental analysis study was to collect lichens for elemental analysis on Long Island (Wetmore, 1996) and the three localities where it was done in the 1987 study (Wetmore, 1988). Comparisons were to be made to detect any changes in the accumulation of elements that might have occurred since the previous studies. All work was done at the University of Minnesota with frequent consultation with Dr. James Bennett, USGS, Biological Resource Division, Madison, Wisc. and with personnel in the park.

The park personnel have been very helpful during the field work in providing boat transportation to the islands 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

This study completes a survey of the islands not previously visited. Now at least one locality has been studied on all islands of the Apostle Islands National Lakeshore. In the original study (Wetmore, 1988) it was not possible to collect on all islands. In the 1995 study (Wetmore & Bennett, 1996) collections were made on Long Island.

This report has two parts: the lichen flora, and the restudy of elemental analysis.

PART I. LICHEN FLORAS

Methods

Field work was done during July and August 2001. Collections were made at 11 localities on Bear Isl., Eagle Isl., Gull Isl., Ironwood Isl., Michigan Isl., North Twin Isl., Oak Isl., and York Isl. and 360 lichen collections were obtained. Full locality information is given in Appendix I and shown on Fig. 1. Because of island access problems most localities were near the shores of the islands. 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. 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 entered into the computerized data base maintained there.

The following lists of lichens is based on my collections. There are no literature reports of lichens previously collected on these islands. There are a few additional unidentified

species. In the first column an "+" indicates a new record for the park. None of the new records have known sensitivity to sulfur dioxide so no indication of sensitivity is indicated on this list. Appendix II give lists of lichens by locality and Appendix III gives a total species list for the park with the rare species marked.

2001 Species list

This list includes all 143 species collected in 2001. There were 21 new records found and they are indicated by "+". None of the new records have known sensitivity to sulfur dioxide.

Arthonia caesia (Flotow) Körber
Arthonia punctiformis Ach.
Arthonia radiata (Pers.) Ach.
+*Arthothelium ruanum* (Massal.) Körber
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
+*Bacidia polychroa* (Th. Fr.) Körber
+*Bacidia sabuletorum* (Schreber) Lettau
Bacidia schweinitzii (Fr. ex Michener) A. Schneider
+*Bacidina inundata* (Fr.) Vezda
+*Baeomyces rufus* (Hudson) Rebert.
Bryoria furcellata (Fr.) Brodo & Hawksw.
Bryoria trichodes (Michaux) Brodo & Hawksw.
Buellia disciformis (Fr.) Mudd
Buellia stillingiana J. Steiner
Calicium parvum Tibell
Caloplaca holocarpa (Hoffm. ex Ach.) Wade
Candelaria concolor (Dickson) Stein
Candelariella aurella (Hoffm.) Zahlbr.
Candelariella efflorescens Harris & Buck
Candelariella vitellina (Hoffm.) Müll. Arg.
Cetraria americana (Spreng.) ined.
Cetraria pinastri (Scop.) Gray
Cetrelia chicitae (Culb.) Culb. & C. Culb.
Cetrelia olivetorum (Nyl.) Culb. & C. Culb.
Chaenotheca brunneola (Ach.) Müll. Arg.
Chrysothrix candelaris (L.) Laund.
Cladina mitis (Sandst.) Hustich
Cladina rangiferina (L.) Nyl.
Cladina stellaris (Opiz) Brodo
Cladonia bacillaris Nyl.
Cladonia cenotea (Ach.) Schaerer

Cladonia cervicornis (Ach.) Flotow
Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel
Cladonia coniocraea (Flörke) Sprengel
Cladonia cornuta (L.) Hoffm.
Cladonia crispata (Ach.) Flotow
Cladonia cristatella Tuck.
Cladonia gracilis (L.) Willd.
Cladonia grayi G. Merr. ex Sandst.
Cladonia merochlorophaea Asah.
Cladonia phyllophora Hoffm.
Cladonia pleurota (Flörke) Schaerer
Cladonia pyxidata (L.) Hoffm.
Cladonia scabriuscula (Delise) Nyl.
Cladonia squamosa Hoffm.
Collema subflaccidum Degel.
Conotrema urceolatum (Ach.) Tuck.
Cresponea chloroconia (Tuck.) Egea & Torrente
Cyphelium lucidum (Th. Fr.) Th. Fr.
Dimerella lutea (Dickson) Trevisan
Dimerella pineti (Ach.) Vezda
Endocarpon pusillum Hedwig
Evernia mesomorpha Nyl.
Flavoparmelia caperata (L.) Hale
Flavopunctelia flaventior (Stirton) Hale
Graphis scripta (L.) Ach.
Heterodermia speciosa (Wulfen) Trevisan
Hypocenomyce scalaris (Ach.) Choisy
Hypogymnia physodes (L.) Nyl.
Imshaugia aleurites (Ach.) S. Meyer
Julella sericea (Massal.) Coppins
+*Lecanora argentata* (Ach.) Malme
Lecanora caesiorubella subsp. *caesiorubella* Ach.
Lecanora carpinea (L.) Vainio
Lecanora circumborealis Brodo & Vitik.
Lecanora dispersa (Pers.) Sommerf.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora muralis (Schreber) Rabenh.
Lecanora pulicaris (Pers.) Ach.
Lecanora symmicta (Ach.) Ach.
Lecanora thysanophora Harris in Harris & Tonsb.
+*Lecidella euphorea* (Flörke) Hertel
Lecidella stigmatea (Ach.) Hertel & Leuckert
Lepraria lobificans Nyl.
Leptogium cyanescens (Rabenh.) Körber
Lobaria pulmonaria (L.) Hoffm.
Loxospora pustulata (Brodo & Culb.) Harris
Melanelia exasperatula (Nyl.) Essl.

Melanelia septentrionalis (Lynge) Essl.
Melanelia subargentifera (Nyl.) Essl.
Melanelia subaurifera (Nyl.) Essl.
Micarea melaena (Nyl.) Hedl.
+*Mycobilimbia hypnorum* (Lib.) Kalb & Hafellner
+*Mycobilimbia tetramera* (De Not.) W. Brunnbauer
Myelochroa aurulenta (Tuck.) Elix & Hale
Ochrolechia trochophora (Vainio) Oshio
Opegrapha varia Pers.
Parmelia saxatilis (L.) Ach.
Parmelia squarrosa Hale
Parmelia sulcata Taylor
Parmotrema crinitum (Ach.) Choisy
Peltigera canina (L.) Willd.
Peltigera elisabethae Gyelnik
Peltigera rufescens (Weiss) Humb.
Pertusaria amara (Ach.) Nyl.
Pertusaria consocians Dibben
Pertusaria macounii (Lamb) Dibben
Pertusaria ophthalmiza (Nyl.) Nyl.
Pertusaria velata (Turner) Nyl.
+*Phacopsis oxyspora* (Tul.) Triebel & Rambold
+*Phaeocalicium compressulum* (Nyl. ex Szat.) A. Schmidt
+*Phaeocalicium polyporaeum* (Nyl.) Tibell
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia orbicularis (Necker) Moberg
Phaeophyscia rubropulchra (Degel.) Essl.
Phaeophyscia sciastra (Ach.) Moberg
Phlyctis argena (Sprengel) Flotow
Physcia adscendens (Fr.) H. Olivier
Physcia aipolia (Ehrh. ex Humb.) Fűrnr.
Physcia caesia (Hoffm.) Fűrnr.
Physcia dubia (Hoffm.) Lettau
Physcia millegrana Degel.
Physcia stellaris (L.) Nyl.
Physconia detera (Nyl.) Poelt
Physconia leucoleiptes (Tuck.) Essl.
Placynthiella dasaea (Stirton) To/nsberg
Placynthium nigrum (Hudson) Gray
+*Porpidia crustulata* (Ach.) Hertel & Knoph
+*Porpidia diversa* (Lowe) Gowan
Porpidia macrocarpa (DC.) Hertel & A. J. Schwab
Protoblastenia rupestris (Scop.) J. Steiner
+*Psilolechia lucida* (Ach.) Choisy
Punctelia rudecta (Ach.) Krog
Punctelia subrudecta (Nyl.) Krog
Pyxine sorediata (Ach.) Mont.

Ramalina americana Hale
Ramalina dilacerata (Hoffm.) Hoffm.
Ramalina intermedia (Delise ex Nyl.) Nyl.
Rinodina ascociscana Tuck.
+*Staurothele areolata* (Ach.) Lettau
+*Strangospora microhaema* (Norman) Anders.
Trapeliopsis granulosa (Hoffm.) Lumbsch
Trapeliopsis viridescens (Schrader) Coppins & James
Usnea filipendula Stirton
Usnea hirta (L.) F. Wigg.
Usnea subfloridana Stirton
+*Verrucaria margacea* (Wahlenb.) Wahlenb.
Xanthoria elegans (Link) Th. Fr.
Xanthoria fallax (Hepp) Arn.
+*Xanthoria fulva* (Hoffm.) Poelt & Petutschnig
+*Xanthoria polycarpa* (Hoffm.) Rieber
+*Xanthoria sorediata* (Vainio) Poelt
Xylographa opegraphella Nyl. ex Rothr.

Discussion of flora

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 on these islands. Some of the lichens under bird perches, especially on Eagle and Gull Isl., are in poor health but this is probably due to the heavy fertilization from the birds, as even the trees are dying. The large number of new records this year is largely because several of these localities were on rocky points of the islands near the shore. Few such habitats had been visited in previous collecting because of limits on where boats could land and the uncertainty of where the different inland habitats might be.

In Appendix III the total lichen species list shows many species found only once. This indicates that there are many different habitats so that, even though at least one collection site was on each island, not all habitats were repeatedly visited. There are probably also additional unsampled habitats in the internal parts of some islands. Some habitats that were not studied are rock cliffs and ledges in the interior of the islands, white

cedar (*Thuja*) and black ash (*Fraxinus*) swamps, and streams or springs with high moisture. Further study of these areas may provide additional species for the park. Additional collecting should be done in these habitats and also any old-growth forests, especially conifer forests. The apparent rarity of the singleton species might therefore be misleading, and should not be interpreted literally.

PART II. ELEMENTAL ANALYSIS OF LICHENS

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.

Elemental Analyses of Four Lichen Species from Apostle Islands NL, 1987 – 2001

Lichens have been sampled for elemental chemistry at Apostle Islands National Lakeshore three times: 1987, 1995 and 2001. Four species have been sampled in the last two years of sampling: *Cladina rangiferina*, *Evernia mesomorpha*, *Hypogymnia physodes* and *Parmelia sulcata*. The last species was not sampled in 1987. A total of 128 samples were collected, as shown in Table 1. The data for all three years are shown in Appendix V, which is also available as an Excel spreadsheet file.

Table 1. Sample sizes of four lichen species from Apostle Islands.

Species	1987	1995	2000	2001	Total
<i>Cladina</i>	9	18	2	12	41
<i>Evernia</i>	9	12	2	9	32
<i>Hypogymnia</i>	9	12	2	9	32
<i>Parmelia</i>	0	12	2	9	23
Total	27	54	8	39	128

Methods

Four sampling localities were used: Raspberry Island, Long Island, Stockton Island and Outer Island. Appendix IV gives the latitude and longitude of these localities as taken by GPS during the present study. In the present study the locality on Raspberry Isl. for *Evernia mesomorpha*, *Hypogymnia physodes*, and *Parmelia sulcata* was moved to the west side of the island because sufficient material no longer exists at the old locality.

Ten to 20 grams of each species were collected at each locality in aggregate samples from several substrates and stored in breathable sample bags and air dried.

Raspberry and Long island are close to the mainland, while Stockton and Outer are far off from the mainland. Long Island was only sampled in 1995 and 2000. Samples were collected in 2000 in order to start the work in advance, and the rest of the islands were sampled in 2001. Data for Long Island in 2000 were merged with the data from the other islands in 2001 and considered to be sampled in one year. The total number of samples collected from each island across species and years is Raspberry – 33, Long – 23, Stockton – 33, and Outer – 39.

Lichens were air dried and cleaned of all bark and detritus 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 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.

Sixteen elements were measured in the samples: Al, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S and Zn. Boron levels in all species at Long Island in 2000 were all below detection limit and were not available. Six other below detection limits values in other elements were substituted with 0.7 times the detection limit because the number of values were less than one third of the total data available for that element (Bennett et al., 2000).

Statistical analyses of the data were performed as follows. The effects of years of sampling and species were analyzed with a two way factorial analysis of variance for each element. One-way analyses of variance of the effect of year of sampling were performed for each element for each species for tabular presentation, but are not discussed in detail. Comparison of the two near (Raspberry and Long islands) versus the two far off (Stockton and Outer islands) islands were performed using t tests for each element using a near/far dummy variable. Differences among islands were tested with one-way analyses of variance of each element across years and species.

Results

Of the 16 elements, 11 have changed significantly over time: B, Cd, Cr, Cu, Fe, K, Mn, Ni, Pb, S and Zn (Tables 2, 3, 4 and 5). Al, Ca, Mg, Na and P have not changed significantly. Of those that have changed significantly, B, Cd, Cu, K, Mn, Pb and Zn have all decreased, while Cr, Fe, Ni and S have increased. Significant increases ranged

from 5 to 134% and averaged 39.6%, while significant decreases ranged from 1 to 87% and averaged 39.2%.

Table 2. Three year chemical element averages for *Cladina rangiferina*. Elements that are significantly different between years are shown in bold print, as determined by F probabilities less than 0.05 in one-way analyses of variance. Percent changes from 1987 to 2001 are shown in the last column.

Cladina					
Element	1987	1995	2001	Grand Average	% Change – 1987 to 2001
Al	205.2	223.6	316.1	251.1	54.0
B	5.6	0.6	0.7	1.8	-87.0
Ca	525.1	626.0	765.6	651.5	45.8
Cd	0.2	0.2	0.1	0.1	-20.7
Cr	0.3	0.4	0.6	0.5	73.3
Cu	3.4	2.3	1.7	2.3	-51.0
Fe	212.9	306.7	497.6	351.3	133.7
K	1672.0	1420.9	1292.4	1432.1	-22.7
Mg	280.7	259.0	303.0	278.8	8.0
Mn	38.5	82.1	40.2	58.2	4.5
Na	23.0	19.8	27.0	23.0	17.6
Ni	0.4	0.5	0.6	0.5	75.9
P	424.8	443.2	393.2	422.1	-7.4
Pb	2.0	1.7	1.4	1.7	-27.1
S	565.0	427.9	561.8	503.7	-0.6
Zn	14.0	15.0	15.5	15.0	10.6

Table 3. Three year chemical element averages for *Evernia mesomorpha*. See Table 2 for details.

Evernia					
Element	1987	1995	2001	Grand Average	% Change - 1987 to 2001
Al	552.7	504.4	478.0	508.9	-13.5
B	7.1	2.2	2.3	3.7	-67.5
Ca	707.7	942.9	1375.5	1025.5	94.4
Cd	0.3	0.3	0.3	0.3	-5.1
Cr	1.0	1.4	1.0	1.1	4.9
Cu	8.2	5.4	3.3	5.5	-59.3
Fe	727.0	900.7	1054.8	904.8	45.1
K	2547.1	2300.9	2133.3	2312.6	-16.2
Mg	372.9	363.8	357.4	364.2	-4.1
Mn	45.6	44.8	45.9	45.4	0.6
Na	40.1	39.8	35.2	38.3	-12.3
Ni	0.9	1.2	1.3	1.1	49.7
P	622.3	586.7	601.8	601.9	-3.3
Pb	7.3	4.4	3.6	4.9	-50.2
S	1241.1	1089.5	1384.3	1233.5	11.5
Zn	31.3	32.8	30.1	31.5	-3.9

Table 4. Three year chemical element averages for *Hypogymnia physodes*. See Table 2 for details.

Hypogymnia					
Element	1987	1995	2001	Grand Average	% Change - 1987 to 2001
Al	613.3	600.3	570.7	593.8	-6.9
B	6.6	2.1	2.5	3.6	-62.3
Ca	13998.3	16612.7	18511.3	16530.0	32.2
Cd	1.0	1.4	1.1	1.2	17.2
Cr	1.1	1.4	1.1	1.2	5.8
Cu	10.5	8.3	5.6	8.0	-46.7
Fe	706.5	944.2	1025.9	905.4	45.2
K	3355.8	3035.3	2732.4	3021.3	-18.6
Mg	824.2	778.8	850.5	816.2	3.2
Mn	240.2	214.6	205.4	218.7	-14.5
Na	33.6	31.3	33.8	32.8	0.8
Ni	1.3	1.7	1.7	1.6	29.8
P	754.8	703.9	788.4	747.3	4.4
Pb	15.8	14.0	9.3	12.9	-41.5
S	1020.6	972.0	1206.3	1066.2	18.2
Zn	65.6	81.4	66.0	71.6	0.6

Table 5. Two year chemical element averages for *Parmelia sulcata*. See Table 2 for details.

Parmelia				
Element	1995	2001	Grand Average	% Change - 1995 to 2001
Al	667.1	667.1	667.1	0.0
B	4.0	3.9	3.9	-1.3
Ca	2790.5	3543.7	3150.7	27.0
Cd	0.6	0.5	0.6	-9.9
Cr	1.1	1.1	1.1	4.6
Cu	11.4	6.8	9.2	-39.8
Fe	918.8	1036.2	974.9	12.8
K	3549.1	2835.9	3208.0	-20.1
Mg	532.7	560.0	545.8	5.1
Mn	173.2	134.4	154.6	-22.4
Na	30.5	27.9	29.3	-8.4
Ni	1.4	1.6	1.5	10.6
P	1224.3	1075.5	1153.2	-12.2
Pb	13.1	10.9	12.1	-17.2
S	1266.3	1254.3	1260.6	-0.9
Zn	89.1	80.2	84.9	-9.9

All elements were significantly different among species. With one exception (Mn in 1995 was lowest in *Evernia*), *Cladina* was always lowest in all elements. For the three other species, usually *Hypogymnia* or *Parmelia* was highest in concentration.

For some elements there was a significant year by species interaction: Al, Cd, Cr, Cu, Na, Pb, S and Zn. Usually this meant that the change over time of the element varied among species, with some species decreasing while others increased.

Some elements varied significantly among the four islands (using data across species and years): B, Cr, Fe, K, Mg, Na, Ni, P and Pb (Table 6). With one exception, these elements were highest at Raspberry Island, and generally decreased from west to east. The exception was Pb, which was highest at Long and Stockton Islands.

Table 6. Element concentrations at four Apostle Islands averaged across lichen species and years of sampling.

Element	Raspberry	Long	Stockton	Outer	% Change – Outer to Raspberry
Al	535.2	460.1	478.8	432.9	+24
B	3.55	1.56	3.78	2.71	+31
Ca	6159	3141	5344	5362	+15
Cd	0.592	0.498	0.348	0.622	-5
Cr	1.09	0.97	0.91	0.81	+35
Cu	5.78	6.30	5.37	5.76	0
Fe	899.5	680.0	769.0	616.7	+46
K	2796	2597	2157	2051	+36
Mg	652.4	419.1	435.6	415.7	+57
Mn	117.2	88.2	137.2	101.8	+15
Na	35.3	33.8	26.0	27.8	+27
Ni	1.31	1.18	1.07	0.96	+36
P	861.8	758.5	585.7	558.8	+54
Pb	6.35	9.04	8.71	5.43	+17
S	1065	855.3	993.9	913.0	+17
Zn	48.5	47.0	52.8	36.9	+31

Seven elements were significantly higher on the two near islands compared to the two far islands: Cr, Fe, K, Mg, Na, Ni and P (Table 7). No elements were significantly lower on the near islands.

Table 7. Element concentrations at two sites near to the mainland and two sites far from the mainland Apostle Islands averaged across lichen species and years of sampling.

Element	Near	Far	% Change – Far to near
Al	504.3	453.9	+11
B	2.93	3.20	-8
Ca	4919	5354	-8
Cd	0.553	0.496	+11
Cr	1.04	0.85	+22
Cu	5.99	5.58	+7
Fe	809.4	686.5	+18
K	2714	2100	+29
Mg	556.5	424.8	+31
Mn	105.3	118.0	-11
Na	34.7	27.0	+29
Ni	1.25	1.01	+24
P	819.3	571.1	+43
Pb	7.46	6.93	+8
S	979.0	950.1	+3
Zn	47.9	44.2	+8

Discussion

Of those elements that have significantly decreased over time, only B, Cu, K, Pb and possibly Mn have consistently decreased for all four species. Other elements that decreased did not do so consistently among species. The decrease in Pb is probably due to lead being phased out of gasoline. Copper may have decreased because of the decline in Cu mining in the upper Great Lakes. No plausible explanation for the decline in the other elements can be suggested at this time.

The four elements that have increased over time have not done so consistently. Iron is the exception, however, as all four species have increased from year to year. Chromium has increased for all four species when 2001 is compared with 1987, but *Evernia* and *Hypogymnia* actually peaked in 1995. Nickel has increased but appears to

be leveling off for *Hypogymnia* and *Evernia*. Sulfur has increased for three of the species, but appears to be level for *Parmelia*. These four elements could be increasing from soil dust exposure, but also from air pollution, although sulfur has been decreasing in recent years as sulfur emissions have been controlled. These elements should be watched in the future.

Nine elements were 17 to 57% higher at Raspberry Island than at Outer Island, with one exception. This may be due to an effect of longitude, or it may be proximity to the mainland, as suggested by the near versus far island comparisons. Lead was higher at Long and Stockton islands. On Long Isl. this might be due to mainland proximity. The higher levels on Stockton probably cannot be explained by the boat dock area that is about one mile away.

Half of the elements were measured with values that exceeded the enrichment thresholds for *Hypogymnia physodes* in the literature (Bennett 2000): Al, Ca, Cd, K, Mg, Mn, P and S. Maximum elevated values for Al, K, Mn and S were observed in 1987, for Ca and Cd in 1995, and for Mg and P in 2001. These time trends have little meaning because the second highest values were observed in other years for these elements. There may be a pattern to these elevated elements: Al, Cd and S may be elevated due to pollution, inducing stress in the lichen, which counteracts the stress by taking up more nutritional elements, including Ca, K, Mg and P. Conversely, elevated Ca may indicate accumulation of excess calcium oxalate, a compound thought to be involved in water balance, light attenuation, and sulfur reduction. These elevated elements should be studied in the future to monitor the situation.

The same four species of lichen were studied over an 11 year time span at the Boundary Waters Canoe Area Wilderness in northern Minnesota (Bennett & Wetmore, 1999). The four elements that increased in time at Apostle Islands decreased at the Boundary Waters. Boron is the only element that decreased in both studies. However, approximately the same elements decreased or increased from west to east in both studies across the four species. Thus the two studies resulted in comparable geographic patterns, but not comparable time trends. The Boundary Waters study spanned 1986 to 1997, and the Apostle Islands study 1987 to 2001. Perhaps the extra four years in the latter study explains the differences in time trends. The two study areas are geographically about 150 miles apart.

The five elements in *Parmelia sulcata* that changed in this study compared fairly well with the changes in the same species at Theodore Roosevelt National Park over an earlier 16 year time span (Bennett & Wetmore 2000), even though the study areas are about 600 miles apart. Actual concentrations, however, were only comparable for K and S. Al, B, Ca, Cr, Fe, Mg, Na and Ni were higher at Theodore Roosevelt, while Cd, Cu, Mn, P, Pb and Zn were higher at Apostle Islands. The higher elements at Apostle Islands are elements more associated with anthropogenic emissions, which may have had a longer history at this park than at Theodore Roosevelt.

Conclusions from Elemental Analysis

Lichen chemistry at Apostle Islands is complex. It is a positive sign that Pb and Cu are decreasing overall, but the increase in S and Cr is troubling. When coupled with the observations that elements tend to be higher near the mainland or near anthropogenic activities, and that some elements are enriched in *Hypogymnia*, a picture emerges of a growing problem for lichens. Apostle Islands may not be as pristine as is thought. These

warning signs suggest that a more detailed study of some islands is warranted, as well as more frequent monitoring of two of the species in more focused localities.

RECOMMENDATIONS

It is recommended that additional collecting be done in selected habitats in the interior of the islands. Special search should be made for rock habitats, moist habitats, and old-growth forest areas. Further collecting should also be done on more rocky points near the shores.

It is also recommended that elemental analysis be continued at 5-year intervals.

It is recommended that a more detailed study of some islands is warranted, as well as more frequent monitoring of *Hypogymnia physodes* and *Parmelia sulcata* at near and far localities from the mainland. This latter effort is needed to characterize the effect of mainland impacts more accurately. The islands for additional sites will have to be selected with regard to availability of these two species in adequate quantities for analysis.

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APPENDIX I

2001 Collection localities

These localities were visited in 2001. The first numbers are the collection numbers of C. Wetmore and are listed sequentially by date of collection. The latitude and longitude were taken with a GPS unit at the collection site and rounded to the nearest second.

Loc. 1 - 86708-86748, Ashland Co. North end of Oak Isl. Along stream and valley in from campground with yellow and white birch, maples, hemlock, and *Thuja*, elev. 650 ft. Sec. 22, T52N, R3W. 46°57'25"N, 90°43'42"W. 6 July 2001.

Loc. 2 - 86749-86775, Ashland Co. North end of Oak Isl. On NE facing ridge with sugar maple, yellow birch, and some hemlock, elev. 800 ft. Sec. 22, T52N, R3W. 46°57'25"N, 90°43'56"W. 6 July 2001.

Loc. 3 - 86887-86928, Ashland Co. SW tip of Michigan Isl. Above sand spit with balsam fir and scattered red and white pine, elev. 615 ft. Sec. 20, T51N, R1W. 46°52'32"N, 90°30'55"W. 9 July 2001.

Loc. 4 - 86929-86966, Bayfield Co. Southern tip of York Isl. Back from sand spit in balsam fir, yew, birch and some *Thuja*, elev. 620 ft. Sec. 15, T52N, R4W. 46°58'07"N, 90°51'37"W. 10 July 2001.

Loc. 5 - 86967-87021, Ashland Co. Bear Isl. Rocky point on NE shore and in woods with yew, balsam fir, and birch, elev. 615 ft. Sec. 28, T53N, R3W. 47°01'34"N, 90°44'47"W. 11 July 2001.

Loc. 6 - 87022-87064, Ashland Co. North tip of North Twin Isl. On shore rocks and in woods behind with yew, balsam fir, yellow birch, hemlock, and mountain ash, elev. 615 ft. Sec. 14, T53N, R2W. 47°04'31"N, 90°35'13"W. 11 July 2001.

Loc. 7 - 87065-87115, Ashland Co. South shore of Ironwood Isl. E of sand spit. In dense woods near shore with yew, balsam fir, yellow birch, and *Thuja*, elev. 620 ft. Sec. 9, T52N, R2W. 46°59'27"N, 90°36'47"W. 12 July 2001.

Loc. 8 - 87116-87136, Ashland Co. Southern end of Ironwood Isl. on west side of sand spit. Shoreline woods with yew, *Thuja*, balsam fir and old birch, elev. 620 ft. Sec. 9, T52N, R2W. 46°59'28"N, 90°37'08"W. 12 July 2001.

Loc. 9 - 87428-87449, Bayfield Co. Eagle Isl. At north end above point with yew, mountain ash, mountain maple, and birch, elev. 620 ft. 46°56'47"N, 91°02'07"W. 27 Aug. 2001.

Loc. 10 - 87450-87461, Bayfield Co. Eagle Isl. On rock cliffs on east side, elev. 610 ft.
46°56'42"N, 91°02'03"W. 27 Aug. 2001.

Loc. 11 - 87462-87469, Ashland Co. Gull Isl. Low island with rock cobble and low
elderberry, mountain ash, and *Ilex verticillata*, elev. 605 ft. Sec. 12, T51N, R1W.
46°54'24"N, 90°26'33"W. 28 Aug. 2001.

Appendix II

Lists of species found at each of the localities visited in 2001.

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before & after every change in
columns

Species at NE point of BEAR ISL.

Ashland Co. Bear Isl. Rocky point on NE shore and in woods with yew, balsam fir, and birch, elev. 615 ft. Sec. 28, T53N, R3W. 47°01'34"N, 90°44'47"W. 11 July 2001. Coll. # 86967-87021.

ins. >

- Bacidina inundata*
- Baeomyces rufus*
- Bryoria furcellata*
- Buellia stillingiana*
- Candelariella aurella*
- Cetraria pinastri*
- Cladonia cenotea*
- Cladonia coniocraea*
- Cladonia merochlorophaea*
- Cladonia pleurota*
- Cladonia scabriuscula*
- Cladonia squamosa*
- Cresponea chloroconia*
- Endocarpon pusillum*
- Evernia mesomorpha*
- Flavoparmelia caperata*
- Flavopunctelia flaventior*
- Hypogymnia physodes*
- Lecanora circumborealis*
- Lecanora hybocarpa*
- Lecanora muralis*
- Lecanora symmicta*
- Lecanora thysanophora*
- Lecidella stigmatea*

- Loxospora pustulata*
- Melanelia subaurifera*
- Mycobilimbia hypnorum*
- Mycobilimbia tetramera*
- Opegrapha varia*
- Parmelia squarrosa*
- Pertusaria amara*
- Phaeophyscia sciastra*
- Phlyctis argena*
- Physcia caesia*
- Physconia detera*
- Porpidia crustulata*
- Porpidia diversa*
- Porpidia macrocarpa*
- Protoblastenia rupestris*
- Psilolechia lucida*
- Punctelia rudecta*
- Punctelia subrudecta*
- Ramalina intermedia*
- Staurothele areolata*
- Trapeliopsis viridescens*
- Usnea subfloridana*
- Xanthoria elegans*

Count of Species: 47

ins. ^

Species at EAGLE ISL. at N end

Bayfield Co. Eagle Isl. At north end above point with yew, mountain ash, mountain maple, and birch, elev. 620 ft. 46°56'47"N, 91°02'07"W. 27 Aug. 2001. Coll. # 87428-87449.

Bacidina inundata
Buellia stillingiana
Candelaria concolor
Flavoparmelia caperata
Graphis scripta
Lecanora symmicta
Parmelia squarrosa
Parmelia sulcata
Phaeophyscia rubropulchra
Count of Species: 17

Physcia adscendens
Physcia caesia
Physcia millegrana
Physcia stellaris
Physconia detersa
Ramalina intermedia
Usnea subfloridana
Xanthoria polycarpa

Species at EAGLE ISL. rock cliffs on NE end

Bayfield Co. Eagle Isl. On rock cliffs on east side, elev. 610 ft. 46°56'42"N, 91°02'03"W. 27 Aug. 2001. Coll. # 87450-87461.

Bacidia sabuletorum
Bacidina inundata
Caloplaca holocarpa
Lepraria lobificans
Count of Species: 6

Physcia dubia
Ramalina intermedia

Species at GULL ISL.

Ashland Co. Gull Isl. Low island with rock cobble and low elderberry, mountain ash, and *Ilex verticillata*, elev. 605 ft. Sec. 12, T51N, R1W. 46°54'24"N, 90°26'33"W. 28 Aug. 2001. Coll. # 87462-87469.

Arthonia punctiformis
Arthonia radiata
Candelaria concolor
Phaeophyscia ciliata
Count of Species: 7

Phaeophyscia orbicularis
Physcia stellaris
Xanthoria fallax

Species at S shore of IRONWOOD ISL. E of sand spit

Ashland Co. South shore of Ironwood Isl. E of sand spit. In dense woods near shore with yew, balsam fir, yellow birch, and *Thuja*, elev. 620 ft. Sec. 9, T52N, R2W. 46°59'27"N, 90°36'47"W. 12 July 2001. Coll. # 87065-87115.

Bacidia polychroa
Buellia stillingiana
Candelaria concolor
Candelariella efflorescens

Candelariella vitellina
Cetrelia olivetorum
Cladina rangiferina
Cladonia cervicornis

Cladonia coniocraea
Cladonia cornuta
Cladonia cristatella
Cladonia gracilis
Cladonia phyllophora
Cladonia pleurota
Cladonia scabriuscula
Dimerella pineti
Evernia mesomorpha
Flavoparmelia caperata
Flavopunctelia flaventior
Graphis scripta
Heterodermia speciosa
Hypogymnia physodes
Lecanora caesiorubella
Lecanora symmicta

Lecanora thysanophora
Lobaria pulmonaria
Melanelia subaurifera
Parmelia squarrosa
Parmelia sulcata
Pertusaria amara
Pertusaria ophthalmiza
Phaeocalicium compressulum
Phaeophyscia rubropulchra
Phlyctis argena
Physcia adscendens
Physconia detersa
Placynthiella dasaea
Punctelia rudecta
Punctelia subrudecta
Ramalina dilacerata
Ramalina intermedia

Count of species: 41

Species at S end of IRONWOOD ISL. W of sand spit

Ashland Co. Southern end of Ironwood Isl. on west side of sand spit. Shoreline woods with yew, *Thuja*, balsam fir and old birch, elev. 620 ft. Sec. 9, T52N, R2W. 46°59'28"N, 90°37'08"W. 12 July 2001. Coll. # 87116-87136.

Buellia stillingiana
Cetraria pinastris
Cetrelia olivetorum
Cresponia chloroconia
Flavoparmelia caperata
Heterodermia speciosa
Hypogymnia physodes
Lecanora hybocarpa
Melanelia exasperatula
Melanelia subaurifera

Opegrapha varia
Parmelia sulcata
Pertusaria amara
Phacopsis oxyspora
Physconia detersa
Punctelia rudecta
Punctelia subrudecta
Ramalina intermedia

Count of Species: 18

Species at SW tip of MICHIGAN ISL.

Ashland Co. SW tip of Michigan Isl. Above sand spit with balsam fir and scattered red and white pine, elev. 615 ft. Sec. 20, T51N, R1W. 46°52'32"N, 90°30'55"W. 9 July 2001. Coll. # 86887-86928.

Buellia stillingiana
Calicium parvum
Cetraria americana
Cetraria pinastri
Cladina mitis
Cladina rangiferina
Cladina stellaris
Cladonia bacillaris
Cladonia cenotea
Cladonia cervicornis
Cladonia coniocraea
Cladonia crispata
Cladonia cristatella
Cladonia gracilis
Cladonia merochlorophaea
Cyphelium lucidum
Evernia mesomorpha
Flavoparmelia caperata
Flavopunctelia flaventior
Count of species: 38

Hypocenomyce scalaris
Hypogymnia physodes
Imshaugia aleurites
Lecanora caesiorubella
Lecanora pulicaris
Lecanora symmicta
Melanelia septentrionalis
Melanelia subaurifera
Micarea melaena
Parmelia sulcata
Phaeophyscia rubropulchra
Physcia millegrana
Punctelia rudecta
Punctelia subrudecta
Ramalina dilacerata
Trapeliopsis granulosa
Usnea filipendula
Usnea subfloridana
Xylographa opegraphella

Species at N tip of NORTH TWIN ISL.

Ashland Co. North tip of North Twin Isl. On shore rocks and in woods behind with yew, balsam fir, yellow birch, hemlock, and mountain ash, elev. 615 ft. Sec. 14, T53N, R2W. 47°04'31"N, 90°35'13"W. 11 July 2001. Coll. # 87022-87064.

Arthonia caesia
Arthothelium ruanum
Aspicilia caesiocinerea
Buellia disciformis
Caloplaca holocarpa
Cladonia chlorophaea
Cladonia pyxidata
Flavoparmelia caperata
Graphis scripta
Hypogymnia physodes
Lecanora dispersa
Lecanora muralis

Lecanora symmicta
Lecidella euphorea
Lecidella stigmatea
Lobaria pulmonaria
Melanelia subaurifera
Parmelia squarrosa
Parmelia sulcata
Peltigera elisabethae
Peltigera rufescens
Phaeophyscia rubropulchra
Phaeophyscia sciastra
Physcia adscendens

Physcia aipolia
Physcia caesia
Physcia millegrana
Physconia detersa
Placynthium nigrum
Porpidia diversa
Porpidia macrocarpa
Protoblastenia rupestris
Count of species: 40

Ramalina americana
Ramalina dilacerata
Ramalina intermedia
Staurothele areolata
Verrucaria margacea
Xanthoria fulva
Xanthoria polycarpa
Xanthoria sorediata

Species at locality: valley N end of OAK ISL.

Ashland Co. North end of Oak Isl. Along stream and valley in from campground with yellow and white birch, maples, hemlock, and *Thuja*, elev. 650 ft. Sec. 22, T52N, R3W. 46°57'25"N, 90°43'42"W. 6 July 2001. Coll. # 86708-86748.

Bacidia schweinitzii
Buellia stillingiana
Cetrelia chicitae
Cetrelia olivetorum
Chaenotheca brunneola
Chrysothrix candelaris
Cladonia bacillaris
Cladonia coniocraea
Cladonia squamosa
Dimerella lutea
Dimerella pineti
Evernia mesomorpha
Flavoparmelia caperata
Graphis scripta
Hypogymnia physodes
Julella sericea
Lecanora circumborealis
Lecanora symmicta
Lecanora thysanophora
Count of Species: 36

Leptogium cyanescens
Lobaria pulmonaria
Melanelia subargentifera
Myelochroa aurulenta
Parmelia sulcata
Peltigera canina
Pertusaria consocians
Pertusaria velata
Phaeocalicium polyporaeum
Phaeophyscia rubropulchra
Physconia detersa
Punctelia rudecta
Pyxine sorediata
Ramalina intermedia
Trapeliopsis viridescens
Usnea hirta
Usnea subfloridana

Species at ridge N end of OAK ISL.

Ashland Co. North end of Oak Isl. On NE facing ridge with sugar maple, yellow birch, and some hemlock, elev. 800 ft. Sec. 22, T52N, R3W. 46°57'25"N, 90°43'56"W. 6 July 2001. Coll. # 86749-86775.

Candelaria concolor
Cladonia pyxidata
Collema subflaccidum
Conotrema urceolatum
Flavoparmelia caperata
Graphis scripta
Lecanora argentata
Lecanora carpinea
Lecanora thysanophora
Melanelia subargentifera

Myelochroa aurulenta
Ochrolechia trochophora
Parmelia squarrosa
Parmotrema crinitum
Pertusaria macounii
Phaeophyscia rubropulchra
Physcia aipolia
Physconia leucoleiptes
Rinodina ascociscana
Strangospora microhaema
Xanthoria fulva

Count of Species: 21

Species at S tip of YORK ISL.

Bayfield Co. Southern tip of York Isl. Back from sand spit in balsam fir, yew, birch and some *Thuja*, elev. 620 ft. Sec. 15, T52N, R4W. 46°58'07"N, 90°51'37"W. 10 July 2001. Coll. # 86929-86966.

Bryoria trichodes
Buellia stillingiana
Candelaria concolor
Cladonia grayi
Evernia mesomorpha
Flavoparmelia caperata
Flavopunctelia flaventior
Graphis scripta
Heterodermia speciosa
Hypogymnia physodes
Lecanora caesiorubella
Lecanora symmicta
Melanelia exasperatula
Melanelia septentrionalis
Melanelia subaurifera
Parmelia saxatilis

Parmelia squarrosa
Parmelia sulcata
Phaeophyscia rubropulchra
Phlyctis argena
Physcia millegrana
Physcia stellaris
Physconia detersa
Punctelia rudecta
Punctelia subrudecta
Ramalina americana
Ramalina dilacerata
Usnea hirta
Xanthoria polycarpa

Count of Species: 29

Appendix III

Total list of species for the park.

This total species list includes all previous collections made by C. Wetmore including the ones found in 2001.

Acarospora americana Magn.
Acarospora fuscata (Schrader) Arn.
Amandinea punctata (Hoffm.) Coppins & Scheid.
Anaptychia palmulata (Michaux) Vainio
Anisomeridium bifforme (Borrer) Harris RARE
Arthonia byssacea (Weigel) Almq.
Arthonia caesia (Flotow) Körber
Arthonia patellulata Nyl.
Arthonia punctiformis Ach.
Arthonia radiata (Pers.) Ach.
Arthonia spadicea Leighton RARE
Arthothelium ruanum (Massal.) Körber RARE
Arthrosporium populorum Massal. RARE
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.
Aspicilia cinerea (L.) Körber RARE
Bacidia bagliettoana (Massal. & De Not.) Jatta RARE
Bacidia laurocerasi (del. ex Duby) Ozenda & Clauzade RARE
Bacidia polychroa (Th. Fr.) Körber RARE
Bacidia rubella (Hoffm.) Massal. RARE
Bacidia sabuletorum (Schreber) Lettau
Bacidia schweinitzii (Fr. ex Michener) A. Schneider
Bacidia suffusa (Fr.) A. Schneider
Bacidina inundata (Fr.) Vezda
Baeomyces rufus (Hudson) Rebent. RARE
Biatora epixanthoides (Nyl.) Diederich
Biatora helvola (Körber) Hellbom
Biatora vernalis (L.) Fr. RARE
Bryoria capillaris (Ach.) Brodo & Hawksw.
Bryoria furcellata (Fr.) Brodo & Hawksw.
Bryoria nadvornikiana (Gyelnik) Brodo & Hawksw.
Bryoria trichodes (Michaux) Brodo & Hawksw.
Buellia arnoldii Servít & Nádv.
Buellia disciformis (Fr.) Mudd
Buellia schaeereri de Not.
Buellia stillingiana J. Steiner
Calicium abietinum Pers.
Calicium glaucellum Ach.
Calicium parvum Tibell
Calicium salicinum Pers.

Calicium trabinellum (Ach.) Ach
Caloplaca arenaria (Pers.) Müll. Arg.
Caloplaca cerina (Ehrh. ex Hedwig) Th. Fr.
Caloplaca flavovirescens (Wulfen) Dalla Torre & Sarnth. RARE
Caloplaca holocarpa (Hoffm. ex Ach.) Wade
Candelaria concolor (Dickson) Stein
Candelaria fibrosa (Fr.) Müll. Arg.
Candelariella aurella (Hoffm.) Zahlbr.
Candelariella efflorescens Harris & Buck
Candelariella vitellina (Hoffm.) Müll. Arg.
Cetraria americana (Spreng.) ined.
Cetraria fendleri (Nyl.) Tuck. RARE
Cetraria orbata (Nyl.) Fink
Cetraria pinastri (Scop.) Gray
Cetraria sepincola (Ehrh.) Ach.
Cetrelia chicitae (Culb.) Culb. & C. Culb.
Cetrelia olivetorum (Nyl.) Culb. & C. Culb.
Chaenotheca brunneola (Ach.) Müll. Arg.
Chaenotheca chrysocephala (Turner ex Ach.) Th. Fr.
Chaenotheca ferruginea (Turner & Borrer) Mig.
Chaenotheca furfuracea (L.) Tibell RARE
Chaenotheca laevigata Nád. RARE
Chaenotheca stemonea (Ach.) Müll. Arg. RARE
Chaenotheca trichialis (Ach.) Th. Fr.
Chaenotheca xyloxena Nád.
Chaenothecopsis debilis (Turner & Borrer ex Sm.) Tibell RARE
Chaenothecopsis pusilla (Ach.) A. Schmidt RARE
Chaenothecopsis rubescens Vainio RARE
Chaenothecopsis savonica (Räs.) Tibell
Chrysothrix candelaris (L.) Laund.
Cladina arbuscula (Wallr.) Hale & Culb. RARE
Cladina mitis (Sandst.) Hustich
Cladina rangiferina (L.) Nyl.
Cladina stellaris (Opiz) Brodo
Cladina stygia (Fr.) Ahti
Cladonia amaurocraea (Flörke) Schaerer
Cladonia bacillaris Nyl.
Cladonia botrytes (K. Hagen) Willd.
Cladonia caespiticia (Pers.) Flörke
Cladonia cenotea (Ach.) Schaerer
Cladonia cervicornis (Ach.) Flotow
Cladonia chlorophaea (Flörke ex Sommerf.) Sprengel
Cladonia coniocraea (Flörke) Sprengel
Cladonia cornuta (L.) Hoffm.
Cladonia crispata (Ach.) Flotow
Cladonia cristatella Tuck.
Cladonia cryptochlorophaea Asah.

Cladonia decorticata (Flörke) Sprengel
Cladonia deformis (L.) Hoffm.
Cladonia digitata (L.) Hoffm. RARE
Cladonia farinacea (Vainio) Evans RARE
Cladonia fimbriata (L.) Fr. RARE
Cladonia furcata (Hudson) Schrader RARE
Cladonia gracilis (L.) Willd.
Cladonia grayi G. Merr. ex Sandst.
Cladonia humilis (With.) Laund. RARE
Cladonia incrassata Flörke RARE
Cladonia macilenta Hoffm. RARE
Cladonia merochlorophaea Asah.
Cladonia multiformis G. Merr.
Cladonia phyllophora Hoffm.
Cladonia pleurota (Flörke) Schaerer
Cladonia pyxidata (L.) Hoffm.
Cladonia ramulosa (With.) Laund.
Cladonia rei Schaerer
Cladonia scabriuscula (Delise) Nyl.
Cladonia squamosa Hoffm.
Cladonia subulata (L.) F. Wigg.
Cladonia sulphurina (Michaux) Fr. RARE
Cladonia turgida Hoffm. RARE
Cladonia uncialis (L.) F. Wigg.
Collema subflaccidum Degel.
Conotrema urceolatum (Ach.) Tuck.
Cresponea chloroconia (Tuck.) Egea & Torrente
Cyphelium lucidum (Th. Fr.) Th. Fr.
Cyphelium tigillare (Ach.) Ach.
Dermatocarpon miniatum (L.) W. Mann RARE
Dimerella lutea (Dickson) Trevisan
Dimerella pineti (Ach.) Vezda
Endocarpon pusillum Hedwig
Evernia mesomorpha Nyl.
Flavoparmelia caperata (L.) Hale
Flavopunctelia flaventior (Stirton) Hale
Flavopunctelia soledica (Nyl.) Hale RARE
Graphis scripta (L.) Ach.
Heteroderma hypoleuca (Muhl.) Trevisan
Heteroderma speciosa (Wulfen) Trevisan
Hypocenomyce anthracophila (Nyl.) James & G. Schneid.
Hypocenomyce friesii (Ach.) James & Gotth. Schneider
Hypocenomyce scalaris (Ach.) Choisy
Hypogymnia physodes (L.) Nyl.
Hypogymnia tubulosa (Schaerer) Hav.
Icmadophila ericetorum (L.) Zahlbr.
Imshaugia aleurites (Ach.) S. Meyer

Imshaugia placorodia (Ach.) S. Meyer RARE
Julella sericea (Massal.) Coppins
Lecania naegelii (Hepp) Diederich & v. d. Boom
Lecanora albella (Pers.) Ach.
Lecanora allophana Nyl.
Lecanora argentata (Ach.) Malme RARE
Lecanora caesiorubella Ach. subsp. *caesiorubella*
Lecanora carpinea (L.) Vainio
Lecanora cateilea (Ach.) Massal. RARE
Lecanora cenisia Ach. RARE
Lecanora circumborealis Brodo & Vitik.
Lecanora dispersa (Pers.) Sommerf.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora impudens Degel.
Lecanora muralis (Schreber) Rabenh.
Lecanora piniperda Körber RARE
Lecanora polytropa (Hoffm.) Rabenh. RARE
Lecanora pulicaris (Pers.) Ach.
Lecanora rugosella Zahlbr.
Lecanora saligna (Schrader) Zahlbr. RARE
Lecanora sambuci (Pers.) Nyl. RARE
Lecanora strobilina (Sprengel) Kieffer
Lecanora symmicta (Ach.) Ach.
Lecanora thysanophora Harris in Harris & Tonsb.
Lecanora wisconsinensis Magn.
Lecidea nylanderii (Anzi) Th. Fr.
Lecidea plebeja Nyl.
Lecidea symmictella Nyl. RARE
Lecidella asema (Nyl.) Knoph & Hertel RARE
Lecidella euphorea (Flörke) Hertel RARE
Lecidella stigmatea (Ach.) Hertel & Leuckert
Lepraria lobificans Nyl.
Leptogium cyanescens (Rabenh.) Körber
Leptogium lichenoides (L.) Zahlbr. RARE
Leptogium saturninum (Dickson) Nyl. RARE
Leptorhaphis epidermidis (Ach.) Th. Fr.
Lobaria pulmonaria (L.) Hoffm.
Lobaria quercizans Michaux
Lopadium pezizoideum (Ach.) Körber RARE
Loxospora pustulata (Brodo & Culb.) Harris
Melanelia albertana (Ahti) Essl. RARE
Melanelia exasperata (De Not.) Essl. RARE
Melanelia exasperatula (Nyl.) Essl.
Melanelia olivacea (L.) Essl.
Melanelia septentrionalis (Lynge) Essl.
Melanelia subargentifera (Nyl.) Essl.
Melanelia subaurifera (Nyl.) Essl.

Melanelia subolivacea (Nyl.) Essl. RARE
Micarea melaena (Nyl.) Hedl.
Micarea prasina Fr.
Multiclavula mucida (Fr.) R. Petersen RARE
Mycobilimbia berengeriana (Massal.) Hafellner & Wirth
Mycobilimbia hypnorum (Lib.) Kalb & Hafellner RARE
Mycobilimbia tetramera (De Not.) W. Brunnbauer RARE
Mycoblastus sanguinarius (L.) Norman
Mycocalicium subtile (Pers.) Szat.
Myelochroa aurulenta (Tuck.) Elix & Hale
Myelochroa galbina (Ach.) Elix & Hale
Nephroma helveticum Ach. RARE
Nephroma parile (Ach.) Ach.
Ochrolechia arborea (Kreyer) Almb.
Ochrolechia mexicana Vainio RARE
Ochrolechia trochophora (Vainio) Oshio
Opegrapha prosodea Ach.
Opegrapha varia Pers.
Pachyphiale fagicola (Hepp) Zwackh
Parmelia saxatilis (L.) Ach.
Parmelia squarrosa Hale
Parmelia sulcata Taylor
Parmeliopsis ambigua (Wulfen) Nyl.
Parmeliopsis hyperopta (Ach.) Arn.
Parmotrema crinitum (Ach.) Choisy
Peltigera canina (L.) Willd.
Peltigera didactyla (With.) Laund.
Peltigera elisabethae Gyelnik
Peltigera evansiana Gyelnik
Peltigera horizontalis (Hudson) Baumg. RARE
Peltigera lepidophora (Vainio) Bitter
Peltigera malacea (Ach.) Funck RARE
Peltigera membranacea (Ach.) Nyl.
Peltigera polydactylon (Necker) Hoffm.
Peltigera praetextata (Flörke ex Sommerf.) Zopf
Peltigera rufescens (Weiss) Humb.
Peltigera scabrosa Th. Fr. RARE
Pertusaria alpina Hepp ex Ahles RARE
Pertusaria amara (Ach.) Nyl.
Pertusaria consocians Dibben
Pertusaria macounii (Lamb) Dibben
Pertusaria multipunctoides Dibben RARE
Pertusaria ophthalmiza (Nyl.) Nyl.
Pertusaria rubefacta Erichsen RARE
Pertusaria velata (Turner) Nyl.
Phacopsis oxyspora (Tul.) Triebel & Rambold RARE
Phaeocalicium compressulum (Nyl. ex Szat.) A. Schmidt RARE

Phaeocalicium polyporaeum (Nyl.) Tibell RARE
Phaeophyscia cernohorskyi (Nádv.) Essl. RARE
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia orbicularis (Necker) Moberg
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Essl.
Phaeophyscia sciastra (Ach.) Moberg
Phlyctis argena (Sprengel) Flotow
Physcia adscendens (Fr.) H. Olivier
Physcia aipolia (Ehrh. ex Humb.) Fűrnr.
Physcia caesia (Hoffm.) Fűrnr.
Physcia dubia (Hoffm.) Lettau
Physcia millegrana Degel.
Physcia phaea (Tuck.) Thoms. RARE
Physcia stellaris (L.) Nyl.
Physconia detersa (Nyl.) Poelt
Physconia leucoleiptes (Tuck.) Essl.
Placynthiella dasaea (Stirton) Tønsberg
Placynthiella icmalea (Ach.) Coppins & James
Placynthiella oligotropha (Laund.) Coppins & James
Placynthium nigrum (Hudson) Gray
Platismatia tuckermanii (Oakes) Culb. & C. Culb.
Porpidia crustulata (Ach.) Hertel & Knoph RARE
Porpidia diversa (Lowe) Gowan
Porpidia macrocarpa (DC.) Hertel & A. J. Schwab
Protoblastenia rupestris (Scop.) J. Steiner
Pseudevernia consocians (Vainio) Hale & Culb. RARE
Pseudocyphellaria crocata (L.) Vainio RARE
Psilolechia lucida (Ach.) Choisy RARE
Punctelia hypoleucites (Nyl.) Krog RARE
Punctelia rudecta (Ach.) Krog
Punctelia subrudecta (Nyl.) Krog
Pyrenula pseudobufonia (Rehm) Harris
Pyrrhospora elabens (Fr.) Hafellner RARE
Pyxine sorediata (Ach.) Mont.
Ramalina americana Hale
Ramalina dilacerata (Hoffm.) Hoffm.
Ramalina intermedia (Delise ex Nyl.) Nyl.
Rhizocarpon grande (Flörke ex Flotow) Arnold RARE
Rhizocarpon petraeum (Wulfen) Massal. RARE
Rinodina ascociscana Tuck.
Rinodina dakotensis Magn. RARE
Rinodina milliaria Tuck.
Rinodina subminuta Magn. RARE
Rinodina turfacea (Wahlenb.) Körber RARE
Scoliciosporum chlorococcum (Stenh.) Vezda
Scoliciosporum umbrinum (Ach.) Arnold

Sphinctrina anglica (Nyl.) Triebel et al. RARE
Sphinctrina turbinata (Pers. : Fr.) De Not.
Staurothele areolata (Ach.) Lettau
Staurothele drummondii (Tuck.) Tuck. RARE
Stenocybe major (Nyl.) Körber
Stenocybe pullatula (Ach.) Stein RARE
Stereocaulon paschale (L.) Hoffm. RARE
Stereocaulon saxatile Magn.
Strangospora microhaema (Norman) Anders. RARE
Strigula stigmatella (Ach.) Harris
Thelocarpon laureri (Flotow) Nyl. RARE
Trapelia involuta (Taylor) Hertel RARE
Trapelia placodioides Coppins & James
Trapeliopsis flexuosa (Fr.) Coppins & James RARE
Trapeliopsis granulosa (Hoffm.) Lumbsch
Trapeliopsis viridescens (Schrader) Coppins & James
Umbilicaria mammulata (Ach.) Tuck. RARE
Usnea cavernosa Tuck.
Usnea ceratina Ach.
Usnea filipendula Stirton
Usnea hirta (L.) F. Wigg.
Usnea lapponica Vainio
Usnea subfloridana Stirton
Verrucaria glaucovirens Grummann RARE
Verrucaria margacea (Wahlenb.) Wahlenb. RARE
Verrucaria muralis Ach.
Verrucaria nigrescentoidea Fink RARE
Xanthoparmelia cumberlandia (Gyelnik) Hale
Xanthoria elegans (Link) Th. Fr.
Xanthoria fallax (Hepp) Arn.
Xanthoria fulva (Hoffm.) Poelt & Petutschnig
Xanthoria hasseana Räs.
Xanthoria polycarpa (Hoffm.) Rieber
Xanthoria soreciata (Vainio) Poelt RARE
Xanthoria ulophyllodes Räs.
Xylographa opegraphella Nyl. ex Rothr.
 Count of species: 310

Appendix IV

Latitude and Longitude of elemental analysis localities

The readings were taken with a GPS at the sites of the 2000 and 2001 collections for elemental analysis and are rounded to the nearest second.

Stockton Isl.	46°55'36"N, 90°33'10"W	9 Jul. 2001
Outer Isl.	46°59'46"N, 90°27'55"W	9 Jul. 2001
New Raspberry Isl.	45°58'28"N, 90°47'58"W	10 Jul. 2001
Old Raspberry Isl.	46°58'15"N, 90°47'25"W	10 Jul. 2001
Long Isl.	46°43'38"N, 90°47'04"W	10 Aug. 2000

The Old Raspberry Isl. locality was used for all species in the previous studies but only for *Cladina rangiferina* in the 2001 study. The New Raspberry Isl. locality was used in the 2001 study for *Evernia mesomorpha*, *Hypogymnia physodes*, and *Parmelia sulcata*.

APPENDIX V

Elemental analysis data

The following table gives elemental values for all three Apostle Islands elemental analysis studies. See Statistical Analysis section for statistical analysis of the data.

Year	Locality	Species	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Zn
1987	Raspberry	Cladina	248.9	6.2	613.4	0.2	0.4	3.8	261.3	1765.0	311.2	34.6	29.0	0.3	475.6	2.8	650.0	16.5
1987	Raspberry	Cladina	234.7	5.5	642.7	0.2	0.3	3.9	247.4	1800.2	316.3	33.6	27.9	0.3	467.9	1.5	780.0	17.2
1987	Raspberry	Cladina	219.2	5.9	652.9	0.2	0.4	3.9	269.5	1885.3	328.7	34.4	28.8	0.5	509.7	1.9	640.0	16.8
1987	Raspberry	Evernia	593.8	6.5	999.3	0.3	1.0	5.8	899.6	2961.2	418.5	44.9	41.0	1.0	743.7	6.2	1360.0	28.3
1987	Raspberry	Evernia	583.9	7.4	909.6	0.4	0.9	6.4	901.4	2866.9	396.4	42.6	41.6	0.8	755.4	7.8	1220.0	29.1
1987	Raspberry	Evernia	561.3	7.2	1055.4	0.4	0.9	6.3	876.2	2769.1	393.9	54.2	40.9	1.1	716.9	6.7	1350.0	27.4
1987	Raspberry	Hypogymnia	802.0	6.8	20344.0	0.9	1.2	16.2	873.8	3869.2	1060.6	161.4	44.9	1.6	907.1	16.5	990.0	53.9
1987	Raspberry	Hypogymnia	942.6	7.1	19771.0	0.8	1.7	16.4	1025.8	4043.5	1216.3	153.9	55.4	2.0	1000.6	14.9	990.0	51.0
1987	Raspberry	Hypogymnia	921.0	7.4	19151.0	0.8	1.3	17.1	960.7	4038.1	1262.9	183.3	59.1	2.1	1014.9	14.6	1050.0	51.2
1987	Stockton	Cladina	202.0	5.5	451.7	0.2	0.3	2.8	192.8	1366.6	252.5	54.2	17.8	0.3	348.8	2.3	475.0	13.0
1987	Stockton	Cladina	194.4	5.3	419.7	0.2	0.3	3.6	195.1	1418.0	226.9	39.3	22.2	0.5	338.6	3.2	480.0	11.9
1987	Stockton	Cladina	189.3	6.4	490.8	0.2	0.3	3.0	177.8	1347.0	256.3	60.1	19.1	0.3	343.5	2.4	460.0	12.9
1987	Stockton	Evernia	596.3	8.4	478.4	0.2	1.0	6.6	675.3	2323.3	372.8	60.9	36.4	0.8	545.2	10.2	1250.0	39.1
1987	Stockton	Evernia	579.0	8.1	424.0	0.1	0.9	5.9	637.5	2122.0	340.9	55.6	33.9	0.8	492.7	9.2	1180.0	37.8
1987	Stockton	Evernia	594.3	7.5	453.2	0.2	0.9	6.7	706.1	2132.4	336.6	54.4	30.9	0.7	476.1	8.9	1320.0	35.8
1987	Stockton	Hypogymnia	462.8	6.9	9978.9	0.7	1.0	6.2	545.4	2797.1	631.1	423.9	18.4	0.8	592.2	18.2	720.0	85.4
1987	Stockton	Hypogymnia	488.8	6.8	10642.0	0.6	0.9	6.6	560.2	2988.2	644.0	426.2	17.3	1.5	608.4	16.2	640.0	91.6
1987	Stockton	Hypogymnia	497.9	6.8	11182.0	0.7	1.0	6.6	579.3	3027.6	632.2	418.3	18.1	1.0	634.8	16.0	765.0	90.6
1987	Outer	Cladina	201.1	5.3	513.4	0.2	0.4	3.5	219.5	1736.9	303.2	33.0	25.8	0.3	419.7	1.2	500.0	13.0
1987	Outer	Cladina	174.6	4.3	418.1	0.2	0.2	3.2	174.2	1979.5	238.0	22.3	17.5	0.3	482.2	1.7	580.0	11.9
1987	Outer	Cladina	182.8	6.1	523.1	0.1	0.3	3.3	178.7	1749.6	293.1	34.9	18.9	0.3	437.3	0.8	520.0	12.9
1987	Outer	Evernia	491.0	6.5	657.9	0.4	1.0	12.1	610.0	2560.4	362.7	32.1	46.9	0.8	603.9	5.2	1090.0	27.7
1987	Outer	Evernia	492.9	5.7	689.1	0.4	1.1	11.8	632.3	2585.9	366.7	32.9	45.4	0.9	639.0	6.5	1250.0	28.1
1987	Outer	Evernia	482.3	6.3	702.4	0.4	1.0	12.0	604.6	2602.7	367.3	33.1	44.3	0.8	628.1	5.0	1150.0	28.6
1987	Outer	Hypogymnia	439.9	6.2	10790.0	1.2	0.8	7.7	533.4	3127.5	636.8	119.4	29.5	0.8	654.8	16.2	1260.0	52.6
1987	Outer	Hypogymnia	477.3	5.9	11488.0	1.5	1.0	8.9	642.7	3283.9	679.7	138.7	30.3	1.0	726.7	14.9	1250.0	57.0
1987	Outer	Hypogymnia	487.3	5.7	12638.0	1.5	0.9	8.6	637.0	3026.9	654.5	137.0	28.9	1.2	653.9	14.8	1520.0	56.7
1995	Raspberry	Cladina	210.5	0.6	632.8	0.2	0.5	1.7	297.7	1177.9	284.9	38.7	16.0	0.6	365.4	1.9	273.0	11.8
1995	Raspberry	Cladina	198.3	0.5	554.6	0.1	0.5	1.5	257.0	996.9	214.1	29.1	15.5	0.6	299.9	1.2	361.0	9.7
1995	Raspberry	Cladina	224.7	0.5	545.8	0.1	0.4	1.4	312.5	1010.5	221.3	26.7	16.5	0.5	295.6	1.8	419.5	9.0
1995	Raspberry	Evernia	521.5	2.5	1923.9	0.4	1.6	4.4	942.5	2657.4	481.0	56.1	45.6	1.4	659.3	3.7	902.0	39.2
1995	Raspberry	Evernia	539.8	2.2	1850.4	0.3	1.4	4.6	942.1	2930.5	509.6	70.9	44.0	1.1	791.2	3.1	1160.0	40.6
1995	Raspberry	Evernia	513.7	2.3	1692.7	0.3	1.5	4.3	884.8	2659.1	481.6	51.6	43.0	1.1	642.8	3.4	1240.0	36.9
1995	Raspberry	Hypogymnia	598.9	2.3	16854.0	1.7	1.6	6.7	987.2	3683.4	1108.3	226.6	37.1	1.9	815.9	9.9	1020.0	91.0
1995	Raspberry	Hypogymnia	597.6	2.5	18335.0	1.6	1.6	7.0	1009.2	4033.6	1167.6	255.0	38.9	1.9	945.6	10.2	1220.0	97.7
1995	Raspberry	Hypogymnia	573.0	2.5	19843.0	1.7	1.5	6.9	950.9	3666.2	1086.6	204.7	36.2	2.0	829.8	10.2	1260.0	90.3

Year	Locality	Species	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Zn
1995	Raspberry	Parmelia	724.7	4.2	3398.1	0.7	1.3	9.6	1012.3	4146.9	733.9	191.7	32.1	1.5	1563.6	11.1	1220.0	99.3
1995	Raspberry	Parmelia	656.8	4.4	4024.4	0.7	1.3	8.3	911.4	4000.0	757.5	222.3	31.2	1.5	1593.5	10.4	1260.0	106.9
1995	Raspberry	Parmelia	638.3	3.9	3431.1	0.6	1.0	8.5	906.9	4064.8	715.2	185.8	28.7	1.1	1480.8	9.2	1365.0	95.5
1995	Long	Cladina	232.6	0.6	658.7	0.2	0.4	2.9	323.5	1835.5	268.6	76.2	22.8	0.5	554.9	1.7	444.0	17.0
1995	Long	Cladina	239.7	0.6	583.4	0.2	0.6	2.9	334.4	1912.4	281.8	59.1	23.4	0.7	559.3	1.7	457.0	16.7
1995	Long	Cladina	243.8	0.6	639.7	0.2	0.4	2.9	341.0	1880.1	272.4	69.1	21.2	0.5	546.8	1.7	465.0	16.9
1995	Long	Cladina	277.7	0.9	626.7	0.2	0.5	3.0	383.8	1752.6	305.5	98.7	23.6	0.4	545.7	2.1	472.0	18.1
1995	Long	Cladina	242.1	0.9	607.2	0.2	0.5	2.7	325.3	1702.6	277.8	90.3	23.2	0.5	528.9	1.9	515.0	18.5
1995	Long	Cladina	262.4	0.9	602.5	0.2	0.5	3.0	356.3	1710.7	286.9	90.6	24.1	0.5	532.7	1.9	552.0	17.6
1995	Long	Evernia	383.5	1.9	646.6	0.5	1.3	7.1	654.8	2503.0	315.5	33.5	50.4	1.2	672.0	4.8	928.0	32.8
1995	Long	Evernia	462.9	1.8	665.6	0.4	1.4	6.2	795.0	2557.1	344.5	37.0	46.0	1.2	735.7	4.9	1130.0	33.4
1995	Long	Evernia	409.0	1.8	650.6	0.5	1.4	6.7	683.5	2522.1	328.7	34.8	51.1	1.3	752.4	5.2	1130.0	31.3
1995	Long	Hypogymnia	684.8	1.7	7932.0	1.1	1.7	9.7	879.9	2915.8	591.5	128.1	38.4	2.1	756.6	16.2	866.0	64.6
1995	Long	Hypogymnia	754.3	1.9	8124.3	1.3	1.5	11.2	1105.8	3426.9	713.5	140.9	38.2	1.9	903.6	16.2	876.3	78.5
1995	Long	Hypogymnia	543.2	1.5	6861.1	1.1	1.1	9.0	733.6	3142.1	597.9	129.8	34.9	1.6	779.1	13.6	966.0	62.4
1995	Long	Parmelia	633.7	2.9	2236.4	0.5	1.1	12.1	1046.4	3840.0	491.2	70.4	43.8	1.7	1291.4	12.2	1280.0	87.8
1995	Long	Parmelia	614.4	2.6	2245.4	0.5	1.1	11.8	1045.3	4015.5	490.3	73.4	40.4	1.5	1289.2	13.8	1280.0	90.0
1995	Long	Parmelia	645.1	2.8	2254.4	0.6	1.1	12.8	984.1	3795.8	474.7	72.3	42.0	1.8	1167.1	14.1	1460.0	96.1
1995	Stockton	Cladina	192.4	0.6	836.5	0.1	0.3	2.1	267.9	1618.4	291.8	69.4	15.1	0.3	535.3	1.7	456.0	17.8
1995	Stockton	Cladina	241.8	0.9	770.3	0.2	0.4	2.3	301.9	1638.4	314.1	88.2	14.1	0.5	560.3	1.7	465.0	19.9
1995	Stockton	Cladina	261.1	0.8	734.7	0.2	0.5	2.3	353.4	1420.1	274.5	74.6	14.2	0.5	463.5	1.7	528.0	17.0
1995	Stockton	Evernia	514.4	2.1	626.1	0.2	1.4	4.8	1024.7	1754.3	293.7	34.4	40.8	1.2	436.8	5.7	1020.0	28.0
1995	Stockton	Evernia	559.7	2.8	535.9	0.2	1.4	4.2	1260.8	1576.2	284.5	33.9	30.8	1.1	376.9	5.4	1070.0	28.0
1995	Stockton	Evernia	529.6	2.5	612.0	0.2	1.3	4.3	1101.0	1676.2	291.1	36.3	32.6	1.1	400.7	5.3	1080.0	29.1
1995	Stockton	Hypogymnia	523.1	2.2	15002.0	0.8	1.3	7.7	1007.6	3065.5	685.6	227.0	27.7	1.5	635.8	14.9	842.0	82.3
1995	Stockton	Hypogymnia	606.8	2.3	16393.0	0.8	1.3	7.8	1142.3	2774.2	701.3	241.8	26.5	1.5	632.1	16.4	965.0	95.8
1995	Stockton	Hypogymnia	694.0	2.2	18982.0	0.8	1.5	7.2	1303.5	2462.1	675.0	205.5	26.0	1.7	550.5	19.5	984.0	99.2
1995	Stockton	Parmelia	752.6	5.2	2428.6	0.3	1.1	12.5	984.7	3112.0	428.4	233.2	25.2	1.4	1041.1	20.9	1200.0	84.7
1995	Stockton	Parmelia	582.2	4.5	2614.7	0.3	0.9	10.5	812.7	3333.8	430.0	193.1	22.7	1.2	1130.0	15.2	1210.0	82.5
1995	Stockton	Parmelia	748.8	4.7	2733.1	0.6	1.1	11.5	1040.7	3559.1	483.3	248.5	27.0	1.4	1223.3	17.1	1220.0	87.8
1995	Outer	Cladina	192.9	0.3	563.0	0.1	0.3	2.1	271.4	1322.1	243.9	110.4	17.6	0.4	393.7	1.7	402.0	13.7
1995	Outer	Cladina	189.7	0.6	563.0	0.1	0.3	2.0	283.0	1172.0	220.1	103.1	22.1	0.4	332.0	1.7	408.0	12.5
1995	Outer	Cladina	193.2	0.5	520.0	0.1	0.3	2.1	262.7	1134.6	216.0	105.8	19.9	0.4	323.0	1.7	413.5	11.8
1995	Outer	Cladina	201.1	0.5	613.7	0.2	0.3	2.0	267.8	1048.6	222.4	115.5	21.8	0.4	368.3	1.7	343.0	13.7
1995	Outer	Cladina	202.5	0.5	597.2	0.2	0.3	2.0	284.0	1100.1	223.8	114.4	22.1	0.4	376.7	1.7	362.0	13.7
1995	Outer	Cladina	218.3	0.5	618.3	0.2	0.6	2.3	297.3	1142.4	241.5	116.9	23.3	0.4	396.3	1.7	366.0	14.7

Year	Locality	Species	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Zn
1995	Outer	Evernia	484.8	2.4	633.7	0.3	1.2	6.5	767.7	2052.3	315.1	47.1	29.8	1.3	464.3	3.3	997.0	29.1
1995	Outer	Evernia	648.9	2.2	756.6	0.3	1.5	6.6	982.9	2522.5	383.6	45.9	33.1	1.5	617.6	4.2	1037.0	35.4
1995	Outer	Evernia	485.5	2.4	720.7	0.3	1.3	5.7	767.9	2200.3	336.4	55.7	30.2	1.1	490.7	3.5	1380.0	30.3
1995	Outer	Hypogymnia	475.8	1.9	24776.0	2.1	1.1	8.7	646.8	2589.4	643.1	261.6	24.4	1.6	603.0	11.7	812.0	80.8
1995	Outer	Hypogymnia	686.6	2.2	17719.0	1.5	1.5	9.6	959.9	2313.2	813.4	312.7	27.1	1.7	533.8	14.8	925.0	71.2
1995	Outer	Hypogymnia	465.4	1.6	28531.0	2.4	0.9	8.2	604.0	2350.8	561.9	241.9	20.3	1.6	461.1	14.7	928.0	63.4
1995	Outer	Parmelia	726.3	4.0	2575.9	0.8	1.0	13.2	819.4	2740.9	453.2	165.5	24.9	1.4	889.4	12.9	1210.0	75.2
1995	Outer	Parmelia	677.5	4.3	2993.1	0.8	1.0	12.7	799.5	3146.3	506.0	244.7	25.2	1.1	1125.6	10.9	1230.0	79.6
1995	Outer	Parmelia	604.9	4.0	2551.2	0.9	0.9	12.7	661.5	2834.1	429.0	177.8	22.6	1.2	897.1	9.9	1260.0	83.6
2001	Long	Cladina	195.7		986.3	0.1	0.4	1.3	222.0	1642.8	294.3	88.5	22.2	0.3	550.2	0.8	391.1	17.3
2001	Long	Cladina	193.4		922.7	0.1	0.4	1.3	226.7	1516.7	280.8	66.6	30.5	0.3	507.3	0.8	414.0	20.7
2001	Long	Evernia	349.4		699.1	0.2	1.0	3.0	643.2	2240.7	300.9	26.2	38.0	0.8	514.5	4.9	946.6	31.6
2001	Long	Evernia	354.0		686.5	0.2	0.9	3.6	710.8	2264.3	328.9	32.3	34.1	0.6	466.4	9.0	1030.9	31.4
2001	Long	Hypogymnia	465.5		12649.8	1.0	1.0	5.9	707.9	3186.0	705.0	184.7	32.6	2.0	843.4	15.1	892.1	62.6
2001	Long	Hypogymnia	552.7		14054.1	1.1	1.1	6.5	840.6	3303.3	688.2	197.8	33.4	2.2	882.9	14.8	947.4	63.5
2001	Long	Parmelia	982.7		2499.3	0.6	1.5	9.8	1208.7	3005.5	451.0	87.8	32.7	1.7	942.3	32.1	1103.7	90.4
2001	Long	Parmelia	858.8		4415.8	0.6	1.4	9.6	1086.9	3056.4	548.8	139.3	31.3	1.8	1122.4	18.5	1124.1	81.6
2001	Raspberry	Cladina	503.0	1.2	899.0	0.2	1.1	2.5	1138.9	1488.7	463.5	41.7	35.4	1.3	482.1	1.9	840.0	21.3
2001	Raspberry	Cladina	464.4	1.2	877.7	0.2	0.9	2.4	859.5	1447.4	404.0	38.5	35.0	1.1	482.6	2.2	930.0	21.1
2001	Raspberry	Cladina	523.2	1.5	954.6	0.2	1.0	2.6	1052.7	1406.4	396.6	41.0	36.8	1.3	481.2	2.5	940.0	21.3
2001	Raspberry	Evernia	539.0	2.4	2156.6	0.4	1.1	3.4	1360.0	2496.7	442.6	83.2	41.3	1.6	811.8	3.3	1550.0	32.4
2001	Raspberry	Evernia	592.5	2.6	2902.0	0.4	1.3	3.6	1660.2	2793.3	493.0	96.3	40.3	1.6	995.9	3.3	1570.0	38.2
2001	Raspberry	Evernia	525.8	2.5	2021.0	0.4	1.2	3.6	1354.3	2663.7	467.9	73.0	41.5	1.5	907.0	3.8	1610.0	33.4
2001	Raspberry	Hypogymnia	629.9	2.0	15739.0	1.2	1.2	5.0	1102.9	3435.2	1202.0	243.1	38.6	1.8	1214.6	5.9	1120.0	53.0
2001	Raspberry	Hypogymnia	620.1	2.1	12605.0	1.0	1.2	4.9	1164.1	3071.4	1037.5	222.1	32.5	1.7	984.3	7.6	1150.0	54.4
2001	Raspberry	Hypogymnia	673.3	2.2	13630.0	1.1	1.3	5.1	1392.1	3425.6	1290.9	289.9	36.7	1.9	1229.7	6.1	1280.0	56.7
2001	Raspberry	Parmelia	523.2	4.1	5368.8	0.8	1.0	4.6	1013.8	2962.9	644.3	151.4	25.2	1.6	1305.7	8.5	1080.0	91.5
2001	Raspberry	Parmelia	464.3	3.5	4239.5	0.7	1.0	4.2	941.9	3105.9	580.2	149.9	25.7	1.4	1339.6	7.5	1145.0	74.6
2001	Raspberry	Parmelia	497.7	3.7	4621.2	0.8	1.0	4.1	913.7	2955.8	639.2	135.6	24.2	1.4	1328.5	8.0	1210.0	83.5
2001	Stockton	Cladina	296.6	0.6	660.0	0.1	0.6	1.7	389.3	1076.8	278.7	43.2	24.0	0.6	258.1	1.2	550.0	14.5
2001	Stockton	Cladina	311.4	0.6	661.1	0.1	0.5	1.7	400.8	1163.4	297.6	41.8	24.1	0.6	283.3	1.2	550.0	14.4
2001	Stockton	Cladina	272.7	0.7	614.4	0.1	0.5	1.5	337.7	1098.9	279.5	35.2	21.2	0.6	263.3	1.2	640.0	11.8
2001	Stockton	Evernia	537.7	2.7	795.1	0.2	1.0	3.2	1144.3	1747.6	310.9	30.6	32.5	1.5	452.3	3.2	1410.0	28.0
2001	Stockton	Evernia	454.6	2.5	807.6	0.2	0.9	3.1	991.5	1719.7	300.0	34.4	29.9	1.3	429.4	2.6	1550.0	27.2
2001	Stockton	Evernia	554.1	2.6	1165.5	0.2	1.0	3.7	1271.0	1828.0	322.1	32.1	33.9	1.5	490.7	3.9	1550.0	31.5
2001	Stockton	Hypogymnia	508.8	3.0	21693.0	0.7	1.0	5.4	825.0	2272.4	787.7	251.5	30.7	1.5	641.5	10.4	1350.0	85.0

Year	Locality	Species	Al	B	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Pb	S	Zn
2001	Stockton	Hypogymnia	478.8	3.1	25420.0	0.7	1.0	6.3	920.2	2310.5	637.0	165.6	31.1	1.5	575.3	11.4	1360.0	87.8
2001	Stockton	Hypogymnia	486.3	3.0	17882.0	0.6	1.0	6.1	950.7	2360.0	682.1	182.4	33.8	1.4	635.0	11.0	1460.0	91.7
2001	Stockton	Parmelia	617.0	4.2	3477.5	0.3	1.0	6.1	1017.3	3074.9	563.4	146.5	27.0	1.6	1097.1	9.0	1240.0	85.4
2001	Stockton	Parmelia	574.5	4.5	3669.9	0.3	1.0	6.3	1009.0	2708.3	533.9	138.3	27.6	1.5	971.7	8.8	1390.0	81.9
2001	Stockton	Parmelia	696.8	4.7	2704.7	0.3	1.1	7.2	1251.1	2297.3	536.0	146.9	26.8	1.6	862.7	11.2	1420.0	92.4
2001	Outer	Cladina	268.3	0.3	609.8	0.1	0.4	1.2	379.7	985.6	198.7	21.8	24.3	0.5	276.0	1.6	410.0	10.1
2001	Outer	Cladina	261.8	0.5	715.8	0.1	0.5	1.3	371.8	1282.2	272.9	23.8	24.4	0.5	393.2	1.2	420.0	12.4
2001	Outer	Cladina	283.1	0.5	667.8	0.1	0.4	1.3	389.8	1208.8	247.6	24.6	24.9	0.3	366.7	1.2	450.0	11.6
2001	Outer	Cladina	283.3	0.5	716.8	0.1	0.5	1.5	377.7	1250.8	275.4	34.4	24.5	0.5	382.6	1.2	420.0	13.5
2001	Outer	Cladina	274.3	0.5	735.3	0.1	0.5	1.5	396.7	1219.5	275.1	31.1	24.3	0.5	375.5	1.2	440.0	13.2
2001	Outer	Cladina	294.4	0.6	697.2	0.1	0.6	1.7	422.8	1305.3	277.9	30.4	26.6	0.5	402.6	2.0	470.0	13.7
2001	Outer	Evernia	476.1	2.1	1217.2	0.3	0.9	3.2	865.3	1931.6	323.6	31.2	32.2	1.1	520.5	2.1	1220.0	26.1
2001	Outer	Evernia	440.7	1.7	1332.7	0.3	0.9	3.3	818.2	1905.4	318.2	32.2	31.1	1.1	517.8	2.0	1380.0	25.9
2001	Outer	Evernia	434.0	1.6	1347.5	0.3	0.8	3.0	784.0	1875.8	323.7	33.5	32.5	1.3	513.3	1.9	1410.0	25.1
2001	Outer	Hypogymnia	605.2	2.4	26267.0	1.6	1.2	6.3	1137.5	2276.8	729.2	171.1	35.2	1.8	612.5	6.9	1110.0	53.9
2001	Outer	Hypogymnia	512.4	2.2	21591.0	1.6	1.0	4.5	990.9	2099.0	819.9	191.7	32.5	1.5	518.7	5.3	1220.0	51.7
2001	Outer	Hypogymnia	744.9	2.4	22093.0	1.6	1.3	5.5	1253.2	2316.3	776.5	159.6	34.8	1.8	534.3	7.3	1380.0	65.0
2001	Outer	Parmelia	806.0	3.8	3277.3	0.6	1.2	9.4	1141.4	2924.3	619.0	132.2	31.5	1.7	1087.0	6.0	1300.0	58.2
2001	Outer	Parmelia	708.1	3.1	2509.0	0.6	1.2	7.5	1076.5	2508.8	499.6	102.2	27.6	1.6	868.8	5.3	1385.0	70.3
2001	Outer	Parmelia	608.6	3.5	2197.7	0.6	0.9	6.3	738.3	2594.7	544.6	147.7	27.8	1.3	905.1	4.7	1400.0	72.9

