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# 1995 LICHEN STUDIES

# IN

# APOSTLE ISLANDS NATIONAL LAKESHORE

Final Report

National Biological Service
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and
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Purchase Order 1443PX614095145

by

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ABSTRACT

This study of the lichens of the Apostle Islands was in two separate parts. Part one was to survey the lichens on Long Island in all vegetational types noting the species sensitive to sulfur dioxide and the substrates on which the lichens grew. Part two was to make collections for elemental analysis on Long Island and at the three localities sampled in 1987 and compare the results of elemental analysis in 1987 with those from 1995.

The lichen flora of Long Island is quite diverse with 88 species found including 14 new species records for the park. There were four species very sensitive to sulfur dioxide. All of the lichens found were in good health and with normal fertility. The new species records are mainly due to the abundance of jack pines and red oaks.

The lichens studied by elemental analysis show normal ranges of all elements in 1995 with no correlation between elements and localities. In comparison of the 1995 data with the 1987 data there are several noticable changes. Some elements have increased and some have decreased. The increase of Cr and Ni should be studied further as possible indicators of anthropogenic pollution.

Recommendations are made for protection of Long Island, for moving the elemental monitoring site on Raspberry Island and for periodic (5 years) restudy of the lichens by elemental analysis.

## PREFACE

This report covers two projects on the lichens of Apostle Islands National Lakeshore. Under a purchase order from the National Biological Service number 83160-5-0083 a restudy of lichen elemental analysis was to be done. Under purchase order number 1443PX614095145 from the National Park Service a lichen study was to be performed on Long Island.

The elemental analysis study was to collect lichens for elemental analysis on Long Island 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 during the past eight years.

At the time of the 1987 study of the lichen flora of the park, Long Island was not included. The present study was to collect lichens in all vegetational types on Long Island, compile a species list, and indicate the sensitivities of the lichens found. 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, National Biological Service, Madison, Wisc. 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 by providing transportation to the collecting sites. The study was made possible by funds from the National Park Service and the National Biological 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. Some are damaged or killed by levels of sulfur dioxide as low as 13 $\mu$g/cubic meter (annual average) or by nitrogen oxides at 3834-7668 $\mu$g/cubic meter or by other strongly oxidizing compounds such as ozone. Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over 300 $\mu$g/cubic meter. The algae of the thallus are the first to be damaged in areas with air pollution and the first indication of damage is discoloring and death of the algae, which quickly leads to the death of the lichen. Lichens are more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry. The nature of the substrate is also important in determining the sensitivity to sulfur dioxide since substrates with high pH seem to buffer the fallout and permit the persistence of more sensitive species than one would expect. After the lichen dies it disappears from the substrate within a few months to a year as it disintegrates and decomposes (Wetmore, 1982).

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

Long Island is located at the southern end of the park and consists of a barrier spit with extensive stands of jack pine (Pinus banksiana), red pine (Pinus resinosa), oaks (mostly red oak, Quercus rubra), sugar maple (Acer saccharum), red maple (Acer rubrum) and shore-line brush. There is one small stand of cottonwood (Populus deltoides) and quaking aspen (Populus tremuloides) near the western end of the island. Between the sand ridges are many low swampy areas.

## PART I. THE LICHENS OF LONG ISLAND

Long Island, acquired by the park in 1986, was not studied in 1987. This study was part of an effort to complete baseline biological inventories on Long Island and to identify important habitats and sensitive species.

### METHODS

Field work was done during August, 1995. Collections on Long Island were made in the three main vegetational types (oak woodland, red pine stand, jack pine stand) and 165 lichen collections were obtained. All localities were near the center of the island. 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 one locality (on the jack pine ridge) additional material of selected species was collected for chemical analysis. 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.

## LICHEN FLORA

The following list of lichens is based on my collections. There are no literature reports of lichens previously collected on Long Island. This list includes 88 species collected for this study. There are a few additional unidentified species. The first list gives the total species list for Long Island with the authorities. In the first column an asterisk (*) indicates a new record for the park. In the next column 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.

Followig the total species list are the species lists by vegetational type with indications of substrates.

## TOTAL SPECIES LIST

*= new species for the park

Arthonia caesia (Flot.) Körb.
Arthonia patellulata Nyl.
Bacidia naegelii (Hepp) Zahlbr.
S Bryoria furcellata (Fr.) Brodo & Hawksw.
Buellia schaereri De Not.
I Buellia stillingiana Steiner
* Calicium glaucellum Ach.
* Calicium parvum Tibell
S-I Caloplaca cerina (Ehrh.) Th. Fr.
I Caloplaca holocarpa (Hoffm.) Wade
S-I Candelaria concolor (Dicks.) B. Stein
* Candelariella aurella (Hoffm.) Zahlbr.
Candelariella efflorescens R. Harris & Buck
* Cetraria fendleri (Nyl.) Tuck.
Cetraria halei W. & C. Culb.
I Cetraria pinastri (Scop.) Gray

I Cetraria sepincola (Ehrh.) Ach.
Chaenotheca brunneola (Ach.) Müll. Arg.
Cladina mitis (Sandst.) Hustich
Cladina rangiferina (L.) Nyl.
Cladina stellaris (Opiz) Brodo
Cladonia bacillaris Nyl.
Cladonia botrytes (Hagen) Willd.
I Cladonia coniocraea (Flörke) Spreng.
Cladonia cornuta (L.) Hoffm.
I Cladonia cristatella Tuck.
Cladonia grayi G. K. Merr. ex Sandst.
Cladonia multiformis G. K. Merr.
Cladonia pyxidata (L.) Hoffm.
Cladonia ramulosa (With.) Laundon
Cyphelium lucidum (Th. Fr.) Th. Fr.
I Evernia mesomorpha Nyl.
Heterodermia speciosa (Wulf.) Trev.
I Hypocenomyce scalaris (Ach. in Lilj.) Choisy
I Hypogymnia physodes (L.) Nyl.
I Imshaugia aleurites (Ach.) S. F. Meyer
* Imshaugia placorodia (Ach.) S. F. Meyer
I Lecanora allophana Nyl.
I Lecanora carpinea (L.) Vain.
T Lecanora dispersa (Pers.) Somm.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora impudens Degel.
I Lecanora pulicaris (Pers.) Ach.
* Lecanora sambuci (Pers.) Nyl.
I Lecanora symmicta (Ach.) Ach.
Lecanora thysanophora Harris ined.
* S Lecidea nylanderi (Anzi) Th. Fr.
* Micarea prasina Fr.
Mycocalicium subtile (Pers.) Szat.
Ochrolechia arborea (Kreyer) Almb.
I Parmelia caperata (L.) Ach.
Parmelia flaventior Stirt.
I Parmelia rudecta Ach.
* I Parmelia saxatilis (L.) Ach.
Parmelia septentrionalis (Lynge) Ahti
S Parmelia squarrosa Hale
I-T Parmelia subargentifera Nyl.
(S) Parmelia subaurifera Nyl.
I Parmelia subrudecta Nyl.
I-T Parmelia sulcata Tayl.
I Parmeliopsis ambigua (Wulf. in Jacq.) Nyl.
I Parmeliopsis hyperopta (Ach.) Arn.
Peltigera canina (L.) Willd.
Peltigera elisabethae Gyeln.
Peltigera praetextata (Flörke ex Somm.) Zopf
* I Pertusaria multipunctoides Dibb.
* Phaeophyscia cernohorskyi (Nadv.) Essl.
Phaeophyscia ciliata (Hoffm.) Moberg
Phaeophyscia orbicularis (Neck.) Moberg
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Essl.

I Physcia adscendens (Th. Fr.) Oliv.
I Physcia aipolia (Ehrh. ex Humb.) Fürnr.
I Physcia millegrana Degel.
* Physconia leucoleiptes (Tuck.) Essl.
Placynthiella oligotropha (Laund.) Coppins & James
Platismatia tuckermanii (Oakes) W. & C. Culb.
* Pyrenula pseudobufonia (Rehm.) R. Harris
S Ramalina americana Hale
I Ramalina dilacerata (Hoffm.) Hoffm.
I Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda
Trapeliopsis granulosa (Hoffm.) Lumbsch.
S-I Usnea hirta (L.) Weber ex Wigg.
Usnea lapponica Vain.
S-I Usnea subfloridana Stirt.
* Verrucaria glaucovirens Grumm.
S-I Xanthoria fallax (Hepp in Arn.) Arn.
I Xanthoria polycarpa (Hoffm.) Rieber

## SPECIES BY VEGETATION TYPE

LONG ISL., RED OAK STAND 14 August 1995
Arthonia caesia on red oak
Buellia schaereri on red pine
Buellia stillingiana on red oak
Calicium glaucellum on log, on pine snag
Candelaria concolor on red oak
Candelariella efflorescens on red oak
Cetraria halei on fallen jack pine
Cetraria pinastri on log
Chaenotheca brunneola on pine snag
Cladina mitis on soil
Cladina rangiferina on soil
Cladonia botrytes on log
Cladonia cornuta on stick on ground
Cladonia cristatella on log
Cladonia ramulosa on log
Cyphelium lucidum on red pine
Evernia mesomorpha on oak
Hypocenomyce scalaris on pine snag
Hypogymnia physodes on oak
Imshaugia aleurites on jack pine
Lecanora carpinea on red oak
Lecanora symmicta on red oak
Lecanora thysanophora on red oak
Lecidea nylanderi on jack pine
Micarea prasina on log
Mycocalicium subtile on pine snag
Ochrolechia arborea on red oak
Parmelia caperata on oak
Parmelia flaventior on jack pine
Parmelia septentrionalis on huckelberry
Parmelia squarrosa on red oak
Parmelia subaurifera on red maple
Parmelia subrudecta on red oak
Parmelia sulcata on oak

Peltigera praetextata on log
Pertusaria multipunctoides on red oak
Physcia adscendens on red maple
Physcia aipolia on red maple
Physcia millegrana on red maple
Pyrenula pseudobufonia on red oak
Ramalina americana on oak
Ramalina dilacerata on red oak
Scoliciosporum chlorococcum on jack pine
Trapeliopsis granulosa on log
Usnea hirta on jack pine

LONG ISL., RED PINE STAND 14 August 1995
Arthonia caesia on red oak
Bryoria furcellata on red pine
Buellia schaereri on red pine
Calicium parvum on red pine
Cetraria pinastri on huckelberry
Cetraria sepincola on juniper
Cladina rangiferina on soil
Cladina stellaris on soil
Cladonia coniocraea on stump
Cladonia grayi on soil
Cladonia multiformis on soil
Cladonia ramulosa on rotten log
Cyphelium lucidum on red pine
Evernia mesomorpha on jack pine
Hypocenomyce scalaris on red pine
Hypogymnia physodes on red pine
Imshaugia aleurites on jack pine snag
Lecanora symmicta on red oak
Micarea prasina on stump
Mycocalicium subtile on pine snag
Parmelia caperata on red pine
Parmelia flaventior on red pine
Parmelia rudecta on red pine
Parmelia subaurifera on juniper, on red pine
Parmelia sulcata on pine log
Parmeliopsis ambigua on juniper
Parmeliopsis hyperopta on juniper
Usnea hirta on red pine

LONG ISL., JACK PINE RIDGE 15 August 1995
Arthonia patellulata on quaking aspen
Bacidia naegelii on quaking aspen
Bryoria furcellata on jack pine
Buellia schaereri on jack pine
Calicium glaucellum on pine snag
Caloplaca cerina on quaking aspen
Caloplaca holocarpa on cottonwood, on quaking aspen
Candelaria concolor on cottonwood
Candelariella aurella on bricks of building, on cement
Cetraria fendleri on jack pine
Cetraria halei on jack pine
Cetraria pinastri on jack pine

Cetraria sepincola on jack pine
Cladina mitis on soil
Cladina rangiferina on soil
Cladina stellaris on soil
Cladonia bacillaris on boards, on jack pine snag
Cladonia coniocraea on base of jack pine
Cladonia cristatella on soil
Cladonia grayi on log
Cladonia pyxidata on soil
Evernia mesomorpha on jack pine
Heterodermia speciosa on cottonwood
Hypocenomyce scalaris on jack pine snag, on pine stump
Hypogymnia physodes on jack pine
Imshaugia aleurites on pine stump
Imshaugia placorodia on jack pine
Lecanora allophana on cottonwood
Lecanora dispersa on bricks of building
Lecanora hybocarpa on jack pine
Lecanora impudens on cottonwood
Lecanora pulicaris on jack pine
Lecanora sambuci on quaking aspen
Lecanora symmicta on jack pine
Lecidea nylanderi on jack pine
Mycocalicium subtile on pine snag
Ochrolechia arborea on jack pine
Parmelia caperata on jack pine
Parmelia flaventior on jack pine
Parmelia rudecta on jack pine
Parmelia saxatilis on jack pine
Parmelia subargentifera on cottonwood
Parmelia subaurifera on jack pine
Parmelia subrudecta on jack pine
Parmelia sulcata on jack pine
Parmeliopsis ambigua on jack pine
Parmeliopsis hyperopta on jack pine
Peltigera canina on building
Peltigera elisabethae on building
Phaeophyscia cernohorskyi on cottonwood
Phaeophyscia ciliata on cottonwood
Phaeophyscia orbicularis on cement
Phaeophyscia pusilloides on rock
Phaeophyscia rubropulchra on quaking aspen
Physcia adscendens on cement of building
Physcia aipolia on cottonwood
Physcia millegrana on fallen cottonwood branch
Physconia leucoleiptes on cottonwood
Placynthiella oligotropha on soil
Platismatia tuckermanii on jack pine
Scoliciosporum chlorococcum on jack pine
Usnea hirta on jack pine
Usnea lapponica on jack pine
Usnea subfloridana on jack pine
Verrucaria glaucovirens on cement
Xanthoria fallax on cottonwood
Xanthoria polycarpa on fallen cottonwood branch

## DISCUSSION OF FLORA

This list of species for Long Island has 88 species including 14 new records for the park. Long Island is one of the richest lichen areas in the park both in numbers of species and abundance of lichens. This is mainly because jack pines were quite rare on the other islands. Open oak stands were also not common on the other islands and these two vegetation types provided excellent habitats for lichens. Another factor is the open sand areas around the pines where extensive mats of fruticose lichens grow. The brush and low bushes rarely had lichen species not also found on the trees.

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 Long Island. Lichens are not known to be sensitive to acid precipitation, but Sigal & Johnston (1986) reported that some species of Umbilicaria show damage from experimentally applied acid precitation. No species of this genus were found in the park so no conclusions can be drawn about this environmental contaminant.

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. One additional species in the most sensitive class was found on Long Island - Lecidea nylanderi. Three other species found on the other islands were also found on Long Island. These observations indicate that there is no air quality degradation on Long Island due to sulfur dioxide that causes observable damage to the lichen flora.

## 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.

Four species of lichens were collected for elemental analysis at the three localities sampled in the 1987 study and also on Long Island.

## METHODS

Lichen samples of four 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, Parmelia sulcata and Evernia mesomorpha on conifer trees. These species were selected because they are the only ones present in abundance and relatively easy to clean. Three of these were included in the original study but Parmelia sulcata was added in the 1995 study.

The three localities in the 1987 study were the southern tip of Outer Island, Raspberry Island near the cove and Stockton Island near the north end of the peninsula. On Long Island the collection came from the jack pines east of the old lighthouse. 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. 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.

Table 1. Analysis of Apostle Isl. Lichens - 1995
Values in ppm of thallus dry weight

| Species | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C. rangiferina | 323 | 1135 | 520 | 216 | 193 | 263 | 19.9 | 105.8 | 11.8 | 2.1 | 0.5 | <1.7 | <0.4 | 0.3 | 0.1 | 414 | Outer Isl. |
| C. rangiferina | 332 | 1172 | 563 | 220 | 190 | 283 | 22.1 | 103.1 | 12.5 | 2.0 | 0.6 | <1.7 | <0.4 | 0.3 | 0.1 | 408 | Outer Isl. |
| C. rangiferina | 394 | 1322 | 563 | 244 | 193 | 271 | 17.6 | 110.4 | 13.7 | 2.1 | <0.5 | <1.7 | <0.4 | 0.3 | 0.1 | 402 | Outer Isl. |
| C. rangiferina | 377 | 1100 | 597 | 224 | 203 | 284 | 22.1 | 114.4 | 13.7 | 2.0 | 0.5 | <1.7 | <0.4 | 0.3 | 0.2 | 362 | Outer Isl.@ |
| C. rangiferina | 396 | 1142 | 618 | 241 | 218 | 297 | 23.3 | 116.9 | 14.7 | 2.3 | 0.5 | <1.7 | <0.4 | 0.6 | 0.2 | 366 | Outer Isl.@ |
| C. rangiferina | 368 | 1049 | 614 | 222 | 201 | 268 | 21.8 | 115.5 | 13.7 | 2.0 | 0.5 | <1.7 | <0.4 | 0.3 | 0.2 | 343 | Outer Isl.@ |
| C. rangiferina | 535 | 1618 | 836 | 292 | 192 | 268 | 15.1 | 69.4 | 17.8 | 2.1 | 0.6 | <1.7 | <0.4 | 0.3 | 0.1 | 456 | Stockton Isl. |
| C. rangiferina | 464 | 1420 | 735 | 274 | 261 | 353 | 14.2 | 74.6 | 17.0 | 2.3 | 0.8 | <1.7 | 0.5 | 0.5 | 0.2 | 528 | Stockton Isl. |
| C. rangiferina | 560 | 1638 | 770 | 314 | 242 | 302 | 14.1 | 88.2 | 19.9 | 2.3 | 0.9 | <1.7 | 0.5 | 0.4 | 0.2 | 465 | Stockton Isl. |
| C. rangiferina | 365 | 1178 | 633 | 285 | 210 | 298 | 16.0 | 38.7 | 11.8 | 1.7 | 0.6 | 1.9 | 0.6 | 0.5 | 0.2 | 273 | Raspberry Isl. |
| C. rangiferina | 296 | 1011 | 546 | 221 | 225 | 312 | 16.5 | 26.7 | 9.0 | 1.4 | 0.5 | 1.8 | 0.5 | 0.4 | 0.1 | 420 | Raspberry Isl. |
| C. rangiferina | 300 | 997 | 555 | 214 | 198 | 257 | 15.5 | 29.1 | 9.7 | 1.5 | 0.5 | <1.7 | 0.6 | 0.5 | 0.1 | 361 | Raspberry Isl. |
| C. rangiferina | 559 | 1912 | 583 | 282 | 240 | 334 | 23.4 | 59.1 | 16.7 | 2.9 | 0.6 | <1.7 | 0.7 | 0.6 | 0.2 | 457 | Long Isl. |
| C. rangiferina | 547 | 1880 | 640 | 272 | 244 | 341 | 21.2 | 69.1 | 16.9 | 2.9 | 0.6 | <1.7 | 0.5 | 0.4 | 0.2 | 465 | Long Isl. |
| C. rangiferina | 555 | 1836 | 659 | 269 | 233 | 323 | 22.8 | 76.2 | 17.0 | 2.9 | 0.6 | <1.7 | 0.5 | 0.4 | 0.2 | 444 | Long Isl. |
| C. rangiferina | 546 | 1753 | 627 | 306 | 278 | 384 | 23.6 | 98.7 | 18.1 | 3.0 | 0.9 | 2.1 | 0.4 | 0.5 | 0.2 | 472 | Long Isl.@ |
| C. rangiferina | 529 | 1703 | 607 | 278 | 242 | 325 | 23.2 | 90.3 | 18.5 | 2.7 | 0.9 | 1.9 | 0.5 | 0.5 | 0.2 | 515 | Long Isl.@ |
| C. rangiferina | 533 | 1711 | 603 | 287 | 262 | 356 | 24.1 | 90.6 | 17.6 | 3.0 | 0.9 | 1.9 | 0.5 | 0.5 | 0.2 | 552 | Long Isl.@ |
| E. mesomorpha | 491 | 2200 | 721 | 336 | 485 | 768 | 30.2 | 55.7 | 30.3 | 5.7 | 2.4 | 3.5 | 1.1 | 1.3 | 0.3 | 1380 | Outer Isl. |
| E. mesomorpha | 464 | 2052 | 634 | 315 | 485 | 768 | 29.8 | 47.1 | 29.1 | 6.5 | 2.4 | 3.3 | 1.3 | 1.2 | 0.3 | 997 | Outer Isl. |
| E. mesomorpha | 618 | 2523 | 757 | 384 | 649 | 983 | 33.1 | 45.9 | 35.4 | 6.6 | 2.2 | 4.2 | 1.5 | 1.5 | 0.3 | 1037 | Outer Isl. |
| E. mesomorpha | 377 | 1576 | 536 | 285 | 560 | 1261 | 30.8 | 33.9 | 28.0 | 4.2 | 2.8 | 5.4 | 1.1 | 1.4 | 0.2 | 1070 | Stockton Isl. |
| E. mesomorpha | 401 | 1676 | 612 | 291 | 530 | 1101 | 32.6 | 36.3 | 29.1 | 4.3 | 2.5 | 5.3 | 1.1 | 1.3 | 0.2 | 1080 | Stockton Isl. |
| E. mesomorpha | 437 | 1754 | 626 | 294 | 514 | 1025 | 40.8 | 34.4 | 28.0 | 4.8 | 2.1 | 5.7 | 1.2 | 1.4 | 0.2 | 1020 | Stockton Isl. |
| E. mesomorpha | 791 | 2931 | 1850 | 510 | 540 | 942 | 44.0 | 70.9 | 40.6 | 4.6 | 2.2 | 3.1 | 1.1 | 1.4 | 0.3 | 1160 | Raspberry Isl. |
| E. mesomorpha | 643 | 2659 | 1693 | 482 | 514 | 885 | 43.0 | 51.6 | 36.9 | 4.3 | 2.3 | 3.4 | 1.1 | 1.5 | 0.3 | 1240 | Raspberry Isl. |
| E. mesomorpha | 659 | 2657 | 1924 | 481 | 522 | 942 | 45.6 | 56.1 | 39.2 | 4.4 | 2.5 | 3.7 | 1.4 | 1.6 | 0.4 | 902 | Raspberry Isl. |
| E. mesomorpha | 736 | 2557 | 666 | 345 | 463 | 795 | 46.0 | 37.0 | 33.4 | 6.2 | 1.8 | 4.9 | 1.2 | 1.4 | 0.4 | 1130 | Long Isl. |
| E. mesomorpha | 752 | 2522 | 651 | 329 | 409 | 684 | 51.1 | 34.8 | 31.3 | 6.7 | 1.8 | 5.2 | 1.3 | 1.4 | 0.5 | 1130 | Long Isl. |
| E. mesomorpha | 672 | 2503 | 647 | 315 | 383 | 655 | 50.4 | 33.5 | 32.8 | 7.1 | 1.9 | 4.8 | 1.2 | 1.3 | 0.5 | 928 | Long Isl. |
| H. physodes | 534 | 2313 | 17719 | 813 | 687 | 960 | 27.1 | 312.7 | 71.2 | 9.6 | 2.2 | 14.8 | 1.7 | 1.5 | 1.5 | 925 | Outer Isl. |
| H. physodes | 461 | 2351 | 28531 | 562 | 465 | 604 | 20.3 | 241.9 | 63.4 | 8.2 | 1.6 | 14.7 | 1.6 | 0.9 | 2.4 | 928 | Outer Isl. |
| H. physodes | 603 | 2589 | 24776 | 643 | 476 | 647 | 24.4 | 261.6 | 80.8 | 8.7 | 1.9 | 11.7 | 1.6 | 1.1 | 2.1 | 812 | Outer Isl. |
| H. physodes | 550 | 2462 | 18982 | 675 | 694 | 1304 | 26.0 | 205.5 | 99.2 | 7.2 | 2.2 | 19.5 | 1.7 | 1.5 | 0.8 | 984 | Stockton Isl. |
| H. physodes | 632 | 2774 | 16393 | 701 | 607 | 1142 | 26.5 | 241.8 | 95.8 | 7.8 | 2.3 | 16.4 | 1.5 | 1.3 | 0.8 | 965 | Stockton Isl. |
| H. physodes | 636 | 3066 | 15002 | 686 | 523 | 1008 | 27.7 | 227.0 | 82.3 | 7.7 | 2.2 | 14.9 | 1.5 | 1.3 | 0.8 | 842 | Stockton Isl. |
| H. physodes | 830 | 3666 | 19843 | 1087 | 573 | 951 | 36.2 | 204.7 | 90.3 | 6.9 | 2.5 | 10.2 | 2.0 | 1.5 | 1.7 | 1260 | Raspberry Isl. |
| H. physodes | 816 | 3683 | 16854 | 1108 | 599 | 987 | 37.1 | 226.6 | 91.0 | 6.7 | 2.3 | 9.9 | 1.9 | 1.6 | 1.7 | 1020 | Raspberry Isl. |
| H. physodes | 946 | 4034 | 18335 | 1168 | 598 | 1009 | 38.9 | 255.0 | 97.7 | 7.0 | 2.5 | 10.2 | 1.9 | 1.6 | 1.6 | 1220 | Raspberry Isl. |
| H. physodes | 757 | 2916 | 7932 | 591 | 685 | 880 | 38.4 | 128.1 | 64.6 | 9.7 | 1.7 | 16.2 | 2.1 | 1.7 | 1.1 | 866 | Long Isl. |
| H. physodes | 904 | 3427 | 8124 | 714 | 754 | 1106 | 38.2 | 140.9 | 78.5 | 11.2 | 1.9 | 16.2 | 1.9 | 1.5 | 1.3 | 876 | Long Isl. |
| H. physodes | 779 | 3142 | 6861 | 598 | 543 | 734 | 34.9 | 129.8 | 62.4 | 9.0 | 1.5 | 13.6 | 1.6 | 1.1 | 1.1 | 966 | Long Isl. |
| P. sulcata | 1126 | 3146 | 2993 | 506 | 678 | 800 | 25.2 | 244.7 | 79.6 | 12.7 | 4.3 | 10.9 | 1.1 | 1.0 | 0.8 | 1230 | Outer Isl. |
| P. sulcata | 897 | 2834 | 2551 | 429 | 605 | 662 | 22.6 | 177.8 | 83.6 | 12.7 | 4.0 | 9.9 | 1.2 | 0.9 | 0.9 | 1260 | Outer Isl. |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P. sulcata | 889 | 2741 | 2576 | 453 | 726 | 819 | 24.9 | 165.5 | 75.2 | 13.2 | 4.0 | 12.9 | 1.4 | 1.0 | 0.8 | 1210 | Outer Isl. |
| P. sulcata | 1130 | 3334 | 2615 | 430 | 582 | 813 | 22.7 | 193.1 | 82.5 | 10.5 | 4.5 | 15.2 | 1.2 | 0.9 | 0.3 | 1210 | Stockton Isl. |
| P. sulcata | 1041 | 3112 | 2429 | 428 | 753 | 985 | 25.2 | 233.2 | 84.7 | 12.5 | 5.2 | 20.9 | 1.4 | 1.1 | 0.3 | 1200 | Stockton Isl. |
| P. sulcata | 1223 | 3559 | 2733 | 483 | 749 | 1041 | 27.0 | 248.5 | 87.8 | 11.5 | 4.7 | 17.1 | 1.4 | 1.1 | 0.6 | 1220 | Stockton Isl. |
| P. sulcata | 1594 | 4000 | 4024 | 758 | 657 | 911 | 31.2 | 222.3 | 106.9 | 8.3 | 4.4 | 10.4 | 1.5 | 1.3 | 0.7 | 1260 | Raspberry Isl. |
| P. sulcata | 1564 | 4147 | 3398 | 734 | 725 | 1012 | 32.1 | 191.7 | 99.3 | 9.6 | 4.2 | 11.1 | 1.5 | 1.3 | 0.7 | 1220 | Raspberry Isl. |
| P. sulcata | 1481 | 4065 | 3431 | 715 | 638 | 907 | 28.7 | 185.8 | 95.5 | 8.5 | 3.9 | 9.2 | 1.1 | 1.0 | 0.6 | 1365 | Raspberry Isl. |
| P. sulcata | 1291 | 3840 | 2236 | 491 | 634 | 1046 | 43.8 | 70.4 | 87.8 | 12.1 | 2.9 | 12.2 | 1.7 | 1.1 | 0.5 | 1280 | Long Isl. |
| P. sulcata | 1167 | 3796 | 2254 | 475 | 645 | 984 | 42.0 | 72.3 | 96.1 | 12.8 | 2.8 | 14.1 | 1.8 | 1.1 | 0.6 | 1460 | Long Isl. |
| P. sulcata | 1289 | 4016 | 2245 | 490 | 614 | 1045 | 40.4 | 73.4 | 90.0 | 11.8 | 2.6 | 13.8 | 1.5 | 1.1 | 0.5 | 1280 | Long Isl. |

| Standards | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NBS-Peach | 1192 | 3660 | 4539 | 1157 | 458 | 191 | 17.6 | 703.4 | 65.3 | 2.9 | 16.5 | 11.1 | 1.5 | 1.7 | 0.2 | NA | NBS Peach |
| NBS-Peach | 1201 | 3587 | 4498 | 1165 | 458 | 191 | 19.0 | 699.2 | 71.9 | 3.1 | 16.5 | 13.3 | 1.9 | 2.0 | 0.3 | NA | NBS Peach |
| NBS-Peach | 1191 | 3664 | 4639 | 1162 | 469 | 189 | 16.6 | 717.0 | 64.9 | 2.7 | 16.1 | 10.8 | 1.3 | 1.9 | 0.6 | NA | NBS Peach |
| Blank | <0.7 | <14 | <0.8 | <4 | <4 | <0.4 | <3.6 | <0.1 | <0.14 | <0.52 | <0.5 | <1.7 | <0.5 | <0.3 | <0.12 | NA | Blank |
| Blank | <0.7 | <14 | <0.8 | <4 | <4 | <0.4 | <3.6 | <0.1 | <0.14 | <0.52 | <0.5 | <1.7 | <0.5 | <0.3 | <0.12 | NA | Blank |
| Blank | <0.7 | <14 | <0.8 | <4 | <4 | <0.4 | <3.6 | <0.1 | <0.14 | <0.52 | <0.5 | <1.7 | <0.5 | <0.3 | <0.12 | NA | Blank |
| C. stellaris | 195 | 667 | 235 | 267 | 458 | 618 | 77.3 | 20.9 | 18.0 | 2.1 | 0.9 | 13.3 | 1.1 | 0.9 | 0.2 | 397 | Lich. Stand. |
| C. stellaris | 195 | 662 | 235 | 271 | 462 | 606 | 78.7 | 20.4 | 17.3 | 2.3 | 1.1 | 14.4 | 1.3 | 1.0 | 0.2 | 389 | Lich. Stand. |
| C. stellaris | 194 | 672 | 244 | 266 | 470 | 615 | 78.2 | 21.0 | 17.2 | 1.9 | 0.7 | 12.7 | 1.0 | 1.1 | <0.12 | 419 | Lich. Stand. |

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

Cladina rangiferina

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 350 | 1210 | 549 | 227 | 192 | 272 | 19.9 | 106.5 | 12.7 | 2.1 | *0.5 | # | # | 0.3 | 0.1 | 408 | Outer Isl. |
| Std. Dev. | 38 | 99 | 25 | 15 | 2 | 10 | 2.2 | 3.7 | 0.9 | <.1 | 0.1 | # | # | <.1 | <.1 | 6 | Outer Isl. |
| Mean | 380 | 1097 | 610 | 229 | 207 | 283 | 22.4 | 115.6 | 14.0 | 2.1 | 0.5 | # | # | 0.4 | 0.2 | 357 | Outer Isl.@ |
| Std. dev. | 14 | 47 | 11 | 11 | 10 | 15 | 0.8 | 1.2 | 0.6 | 0.2 | <.1 | # | # | 0.2 | <.1 | 12 | Outer Isl.@ |
| Mean | 520 | 1559 | 780 | 293 | 232 | 308 | 14.5 | 77.4 | 18.2 | 2.2 | 0.8 | # | *0.4 | 0.4 | 0.2 | 483 | Stockton Isl. |
| Std. Dev. | 50 | 121 | 52 | 20 | 35 | 43 | 0.6 | 9.7 | 1.5 | 0.2 | 0.1 | # | 0.1 | 0.1 | <.1 | 39 | Stockton Isl. |
| Mean | 320 | 1062 | 578 | 240 | 211 | 289 | 16.0 | 31.5 | 10.2 | 1.5 | 0.5 | *1.6 | 0.6 | 0.5 | 0.1 | 351 | Raspberry Isl. |
| Std. dev. | 39 | 101 | 48 | 39 | 13 | 29 | 0.5 | 6.4 | 1.4 | 0.1 | 0.1 | 0.4 | 0.1 | <.1 | <.1 | 74 | Raspberry Isl. |
| Mean | 554 | 1876 | 627 | 274 | 239 | 333 | 22.5 | 68.1 | 16.9 | 2.9 | 0.6 | 1.7 | 0.5 | 0.5 | 0.2 | 455 | Long Isl. |
| Std. dev. | 6 | 39 | 39 | 7 | 6 | 9 | 1.1 | 8.6 | 0.2 | <.1 | <.1 | <.1 | 0.1 | 0.1 | <.1 | 11 | Long Isl. |
| Mean | 536 | 1722 | 612 | 290 | 261 | 355 | 23.6 | 93.2 | 18.1 | 2.9 | 0.9 | 2.0 | 0.5 | 0.5 | 0.2 | 513 | Long Isl.@ |
| Std. dev. | 9 | 27 | 13 | 14 | 18 | 29 | 0.4 | 4.8 | 0.5 | 0.2 | <.1 | 0.1 | 0.1 | <.1 | <.1 | 40 | Long Isl.@ |

Evernia mesomorpha

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 524 | 2258 | 704 | 345 | 540 | 840 | 31.0 | 49.5 | 31.6 | 6.3 | 2.4 | 3.7 | 1.3 | 1.4 | 0.3 | 1138 | Outer Isl. |
| Std. dev. | 82 | 240 | 63 | 35 | 95 | 124 | 1.8 | 5.3 | 3.4 | 0.5 | 0.1 | 0.5 | 0.2 | 0.1 | <.1 | 211 | Outer Isl. |
| Mean | 405 | 1669 | 591 | 290 | 535 | 1129 | 34.7 | 34.9 | 28.3 | 4.4 | 2.5 | 5.5 | 1.1 | 1.3 | 0.2 | 1057 | Stockton Isl. |
| Std. dev. | 30 | 89 | 49 | 5 | 23 | 120 | 5.3 | 1.3 | 0.6 | 0.3 | 0.4 | 0.2 | 0.1 | <.1 | <.1 | 32 | Stockton Isl. |
| Mean | 698 | 2749 | 1822 | 491 | 525 | 923 | 44.2 | 59.5 | 38.9 | 4.5 | 2.3 | 3.4 | 1.2 | 1.5 | 0.3 | 1101 | Raspberry Isl. |
| Std. dev. | 81 | 157 | 118 | 16 | 13 | 33 | 1.3 | 10.1 | 1.9 | 0.2 | 0.1 | 0.3 | 0.1 | 0.1 | <.1 | 177 | Raspberry Isl. |
| Mean | 720 | 2527 | 654 | 330 | 418 | 711 | 49.2 | 35.1 | 32.5 | 6.6 | 1.8 | 5.0 | 1.2 | 1.4 | 0.5 | 1063 | Long Isl. |
| Std. dev. | 42 | 27 | 10 | 15 | 41 | 74 | 2.7 | 1.7 | 1.1 | 0.5 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 117 | Long Isl. |

Hypogymnia physodes

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 533 | 2418 | 23675 | 673 | 543 | 737 | 23.9 | 272.1 | 71.8 | 8.8 | 1.9 | 13.7 | 1.6 | 1.2 | 2.0 | 888 | Outer Isl. |
| Std. dev. | 71 | 150 | 5489 | 128 | 125 | 194 | 3.4 | 36.5 | 8.7 | 0.7 | 0.3 | 1.7 | 0.1 | 0.3 | 0.5 | 66 | Outer Isl. |
| Mean | 606 | 2767 | 16792 | 687 | 608 | 1151 | 26.7 | 224.8 | 92.4 | 7.5 | 2.2 | 16.9 | 1.6 | 1.4 | 0.8 | 930 | Stockton Isl. |
| Std. dev. | 48 | 302 | 2020 | 13 | 85 | 148 | 0.9 | 18.3 | 8.9 | 0.3 | 0.1 | 2.4 | 0.1 | 0.1 | <.1 | 77 | Stockton Isl. |
| Mean | 864 | 3794 | 18344 | 1121 | 590 | 982 | 37.4 | 228.7 | 93.0 | 6.9 | 2.4 | 10.1 | 1.9 | 1.6 | 1.7 | 1167 | Raspberry Isl. |
| Std. dev. | 71 | 207 | 1495 | 42 | 15 | 29 | 1.4 | 25.2 | 4.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 129 | Raspberry Isl. |
| Mean | 813 | 3162 | 7639 | 634 | 661 | 906 | 37.2 | 132.9 | 68.5 | 10.0 | 1.7 | 15.3 | 1.9 | 1.4 | 1.2 | 903 | Long Isl. |
| Std. dev. | 79 | 256 | 681 | 69 | 108 | 187 | 2.0 | 7.0 | 8.7 | 1.2 | 0.2 | 1.5 | 0.2 | 0.3 | 0.1 | 55 | Long Isl. |

Parmelia sulcata

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 971 | 2907 | 2707 | 463 | 670 | 760 | 24.2 | 196.0 | 79.5 | 12.9 | 4.1 | 11.3 | 1.2 | 1.0 | 0.8 | 1233 | Outer Isl. |
| Std. dev. | 134 | 212 | 248 | 39 | 61 | 86 | 1.4 | 42.6 | 4.2 | 0.3 | 0.2 | 1.5 | 0.2 | 0.1 | 0.1 | 25 | Outer Isl. |
| Mean | 1131 | 3335 | 2592 | 447 | 695 | 946 | 25.0 | 224.9 | 85.0 | 11.5 | 4.8 | 17.7 | 1.4 | 1.0 | 0.4 | 1210 | Stockton Isl. |
| Std. dev. | 91 | 224 | 153 | 31 | 97 | 119 | 2.2 | 28.6 | 2.6 | 1.0 | 0.4 | 2.9 | 0.1 | 0.1 | 0.1 | 10 | Stockton Isl. |
| Mean | 1546 | 4071 | 3618 | 736 | 673 | 944 | 30.6 | 199.9 | 100.6 | 8.8 | 4.1 | 10.2 | 1.4 | 1.2 | 0.6 | 1282 | Raspberry Isl. |
| Std. dev. | 58 | 74 | 352 | 21 | 45 | 60 | 1.8 | 19.6 | 5.8 | 0.7 | 0.3 | 0.9 | 0.2 | 0.2 | 0.1 | 75 | Raspberry Isl. |
| Mean | 1249 | 3884 | 2245 | 485 | 631 | 1025 | 42.1 | 72.0 | 91.3 | 12.2 | 2.8 | 13.4 | 1.7 | 1.1 | 0.5 | 1340 | Long Isl. |
| Std. dev. | 71 | 116 | 9 | 9 | 16 | 36 | 1.7 | 1.5 | 4.3 | 0.5 | 0.2 | 1.0 | 0.2 | <.1 | <.1 | 104 | Long Isl. |

| Standards | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 1195 | 3637 | 4559 | 1161 | 462 | 191 | 17.7 | 706.5 | 67.4 | 2.9 | 16.4 | 11.7 | 1.6 | 1.9 | 0.4 | | NBS Peach |
| Std. Dev. | 6 | 43 | 73 | 4 | 6 | 1 | 1.2 | 9.3 | 3.9 | 0.2 | 0.2 | 1.4 | 0.3 | 0.2 | 0.2 | | NBS Peach |
| Mean | 195 | 667 | 238 | 268 | 463 | 613 | 78.1 | 20.8 | 17.5 | 2.1 | 0.9 | 13.5 | 1.1 | 1.0 | 0.2 | 402 | Lichen Standard |
| Std. Dev. | 1 | 5 | 5 | 3 | 6 | 6 | 0.7 | 0.3 | 0.5 | 0.2 | 0.2 | 0.9 | 0.2 | 0.1 | *0.1 | 15 | Lichen Standard |

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

Table 3. Comparison of 1987 and 1995 Analysis of Apostle Isl Lichens
Values in ppm of thallus dry weight

| *Cladina rangiferina* | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 350 | 1210 | 549 | 227 | 192 | 272 | 19.9 | 106.5 | 12.7 | 2.1 | *0.5 | # | # | 0.3 | 0.1 | 408 | Outer Isl. |
| Std. dev. | 38 | 99 | 25 | 15 | 2 | 10 | 2.2 | 3.7 | 0.9 | <.1 | 0.1 | # | # | <.1 | <.1 | 6 | Outer Isl. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 380 | 1097 | 610 | 229 | 207 | 283 | 22.4 | 115.6 | 14.0 | 2.1 | 0.5 | # | # | 0.4 | 0.2 | 357 | Outer Isl.@ |
| Std. dev. | 14 | 47 | 11 | 11 | 10 | 15 | 0.8 | 1.2 | 0.6 | 0.2 | <.1 | # | # | 0.2 | <.1 | 12 | Outer Isl.@ |
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 520 | 1559 | 780 | 293 | 232 | 308 | 14.5 | 77.4 | 18.2 | 2.2 | 0.8 | # | *0.4 | 0.4 | 0.2 | 483 | Stockton Isl. |
| Std. dev. | 50 | 121 | 52 | 20 | 35 | 43 | 0.6 | 9.7 | 1.5 | 0.2 | 0.1 | # | 0.4 | 0.1 | <.1 | 39 | Stockton Isl. |
| 1987 | | | | | | | | | | | | | | | | | |
| Mean | 484 | 1817 | 636 | 319 | 234 | 259 | 28.5 | 34.2 | 16.9 | 3.8 | 5.8 | 2.0 | 0.4 | 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 | 0.1 | <.1 | <.1 | 78 | Raspberry Isl. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 320 | 1062 | 578 | 240 | 211 | 289 | 16.0 | 31.5 | 10.2 | 1.5 | 0.5 | *1.6 | 0.6 | 0.5 | 0.1 | 351 | Raspberry Isl. |
| Std. dev. | 39 | 101 | 48 | 39 | 13 | 29 | 0.5 | 6.4 | 1.4 | 0.1 | 0.1 | 0.4 | 0.1 | <.1 | <.1 | 74 | Raspberry Isl. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 554 | 1876 | 627 | 274 | 239 | 333 | 22.5 | 68.1 | 16.9 | 2.9 | 0.6 | 1.7 | 0.5 | 0.5 | 0.2 | 455 | Long Isl. |
| Std. dev. | 6 | 39 | 39 | 7 | 6 | 9 | 1.1 | 8.6 | 0.2 | <.1 | <.1 | <.1 | 0.1 | 0.1 | <.1 | 11 | Long Isl. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 536 | 1722 | 612 | 290 | 261 | 355 | 23.6 | 93.2 | 18.1 | 2.9 | 0.9 | 2.0 | 0.5 | 0.5 | 0.2 | 513 | Long Isl.@ |
| Std. dev. | 9 | 27 | 13 | 14 | 18 | 29 | 0.4 | 4.8 | 0.5 | 0.2 | <.1 | 0.1 | 0.1 | <.1 | <.1 | 40 | Long Isl.@ |

Evernia mesomorpha

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 524 | 2258 | 704 | 345 | 540 | 840 | 31.0 | 49.5 | 31.6 | 6.3 | 2.4 | 3.7 | 1.3 | 1.4 | 0.3 | 1138 | Outer Isl. |
| Std. dev. | 82 | 240 | 63 | 35 | 95 | 124 | 1.8 | 5.3 | 3.4 | 0.5 | 0.1 | 0.5 | 0.2 | 0.1 | <.1 | 211 | Outer Isl. |
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 405 | 1669 | 591 | 290 | 535 | 1129 | 34.7 | 34.9 | 28.3 | 4.4 | 2.5 | 5.5 | 1.1 | 1.3 | 0.2 | 1057 | Stockton Isl. |
| Std. dev. | 30 | 89 | 49 | 5 | 23 | 120 | 5.3 | 1.3 | 0.6 | 0.3 | 0.4 | 0.2 | 0.1 | <.1 | <.1 | 32 | Stockton Isl. |
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 698 | 2749 | 1822 | 491 | 525 | 923 | 44.2 | 59.5 | 38.9 | 4.5 | 2.3 | 3.4 | 1.2 | 1.5 | 0.3 | 1101 | Raspberry Isl. |
| Std. dev. | 81 | 157 | 118 | 16 | 13 | 33 | 1.3 | 10.1 | 1.9 | 0.2 | 0.1 | 0.3 | 0.1 | 0.1 | <.1 | 177 | Raspberry Isl. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 720 | 2527 | 654 | 330 | 418 | 711 | 49.2 | 35.1 | 32.5 | 6.6 | 1.8 | 5.0 | 1.2 | 1.4 | 0.5 | 1063 | Long Isl. |
| Std. dev. | 42 | 27 | 10 | 15 | 41 | 74 | 2.7 | 1.7 | 1.1 | 0.5 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 117 | Long Isl. |

Hypogymnia physodes

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 533 | 2418 | 23675 | 673 | 543 | 737 | 23.9 | 272.1 | 71.8 | 8.8 | 1.9 | 13.7 | 1.6 | 1.2 | 2.0 | 888 | Outer Isl. |
| Std. dev. | 71 | 150 | 5489 | 128 | 125 | 194 | 3.4 | 36.5 | 8.7 | 0.7 | 0.3 | 1.7 | 0.1 | 0.3 | 0.5 | 66 | Outer Isl. |
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 606 | 2767 | 16792 | 687 | 608 | 1151 | 26.7 | 224.8 | 92.4 | 7.5 | 2.2 | 16.9 | 1.6 | 1.4 | 0.8 | 930 | Stockton Isl. |
| Std. dev. | 48 | 302 | 2020 | 13 | 85 | 148 | 0.9 | 18.3 | 8.9 | 0.3 | 0.1 | 2.4 | 0.1 | 0.1 | <.1 | 77 | Stockton Isl. |
| 1987 | | | | | | | | | | | | | | | | | |
| 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. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 864 | 3794 | 18344 | 1121 | 590 | 982 | 37.4 | 228.7 | 93.0 | 6.9 | 2.4 | 10.1 | 1.9 | 1.6 | 1.7 | 1167 | Raspberry Isl. |
| Std. dev. | 71 | 207 | 1495 | 42 | 15 | 29 | 1.4 | 25.2 | 4.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 129 | Raspberry Isl. |
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 813 | 3162 | 7639 | 634 | 661 | 906 | 37.2 | 132.9 | 68.5 | 10.0 | 1.7 | 15.3 | 1.9 | 1.4 | 1.2 | 903 | Long Isl. |
| Std. dev. | 79 | 256 | 681 | 69 | 108 | 187 | 2.0 | 7.0 | 8.7 | 1.2 | 0.2 | 1.5 | 0.2 | 0.3 | 0.1 | 55 | Long Isl. |

Parmelia sulcata

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S | Locality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | | | | | | | | | | | | | | | | | |
| Mean | 971 | 2907 | 2707 | 463 | 670 | 760 | 24.2 | 196.0 | 79.5 | 12.9 | 4.1 | 11.3 | 1.2 | 1.0 | 0.8 | 1233 | Outer Isl. |
| Std. dev. | 134 | 212 | 248 | 39 | 61 | 86 | 1.4 | 42.6 | 4.2 | 0.3 | 0.2 | 1.5 | 0.2 | 0.1 | 0.1 | 25 | Outer Isl. |
| Mean | 1131 | 3335 | 2592 | 447 | 695 | 946 | 25.0 | 224.9 | 85.0 | 11.5 | 4.8 | 17.7 | 1.4 | 1.0 | 0.4 | 1210 | Stockton Isl. |
| Std. dev. | 91 | 224 | 153 | 31 | 97 | 119 | 2.2 | 28.6 | 2.6 | 1.0 | 0.4 | 2.9 | 0.1 | 0.1 | 0.1 | 10 | Stockton Isl. |
| Mean | 1546 | 4071 | 3618 | 736 | 673 | 944 | 30.6 | 199.9 | 100.6 | 8.8 | 4.1 | 10.2 | 1.4 | 1.2 | 0.6 | 1282 | Raspberry Isl. |
| Std. dev. | 58 | 74 | 352 | 21 | 45 | 60 | 1.8 | 19.6 | 5.8 | 0.7 | 0.3 | 0.9 | 0.2 | 0.2 | 0.1 | 75 | Raspberry Isl. |
| Mean | 1249 | 3884 | 2245 | 485 | 631 | 1025 | 42.1 | 72.0 | 91.3 | 12.2 | 2.8 | 13.4 | 1.7 | 1.1 | 0.5 | 1340 | Long Isl. |
| Std. dev. | 71 | 116 | 9 | 9 | 16 | 36 | 1.7 | 1.5 | 4.3 | 0.5 | 0.2 | 1.0 | 0.2 | <.1 | <.1 | 104 | Long Isl. |

Cladina standard

| | P | K | Ca | Mg | Al | Fe | Na | Mn | Zn | Cu | B | Pb | Ni | Cr | Cd | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | | | | | | | | | | | | | | | | |
| Mean | 182 | 633 | 209 | 250 | 334 | 447 | 75.8 | 18.5 | 16.5 | 2.1 | 0.4 | 10.4 | 1.0 | 0.7 | 0.4 | 441 |
| Std. dev. | 0 | 10 | 2 | 2 | 6 | 3 | 0.6 | 0.3 | 0.1 | <.1 | <.1 | 0.4 | 0.1 | <.1 | 0.3 | 1 |
| 1995 | | | | | | | | | | | | | | | | |
| Mean | 195 | 667 | 238 | 268 | 463 | 613 | 78.1 | 20.8 | 17.5 | 2.1 | 0.9 | 13.5 | 1.1 | 1.0 | 0.2 | 402 |
| Std. dev. | 1 | 5 | 5 | 3 | 6 | 6 | 0.7 | 0.3 | 0.5 | 0.2 | 0.2 | 0.9 | 0.2 | 0.1 | *0.1 | 15 |

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

## RESULTS OF 1995 ANALYSIS

Table 1 gives the results of the analyses of the 1995 collections for all replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates of the 1995 study. Table 3 lists the means of both the 1987 and 1995 data. There is no correlation between levels of elements and localities. Long Island, being the nearest island to Ashland, does not stand out as having high levels of most elements.

## STATISTICAL ANALYSIS

We tested the hypothesis that significant changes in element concentrations had occurred in the three lichen species from 1987 to 1995. Data for the element concentrations in the three species at three localities (Raspberry, Stockton and Outer Islands) were used. Long Island was not used because it had not been sampled in 1987. Two-way analyses of variance were performed on each element for each species with locality and year as the sources of variation. The site replicates were used in the analyses of variance in order to test the interaction between locality and year. The sample size for each locality X year treatment was three.

## RESULTS

The results of the analyses of variance are presented in the Appendix I. Means in ppm for each species and element are tabulated. Significant differences at the 0.05 probability level are indicated for those treatment means by bold print.

1. The following elements increased significantly between 1987 and 1995 averaged across sites in all 3 species: Ca and Fe. Chromium decreased in all three species, but was significantly less only in two. Nickel decreased in two species but wasn't measurable in the third.

2. The following elements decreased significantly between 1987 and 1995 averaged across sites in all 3 species: B, Cu, K, Na, and P. Sulfur increased in all three but was signficantly greater only in two. Lead increased significantly in two but was not measurable in the third.

3. The following elements increased significantly from east to west averaged across years in all 3 species: Ca, Fe, Na, and Zn. The following increased significantly in two species: Al, B, Cr, K, Mg and P.

4. No element decreased significantly from east to west averaged across years in all 3 species. However, Mn decreased significantly in two species.

## DISCUSSION AND INTERPRETATION

Over a period of eight years, it appears that two elements associated with anthropogenic activities (Cr and Ni) have increased about 30% or more in three lichen species sampled on three islands. Chromium is known to have increased in the Great Lakes region in recent years (Beaublen et al., 1994) so this finding is consistent with that. On specific islands the increases may be more or less than that. Two other elements associated with soils, Ca and Fe, also increased an average of 35% each for the same period over the same three islands. Iron can also be emitted by anthropogenic activities, e.g. mining and smelting, and may be coupled with the increases of Cr and Ni. The increases were generally greater for the two arboreal species compared to the ground-dwelling species.

Sulfur, along with five or six other elements, decreased an average of 14% for all three species over the eight years, with the greatest decrease occurring in the ground-dwelling species. The decrease in S probably reflects the overall decrease in this air pollutant seen in Wisconsin in recent years. The decrease in K averaged across all three species was 16% with the greatest decrease in the ground-dwelling species. Potassium is a nutritional element that is thought to be tightly coupled to stress phenomena. It generally decreases in tissues due to stress-caused leakage across membranes. It is important to note that even though S decreased in tissues of three species, K still decreased, possible indicating continuing stress from the Cr and Ni pollutants.

The three islands that were sampled are arrayed from east to west, the westernmost one, Raspberry Island, being closest to the mainland. If element concentrations increased from east to west it might suggest that sources on the mainland are the cause of elevated concentrations. However, the elements that were higher at Raspberry Island compared to

Outer Island were the same as those that increased over the eight years: Ca, Fe, Cr and several others. Therefore it appears that those that increase towards the mainland are also those that have increased over time. It is therefore difficult to interpret any meaning from this pattern. It was hypothesized that anthropogenic activity elements would increase with proximity to the mainland where there are settlements. There are noticeable examples in each species or in any one year that support this hypothesis, but as yet there is no overall pattern across the species and years that does.

## CONCLUSIONS

The lichen flora of Long Island is unique in the park. This is partly due to the vegetational types present there. This is established by the 14 new records for the park on this island. This kind of area is very sensitive to physical damage by trampling and fires.

The elemental analysis data for the 1995 collections do not show any consistent trends between levels of elements and species or localities. When comparing the 1987 analysis with the 1995 analysis some lichen elements have increased and some have decreased. The increases may be due to anthropogenic activity and some of the decreases may be due to regional declines in those elements. However, the decrease in K may indicate cellular stress due to other pollution elements.

## RECOMMENDATIONS

Because of the richness and fragility of the lichen growth on Long Island it is recommended that visitor use of the island be minimized (both tourist and scientific). Further, it is recommended that the trail going west from the cabin be improved and well marked to prevent the proliferation of alternate paths. At present it is very difficult to find and stay on one trail. This trail should be well marked all the way to the old buildings near the west end.

The Raspberry Island locality for elemental analysis has degraded significantly in the past 8 years. Trees have been cut down, there is heavier visitor traffic, and the trail has been moved. All of these make it impossible to continue sampling at this locality. Before the next restudy a reconnaisance must be done to look for another site on Raspberry

Island. If no suitable site can be found there the monitoring site may need to be moved to another island.

This study over eight years has detected some significant patterns of element concentrations in three lichen species that suggest air pollutants may be entering the environment of Apostle Islands National Lakeshore. Consequently, it is recommended that repeated sampling using the same design, species, and localities be conducted as time and funds permit, and preferably within the next five years.

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# APPENDIX I

Means in ppm for each species and element are tabulated. Significant differences at the 0.05 probability level are indicated for those treatment means by bold print.

## HYPOGYMNIA

| **Al - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **468.1** | **483.1** | **888.5** | 613.3 |
| 1995 | **542.7** | **608.0** | **590.0** | 580.2 |
| Average | **505.4** | **545.6** | **739.3** | |

| **B - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **5.9** | **6.8** | **7.1** | **6.6** |
| 1995 | **1.9** | **2.2** | **2.4** | **2.2** |
| Average | **3.9** | **4.5** | **4.8** | |

| **Ca - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **11638.7** | **10601.0** | **19755.3** | **13998.3** |
| 1995 | **23675.3** | **16792.3** | **18344.0** | **19603.9** |
| Average | **17657.0** | **13696.7** | **19049.7** | |

| **Cd - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **1.4** | **0.7** | **0.8** | **1.0** |
| 1995 | **2.0** | **0.8** | **1.7** | **1.5** |
| Average | **1.7** | **0.7** | **1.3** | |

| **Cr- Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 0.9 | 1.0 | 1.4 | **1.1** |
| 1995 | 1.2 | 1.4 | 1.6 | **1.4** |
| Average | **1.0** | **1.2** | **1.5** | |

| **Cu - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **8.4** | **6.5** | **16.6** | **10.5** |
| 1995 | **8.8** | **7.6** | **6.9** | **7.8** |
| Average | **8.6** | **7.0** | **11.7** | |

| **Fe - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **604.3** | **561.6** | **953.4** | **706.5** |
| 1995 | **737.0** | **1151.3** | **982.3** | **956.9** |
| Average | **670.7** | **856.5** | **967.9** | |

| **K - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **3146.1** | **2937.6** | **3983.6** | **3355.8** |
| 1995 | **2417.7** | **2767.3** | **3794.3** | **2993.1** |
| Average | **2781.9** | **2852.5** | **3889.0** | |

| **Mg - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 657.0 | 635.8 | 1179.9 | 824.2 |
| 1995 | 672.7 | 687.3 | 1121.0 | 827.0 |
| Average | **664.8** | **661.6** | **1150.5** | |

| **Mn - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **131.7** | **422.8** | **166.2** | 240.2 |
| 1995 | **272.1** | **224.8** | **228.8** | 241.9 |
| Average | **201.9** | **323.8** | **197.5** | |

| **Na - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **29.6** | **17.9** | **53.1** | **33.5** |
| 1995 | **23.9** | **26.7** | **37.4** | **29.4** |
| Average | **26.8** | **22.3** | **45.3** | |

| **Ni - Hypogymnia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 1.0 | 1.1 | 1.9 | **1.3** |
| 1995 | 1.6 | 1.6 | 1.9 | **1.7** |
| Average | **1.3** | **1.3** | **1.9** | |

| P - Hypogymnia | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 678.4 | 611.8 | 974.2 | **754.8** |
| 1995 | 532.7 | 606.0 | 864.0 | **667.6** |
| Average | **605.5** | **608.9** | **919.1** | |

| Pb - Hypogymnia | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **15.3** | **16.8** | **15.3** | **15.8** |
| 1995 | **13.7** | **16.9** | **10.1** | **13.6** |
| Average | **14.5** | **16.9** | **12.7** | |

| S - Hypogymnia | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **1343.3** | **708.3** | **1010.0** | 1020.6 |
| 1995 | **888.3** | **930.3** | **1166.7** | 995.1 |
| Average | **1115.8** | **819.3** | **1088.3** | |

| Zn - Hypogymnia | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **55.4** | **89.2** | **52.0** | **65.6** |
| 1995 | **71.8** | **92.4** | **93.0** | **85.7** |
| Average | **63.6** | **90.8** | **72.5** | |

## EVERNIA

| **Al - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 488.72 | 589.87 | 579.66 | 552.75 |
| 1995 | 539.67 | 534.67 | 525.33 | 533.22 |
| Average | 514.19 | 562.27 | 552.50 | |

| **B - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **6.17** | **8.00** | **7.03** | **7.07** |
| 1995 | **2.33** | **2.47** | **2.33** | **2.38** |
| Average | **4.25** | **5.23** | **4.68** | |

| **Ca - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **683.12** | **451.87** | **988.08** | **707.69** |
| 1995 | **704.00** | **591.33** | **1822.33** | **1039.22** |
| Average | **693.56** | **521.60** | **1405.21** | |

| **Cd - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **0.40** | **0.17** | **0.37** | 0.31 |
| 1995 | **0.30** | **0.20** | **0.33** | 0.28 |
| Average | **0.35** | **0.18** | **0.35** | |

| **Cr - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 1.03 | 0.93 | 0.93 | **0.97** |
| 1995 | 1.33 | 1.37 | 1.50 | **1.40** |
| Average | 1.18 | 1.15 | 1.22 | |

| **Cu - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **11.97** | **6.40** | **6.17** | **8.18** |
| 1995 | **6.27** | **4.43** | **4.43** | **5.04** |
| Average | **9.12** | **5.42** | **5.30** | |

| **Fe - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **615.65** | **672.98** | **892.42** | **727.02** |
| 1995 | **839.67** | **1129.00** | **923.00** | **963.89** |
| Average | **727.66** | **900.99** | **907.71** | |

| **K - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **2583.00** | **2192.57** | **2865.73** | **2547.10** |
| 1995 | **2258.33** | **1668.67** | **2749.00** | **2225.33** |
| Average | **2420.67** | **1930.62** | **2807.37** | |

| **Mg - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **365.57** | **350.12** | **402.92** | 372.87 |
| 1995 | **345.00** | **290.00** | **491.00** | 375.33 |
| Average | **355.29** | **320.06** | **446.96** | |

| **Mn - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **32.70** | **56.97** | **47.23** | 45.63 |
| 1995 | **49.57** | **34.87** | **59.53** | 47.99 |
| Average | **41.13** | **45.92** | **52.38** | |

| **Na - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **45.53** | **33.73** | **41.17** | **40.14** |
| 1995 | **31.03** | **34.73** | **44.20** | **36.66** |
| Average | **38.28** | **34.23** | **42.68** | |

| **Ni - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 0.83 | 0.77 | 0.97 | **0.86** |
| 1995 | 1.30 | 1.13 | 1.20 | **1.21** |
| Average | 1.07 | 0.95 | 1.08 | |

| **P- Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 623.69 | 504.65 | 738.68 | **622.34** |
| 1995 | 524.33 | 405.00 | 697.67 | **542.33** |
| Average | **574.01** | **454.83** | **718.17** | |

| **Pb - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **5.57** | **9.43** | **6.90** | **7.30** |
| 1995 | **3.67** | **5.47** | **3.40** | **4.18** |
| Average | **4,62** | **7.45** | **5.15** | |

| **S - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 1163.33 | 1250.00 | 1310.00 | **1241.11** |
| 1995 | 1138.00 | 1056.67 | 1100.67 | **1098.44** |
| Average | 1150.67 | 1153.33 | 1205.33 | |

| **Zn - Evernia** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **28.13** | **37.57** | **28.27** | 31.32 |
| 1995 | **31.60** | **28.37** | **38.90** | 32.96 |
| Average | **29.87** | **32.97** | **33.58** | |

## CLADINA

| **Al - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **186.18** | **195.22** | **234.23** | 205.21 |
| 1995 | **191.50** | **231.67** | **211.00** | 211.39 |
| Average | **188.84** | **213.44** | **222.62** | |

| **B - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 5.23 | 5.73 | 5.87 | **5.61** |
| 1995 | 0.55 | 0.77 | 0.53 | **0.62** |
| Average | 2.89 | 3.25 | 3.20 | |

| **Ca - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **484.84** | **454.04** | **636.33** | **525.07** |
| 1995 | **541.50** | **780.33** | **578.00** | **633.28** |
| Average | **513.17** | **617.19** | **607.17** | |

| **Cd - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 0.17 | 0.20 | 0.20 | **0.19** |
| 1995 | 0.10 | 0.17 | 0.13 | **0.13** |
| Average | 0.13 | 0.18 | 0.17 | |

| **Cr - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | 0.30 | 0.30 | 0.37 | 0.32 |
| 1995 | 0.30 | 0.40 | 0.47 | 0.39 |
| Average | **0.30** | **0.35** | **0.42** | |

| **Cu - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **3.33** | **3.13** | **3.87** | **3.44** |
| 1995 | **2.05** | **2.23** | **1.53** | **1.94** |
| Average | 2.69 | 2.68 | 2.70 | |

| **Fe - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **190.81** | **188.55** | **259.41** | **212.92** |
| 1995 | **273.00** | **307.67** | **289.00** | **289.89** |
| Average | **231.90** | **248.11** | **274.21** | |

| **K - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **1822.00** | **1377.20** | **1816.83** | **1672.01** |
| 1995 | **1153.50** | **1558.67** | **1062.00** | **1258.06** |
| Average | 1487.75 | 1467.93 | 1439.42 | |

| **Mg - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **278.10** | **245.24** | **318.72** | **280.69** |
| 1995 | **218.00** | **293.33** | **240.00** | **250.44** |
| Average | 248.05 | 269.29 | 279.36 | |

| **Mn - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **30.07** | **51.20** | **34.20** | **38.49** |
| 1995 | **104.45** | **77.40** | **31.50** | **71.12** |
| Average | **67.26** | **64.30** | **32.85** | |

| **Na - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **20.73** | **19.70** | **28.57** | **23.00** |
| 1995 | **21.00** | **14.47** | **16.00** | **17.16** |
| Average | **20.87** | **17.08** | **22.28** | |

| **P - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **446.38** | **343.62** | **484.40** | **424.80** |
| 1995 | **327.50** | **519.67** | **320.33** | **389.17** |
| Average | 386.94 | 431.64 | 402.36 | |

| **S - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **533.33** | **471.67** | **690.00** | **565.00** |
| 1995 | **411.00** | **483.00** | **351.33** | **415.11** |
| Average | 472.17 | 477.33 | 520.67 | |

| **Zn - Cladina** | | | | |
|---|---|---|---|---|
| Year | Outer Island | Stockton Island | Raspberry Island | Average |
| 1987 | **12.60** | **12.60** | **16.83** | 14.01 |
| 1995 | **12.15** | **18.23** | **10.17** | 13.52 |
| Average | **12.37** | **15.42** | **13.50** | |