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LICHENS AND AIR QUALITY IN

CAPE ROMAIN NATIONAL WILDLIFE REFUGE

FINAL REPORT

CONTRACT # FWS6-87-1103

Parmelia rigida

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by

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LICHENS OF CAPE ROMAIN NAT. WILDLIFE REFUGE

PREFACE

Under a grant from the U. S. Fish & Wildlife Service a lichen study was performed in Cape Romain National Wildlife Refuge (NWR). The objectives of the study were to survey the lichens on three islands of the refuge, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the lichen flora with reference to the air quality. The study will also establish baseline data for future restudy and determine the presence of any air quality problems that might be shown by the lichens at the time of the study. All work was done at the University of Minnesota with consultation with Wayne King, Denver and with personnel at the refuge.

The U. S. Fish & Wildlife Service personnel were very helpful during the field work in providing transportation and local information which has contributed significantly to the success of the project. The study was made possible by funds from the U. S. Fish & Wildlife Service. The assistance of all of these is gratefully acknowledged.

INTRODUCTION

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

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Many are damaged or killed by levels of sulfur dioxide, nitrogen oxides, fluorides or ozone alone or in various combinations. Levels of sulfur dioxide as low as 13 μg/cubic meter (annual average) will cause the death of some lichens (LeBlanc et al., 1972). Other lichens are less sensitive and a few can tolerate levels of sulfur dioxide over

300 μg/cubic meter (Laundon, 1967, Trass, 1973). The algae of the thallus are the first to be damaged in areas with air pollution. The first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. 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 more sensitive to air pollution when they are wet and physiologically active and are least sensitive when dry (Nash, 1973, Marsh & Nash, 1979) and are more sensitive when growing on acid substrates (Türk & Wirth, 1975).

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

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

Cape Romain NWR is located about 20 miles northeast of Charleston, South Carolina, and extends northeast along the coast for 22 miles. The refuge includes many coastal islands in the tidewater area but only three have enough elevation above sea level to support forests (Bull Isl., Cape Isl., Lighthouse Isl.) This study was restricted to these three islands. Part of the refuge is designated as a Wilderness Area. The other islands and the shores of these three islands are tidewater wetlands with sedges and rushes and do not have habitats suitable for lichens.

Bull, Cape and Lighthouse Islands have loblolly pines (*Pinus taeda*) and several species of oaks (*Quercus*). Bull Isl. has a well developed mixed hardwood forest with magnolia (*Magnolia*), holly (*Ilex opaca*) and palms. There are also sand spits and sand dunes on these three islands and many of the shorelines above high tide level are covered with woody shrubs.

There are literature reports of only three lichens from the refuge (Dames & Moore, 1985). There have been no lichen floras of any areas of the coastal plain of South Carolina.

The only references to lichens in the coastal plain are found in monographs and revisions of a few genera. These monographs only mention a few of the lichens that might occur along the coastal plain. However, in the absence of more complete lichen floras, all literature references to lichens on the coastal plain of South Carolina have been used as a general indication of what lichens might be found in the Cape Romain NWR. All of the taxa mentioned in these monographs are listed in Appendix III and the references included in the Literature Cited.

METHODS

Field work was done during June and July, 1988 when 308 collections were made at 8 localities on Bull Isl., Cape Isl. and Lighthouse Isl. A complete list of collection localities is given in Appendix I and are indicated on Fig. 1. Localities for collecting were selected first to give a general coverage of the refuge, second, to sample all vegetational types, and third, to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats were studied. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens.

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

LICHEN FLORA

The following list of lichens is based only on my collections. Species found only once are indicated by "Rare". In the first 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/cubic meter. The Intermediate category includes those species present between 50 and 100ug and those in the Tolerant category are present at over 100ug/cubic meter. Species reported in the literature for the coastal plain are given in Appendix III.

SPECIES LIST

Arthonia ochrocincta Will. Rare
Arthonia punctiformis Ach.
Arthonia pyrrhula Nyl. Rare
Arthonia quintaria Nyl.
1 additional unidentified species of *Arthonia*
Arthopyrenia atomarioides Müll. Arg. Rare
Arthothelium interveniens (Nyl.) Zahlbr.
Bacidia trachona (Ach.) Lett. Rare
2 additional unidentified species of *Bacidia*
Brigantiaea leucoxantha (Spreng.) R. Sant. & Hafel.
Buellia leucomela Imsh. Rare — B. curtisii
T *Buellia punctata* (Hoffm.) Mass. — B. polyspora
I *Buellia stillingiana* Steiner Rare
Caloplaca citrina (Hoffm.) Th. Fr. Rare
1 additional unidentified species of *Caloplaca*
Chiodecton sanguineum (Sw.) Vain.
I *Chrysothrix candelaris* (L.) Laund.
Cladina evansii (Abb.) Hale & W. Culb. Rare
Cladina subtenuis (des Abb.) Hale & W. Culb.
Cladonia leporina Fr. Dames & Moore, 1985
Cladonia piedmontensis G. K. Merr. Rare
Cladonia polycarpia G. K. Merr.
Cladonia subradiata (Vain.) Sandst.
Collema subflaccidum Degel. Rare
S *Dimerella lutea* (Dicks.) Trev.
Dirinaria applanata (Fee) Awas.
Dirinaria aspera (Magn.) Awas.
Dirinaria confusa Awas.
Graphis afzelii Ach. Rare
Graphis leucopepla Tuck.
Graphis rimulosa (Mont.) Trev.
2 additional unidentified species of *Graphis* Gyrostomum scyphuliferum
Haematomma puniceum (Sm. ex Ach.) Mass.
Haematomma pustulatum Brodo & W. Culb. Rare (Müll. Arg.)
Heterodermia albicans (Pers.) Swinsc. & Krog
Heterodermia obscurata (Nyl.) Trev. Rare — pulilla alba, Harris ined
Lecanora caesiorubella Ach. subsp. *glaucomodes* (Nyl.) Imsh. & Brodo
Lecanora louisianae B. de Lesd. — L. hybocarpa
2 additional unidentified species of *Lecanora* — L. strobilina
Lepraria finkii (B. de Lesd. in Hue) R. Harris Lecidea varians
Leptogium austroamericanum (Malme) Dodge
Leptogium ~~*azureum* (Sw.) Mont.~~ = denticulatum
Leptogium cyanescens (Rabenh.) Körb. Rare
Micarea prasina Fr. Rare
Ocellularia interposita (Nyl.) Hale Rare
S *Ochrolechia* ~~*rosella*~~ (Müll. Arg.) Vers. pseudoisidiosa africana
I *Opegrapha atra* Pers. Rare
Opegrapha niveoatra (Borr.) Laund.
Parmelia caroliniana Nyl.
Parmelia galbina Ach.
Parmelia hypotropa Nyl. Rare
Parmelia laevigatula Nyl.

Parmelia minarum (Vain.) Skorepa
Parmelia praesorediosa Nyl.
S Parmelia reticulata Tayl.
Parmelia rigida Lynge Dames & Moore, 1985
I Parmelia rudecta Ach.
Parmelia sphaerospora Nyl.
Parmelia tinctorum Del. ex Nyl. Dames & Moore, 1985
Parmelia ultralucens Krog
Parmeliopsis subambigua Gyeln. Rare
Pertusaria leucostoma (Bernh.) Mass.
I Pertusaria multipunctoides Dibb.
Pertusaria sinusmexicani Dibb.
Pertusaria tetrathalamia (Fee) Nyl.
Pertusaria xanthodes Müll. Arg.
Phaeographina explicans Fink Rare
2 additional unidentified species of Phaeographina
Phaeographis ~~dendriticella Müll. Arg.~~ = sericea
Phaeographis inusta (Ach.) Müll. Arg. Rare
Phaeographis punctiformis (Eschw.) Müll. Arg.
1 additional unidentified species of Phaeographis
I Physcia millegrana Degel. Rare
Placynthiella icmalea (Ach.) Coppins & James
Placynthiella uliginosa (Schrad.) Coppins & James Rare
Porina rhaphidosperma Müll. Arg. Rare
Pyrenula cruenta (Mont.) Vain. — Pyrenula cinerea
Pyxine caesiopruinosa (Nyl.) Imsh.
Ramalina willeyi Howe
Rinodina dissa (Stirt.) Mayrh.
Schismatomma palidellum Nyl. — Schismatomma rappii
Strigula elegans (Fee) Müll. Arg. Rare
Thelotrema monosporum Nyl. Rare
Trypethelium virens Tuck. ex Michen. in Darl.
Usnea evansii Mot.
S Usnea strigosa (Ach.) A. Eaton

DISCUSSION OF FLORA

This list of species presents the first thorough listing of lichens from Cape Romain and includes 79 taxa of lichens collected for this study. The most common species are Buellia punctata, Lecanora louisianae, Parmelia rigida, Parmelia tinctorum, Pertusaria leucostoma. The lichen flora is quite diverse for this area even though there are not a lot of species present. The substrates and habitats are quite limited within the refuge and this limits the number of species but some of the trees are covered with lichens. Many species from further south (e.g. Florida) extend north along the coastal plain and were found in the refuge.

Some of the species found only once (marked "Rare" in the list) are rare wherever they are found throughout their distributional range and might be found at other localities with further searching, while others may require special substrates that are rare in the area. The fact that they are rare does not necessarily mean that they are rare because of air quality.

A comparison with the few species known from the coastal plain of South Carolina provides little solid data because there is no complete lichen flora of any place in the southern coastal plain. Some of the species found in the coastal plain may be absent from the refuge because they may require habitats not found in the refuge. Some species may be rare and not found by me, while some of the literature reports may be misidentifications. It is also possible that some may be absent because of present levels of air pollution. The knowledge of tropical and subtropical lichens is very poor and 11 species were found that could not be identified or may be undescribed.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the refuge. These observations indicate that there may be no air quality degradation in the refuge due to sulfur dioxide now, but without historical species data for the area it is impossible to prove that there were no sulfur dioxide effects in the past. However, three of the species in the intermediate sensitivity category to sulfur dioxide were rare, suggesting that further work is needed to determine the role of sulfur dioxide in their current distribution in the refuge.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive species within the area 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. Valid conclusions can be drawn only from the very common species with such a technique because the less common species may be absent due to other factors.

Only a few of the lichens in the refuge have known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983). Species in the most sensitive category are usually absent when sulfur dioxide levels are above 50ug per cubic meter average annual concentrations. There were no lichens present in the Sensitive-Intermediate Category. The species that occur in the refuge in the most sensitive category are as follows.

Dimerella lutea
Ochrolechia rosella
Parmelia reticulata
Usnea strigosa

The distributions of these species are mapped Fig. 2-5. All of these species are too uncommon to be able to draw conclusions from their distributions within the refuge. Some of these mapped species may be absent from certain localities because of their ecological requirements, or they may be uncommon throughout their range, or they may be uncommon because of degraded air quality.

ELEMENTAL ANALYSIS

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

METHODS

Lichen samples of three species were collected in spunbound olefin bags at various localities in the refuge for laboratory analysis. At some localities all three species were not present in quantities needed for the analysis. Species collected and the substrates were <u>Cladonia leporina</u> on soil, <u>Cladina subtenuis</u> on soil and <u>Parmelia rigida</u> on branches of trees. Ten to 20 grams of each species were collected at each locality. These species were selected because they are locally present in abundance and relatively easy to clean.

Five localities were selected for elemental analysis within the refuge and one locality closer to Charleston and are indicated on the map of collection localities. These localities are: Cape Isl. near the pines, Lighthouse Isl. near the old lighthouses, Bull Isl. at Northeast Point, Bull Isl.

east of Moccasin Pond, and Bull Isl. west of the south end of Upper Summerhouse Pond. The locality near Charleston was in the town of Isle Of Palms twelve miles northeast of Charleston.

Lichens were air dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three samples of each collection were submitted for analysis. Some replicates of each species were ground before being divided for analysis and are so marked in the tables. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hrs. Crucibles were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all three

Table 1. Analysis of Cape Romain Lichens
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
Cladina subtenuis	512	1425	238	308	468	407	210.8	11.7	16.6	1.8	3.4	2.7	1.0	0.6	#	725	Cape Isl. @
Cladina subtenuis	518	1419	243	313	454	397	214.6	12.0	16.3	1.8	3.5	5.6	0.5	0.7	#	760	Cape Isl. @
Cladina subtenuis	518	1428	241	318	447	395	218.1	12.1	16.4	1.8	3.6	3.2	1.4	0.9	#	730	Cape Isl. @
Cladina subtenuis	463	1087	384	284	264	377	78.2	9.1	19.7	2.5	1.3	7.6	1.2	0.4	0.2	490	Lighthouse Isl.
Cladina subtenuis	435	1103	332	263	247	355	79.5	9.1	21.8	2.3	1.4	7.5	*0.3	0.5	0.2	540	Lighthouse Isl.
Cladina subtenuis	450	1107	472	270	229	315	76.2	9.4	20.2	3.3	1.3	6.4	4.2	0.3	0.2	510	Lighthouse Isl.
Cladonia leporina	328	859	63	144	452	470	68.2	6.3	10.3	1.3	1.4	6.2	1.3	0.6	0.2	490	Cape Isl. @
Cladonia leporina	333	862	63	148	455	511	65.3	6.6	11.0	1.5	1.4	5.6	1.0	0.7	0.2	500	Cape Isl. @
Cladonia leporina	344	872	64	150	475	527	68.9	6.7	11.3	1.5	1.3	5.8	1.1	0.8	0.2	470	Cape Isl. @
Cladonia leporina	423	1042	151	198	499	718	77.4	8.8	21.9	2.0	1.0	15.1	0.7	0.8	0.1	520	Lighthouse Isl.
Cladonia leporina	471	1098	178	200	464	648	70.9	9.1	23.7	1.8	1.4	13.6	0.8	0.7	*0.1	555	Lighthouse Isl.
Cladonia leporina	427	1053	181	203	499	759	57.4	9.4	23.1	1.8	1.1	17.7	1.0	0.9	0.2	570	Lighthouse Isl.
Parmelia rigida	691	1653	4625	204	364	241	173.3	6.7	20.8	1.8	5.9	4.4	0.5	0.7	0.2	1160	Cape Isl. @
Parmelia rigida	783	1813	5012	220	360	240	174.9	7.0	21.5	2.1	6.3	3.4	*0.3	0.8	0.1	1220	Cape Isl. @
Parmelia rigida	723	1778	4066	205	336	214	179.3	6.7	20.8	2.2	5.9	2.4	0.7	0.7	0.1	1310	Cape Isl. @
Parmelia rigida	993	2639	189	316	536	356	385.1	8.9	28.6	3.0	8.5	3.6	1.6	2.0	0.1	1650	Bull, NE Point
Parmelia rigida	1087	2623	361	342	530	358	445.4	9.4	26.8	3.1	8.8	3.4	0.6	1.0	0.1	1570	Bull, NE Point
Parmelia rigida	1124	2744	271	332	476	314	284.8	9.7	26.2	3.1	7.9	4.6	0.9	0.9	0.1	1570	Bull, NE Point
Parmelia rigida	1615	3260	2394	706	716	408	922.7	23.8	26.3	3.7	4.4	3.7	1.2	1.1	0.2	1920	Bull, Moccasin P
Parmelia rigida	2076	3696	1956	843	720	409	1616.9	24.9	29.6	3.8	5.3	1.9	1.3	1.2	0.2	2090	Bull, Moccasin P
Parmelia rigida	1983	3513	2699	861	684	398	1461.8	25.9	28.6	3.7	5.3	5.3	1.3	1.2	0.2	2040	Bull, Moccasin P
Parmelia rigida	1315	2926	1255	496	413	264	258.5	17.6	24.6	3.3	6.0	2.6	1.1	1.1	0.2	1520	Bull, Summerh. P
Parmelia rigida	1535	3058	1072	546	431	283	199.0	22.7	25.2	3.2	5.3	3.3	1.2	1.2	0.3	1550	Bull, Summerh. P
Parmelia rigida	1249	3011	873	516	361	226	261.7	17.3	22.6	2.9	5.7	4.0	0.8	1.0	*0.1	1500	Bull, Summerh. P
Parmelia rigida	1875	3587	5798	507	635	512	225.0	22.3	45.2	5.3	9.2	9.8	1.6	5.5	0.2	2010	Isle of Palms
Parmelia rigida	1427	3339	5381	444	621	486	252.7	21.7	45.0	5.5	8.9	9.9	1.7	5.6	0.1	1930	Isle of Palms
Parmelia rigida	1690	3563	4817	511	606	477	351.6	20.3	44.6	5.3	9.9	9.7	1.6	5.1	0.1	2280	Isle of Palms

* = 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 2. Summary of Cape Romain Lichens
Values in ppm of thallus dry weight

Cladina subtenuis

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	516	1424	241	313	457	400	214.5	11.9	16.4	1.8	3.5	3.8	1.0	0.8	#	738	Cape Isl. @
Std. dev.	3	5	3	5	11	6	3.7	0.2	0.2	<.1	0.1	1.6	0.5	0.1	#	19	Cape Isl. @
Mean	449	1099	396	272	246	349	78.0	9.2	20.6	2.7	1.3	7.2	*1.9	0.4	0.2	513	Lighthouse Isl.
Std. dev.	14	11	71	10	17	31	1.7	0.2	1.1	0.5	0.1	0.7	2.0	0.1	<.1	25	Lighthouse Isl.

Cladonia leporina

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	335	864	63	147	461	503	67.5	6.5	10.9	1.4	1.4	5.9	1.1	0.7	0.2	487	Cape Isl. @
Std. dev.	8	6	<.1	3	12	30	1.9	0.2	0.5	0.1	<.1	0.3	0.1	0.1	<.1	15	Cape Isl. @
Mean	440	1064	170	200	487	708	68.6	9.1	22.9	1.9	1.2	15.5	0.8	0.8	*0.1	548	Lighthouse Isl.
Std. dev.	26	30	16	2	20	56	10.2	0.3	0.9	0.1	0.2	2.1	0.1	0.1	0.1	26	Lighthouse Isl.

Parmelia rigida

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	732	1748	4567	210	353	232	175.8	6.8	21.0	2.0	6.0	3.4	*0.5	0.7	0.1	1230	Cape Isl. @
Std. dev.	47	84	476	9	15	16	3.1	0.2	0.4	0.2	0.2	1.0	0.2	<.1	0.1	75	Cape Isl. @
Mean	1068	2669	274	330	514	342	371.8	9.3	27.2	3.1	8.4	3.8	1.0	1.3	0.1	1597	Bull, NE Point
Std. dev.	68	66	86	13	33	25	81.1	0.4	1.3	<.1	0.5	0.7	0.5	0.6	<.1	46	Bull, NE Point
Mean	1891	3490	2349	803	707	405	1333.8	24.9	28.2	3.7	5.0	3.6	1.3	1.1	0.2	2017	Bull, Moccasin P
Std. dev.	244	219	373	84	20	6	364.3	1.0	1.7	<.1	0.6	1.7	0.1	0.1	<.1	87	Bull, Moccasin P
Mean	1366	2998	1067	519	402	257	239.7	19.2	24.1	3.1	5.7	3.3	1.0	1.1	*0.2	1523	Bull, Summerh. P
Std. dev.	150	67	191	25	36	29	35.3	3.0	1.3	0.2	0.3	0.7	0.2	0.1	0.1	25	Bull, Summerh. P
Mean	1664	3496	5332	487	621	492	276.4	21.4	44.9	5.4	9.3	9.8	1.6	5.4	0.1	2073	Isle of Palms
Std. dev.	225	137	493	38	15	18	66.6	1.1	0.3	0.1	0.5	0.1	<.1	0.3	0.1	183	Isle of Palms

* = 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

replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. Some of the reported values are below the lower detection limits of the instruments. If one reading was below the detection limit (indicated by * in the tables) 0.7 of the detection limit was used for that reading in the calculations. If two or more readings were below the detection limits (indicated by # in the tables) no calculations were done on that species at that locality. Some samples were ground before being divided into replicates to determine instrument error and are indicated with "@" in the tables.

There are no literature reports on elemental analysis of these species and valid comparisons cannot be made between different species. From these tables it can be seen that there is only a slight correlation between element levels and location in the refuge. The sulfur levels at Isle of Palms near Charleston and at Moccasin Pond on Bull Isl. are above 2000 ppm, and this is quite high for any species.

The sulfur levels in lichens tested range from 470 to 2280 ppm for all samples. Background levels for other species of lichens in clean areas range from 300-1300 ppm (Solberg 1967; Erdman & Gough, 1977; Nieboer et al., 1977; Puckett & Finegan, 1980). Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of Parmelia rigida and Cladonia leporina.

All of the other elements show normal levels at most localities. The high levels of K, Ca, Mg and Na at some localities probably reflect enrichment from the ocean spray. The high levels of lead at Lighthouse Isl. may be due to past activity around the lighthouse. The buildings there were in use until 1943 and most likely lead based paints were used. The buildings have now been removed but the stone lighthouse remains (built in 1857). At Isle of Palms Zn, Cu, Pb and Cr are high and are probably due to automobile and city pollution. Further study of these high lead levels is recommended.

These tables indicate that there may not be air pollution problems in the refuge but because the sulfur levels at some localities on Bull Isl. are as high as Isle of Palms, caution is needed in interpreting these data.

In 1983 an air monitor was established at Moores Landing near the refuge. Data are available for 1983-1988 and show the highest one hour maximum for sulfur dioxide occurring on June 1, 1988, with a concentration value of 221 µg/cubic meter (Air Pollution Measurements of the South Carolina Air Quality Surveillance Network). Dames & Moore (1985) report the sulfur dioxide one hour maximum for 1983 at 80 µg/cubic meter. These levels may not be damaging to most of the lichens now in the area but some of the most sensitive species may have already been eliminated.

Ozone values are fairly high. An Environmental Protection

Agency tabulation from the Moores Landing monitors reported that from March to December, 1987 the maximum one hour value of ozone was 0.107 ppm (occurring on May 2). During the 1988 state considered "ozone season" (April 1 - Oct. 31, 1988) the maximum one hour ozone value recorded was 0.116 ppm which occurred on May 31. Sulfur dioxide and ozone together may produce an enhanced effect on lichens and the levels in Cape Romain may or may not be damaging to lichens.

CONCLUSIONS

The lichen flora of Cape Romain National Wildlife Refuge is quite diverse even though there are not a lot of species present and there is no obvious impoverishment of the lichen flora in any part of the the refuge. However, because there are no historical records from the refuge, there is no way to be sure some species have not already been lost. There are only a few species in the most sensitive category to sulfur dioxide in the refuge and these are relatively uncommon. This rarity may be due more to ecological and climatic conditions than pollution since these species are quite healthy when present. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions but all of the species mapped are too uncommon to be of much value with this mapping technique. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses shows fairly high levels of sulfur in one species at some localities on Bull Isl. and at Isle Of Palms. With the fairly high levels of ozone also present, caution is needed before saying that additional sulfur emissions would not damage the lichen flora.

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APPENDIX I

Collection Localities

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

Charleston County

61272-61316 Bull Isl. Half mile NE of fire tower along Old Fort Road. In oak-pine forest with some sweet gum, magnolia and palms. 21 June 1988.

61317-61368 Bull Isl. Just SW of Jack Creek near north shore. On ridge with loblolly pines, oaks and palms near tidewater swamp area. 21 June 1988.

61369-61412 Bull Isl. Northeast Point on sand dunes and oak-pine forest near tip with oaks, pines, palms and holly. 23 June 1988.

61413-61447 Bull Isl. East of Moccasin Pond on ridge near shore with oaks, pines, palms and holly. 23 June 1988. CHEMICAL ANALYSIS.

61448-61492 Bull Isl. North side of Upper Summerhouse Pond. Around a salt marsh and fresh water pond with oaks and palms. 24 June 1988. CHEMICAL ANALYSIS.

61493-61531 Bull Isl. On ridge near south end of Beach Road 1 mile south of fire tower. On ridge with short oaks and some pines on rolling land. 24 June 1988.

61532-61559 Cape Isl. Along ridge with loblolly pines and sandy openings and in brush near shore. 27 June 1988. CHEMICAL ANALYSIS.

61560-61579 Lighthouse Isl. Near old lighthouse around loblolly pines with open sandy areas and along shore in brushy area. 28 June 1988. CHEMICAL ANALYSIS.

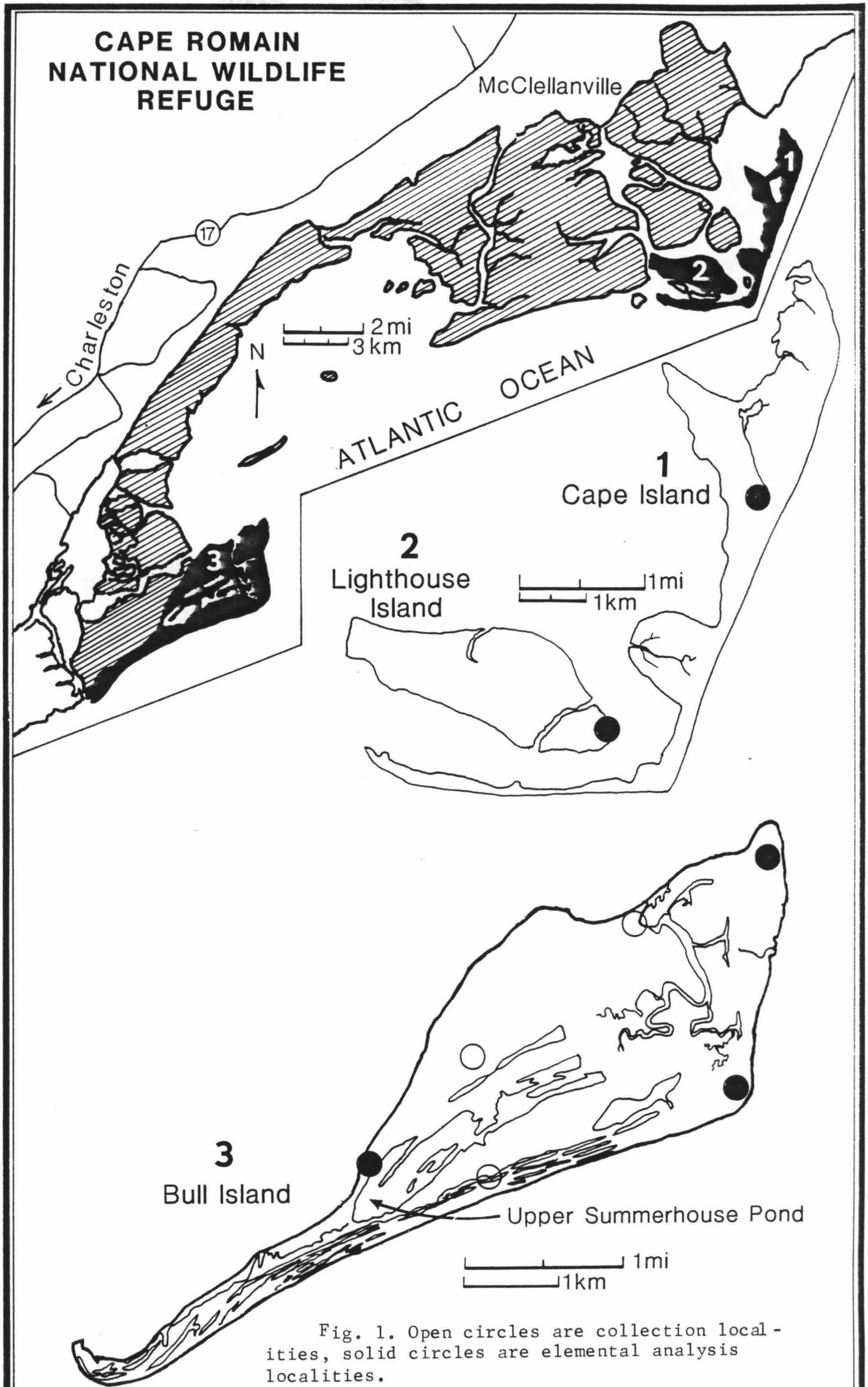

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in Cape Romain National Wildlife Refuge fall within the Sensitive category as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50ug sulfur dioxide per cubic meter (average annual). The intermediate category (I) includes species present between 50ug and 100ug. The S-I group falls between the Sensitive and Intermediate categories. There are no species within the refuge in the S-I category. Open circles on the maps are localities where the species was not found and solid circles are where it was found.

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

Fig. 2 *Dimerella lutea* (Dicks.) Trev.
Fig. 3 *Ochrolechia rosella* (Müll. Arg.)Vers.
Fig. 4. *Parmelia reticulata* Tayl.
Fig. 5. *Usnea strigosa* (Ach.) A. Eaton

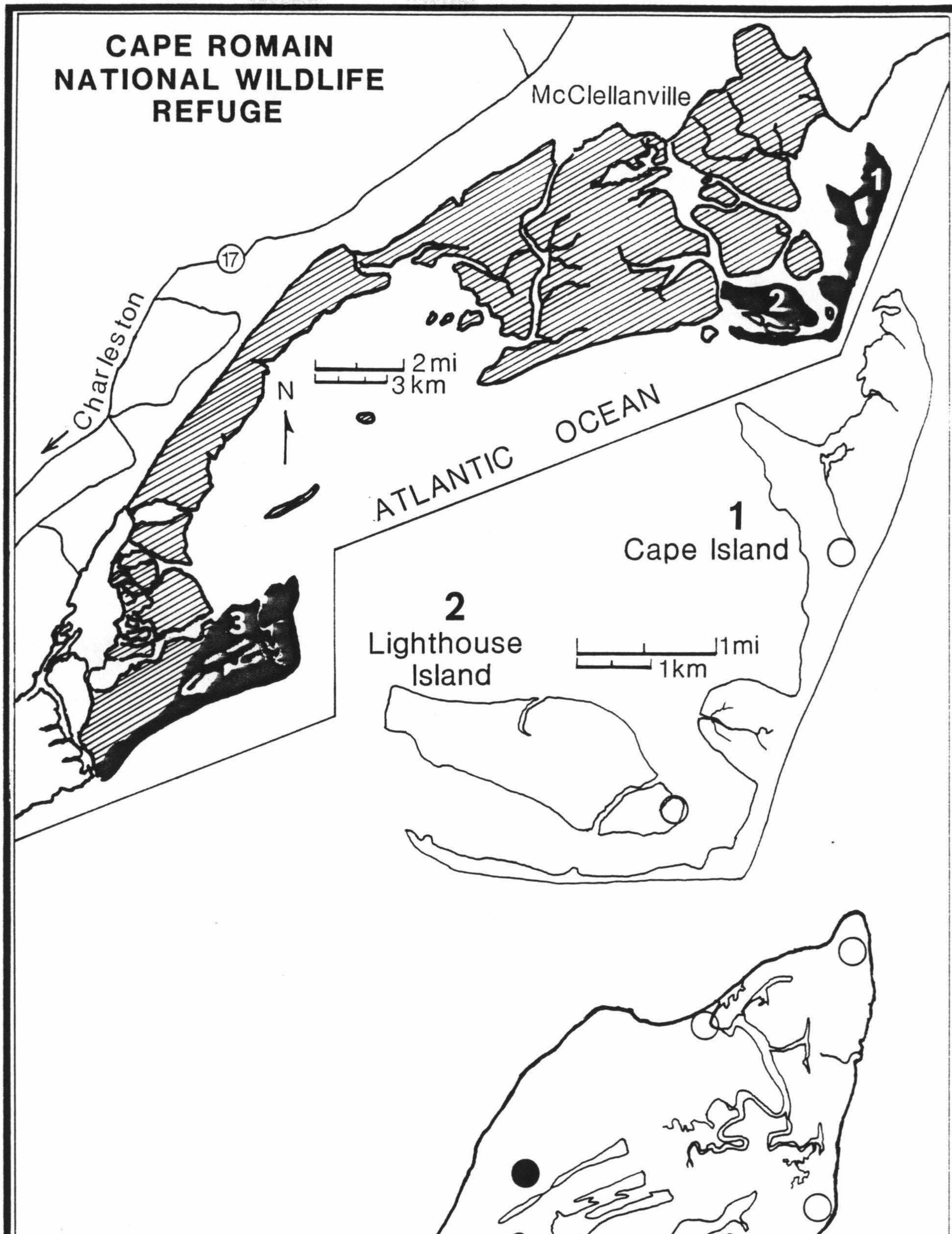

Fig. 2. Distribution of Dimerella lutea

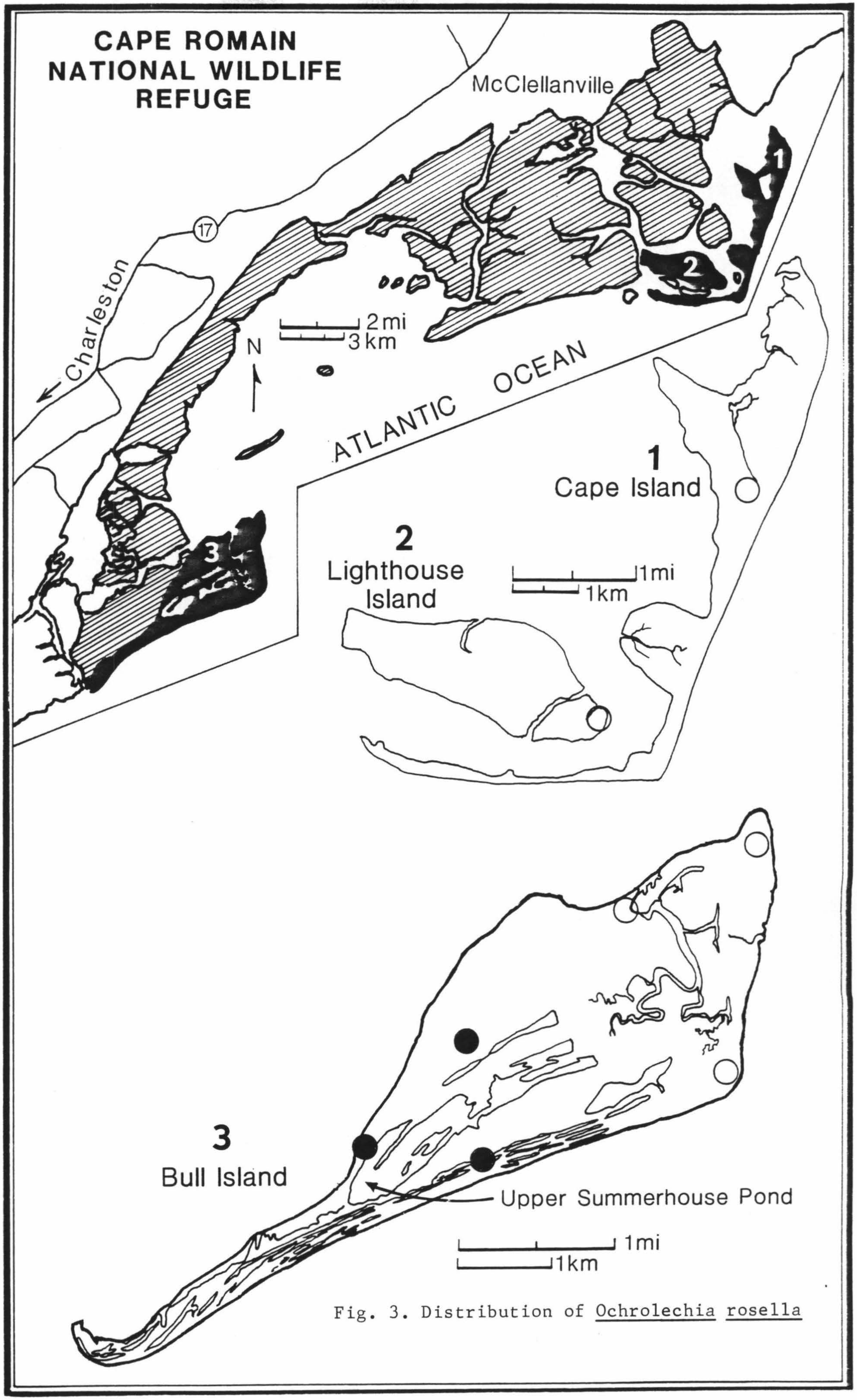

Fig. 3. Distribution of _Ochrolechia_ _rosella_

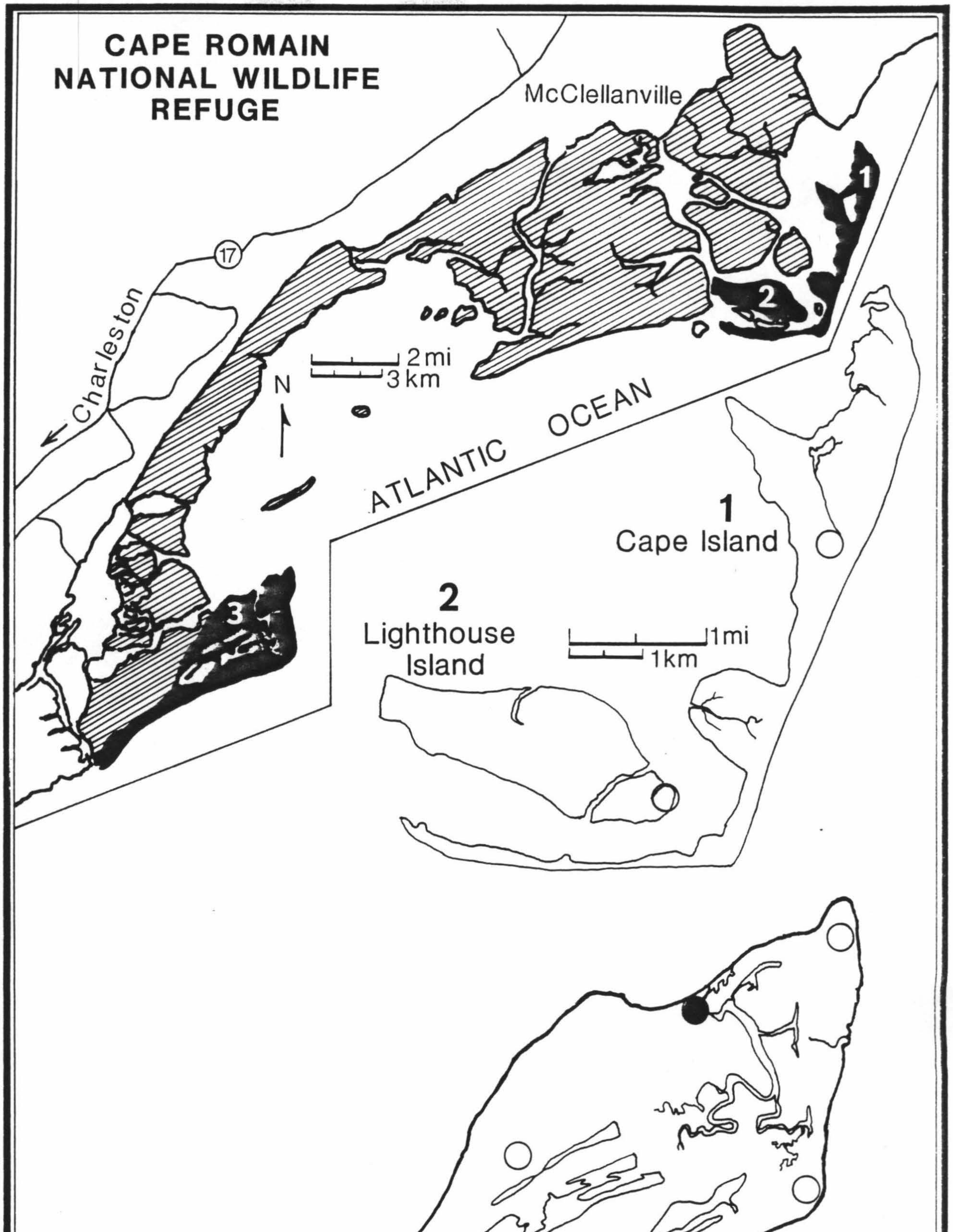

Fig. 4. Distribution of Parmelia reticulata

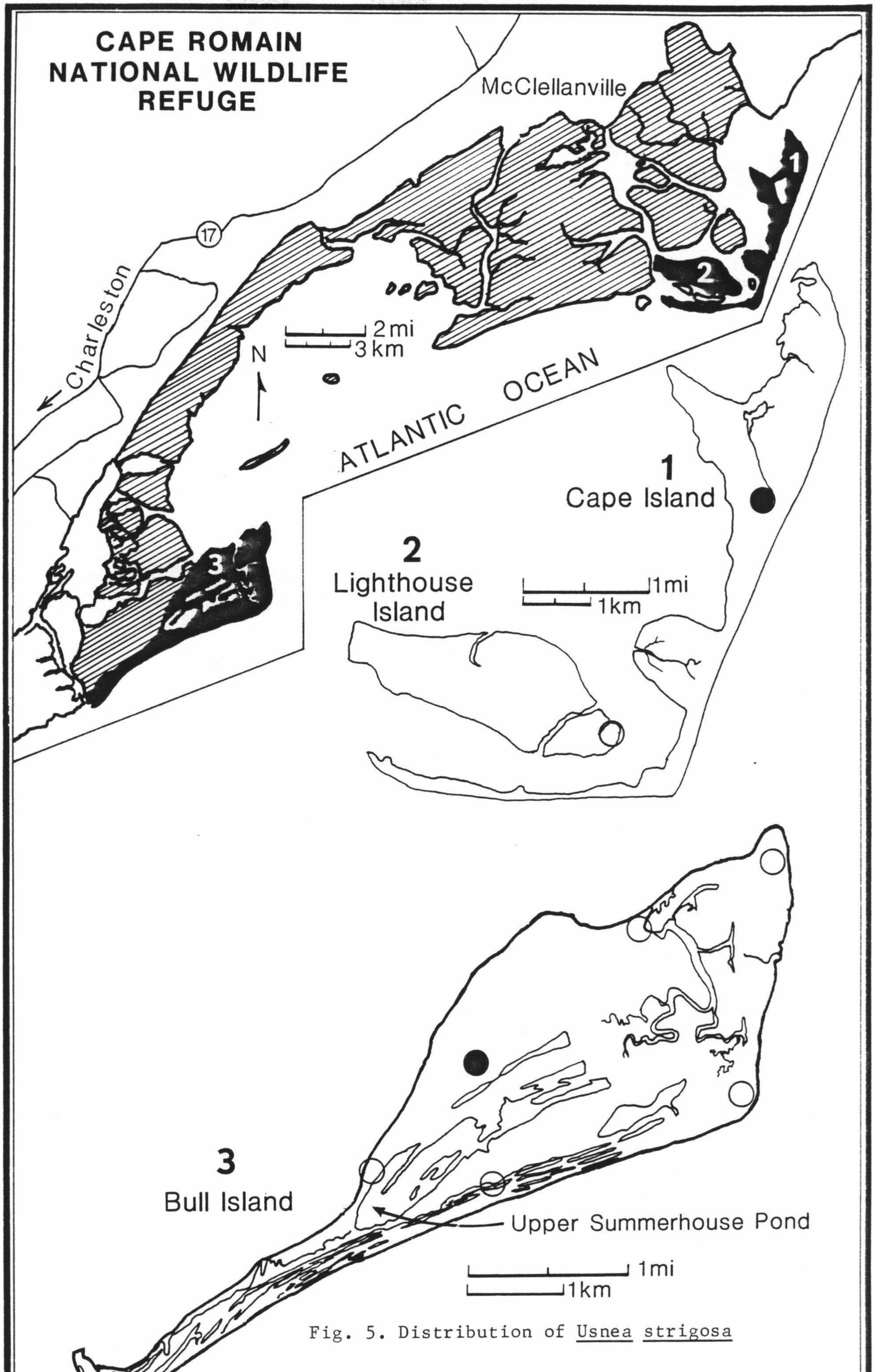

Fig. 5. Distribution of <u>Usnea strigosa</u>

APPENDIX III

Species Reported from Coastal Plain of South Carolina
References are included in Literature Cited.

Catapyrenium tuckermanii (Rav. ex Mont.) Thoms. Thomson, 1987
Chiodecton sanguineum (Sw.) Vain. Culberson, 1964
Cladina evansii (Abb.) Hale & W. Culb. Evans, 1947, Ahti, 1961
Cladina submitis (Evans) Hale & W. Culb. Ahti, 1961
Cladina subtenuis (des Abb.) Hale & W. Culb. Ahti, 1961
Cladonia leporina Fr. Evans, 1947, Dames & Moore, 1985
Cladonia pachycladodes Vain. Evans, 1947
Cladonia polycarpia G. K. Merr. Evans, 1944, Culberson, 1969
Cladonia subsetacea Robb. ex Evans Evans, 1947
Haematomma puniceum (Sm. ex Ach.) Mass. Culberson, 1963
Heterodermia albicans (Pers.) Swinsc. & Krog Culberson, 1966
Heterodermia obscurata (Nyl.) Trev. Culberson, 1966
Hyperphyscia syncolla (Tuck. ex Nyl.) Kalb Thomson, 1963
Lecanora caesiorubella Ach. subsp. glaucomodes Imshaug & Brodo, 1966
Lecanora chlarotera Nyl. Brodo, 1984
Lecanora hybocarpa (Tuck.) Brodo Brodo, 1984
Lecanora imshaugii Brodo in ed. Brodo, 1984
Lecanora louisianae B. de Lesd. Brodo, 1984
Leptogium austroamericanum (Malme) Dodge Sierk, 1964
Leptogium burnetiae Dodge Sierk, 1964
Leptogium cyanescens (Rabenh.) Körb. Sierk, 1964
Leptogium milligranum Sierk Sierk, 1964
Lobaria ravenelii (Tuck.) Yoshim. Jordan, 1973
Parmelia hypotropa Nyl. Culberson, 1973
Parmelia livida Tayl. Culberson, 1961
Parmelia madagascariacea (Hue) Abb. Hale, 1959
Parmelia mellissii Dodge Hale, 1965
Parmelia perforata (Jacq.) Ach. Berry, 1941, Culberson, 1973
Parmelia praesorediosa Nyl. Hale, 1965
Parmelia rigida Lynge Hale, 1965, Culberson, 1973, Dames & Moore, 1985
Parmelia rudecta Ach. Culberson & Culberson, 1956
Parmelia sphaerospora Nyl. Berry, 1941, Hale, 1959
Parmelia rampoddensis Nyl. Hale, 1959
Parmelia tinctorum Del. ex Nyl. Hale, 1965, Dames & Moore, 1985
Parmelia xanthina (Müll. Arg.) Vain. Hale, 1965
Parmeliopsis subambigua Gyeln. Hale, 1967
Peltigera didactyla (With.) Laundon Thomson, 1950
Peltigera polydactyla (Neck.) Hoffm. Thomson, 1950
Peltigera rufescens (Weis.) Humb. Thomson, 1950
Pertusaria hypothamnolica Dibb. Dibben, 1980
Pertusaria paratuberculifera Dibb. Dibben, 1980
Pertusaria tetrathalamia (Fee) Nyl. Dibben, 1980
Pertusaria texana Müll. Arg. Dibben, 1980
Pertusaria velata (Turn.) Nyl. Dibben, 1980
Phaeophyscia ciliata (Hoffm.) Moberg Thomson, 1963
Physcia crispa Nyl. Thomson, 1963

Pyxine caesiopruinosa (Nyl.) Imsh. Imshaug, 1957, Culberson & Hale, 1965
Pyxine sorediata (Ach.) Mont. Imshaug, 1957
Rinodina dissa (Stirt.) Mayrh. Imshaug, 1951