LICHENS AND AIR QUALITY
IN
OKEFENOKEE NATIONAL WILDLIFE REFUGE

Final Report

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by

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ABSTRACT

This project on lichens and air quality in Okefenokee National Wildlife Refuge (NWR) was designed as a base line study of the air quality as determined by the lichens. Field work was done during November and December, 1989, when 1833 collections were made at 34 localities throughout the Okefenokee NWR in Georgia. Localities for collecting were selected to give a general coverage of the refuge and to adequately represent the total lichen flora of the refuge. Undisturbed as well as disturbed habitats were studied. While collecting at each locality, observations were made about the general health of the lichens. At some localities additional material of selected species was collected for chemical analysis.

This list of species presents the first thorough listing of lichens from Okefenokee and includes 186 taxa. The lichen flora is quite diverse, with many species known from Florida and further south being present. The pondcypress trees are usually covered with <u>Parmelia</u> and <u>Usnea</u> species in addition to numerous crustose lichens. Most of the brush is covered with foliose and crustose lichens.

There seems to be 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 refuge that are known to be very sensitive to sulfur dioxide, but two of these are quite common

in Okefenokee. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The most sensitive lichen indicator technique is elemental analysis. The elemental analyses show normal levels of sulfur and other elements in the lichens and in spanish moss at all localities where they were collected.

It is recommended that when new or expanded pollution sources occur near the refuge a partial restudy be done. New lichen samples should be analyzed periodically (every 5-7 years), or when additional pollution is suspected. A total restudy should be done every 10-15 years to detect any changes in the lichen flora due to air quality or climatic changes.

PREFACE

Under a grant from the U. S. Fish & Wildlife Service a lichen study was performed in Okefenokee National Wildlife Refuge (NWR). The objectives of the study were to survey the lichens in the refuge, produce a lichen flora, collect and analyze lichens for chemical contents and evaluate the present lichen flora with reference to the air quality. The study will also establish baseline data for future restudy, and can be used to 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 in consultation with the Denver office and with personnel at the refuge.

The U. S. Fish & Wildlife Service personnel were very helpful during the field work in providing transportation in the refuge 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 up 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 outer protective layer, 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 live for many years. Therefore, they 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 become 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 an important factor in influencing the distribution of lichens.

Lichens are known to be very sensitive to low levels of many atmospheric pollutants. Many are damaged or killed by low levels of sulfur dioxide, nitrogen oxides, fluorides, or ozone- alone or in various combinations. Levels of sulfur dioxide as low as 13 ug/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 ug/cubic meter annual average (Laundon, 1967, Trass, 1973). The algae of the thallus are the first to be damaged by air pollution. The first indication of damage is discoloration due to the death of the algae which results in bleached lobes. This eventually 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). They are also 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 Pseudoparmelia caperata and Umbilicaria mammulata show visible damage due to artificial acid rain. They also report that similar symptoms were found in collections of these species from some localities in North America. On the other hand, Lechowicz (1987) reported that acid rain only slightly reduced growth of Cladina stellaris, but Hutchinson et al. (1986) reported that extremely acid precipitation (pH 2.5-3.0) 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.

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). Lichens are able to accumulate chemical elements in excess of their metabolic needs depending on the level of the elements in the substrate and air. Because lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of lichen thalli growing in areas of high fallout of certain elements will show elevated levels of those elements in the thallus. Toxic elements (such as high levels of sulfur) are also accumulated, and determination of the levels of these toxic elements can provide indications of the levels in the air. Elevated but sublethal levels of sulfur or other elements in lichen thalli might indicate incipient damaging conditions.

Okefenokee NWR is located in southeastern Georgia, with a small part in northern Florida. The outer borders of the refuge include some upland sandy areas with slash pine (Pinus elliottii), oaks (Quercus spp.), and palmetto (Serrenoa repens). The main part of the refuge consists of low wetland with sedges and grasses (called prairies) and raised islands and prairie borders with pondcypress (Taxodium ascendens), the less common baldcypress (T. distichum), hardwoods, pines, and swamp forest of sweetbay (Magnolia virginiana), swamp blackgum (Nyssa sylvatica), and swamp red maple (Acer rubrum). There are also extensive areas of swamp scrub including *Cyrilla* and other woody shrubs. Numerous waterways are scattered throughout the wetlands.

The Suwannee Canal was dug into the swamp about 1891-1892 in an attempt to drain the swamp for logging and agriculture. Many of the ridges along the borders of this canal have brush or pondcypress. The canal provides boat access to parts of the interior, but large areas are inaccessible due to the wet, mucky ground.

Several major fires have burned large portions of the swamp. There were major fires in 1844, 1860, 1910, 1932, and in 1954-1955 large fires burned about 90% of the swamp. Major logging occurred between 1909 and 1927.

There are literature reports of only a few lichens from Okefenokee, but no extensive lichen collecting has ever been done there. The only records are a few scattered reports in monographs (cited in Appendix I). Dr. Thomas Nash collected at one locality in 1970 and Dr. Robert Egan collected at two localities in 1973. Some of their specimens were studied in addition to the present collections.

METHODS

Field work was done during November and December, 1989, when 1833 collections were made at 34 localities throughout the refuge. A complete list of collection localities is given in Appendix II and the locations are indicated on Figure 1. Collection localities 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 based on observations of lichen abundance. Some vegetation types had no lichens (prairies) or were inaccessible, so most collection localities are located around the edge of the swamp or along the canals. Undisturbed as well as disturbed habitats were studied. At each locality voucher specimens of all species found were collected in an area of about 1 ha. to record the total flora for each collection site 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 of collections were done at the University of Minnesota with the aid of comparison material in the herbarium and using thin layer chromatography when 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. Lists of species found at each locality are available from this data base on request.

For elemental analyses of lichens and spanish moss (Tillandsia) sp., samples were collected in spunbound olefin bags at six localities in the refuge. At some localities all species were not present in quantities needed for the analysis. All samples were collected from trees. The lichen samples required collections from many trees to provide enough material for analysis, but the spanish moss was usually collected from just a few trees. Lichens collected were: Parmelia rampoddensis, Parmelia tinctorum, Usnea baileyi, and Usnea mutabilis. These species were selected because they are locally abundant and are relatively easy to clean. Ten to 20 grams of each species were collected at each locality in one bag. The material in each bag was later divided into three parts for the site replicates. No substrates without lichens were included for analysis.

The six localities were selected to provide a general coverage of the refuge. These sites are: 1.) Cowhouse Island at the northeastern part of the refuge, 2.) Pine Island on the western side, 3.) west of Chase Prairie along the Suwannee Canal, 4.) Camp Cornelia among the pines southeast of the refuge headquarters, 5.) Cedar Hammock Canal near the eastern side, and 6.) Mims Island at the southern end of the refuge (Figure 1).

Lichens were air-dried and cleaned of all bark and detritis under a dissecting microscope but thalli were not washed. Three samples from each bag for each species were submitted for analysis. Some samples were ground before being divided into replicates to provide analytical splits to check for instrument errors. The replicates are marked by "@" in the tables. Analyses for sulfur and other elements were performed by the Research Analytical Laboratory at the University of

Minnesota. A ground and pelleted 100-150 mg sample was prepared for total sulfur analysis by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determinations for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were performed simultaneously by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP). 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 was followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP. The usual NBS standards, including NBS peach leaves, were run with the samples from Okefenokee in addition to a lichen standard always included with these analyses.

RESULTS AND DISCUSSION

This species list in Appendix I presents the first thorough listing of lichens from Okefenokee NWR and includes 186 taxa of lichens. The most common species are *Parmelia caroliniana*, *P. formosana*, *P. tinctorum*, *Cladonia beaumontii*, *Buellia stillingiana*, *Haematomma puniceum*, *Graphis afzelii*, and *Usnea strigosa*.

There are no published regional lichen floras available for comparison with Okefenokee NWR lichen flora nor has there been any previous list from the refuge. The lichen flora is quite diverse with many species known from Florida and further south being present. The pondcypress trees on the refuge are usually covered with Parmelia and Usnea species in addition to numerous crustose lichens. Most of the brush is covered with foliose and crustose lichens.

The designation of "Rare" in the species list does not necessarily indicate poor air quality. Some of the species found only once are rare wherever they are found throughout their distributional range and are seldom collected everywhere. Some of these may have narrow ecological tolerances or may require special substrates that are rare in the area. Since there were no rocks at any of the collecting localities in the refuge, saxicolous species are missing.

The knowledge of tropical and subtropical lichens is very poor, and 19 species were found that could not be identified beyond the genus. Some of these are probably undescribed. These species are listed after the appropriate genera in the list.

There were no cases where lichens know to be sensitive to sulfur dioxide were observed to be damaged or killed. Healthy lichens were judged by presence of normal growth form, presence of ascocarps, and absence of necrotic areas. All species normally found fertile were also fertile in the refuge. Usnea baileyi rarely has apothecia, but in the refuge it was frequently found fertile. At some localities some lichens were generally in poor condition with dead lobes. These scattered localities were in forests that recently reached the stage of canopy closure in succession and many different species were in poor health (not just those most sensitive to sulfur dioxide). The changing ecological conditions are probably the cause of lichen damage on Cowhouse Island and at scattered locations along the Suwannee Canal. The spanish moss at all localities looked normal and healthy. In some habitats (especially the pine uplands), the use of fire to manage the forests has eliminated most lichens near or on the ground. The effects of the major fires in the swamp itself are not readily evident but might explain the distribution patterns of some of the species because some lichens require old-growth forests.

These observations indicate that there may be no air quality degradation in the refuge due to sulfur dioxide. However, without better historical species data for the area, it is impossible to prove that there were no sulfur dioxide effects in the past.

Another way of analyzing the lichen flora of an area for air pollution effects is to examine the distributions of the sensitive species within the area. Voids in the distributions might be caused by air pollution. Showman (1975) described and used this technique to assess 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.

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature (Wetmore, 1983), only a few of the lichens in the refuge have known sensitivity to sulfur dioxide. Species in the most sensitive category are usually absent when sulfur dioxide levels are above 50ug/cubic meter (annual average). There were only four species present in the S Category, and only two of these were very abundant (*Parmelia reticulata* and *Usnea strigosa*). The four species that occur in the refuge in the most sensitive category are:

Dimerella lutea (Dicks.) Trev.
Ochrolechia androgyna (Hoffm.) Arn.
Parmelia reticulata Tayl.
Usnea strigosa (Ach.) A. Eaton

The distributions of these species are mapped in Figures 2-5. Open circles on the maps are localities where the species was not found and solid circles are where it was found. There seems to be no pattern to the distributions of these lichens that might indicate directional air pollution effects. The absence of these mapped species at certain localities may be due to special ecological requirements, they may be uncommon throughout their range, or they may be absent because of degraded air quality.

The results of the elemental analyses of lichens and spanish moss are presented in Tables 1-2. Table 1 gives the results of the analyses for the three samples of each species at each locality arranged by species. The three readings with the same locality are site replicates. Table 2 gives the means and standard deviations for each set of three samples of each species at each locality. 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. The samples that were ground before being divided into the three parts (to determine instrument error) are indicated by "@" in the tables. The NBS standards and the lichen standard values were within the usual ranges for all elements.

Bosserman & Hagner (1981) reported on the elemental analysis of some lichens from Okefenokee NWR, but they lumped several species together for their analyses, and the resulting values may not be meaningful. Different species of the same genus can accumulate elements at varying rates, and they should not be lumped together unless it has been shown that these differences are not significant. There are no other reports of elemental analysis of any of the species used in this study; so, comparisons with other studies cannot be made for any of the elements.

The sulfur levels in lichens tested range from 340 to 850 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 ppm in the arctic (Tomassini et al, 1976), while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. The levels of sulfur in Okefenokee NWR lichens fall within the lower end of the range of values for other lichen species in the literature.

The values for all of the other elements are similar to those in the literature, and within Okefenokee NWR the analyses showed similar values at most localities. At Camp Cornelia sodium is surprisingly high in *Usnea baileyi* and manganese is higher in spanish moss. These elevated levels may be due to activities around the refuge headquarters, such as weed or insect spraying, fertilizing, or other factors.

The spanish moss (*Tillandsia*) had higher levels of sulfur than the lichens and ranged from 860 to 1270 ppm. The levels of sulfur and all other elements are similar or slightly lower than those reported for spanish moss from Big Thicket National Preserve, Texas by Benzing (1984). However, the Big Thicket study included both clean and dirty sites. Benzing (1984) reported sulfur levels from 1300 to 2500 ppm.

From these tables it can be seen that there is little correlation between element levels and location in the refuge. Element levels at all localities are quite similar in all species studied. All levels are comparable to reports for other lichens as listed in the Methods section of this report, although none of the species analyzed from Okefenokee NWR have been analyzed previously. There is no indication that there is any air quality problem in the refuge that can be detected with these techniques.

CONCLUSIONS

The present study can only provide a base-line (both floristic and elemental analysis) for future studies because there are no available data on the past lichen flora or elemental analyses of the lichens. The lichen flora of Okefenokee NWR is quite diverse, with many species present, and many lichen thalli at most localities. There seems to be no obvious impoverishment of the lichen flora in any part of the the refuge, except in the pine forests where fire has eliminated most of the lichens. 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 that are known to be sensitive to sulfur dioxide in the refuge and two of these were quite common throughout the refuge. This scarcity of known sensitive species is probably due to the lack of information about the sensitivity of southern lichens to sulfur dioxide rather than to pollution. Almost all of the tolerance levels come from studies of northern species in North America and Europe.

The maps of the distributions of the more sensitive species do not show any significant voids that cannot be explained by normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present or where ecological conditions are not changing (i.e., succession). The elemental analyses show normal levels of sulfur and other elements in the lichens and in spanish moss, and there is no locality (except possibly Camp Cornelia) with higher than usual levels of any of the elements.

RECOMMENDATIONS

This report forms a base-line that can be used to assess changes in lichen communities due to future developments around the refuge. It is recommended that when new or expanded pollution sources occur, a partial restudy be done. The most sensitive lichen indicator technique is the use of elemental analysis, so, new lichen samples should be analyzed periodically (every 5-7 years) or when additional pollution is suspected. A total restudy should be done every 10-15 years to detect any changes in the lichen flora due to air quality or climatic shifts.

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APPENDIX I

Lichen Species List

The following list of 186 taxa of lichens is based only on my collections and does not include those of Egan or Nash. 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/cubic meter, and those species in the Tolerant category are present at over 100ug/cubic meter. References for the species reported in the literature are also listed.

	Acrocordia cavata (Ach.) Harris in Vezda
	Arthonia punctiformis Ach. Rare
	Arthonia pyrrhula Nyl.
	Arthonia reniformis (Pers.) Ach. Rare
	1 additional unidentified Arthonia
	Arthopyrenia cinchonae (Ach.) Müll. Arg.
	Arthopyrenia malaccitula (Nyl.) Zahlbr.
	Arthothelium interveniens (Nyl.) Zahlbr.
	Arthothelium macrothecum (Fee) Mass.
	Bacidia schweinitzii (Tuck.) Schneid.
	Biatorella conspersa (Fee) Vain. Rare
	Brigantiaea leucoxantha (Spreng.) R. Sant. & Hafel.
	Buellia amphidexia Imsh. ex R. Harris
	Buellia bahiana Malme
	Buellia coccinea (Fee) Aptroot Rare
	Buellia curatellae Malme
	Buellia curtisii (Tuck.) Imsh.
	Buellia disciformis (Fr.) Mudd Rare
	Buellia elizae (Tuck.) Tuck. Rare
	Buellia leucomela Imsh. Rare
T	Buellia punctata (Hoffm.) Mass.

Buellia rappii Imsh. ined.
I Buellia stillingiana Steiner Also reported by Imshaug, 1951
Byssoloma leucoblepharum (Nyl.) Vain.
Byssoloma subdiscordans (Nyl.) P. James Rare
Calicium hyperelloides Nyl. Rare
1 additional unidentified Calicium
Catinaria laureri (Hepp ex Th. Fr.) Degel.
Cetraria fendleri (Nyl.) Tuck.
Chaenotheca brunneola (Ach.) Müll. Arg. Rare
Chiodecton montagnaei Tuck.
Chiodecton sanguineum (Sw.) Vain.
I Chrysothrix candelaris (L.) Laund.
Cladina evansii (Abb.) Hale & W. Culb. Powder-Puff deer moss
Cladina subtenuis (des Abb.) Hale & W. Culb.
Cladonia abbreviatula G. K. Merr.
Cladonia beaumontii (Tuck.) Vain.
Cladonia cristatella Tuck.
Cladonia didyma (Fee) Vain.
Cladonia floridana Vain. Rare
Cladonia hypoxantha Tuck.
Cladonia incrassata Flörke Rare
Cladonia leporina Fr.
Cladonia parasitica (Hoffm.) Hoffm. Rare
Cladonia peziziformis (With.) Laundon Rare
Cladonia ramulosa (With.) Laundon Rare
Cladonia rappii Evans
Cladonia santensis Tuck.
Cladonia simulata Robb.
Cladonia subradiata (Vain.) Sandst.
1 additional unidentified Cladonia
Coccocarpia erythroxyli (Spreng.) Swinsc. & Krog.
Coccocarpia palmicola (Spreng.) Arvid. & Galloway
Coccocarpia stellata Tuck.
S Dimerella lutea (Dicks.) Trev.
Dimerella pineti (Schrad. ex Ach.) Vezda Rare
Dirinaria applanata (Fee) Awas.
Dirinaria aspera (Magn.) Awas.
Dirinaria confluens (Fr.) Awas. Rare
Dirinaria picta (Sw.) Clem. & Shear
Graphina incrustans (Fee) Müll. Arg.
Graphina mendax (Nyl.) Müll. Arg. Rare
1 additional unidentified Graphina
Graphis afzelii Ach.
Graphis dumastioides Fink
Graphis insidiosa (Knight & Mitt.) Hook
Graphis subparilis Nyl. Rare
Graphis tenella Ach.
1 additional unidentified Graphis
Haematomma puniceum (Sm. ex Ach.) Mass.
Haematomma pustulatum Brodo & W. Culb.
Heterodermia albicans (Pers.) Swinsc. & Krog
Heterodermia casarettiana (Mass.) Trev.
Heterodermia corallophora (Tayl.) Skorepa

Heterodermia obscurata (Nyl.) Trev.
Heterodermia speciosa (Wulf.) Trev. Rare
Hypocenomyce anthracophila (Nyl.) P. James & G. Schneid. Rare
Lecanora atra (Huds.) Ach. Rare
Lecanora caesiorubella Ach. subsp. glaucomodes (Nyl.) Imsh. & Brodo
Lecanora caesiorubella subsp. prolifera (Fink) R. Harris
[Lecanora cenisia Ach. Reported by Brodo, 1984]
[Lecanora chlarotera Nyl. Reported by Brodo, 1984]
Lecanora cupressi Tuck.
Lecanora hybocarpa (Tuck.) Brodo
Lecanora impudens Degel.
Lecanora louisianae B. de Lesd.
I Lecanora pallida (Schreb.) Rabenh. var. pallida
Lecanora strobilina (Spreng.) Kieff.
2 additional unidentified Lecanora
Lecidea floridensis Nyl.
Lecidea russula Ach.
Lecidea varians Ach.
1 additional unidentified Lecidea
1 unidentified Lepraria
Leptogium austroamericanum (Malme) Dodge
Leptogium corticola (Tayl.) Tuck. Rare
Leptogium cyanescens (Rabenh.) Körb.
Leptogium denticulatum Tuck.
Leptogium floridanum Sierk
Leptogium isidiosellum (Ridd.) Sierk
Leptogium marginellum (Sw.) Gray
Lobaria tenuis Vain.
Lopadium puiggarii (Müll. Arg.) Zahlbr.
1 additional unidentified Lopadium
Megalospora tuberculosa (Fee) Sipman Rare
1 unidentified Melaspilea
Micarea denigrata (Fr.) Hedl. Rare
Micarea prasina Fr.
1 additional unidentified Micarea
Myriotrema glaucescens (Nyl.) Hale Rare
Myriotrema microporum (Mont.) Hale
Normandina pulchella (Borr.) Nyl.
Ocellularia americana Hale Rare
Ocellularia auberiana (Mont.) Hale
Ocellularia cavata (Ach.) Müll. Arg.
Ocellularia sanfordiana (Zahlbr.) Hale
S Ochrolechia androgyna (Hoffm.) Arn.
I Opegrapha atra Pers.
Opegrapha cinerea Chevall. Rare
Opegrapha rimalis Ach.
Opegrapha viridis (Ach.) Nyl.
1 unidentified Pannaria
Parmelia amazonica Nyl.
Parmelia aurulenta Tuck.
Parmelia caroliniana Nyl.
Parmelia confoederata W. Culb.

Parmelia cristifera Tayl.
Parmelia cryptochlorophaea Hale
Parmelia formosana Zahlbr.
Parmelia goebelii Zenk.
Parmelia horrescens Tayl.
Parmelia hypoleucina Stein
Parmelia laevigatula Nyl.
Parmelia livida Tayl.
Parmelia mellissii Dodge
Parmelia michauxiana Zahlbr.
Parmelia minarum (Vain.) Skorepa
Parmelia perforata (Jacq.) Ach. Also reported by Bosserman & Hagner, 1981.
Parmelia praesorediosa Nyl.
Parmelia rampoddensis Nyl.
S *Parmelia reticulata* Tayl.
Parmelia rigida Lynge
I *Parmelia rudecta* Ach.
Parmelia salacinifera Hale
Parmelia sphaerospora Nyl.
Parmelia subisidiosa (Müll. Arg.) Dodge
Parmelia subtinctoria Zahlbr.
Parmelia tinctorum Del. ex Nyl. Also reported by Merrill, 1909.
Parmelia ultralucens Krog
Parmelia xanthina (Müll. Arg.) Vain.
1 additional unidentified *Parmelia*
Parmeliopsis subambigua Gyeln.
I *Pertusaria amara* (Ach.) Nyl. Rare
Pertusaria copiosa Erichs. Also reported by Dibben, 1980.
Pertusaria leucostoma (Bernh.) Mass.
I *Pertusaria multipunctoides* Dibb.
Pertusaria sinusmexicani Dibb.
Pertusaria tetrathalamia (Fee) Nyl.
Pertusaria texana Müll. Arg. Also reported by Dibben, 1980.
Phaeocalicium polyporaeum (Nyl.) Tibell Rare
Phaeographina caesiopruinosa (Fee) Müll. Arg.
Phaeographina scalpturata (Ach.) Müll. Arg. Rare
Phaeographis sericea (Eschw. in Mart.) Müll. Arg.
1 additional unidentified *Phaeographis*
Phaeophyscia rubropulchra (Degel.) Moberg Rare
Phyllopsora corallina (Eschw.) Müll. Arg.
Physcia americana G. K. Merr. in Evans & Meyrow.
Physcia crispa Nyl.
Placynthiella oligotropha (Laund.) Coppins & James Rare
Pyrenula anomala (Ach.) Vain.
Pyrenula cinerea Zahlbr.
Pyrenula citriformis R. Harris
Pyrenula cruenta (Mont.) Vain.
Pyrenula marginata Hook. in Kunth
Pyrenula pseudobufonia (Rehm.) R. Harris Rare
Pyrenula punctella (Nyl.) Trev. Rare

Pyrenula ravenelii (Tuck.) R. Harris
Pyrgillus americanus Nyl.
Pyxine caesiopruinosa (Nyl.) Imsh. Rare
Pyxine daedalea Krog & Sant.
Pyxine eschweileri (Tuck.) Vain.
Pyxine subcinerea Stirt.
Ramalina montagnei De Not.
Ramalina paludosa B. Moore
2 additional unidentified *Ramalina*
Rinodina dissa (Stirt.) Mayrh. Rare
Rinodina lepida (Nyl.) Müll. Arg. Rare
Sticta weigelii (Ach.) Vain.
Strigula elegans (Fee) Müll. Arg. Rare
Thelotrema lepadinum (Ach.) Ach.
Thelotrema subtile Tuck.
Trapeliopsis flexuosa (Fr.) Coppins & James
Tricharia santessonii Hawksw.
Trypethelium mastoideum (Ach.) Ach.
Trypethelium tropicum (Ach.) Müll. Arg.
Trypethelium virens Tuck. ex Michen. in Darl.
Usnea baileyi (Stirt.) Zahlbr.
Usnea dimorpha (Müll. Arg.) Mot.
[*Usnea florida* (L.) Weber ex Wigg. Reported by Bosserman & Hagner, 1981 - possible misidentification]
[*Usnea longissima* Ach. Reported by Bosserman & Hagner - misidentification]
Usnea mutabilis Stirt.
Usnea rubicunda Stirt.
S *Usnea strigosa* (Ach.) A. Eaton Also reported by Bosserman & Hagner, 1981
Usnea trichodea Ach.
2 additional unidentified *Usnea*

APPENDIX II

Collection Localities

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

Charlton Co.

64237-64313 Chesser Isl. across from homestead site. In open hardwoods and slash pine with some palmetto. 14 Nov. 1989.

64314-64350 Two miles north of refuge offices on east side of swamp. In low area at edge of swamp on sandy soil with scrub brush and few pondcypress. 15 Nov. 1989.

64351-64414 Chesser Isl. On west side at edge of swamp near deer field stand. Areas with pondcypress, red maple and swamp scrub brush. 15 Nov. 1989.

64415-64452 Along Suwannee Canal about one mile west of boat landing at visitor center. On ridge at edge of canal with swamp scrub brush, bay and pondcypress. 16 Nov. 1989.

Ware Co.

64453-64504 Two mines west of boat landing along Suwannee Canal east of canal junction at canoe trail. Area with bay trees, pondcypress and swamp scrub brush. 16 Nov. 1989.

64505-64559 Soldiers Camp Isl. near southern end of refuge. In low area with slash pine, pondcypress and some small hardwood trees. 17 Nov. 1989.

64560-64615 Mims Isl. at southern end of swamp. In swamp cove with pondcypress and hardwood trees recently lightly burned. 18 Nov. 1989. CHEMICAL ANALYSIS.

64616-64664 At west end of Moonshine Ridge at southern end of swamp. In swamp scrub brush with small pondcypress and some slash pine. 18 Nov. 1989.

64665-64724 At junction of Suwannee Canal and Cedar Hammock Canal. Along canal ridge and back into open swamp prairie with small pondcypress and with brush along canal. 19 Nov. 1989.

64725-64765 Just east of Coffee Bay Rest Shelter along Suwannee Canal. In dense swamp scrub brush with scattered pondcypress and slash pines. 19 Nov. 1989.

Charlton Co.

64766- Floyds Isl. at southern end near cabin. In old oak and
64813 pine woods with slash pine, live oak and laurel oak on upland. 20 Nov. 1989.

64814- Stephen Foster State Park., Jones Isl. on west side of
64859 swamp. Behind campground in oak and pine forest with lots of palmetto. 21 Nov. 1989.

64860- The Pocket at west side of swamp and at southern edge
64900 of county. In pondcypress area with some slash pine. 21 Nov. 1989.

Ware Co.

64901- At south end of Suwannee River Sill at The Pocket on
64930 west side of the swamp. On pondcypress area at edge of swamp with some hardwood trees. 21 Nov. 1989.

64931- On southeast side of Pine Isl. at Suwannee River Sill
64972 in western part of swamp. In pondcypress and hardwood trees at edge of swamp. 22 Nov. 1989. CHEMICAL ANALYSIS.

Charlton Co.

64973- Northern edge of Middle Isl. near spillway of Suwannee
65023 River Sill. Along stream banks with red maple, oak and some pondcypress. 22 Nov. 1989.

Ware Co.

65024- Cowhouse Isl. about one mile east of park in northeast
65109 part of swamp. In upland oak woods with old live oak and some low areas with red maple. 24 Nov. 1989.

65110- Cowhouse Isl. 0.5 miles east of park in northeast part
65161 of swamp. At edge of swamp in pondcypress and swamp scrub brush. 24 Nov. 1989.

65162- At north end of Cedar Hammock Canal three miles
65213 northwest of boat landing. In pondcypress along edge of swamp prairie with few hardwood trees. 25 Nov. 1989. CHEMICAL ANALYSIS.

Charlton Co.

65214- Hickory Hammock in northwest part of swamp. On upland
65285 of island with oaks, pines and some hickory and magnolia. 27 Nov. 1989.

65286- Along Suwannee Canal 10 miles into swamp just west of
65341 Chase Prairie. In deciduous hardwood forest with some pondcypress and few pines. 28 Nov. 1989.

65342- 1.5 miles east of Bugaboo Isl. along Suwannee Canal.
65405 In pondcypress and hardwood area with some red maple and brush. 28 Nov. 1989.

65406-65448 One mile southeast of Double Lakes in northeast part of swamp in Carters Prairie. Along boat trail in pondcypress and brush at edge of prairie. 29 Nov. 1989.

Ware Co.

65449-65499 One mile west of Chesser Isl. along boat trail. At edge of areas of big dead pondcypress with young cypress and brush at edge of swamp prairie. 29 Nov. 1989.

Clinch Co.

65500-65576 At western edge of swamp two miles north of Rowells Isl. In low area with hardwood trees (black gum and bay) and some pondcypress. 30 Nov. 1989.

Charlton Co.

65577-65634 Kingfisher Landing on east side of swamp. Along bank of canal in dense swamp scrub brush with few pines. 1 Dec. 1989.

Ware Co.

65635-65688 Cowhouse Isl. 1.5 miles south of Okefenokee Swamp Park at north end of swamp. In edge of swamp with black gum and some pond cypress. 1 Dec. 1989. CHEMICAL ANALYSIS.

Charlton Co. Ga.

65802-65869 Camp Cornelia (refuge headquarters) on east side of swamp. In open oak woods west of buildings with turkey oak and some slash pines and other oaks. 6 Dec. 1989. CHEMICAL ANALYSIS

Ware Co.

65870-65924 South of Sapp Prairie in southwest part of swamp. Along west spur of abandoned roadway in swamp with slash pines and bay trees. 7 Dec. 1989.

65925-65984 Southwest of Sapp Prairie on higher peninsula in southwest part of swamp. In wet area with heavy brush, bay and pondcypress and few slash pines. 7 Dec. 1989.

Charlton Co.

65985-66033 North of Suwannee Canal at boat trail to Floyds Isl on west side of Chase Prairie. In older stand of pondcypress with few bay trees. 10 Dec. 1989.

66034-66082 West side of Chase Prairie along Suwannee Canal north of junction of canal and boat trail to Chase Prairie. At edge of prairie with pondcypress, bay and some brush. 10 Dec. 1989. CHEMICAL ANALYSIS.

Ware Co.

66083- West side of Grand Prairie in southeast part of swamp

66126 at Double Lakes. In stand of bay and brush at edge of small lake. 11 Dec. 1989.

Charlton Co.

66127- On east side of Chase Prairie along boat trail. In
66184 area of pondcypress at edge of prairie with few bay trees. 11 Dec. 1989.

Table 1a. Analysis of Okefenokee 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
Usnea baileyi	239	1463	7138	1414	281	244	64.1	53.1	30.9	1.6	2.4	4.0	1.3	0.3	0.3	525	Cowhouse Isl. @
Usnea baileyi	241	1418	9111	1373	194	199	59.6	50.8	29.5	1.6	2.0	5.0	1.0	0.1	0.5	480	Cowhouse Isl. @
Usnea baileyi	232	1425	9383	1195	175	174	60.4	48.1	28.9	1.5	1.8	5.8	*0.3	*0.1	*0.1	510	Cowhouse Isl. @
Usnea baileyi	236	1338	2963	547	214	172	64.8	27.1	17.5	1.1	1.9	3.7	#	0.4	*0.1	490	Pine Isl. @
Usnea baileyi	235	1299	2158	516	198	163	61.2	23.8	16.3	1.2	1.9	4.4	#	0.3	0.1	540	Pine Isl. @
Usnea baileyi	241	1287	3016	582	216	142	64.8	29.8	16.3	1.1	1.7	3.0	#	0.3	0.5	460	Pine Isl. @
Usnea baileyi	194	1198	1365	371	173	173	32.1	12.8	16.0	1.0	0.8	3.4	0.5	#	#	420	W. Chase @
Usnea baileyi	207	1205	1304	346	169	168	28.9	11.6	16.3	1.1	0.9	3.5	1.1	#	#	370	W. Chase @
Usnea baileyi	181	1201	1396	381	184	173	32.7	14.0	16.7	1.0	0.9	2.6	0.9	#	#	470	W. Chase @
Usnea baileyi	225	1307	2198	616	157	169	63.2	11.3	23.3	1.1	1.2	3.9	0.6	0.3	#	440	Cedar Hamm. @
Usnea baileyi	233	1305	2360	616	159	170	70.8	11.3	23.2	1.1	1.2	3.9	0.8	0.5	#	365	Cedar Hamm. @
Usnea baileyi	217	1270	2319	596	168	229	67.4	11.5	22.3	1.1	1.2	3.2	0.9	0.2	#	340	Cedar Hamm. @
Usnea baileyi	249	1320	738	371	139	147	244.9	22.8	22.4	1.7	2.7	4.5	1.1	0.2	#	600	Camp Cornelia @
Usnea baileyi	200	1262	1289	593	196	212	104.6	13.3	19.6	1.5	2.0	3.0	#	0.3	#	440	Mims Isl. @
Usnea baileyi	201	1198	1283	559	171	193	108.6	13.1	19.6	1.6	2.1	2.1	#	0.4	#	520	Mims Isl. @
Usnea baileyi	169	1167	1075	494	183	210	92.9	10.5	18.3	1.4	1.9	2.9	#	0.4	#	490	Mims Isl. @
Usnea mutabilis	353	1302	1536	674	273	199	206.5	50.5	19.9	1.8	2.5	4.5	1.0	0.3	#	580	Camp Cornelia @
Usnea mutabilis	403	1397	2151	728	244	177	192.2	57.4	21.7	1.8	2.2	5.3	1.1	0.2	#	590	Camp Cornelia @
Usnea mutabilis	372	1350	2158	759	262	188	184.9	57.6	20.5	1.7	2.0	5.0	1.4	0.3	#	600	Camp Cornelia @
Parmelia rampoddensis	394	1741	3180	705	257	130	52.0	28.5	29.5	1.8	5.0	3.3	1.0	0.3	0.3	680	Cowhouse Isl.
Parmelia rampoddensis	435	1884	3275	758	274	140	45.7	28.5	30.2	2.2	5.7	7.3	0.6	0.4	0.7	700	Cowhouse Isl.
Parmelia rampoddensis	395	1791	4074	907	293	144	42.5	41.4	35.0	2.1	5.9	6.2	0.5	0.2	0.2	740	Cowhouse Isl.
Parmelia rampoddensis	542	2050	2791	604	244	120	41.5	91.0	21.9	1.9	4.7	4.8	#	0.3	#	650	Pine Isl. @
Parmelia rampoddensis	467	2021	2728	617	270	139	40.1	88.6	22.6	1.9	4.9	6.0	#	0.3	#	580	Pine Isl. @
Parmelia rampoddensis	522	2004	2848	620	257	133	50.4	84.4	21.2	1.9	4.8	5.7	#	0.4	#	710	Pine Isl. @
Parmelia rampoddensis	431	1720	1228	313	378	211	31.0	10.3	31.1	1.4	4.4	5.0	#	0.7	0.2	580	W. Chase
Parmelia rampoddensis	367	1592	756	251	331	188	28.5	7.5	30.9	1.4	3.1	5.0	#	0.6	0.2	640	W. Chase
Parmelia rampoddensis	456	1948	928	271	269	150	27.6	6.1	38.5	1.4	3.5	4.1	#	0.5	0.5	680	W. Chase
Parmelia rampoddensis	358	1686	1436	514	374	212	36.7	25.2	41.6	1.6	3.7	9.2	0.6	0.5	1.2	600	Cedar Hamm.
Parmelia rampoddensis	333	1675	1053	435	514	296	69.0	17.7	37.0	1.7	3.8	11.3	1.5	0.8	0.2	630	Cedar Hamm.
Parmelia rampoddensis	334	1700	1398	563	346	201	81.5	28.4	31.9	1.7	3.9	9.5	1.6	0.6	0.3	720	Cedar Hamm.
Parmelia rampoddensis	454	1962	3177	856	297	151	59.0	29.2	26.3	3.1	4.8	6.6	0.9	0.5	0.2	850	Mims Isl.
Parmelia rampoddensis	533	2105	3030	896	319	165	62.6	31.2	27.1	3.2	4.9	6.3	1.2	0.6	0.2	730	Mims Isl.
Parmelia rampoddensis	529	2153	3713	1006	267	136	58.4	31.8	28.3	3.2	5.2	5.9	1.0	0.3	0.4	700	Mims Isl.
Parmelia tinctorum	489	2110	27574	637	241	109	73.1	22.1	27.6	2.5	3.0	5.7	*0.3	0.5	0.4	760	Mims Isl.
Parmelia tinctorum	342	1711	57402	548	325	94	60.4	27.0	28.0	2.4	2.9	7.5	0.7	0.6	0.5	660	Mims Isl.
Parmelia tinctorum	392	1848	37540	680	296	118	59.1	26.0	22.2	2.8	2.8	8.8	1.0	0.3	0.7	670	Mims Isl.
Cladina substygia	500	1099	208	204	209	106	155.2	12.0	10.7	1.1	1.4	2.3	1.2	0.2	#	320	Camp Cornelia
Cladina substygia	374	971	160	150	300	153	178.3	7.4	9.3	0.9	1.4	2.1	0.9	0.6	#	450	Camp Cornelia
Cladina substygia	434	1137	209	185	208	106	149.5	10.4	9.1	0.9	1.6	1.9	0.7	0.5	#	410	Camp Cornelia
Cladonia leporina	326	768	88	107	1067	350	142.6	8.5	11.6	1.5	1.5	7.7	0.9	1.6	#	470	Camp Cornelia
Cladonia leporina	371	832	81	113	969	320	166.5	7.9	11.6	1.5	1.4	7.8	*0.3	1.4	#	455	Camp Cornelia
Cladonia leporina	365	772	85	112	1049	362	150.8	9.2	11.4	1.4	1.5	7.5	1.3	1.6	#	480	Camp Cornelia

Table 1b. Analysis of Okefenokee spanish moss
Values in ppm of dry weight

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality	
<u>Tillandsia</u>	181	2913	1587	1615	368	299	2090.0	56.3	22.6	3.4	7.3	8.1	2.5	1.0	0.5	1060	Cowhouse Isl.	
<u>Tillandsia</u>	161	2559	1614	1540	405	323	1671.0	50.2	23.6	3.7	7.0	6.9	2.5	0.9	0.5	1110	Cowhouse Isl.	
<u>Tillandsia</u>	180	2489	1475	1457	468	374	1636.7	50.7	20.8	3.9	7.0	10.3	2.2	1.0	0.3	1090	Cowhouse Isl.	
<u>Tillandsia</u>	190	3076	3263	2269	321	237	2861.5	53.6	18.3	3.0	5.6	5.5	3.2	0.6	1.1	1060	Pine Isl.	@
<u>Tillandsia</u>	199	3182	3256	2313	324	242	2778.3	55.7	18.7	3.1	5.8	6.8	2.3	0.7	0.2	1080	Pine Isl.	@
<u>Tillandsia</u>	197	3270	3397	2336	355	263	2944.2	55.7	19.2	3.3	6.0	6.9	3.0	0.8	*0.1	1110	Pine Isl.	@
<u>Tillandsia</u>	140	3745	2222	1301	360	276	325.7	50.3	16.2	2.3	5.6	7.5	1.4	0.7	#	990	W. Chase	
<u>Tillandsia</u>	196	3094	2905	1334	490	358	359.4	42.4	18.2	2.8	4.9	9.3	2.8	0.7	#	1035	W. Chase	
<u>Tillandsia</u>	190	4232	3507	1454	469	347	541.7	50.7	17.4	2.2	5.4	7.9	2.3	0.7	#	1100	W. Chase	
<u>Tillandsia</u>	222	3473	4203	1783	480	366	574.1	61.4	24.2	2.9	5.9	7.5	2.8	1.1	*0.1	1000	Cedar Hamm.	
<u>Tillandsia</u>	232	3406	3024	1524	486	325	611.0	42.9	13.7	1.6	4.8	5.1	0.7	0.6	0.1	860	Cedar Hamm.	
<u>Tillandsia</u>	219	3291	3142	1658	446	325	655.3	52.7	19.1	2.6	5.4	8.1	2.3	0.5	0.3	920	Cedar Hamm.	
<u>Tillandsia</u>	241	5914	2525	1536	296	180	774.6	266.4	33.9	3.4	8.7	5.0	3.0	0.8	#	1100	Camp Cornelia	
<u>Tillandsia</u>	224	5646	2525	1635	302	188	1545.5	298.2	28.5	3.0	9.1	4.3	2.9	0.8	#	1150	Camp Cornelia	
<u>Tillandsia</u>	244	5634	2568	1582	348	227	1250.5	288.3	31.6	3.5	9.4	4.5	2.4	0.8	#	1190	Camp Cornelia	
<u>Tillandsia</u>	273	3268	1952	1450	570	374	381.0	35.0	13.9	2.3	6.9	8.0	1.9	0.7	#	1160	Mims Isl.	
<u>Tillandsia</u>	307	4780	2679	2085	527	338	372.0	41.0	18.8	2.5	7.5	6.3	3.0	0.8	#	1270	Mims Isl.	
<u>Tillandsia</u>	348	4280	2694	2016	583	378	417.4	36.0	18.2	2.9	7.2	7.6	3.1	0.9	#	1185	Mims Isl.	

* = 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

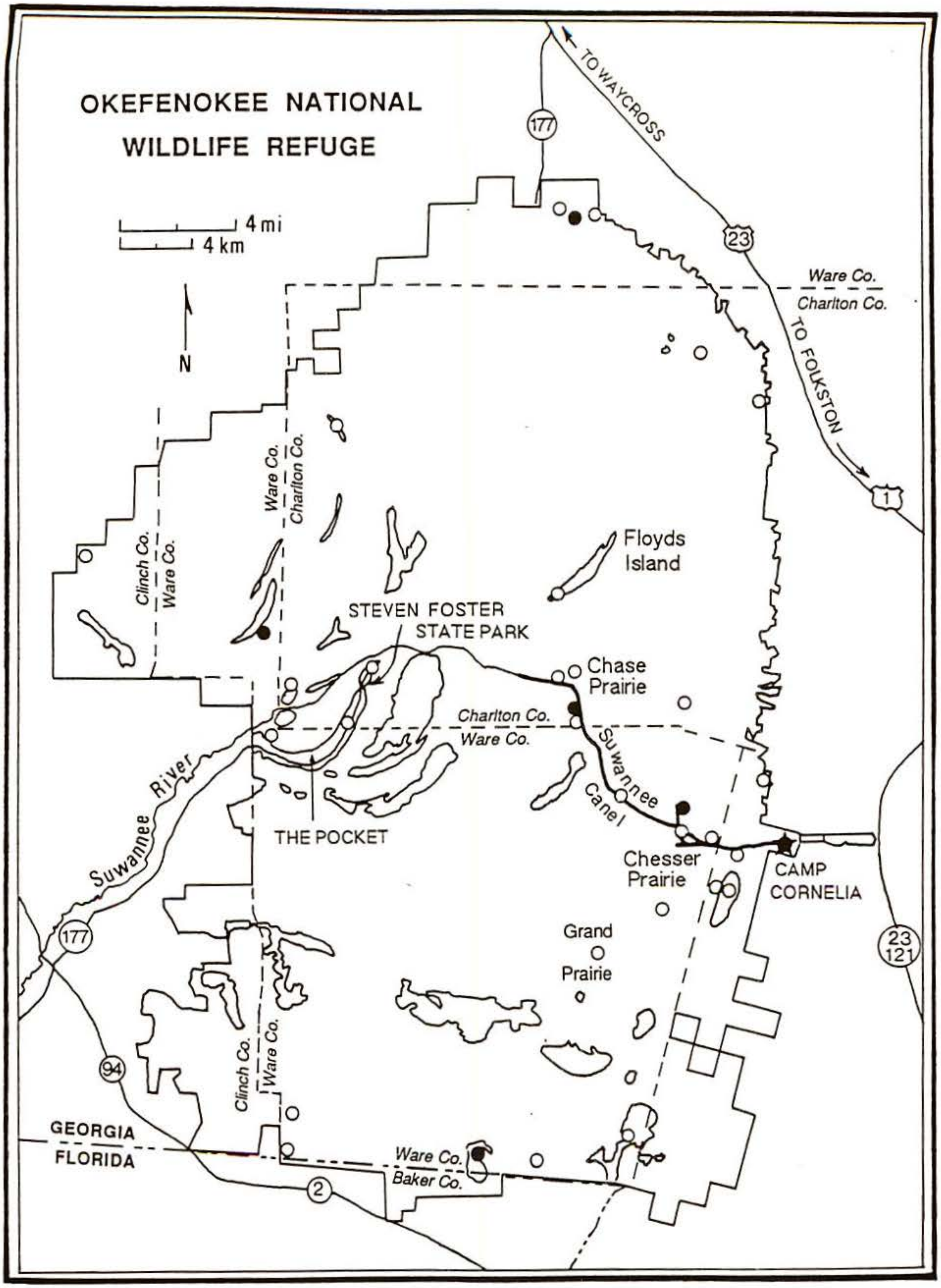

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.

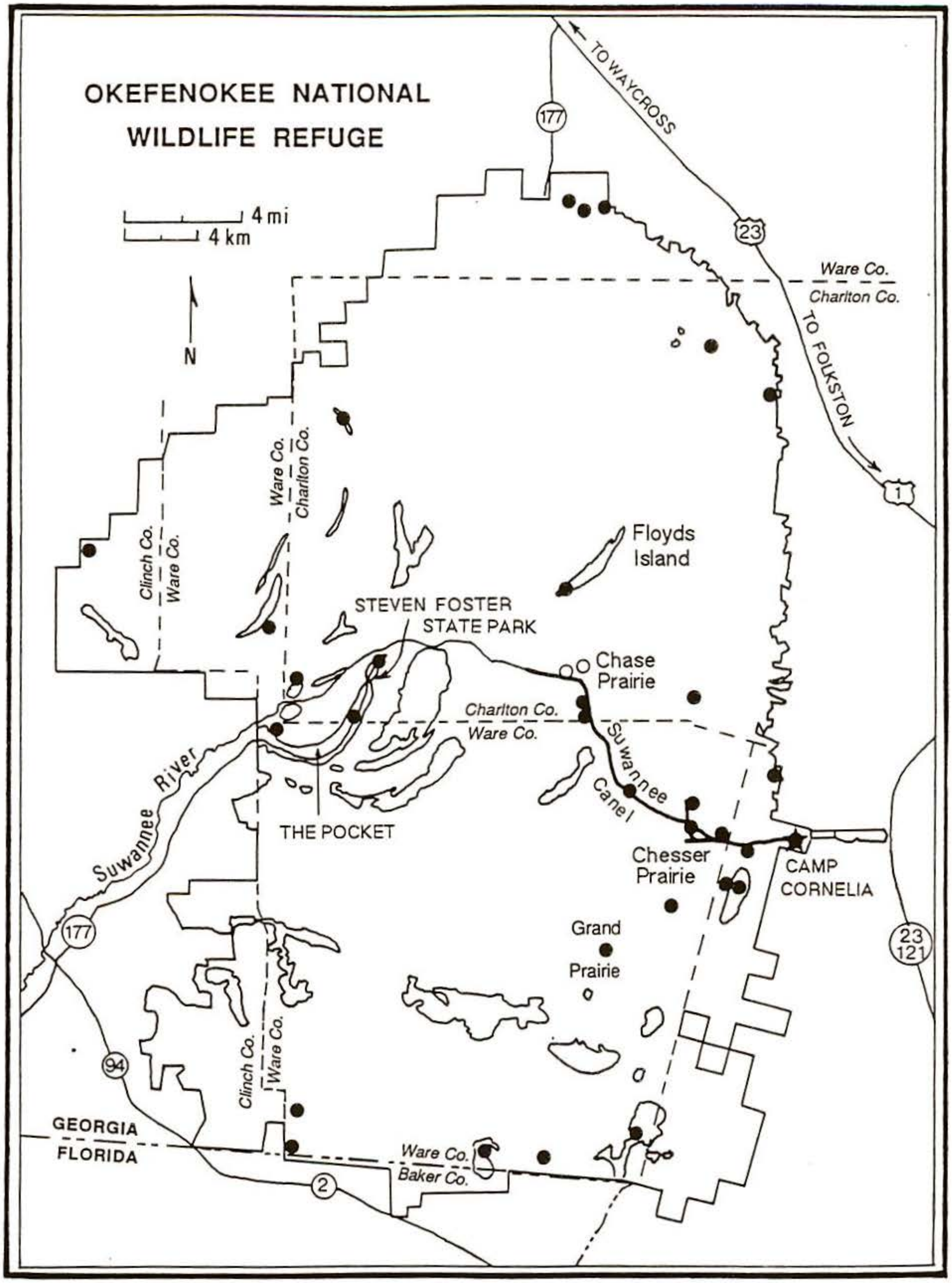

Fig. 5. Distribution of Usnea strigosa