Working

LICHENS AND AIR QUALITY

IN

HOT SPRINGS NATIONAL PARK

Final Report

Prepared for

National Park Service

and

Biological Resources Division
U. S. Geological Survey

by

Clifford M. Wetmore
Plant Biology Department
University of Minnesota
St. Paul, Minnesota
wetmore@tc.umn.edu

and

James P. Bennett
Biological Resources Division
U. S. Geological Survey
University of Wisconsin
Madison, Wisconsin
jpbennet@facstaff.wisc.edu

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ABSTRACT

This study of the lichens of Hot Springs National Park was designed 1) to collect lichens for lichen species lists, 2) to collect lichens for elemental analysis, 3) to study the health and distributions of species most sensitive to air pollution, and 4) to assess the effects of air quality on lichens. Thirty two localities were studied in the park and 1279 collections were made. Samples of four species were also collected at 12 localities for elemental analysis.

The lichen flora is quite diverse for this area. There were 161 species present and one undescribed new species was found in the park. All of the lichens found were in good health and with normal fertility. The lichens studied by elemental analysis showed higher elemental levels in the southwest part of the park. There seemed to be no indications of threatening air quality problems (primarily from sulfur dioxide) to the lichen flora in the park.

Recommendations are for periodic (5 year) restudy of the lichens by elemental analysis. A complete lichen restudy of the lichen flora should be done every 10-15 years. The localities where undescribed species were found should receive protection. If construction or maintenance activities are planned within these areas a lichenologist should be consulted to prevent loss of species. Further investigation of the higher levels of certain elements at some localities should be done.

PREFACE

Under a purchase order from the Biological Resources Division of the US Geological Survey a lichen study was performed in Hot Springs National Park. The objectives were to 1), survey the lichens, 2), produce an inventory of the lichen flora, 3), collect and analyze lichens for chemical contents, and 4), evaluate the lichen flora with reference to the air quality. This establishes baseline data to determine the future change in air quality. All herbarium work was done at the University of Minnesota Herbarium with consultation with Dr. James P. Bennett and with personnel in the parks.

All Park Service personnel have been very helpful during the field work which has contributed significantly to the success of the project. The study was made possible by funds from the USGS Biological Resources Division. Dr. James P. Bennett did the elemental and statistical analysis. 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 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 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 and the first indication of damage is discoloring and death of the algae causing bleached lobes, which quickly leads to the death of the lichen. 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.

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 (less than pH 3.5) 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 sublethal but elevated levels in the air.

This report is divided into two parts. Part I treats the lichen flora and Part II treats the elemental analysis.

Part I

Lichen Flora

The park

The park is located in central Arkansas and was set aside as a Reservation in 1832 and redesignated a national park in 1921. It now has about 5840 acres surrounding the city of Hot Springs with a small section in the center of the city.

Most of the ridges and hillsides have an old forest of mixed hardwoods with oaks (*Quercus*) and hickory (*Carya*) with areas of shortleaf pines (*Pinus echinata*). On the lower slopes and in the valleys are maples (*Acer*), sweetgum (*Liquidambar*), and *Carpinus* and *Magnolia* near steams and ponds. Non-calcareous rock outcrops are common along the ridges. During the winter before the collecting was done there was a severe ice storm that caused much tree damage in some parts of the park. This proved to be a benefit to this study because lichens normally found mainly in the treetops could be collected from the fallen trees and branches.

Prior to this study there were few lichens known from the park and no published lists. In the University of Minnesota herbarium there are seven lichens collected by D. Demaree from the park in 1954, 1960 and 1961, and two collected by W. Connell without a date. The park herbarium has 60 lichen collections made in 1981 by Jewell Moore that were studied along with the new collections. There were no lichen species in these historical collections that were not collected in 2001.

Methods

Field work was done during May, 2001 when 1279 collections were made at 32 localities in the park. A complete list of collection localities is given in Appendix I and the localities are indicated on the map of the park (Fig. 1). Collection localities, about 2 acres in size, were selected 1), first to give a general coverage of the park, 2), to sample all vegetational types, and 3), to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats (such as old roadsides and trails) were studied. No collections were made in the central (city) part of the park. 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. Lichen health was evaluated by looking for damaged or dying lichens on all of the trees where collections were made. The presence of many dead, dying, or abnormal thalli of particular species at a locality would indicate poor health, but an occasional damaged thallus is not significant.

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. All specimens deposited at the University of Minnesota have been entered into the herbarium computerized data base maintained there.

Species list

The following lists of lichens is based on these collections. Species found only once are indicated by "RARE". In the first columns the letters indicate the sensitivity to sulfur dioxide, if known, according to the categories proposed by Wetmore (1983): S=Sensitive, I=Intermediate, T=Tolerant. S-I is intermediate between Sensitive and Intermediate and I-T is intermediate between Intermediate and Tolerant. Species in the Sensitive category are absent when annual average levels of sulfur dioxide are above 50 μg per cubic meter. The Intermediate category includes those species present between 50 and 100 μg and those in the Tolerant category are present at over 100 μg per cubic meter. Those species without sensitivity designations have unknown sensitivity.

T *Amandinea punctata* (Hoffm.) Coppins & Scheid.
Anaptychia palmulata (Michaux) Vainio
Anzia colpodes (Ach.) Stizenb.
Arthonia caesia (Flotow) Körber RARE
I *Arthonia radiata* (Pers.) Ach.
Arthothelium taediosum (Nyl.) Müll. Arg. RARE
Bacidia polychroa (Th. Fr.) Körber
Bacidia schweinitzii (Fr. ex Michener) A. Schneider
Bacidia suffusa (Fr.) A. Schneider RARE
Buellia curtisii (Tuck.) Imsh.
Buellia spuria (Schaerer) Anzi
Buellia stigmaea Tuck.
I *Buellia stillingiana* J. Steiner
Calicium salicinum Pers. RARE
Caloplaca camptidia (Tuck.) Zahlbr. RARE
S-I *Caloplaca cerina* (Ehrh. ex Hedwig) Th. Fr.
Caloplaca cinnabarina (Ach.) Zahlbr. RARE
Caloplaca pollinii (Massal.) Jatta RARE
I-T *Caloplaca vitellinula* (Nyl.) Oliv. RARE
S-I Candelaria concolor (Dickson) Stein
Candelaria fibrosa (Fr.) Müll. Arg.
Candelariella efflorescens Harris & Buck
Canomaculina conferenda (Hale) Elix
Canomaculina subtinctoria (Zahlbr.) Elix
Canoparmelia caroliniana (Nyl.) Elix & Hale
Canoparmelia crozalsiana (B. de Lesd. ex Harm.) Elix & Hale
Canoparmelia texana (Tuck.) Elix & Hale
Catapyrenium tuckermanii (Rav. ex Mont.) Thoms.
I *Cetraria orbata* (Nyl.) Fink RARE
Cetraria viridis Schwein.

I *Chrysothrix candelaris* (L.) Laund.
Cladina subtenuis (Abbayes) Hale & Culb.
Cladonia caespiticia (Pers.) Flörke
I *Cladonia coniocraea* (Flörke) Sprengel
I *Cladonia cristatella* Tuck.
Cladonia cryptochlorophaea Asah. RARE
Cladonia cylindrica (Evans) Evans
Cladonia didyma (Fée) Vainio RARE
Cladonia furcata (Hudson) Schrader
Cladonia grayi G. Merr. ex Sandst.
Cladonia macilenta Hoffm. RARE
Cladonia parasitica (Hoffm.) Hoffm.
Cladonia peziziformis (With.) Laund.
Cladonia piedmontensis G. Merr.
Cladonia pleurota (Flörke) Schaerer RARE
Cladonia pyxidata (L.) Hoffm.
Cladonia robbinsii Evans
Cladonia squamosa Hoffm.
Cladonia strepsilis (Ach.) Grognot RARE
Cladonia subcariosa Nyl.
Coccocarpia palmicola (Sprengel) Arv. & Galloway
Collema conglomeratum Hoffm.
Collema subflaccidum Degel.
Dermatocarpon luridum (With.) Laund. RARE
Dimelaena oreina (Ach.) Norman
Diploschistes actinostomus (Ach.) Zahlbr.
Dirinaria frostii (Tuck.) Hale & Culb.
Flavoparmelia baltimorensis (Gyelnik & Fariss) Hale
I *Flavoparmelia caperata* (L.) Hale
Fuscopannaria leucosticta (Tuck.) Jo/rg.
I *Graphis scripta* (L.) Ach.
Heterodermia albicans (Pers.) Swinscow & Krog
Heterodermia echinata (Taylor) Culb. RARE
Heterodermia granulifera (Ach.) Culb. RARE
Heterodermia hypoleuca (Muhl.) Trevisan
Heterodermia obscurata (Nyl.) Trevisan
Heterodermia speciosa (Wulfen) Trevisan
Homostegia piggotii (Berk. & Broome) P. Karst.
Hypotrachyna livida (Taylor) Hale
Hypotrachyna pustulifera (Hale) Skorepa
Lecanora caesiorubella subsp. *prolifera* (Fink) Harris
Lecanora hybocarpa (Tuck.) Brodo
Lecanora imshaugii Brodo
Lecanora strobilina (Sprengel) Kieffer
Lecanora thysanophora Harris in Harris & Tonsb. RARE

Lecidella euphorea (Flörke) Hertel RARE
Lepraria lobificans Nyl.
Leptogium austroamericanum (Malme) C. W. Dodge
Leptogium chloromelum (Sw. ex Ach.) Nyl. RARE
Leptogium corticola (Taylor) Tuck.
Leptogium cyanescens (Rabenh.) Körber
Leptogium denticulatum Tuck.
Leptogium hirsutum Sierk
Leptogium milligranum Sierk
Loxospora elatina (Ach.) Massal.
Loxospora pustulata (Brodo & Culb.) Harris
Micarea erratica (Körber) Hertel et al. RARE
Micarea peliocarpa (Anzi) Coppins & R. Sant. RARE
Mycocalicium subtile (Pers.) Szat.
Myelochroa aurulenta (Tuck.) Elix & Hale
Myelochroa obsessa (Ach.) Elix & Hale
Nephroma helveticum Ach.
S-I *Normandina pulchella* (Borrer) Nyl. RARE
Ochrolechia africana Vainio
I *Opegrapha varia* Pers.
I *Opegrapha vulgata* Ach.
Pannaria lurida (Mont.) Nyl. RARE
Pannaria tavaresii Jo/rg.
Parmelinopsis horrescens (Taylor) Elix & Hale RARE
Parmelinopsis minarum (Vainio) Elix & Hale
Parmotrema austrosinense (Zahlbr.) Hale
Parmotrema crinitum (Ach.) Choisy RARE
Parmotrema eurysacum (Hue) Hale RARE
Parmotrema hypotropum (Nyl.) Hale
Parmotrema madagascariaceum (Hue) Hale
Parmotrema margaritatum (Hue) Hale
Parmotrema perforatum (Jacq.) Massal.
Parmotrema tinctorum (Delise ex Nyl.) Hale
Parmotrema ultralucens (Krog) Hale
Peltigera canina (L.) Willd.
Peltigera polydactylon (Necker) Hoffm.
Peltigera rufescens (Weiss) Humb.
I *Pertusaria amara* (Ach.) Nyl.
Pertusaria hypothamnolica Dibben
Pertusaria ostiolata Dibben
Pertusaria paratuberculifera Dibben
Pertusaria tetrathalamia (Fée) Nyl.
Pertusaria texana Müll. Arg.
Pertusaria valliculata Dibben
Pertusaria velata (Turner) Nyl.

Phaeophyscia ciliata (Hoffm.) Moberg RARE
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Essl.
I *Physcia aipolia* (Ehrh. ex Humb.) Fürnr.
Physcia americana G. Merr.
Physcia halei Thoms.
I *Physcia millegrana* Degel. RARE
I *Physcia stellaris* (L.) Nyl.
Physcia subtilis Degel.
Placynthiella icmalea (Ach.) Coppins & James
Porpidia albocaerulescens (Wulfen) Hertel & Knoph
Punctelia punctilla (Hale) Krog
I *Punctelia rudecta* (Ach.) Krog
Punctelia semansiana (Culb. & C. Culb.) Krog
Pyrenula caryae Harris RARE
Pyrenula cruenta (Mont.) Vainio RARE
Pyrenula pseudobufonia (Rehm) Harris
Pyxine caesiopruinosa (Tuck.) Imsh. RARE
Pyxine sorediata (Ach.) Mont.
Pyxine subcinerea Stirton
S *Ramalina americana* Hale
Rimelia cetrata (Ach.) Hale & Fletcher
S *Rimelia reticulata* (Taylor) Hale & Fletcher
Rimelia subisidiosa (Müll. Arg.) Hale & Fletcher RARE
Rinodina maculans Müll. Arg.
Sphinctrina turbinata (Pers. : Fr.) De Not.
Teloschistes chrysophthalmus (L.) Th. Fr. RARE
Trapeliopsis flexuosa (Fr.) Coppins & James
Trypethelium virens Tuck. ex Michener
Usnea amblyoclada (Müll. Arg.) Zahlbr.
S *Usnea ceratina* Ach.
Usnea mutabilis Stirton
Usnea rubicunda Stirton
Usnea strigosa (Ach.) Eaton
Usnea subscabrosa Mot.
Xanthoparmelia cumberlandia (Gyelnik) Hale
Xanthoparmelia hypomelaena (Hale) Hale RARE
Xanthoparmelia subramigera (Gyelnik) Hale
Xanthoparmelia substenophylloides Hale
Xanthoparmelia tasmanica (Hook. f. & Taylor) Hale RARE
Xanthoria fulva (Hoffm.) Poelt & Petutschnig

Discussion of lichen flora

This list of species presents the first listing of lichens from the park and includes 161 species found during this study. There are also a few additional unidentified species, some of which may be undescribed. The lichen flora is typical of the Ozark region. The hardwood forests have fewer lichens than conifer and mixed forests because the dense shade is not favorable to the growth of many species. However, the access to fallen trees and branches probably increased the completeness of the collecting. Some of the most common species are *Bacidia schweinitzii, Hypotrachyna livida, Leptogium cyanescens, Pertusaria hypothamnolica, Pertusaria ostiolata,* and *Usnea strigosa*.

One of the unidentified lichens is an undescribed species of *Sticta* according to my student, Tami McDonald. It was found in the Gulpha Gorge (locality # 18).

Some of the species found only once are rare wherever they are found throughout their distributional range and might be found at other localities with further searching and others may require special substrates that are rare in the park. The cases of rarity do not necessarily reflect sensitivity damage from sulfur dioxide.

The few species in the most sensitive category probably does not indicate poor air quality. Most of the species with known sensitivities are northern species which are lacking in the park because of climatic factors. The presence of some lichens with blue green algae (that are more sensitive to sulfur dioxide) also indicates that there is probably no air quality problem in the park.

There were no cases where lichens sensitive to sulfur dioxide were observed to be damaged or killed. All species normally found fertile were also fertile in the park. These observations indicate that there is no air quality degradation in the park due to sulfur dioxide that causes visible damage to the lichen flora.

Part II

Elemental Analyses of Lichens from Hot Springs National Park, Arkansas

James P. Bennett

Introduction

Hot Springs National Park, Garland County, Arkansas is a 5,550 acre national park in the south central U. S. Although the park was created to preserve geothermal features and hot water baths, the acreage includes five mountains of the Ouachita range, and surrounds an urban area (the city of Hot Springs, approximate 2000 population = 36,000). The mountainous areas exist in their natural state, and contain dense forests of oak, hickory and shortleaf pine. Flowering trees are also common, including magnolia, redbud, and dogwood.

The mineralogy of the area is complex and potentially interesting if vegetation is studied for effects of air pollutants because of possible confounding by natural and/or anthropogenic sources. Lichens have been used in national parks for this purpose since 1982 because of their total dependence on atmospheric deposition for their nutrients. Lichens in areas with high sulfur pollution, for example, may contain high levels of sulfur in their tissues. The mountainous areas of the park are result of erosion-resistant remnants of folded layers of novaculite and sandstone, minerals that are mostly composed of silicon, but may contain smaller amounts of Ti, Al, Fe, Mg and Ca. However, proximate to the park are areas enriched in Ti, V, Hg and Br as evidenced by mines or other sources in the region (Mark Blaeuer, personal communication, 11-5-01).

The park also contains an urban area with industrial and power generating sources right next to the park. These may be emitters of sulfur and nitrogen oxides, which could present air quality problems for the park's biota.

Methods

During the floristic survey, on eight days between May 16th and May 27th, 2001, 24 samples of four species of lichen were collected at 12 localities in Hot Springs National Park, Arkansas. The four species were *Cladina subtenuis, Parmotrema perforatum, Usnea amblyoclada,* and *Usnea strigosa*. The distribution of species by locality is given in Table 1.

The park is oriented NE to SW, and the localities were approximately evenly distributed among the NE, central ("C") and SW parts of the park (Fig. 1, Table 1). Locality elevations ranged from 600 to 1300 feet.

The samples were air dried, manually cleaned of debris and foreign materials, ground into a powder in a mill with stainless steel blades, and analyzed for elemental content using ICP-OES and ICP-MS. Elements analyzed included Al, As, B, Br, Ca, Cd, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, P, Pb, S, Se, Ti, V and Zn. Ash content was also measured. B, Br, Cd, Hg, Pb and Ti were analyzed at two separate times due to laboratory errors. Instrument drift was discovered during one run and was corrected using quality control checks performed every 10th sample. Each sample was analyzed in duplicate to measure laboratory precision. Accuracy was measured using NIST tissues SRM 1515 (apple leaves) and SRM 1573a (tomato leaves).

Results

A complete listing of all the elemental data is presented in Appendix 2. There were no below detection limit values, and there was one missing ash value, for a total of 1,103 data points. The data are available in an Excel spreadsheet format upon request.

Precision was measured as the percent difference between the two lab duplicates divided by the overall mean for each element. Paired t tests were used to determine if any duplicate differences were significant statistically. Duplicate pairs for three elements were significantly different at the 0.05 probability level: Ca, Cd and Zn (Fig. 3). Cadmium differences were the greatest at 17%, followed by Pb (9%). All other elements were about 5% different or less, except the ash difference was almost 7%. Although the Cd differences were large on a percent basis and significant statistically, the concentrations were less than 1 ppm and the difference was 0.04 ppm, which is very small.

Accuracy, as measured by recovery of standard reference materials, ranged from 45 to 189% and averaged 110% across twelve macroelements measured by ICP-OES. Recoveries of elements in the standard reference material measured by ICP-MS was much worse and was not used for estimating accuracy for those elements. The recoveries in the standard reference material (NIST 1573) were considered unreliable due to strong element interferences. Instead, the accuracy of nine microelements, estimated using an internal quality control check, averaged 108%, and ranged from 75 to 142%.

Bromine is an important element to study in HOSP because Arkansas is the largest producer of Br in the U. S. and because of the increased use of brominated flame retardants nationwide. The Br data in Appendix II, however, were considered unreliable because of their unusually high values. The tissue samples are being prepared for a second set of bromine analyses, and discussion of the bromine results will be presented at a later date. All bromine results have been omitted from the tables that follow.

Park-wide means across localities for each element in each species are presented in Table 2, the locality means across species are presented in Table 3, and the means grouped by which part of the park the localities are in are presented in Table 4.

Discussion

Cladina subtenuis, a ground dwelling fruticose lichen, usually had the lowest concentrations of elements, while *Parmotrema perforatum*, a foliose epiphytic species, was usually the highest. Foliose epiphytes are usually higher due to greater exposure to atmospheric deposition and higher surface area.

Park-wide means of most elements for *Cladina subtenuis* compare favorably with values for Hercules Glades in Missouri, Cape Romain National Wildlife Refuge and Okefenokee Swamp in Florida (Bennett and Wetmore 2001). Copper and sulfur, however, were higher at HOSP than these other areas. No comparable data for the other species is available.

Ash contents of all samples were all under 4.3%, indicating very little soil contamination of the samples. The highest concentrations of Al, Fe and Cr, which are usually considered to be from soil, were highest in samples from the quarry, a locality where there is considerable truck dumping activity.

Two localities, Mountain Tower and Balanced Rock, have the highest concentrations of the 12 localities, nearly twice as many as the next highest locality and many times more than the other localities. These two localities are both over 1000 feet in elevation and among the highest localities in the park. Mountain Tower is highest in As, Ca, Cd, Ni, S and Ti, and second highest in B, Cu, K and P. Balanced Rock is highest in K, Mg, Mn, P and ash, and second highest in As, Ca, Cd, Cr, Hg, Ni, S and Se. The two localities together, therefore, are highest in As, Ca, Cd, K, Ni, P and S, suggesting these elements may have origins in long-distance transport. The high concentrations of Hg at high elevations as well suggests this may be coming from far away industrial sources in Arkansas.

The highest levels of Cu, Pb and V were found in lichens at Goat Rock, a locality on the side of a ridge facing a highway leading out of the city of Hot Springs.

Summary and Conclusions

The higher concentrations of many elements in the southwest part of the park is confounded by the species sampled in the various parts of the park. The species with the highest concentrations, *Parmotrema*, was sampled more in the southwest part and hardly at all in the northeast part of the park. Low concentrations in the northeast may be due to the prevalence of *Cladina* samples in the part. Further work in the park is needed to clear this problem up by sampling *Parmotrema* and *Cladina* systematically throughout the entire park.

Iron and Cr both increased in the two fruticose species with elevation, but the foliose species showed a decrease with elevation for the same elements (Fig. 4). This effect could be confounded by locality, and should be studied more systematically in the future.

Recommendations

Recommendations are for periodic (5 year) restudy of the lichens by elemental analysis. A complete lichen restudy of the lichen flora should be done every 10-15 years. The localities where undescribed species were found should receive protection. If construction or maintenance activities are planned within these areas a lichenologist should be consulted to prevent loss of species. Further investigation of the higher levels of certain elements at some localities should be done.

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Table 1. Number of lichen collections by locality in Hot Springs National Park, 2001. The numbers after the locality names refer to the collection localities in Appendix I.

Locality	**Part of the park**	**Elevation (feet)**	***Cladina subtenuis***	***Parmotrema perforatum***	***Usnea amblyoclada***	***Usnea strigosa***
Balanced Rock (8)	SW	1100		1		1
Canyon Trail (5)	C	900	1	1		1
Floral Trail (4)	C	750	1			
Goat Rock (2)	C	800		1	1	1
Gulpha Gorge (18)	C	600	1			
Hill E of Desoto Park (29)	NE	800	1			
Hill NW of Desoto Park (14)	NE	1020	1			
NE end of Sunset Trail (15)	NE	850	1			
NW of Mountain Tower (1)	C	1000		1		1
Quarry and log graveyard (6)	SW	780	1	1		
Sunset Trail E of Black Snake Rd (9)	SW	1000	1	1		1
Sunset Trail W of Black Snake Rd (13)	SW	1300	2	1		1

Table 2. Park-wide means (ppm) of element concentrations for four lichen species from Hot Springs National Park. Highest concentrations in each row appear in bold font.

Element	*Cladina subtenuis*	*Parmotrema perforatum*	*Usnea amblyoclada*	*Usnea strigosa*	Average
Al	355.78	**476.16**	286.58	270.36	366.65
As	0.37	0.85	0.81	**0.88**	0.66
B	1.26	2.07	**2.12**	1.45	1.58
Ca	653.72	**6126.46**	2154.90	6043.26	3659.87
Cd	0.14	0.31	0.34	**0.36**	0.26
Cr	0.42	**0.95**	0.39	0.64	0.63
Cu	6.26	**8.83**	7.64	8.05	7.51
Fe	291.25	**458.08**	225.61	248.29	326.43
Hg	0.14	0.22	0.22	**0.24**	0.19
K	1398.67	**2917.53**	1794.55	2367.68	2100.42
Mg	323.50	353.52	228.39	**801.62**	447.82
Mn	67.73	69.65	24.75	**287.30**	121.39
Na	37.94	37.56	43.20	**68.41**	45.67
Ni	0.73	**2.11**	1.00	2.05	1.47
P	461.16	**1102.06**	553.02	763.67	727.54
Pb	2.24	3.85	**9.97**	5.14	3.76
S	822.37	**1739.38**	1022.57	1597.04	1291.84
Se	0.26	**0.61**	0.37	0.51	0.43
Ti	6.61	**15.31**	8.63	11.81	10.53
V	0.83	**1.75**	0.79	1.24	1.20
Zn	19.40	**35.85**	28.58	30.46	27.34
Ash	1.43	**3.33**	1.15	2.52	2.24
Number of samples	20	14	12	2	48

Table 3. Element means for 12 localities across species in Hot Springs National Park. Highest and second highest concentrations in each row appear in bold and italicized fonts, respectively.

Element	Balanced	Canyon	DesotoE	DesotoNW	Floral	Goat	Gulpha	Quarry	SunsetE	SunsetNE	SunsetW	Tower
Al	362.17	358.73	338.36	388.12	323.28	381.49	237.16	**451.78**	378.00	266.24	*405.01*	321.93
As	*0.84*	0.71	0.22	0.44	0.29	0.83	0.32	0.66	0.75	0.38	0.64	**0.85**
B	1.20	1.17	0.54	2.50	**3.03**	2.44	0.50	1.63	1.18	0.58	1.32	*2.72*
Ca	*5865.89*	4288.82	522.70	779.74	538.91	3228.99	614.58	4964.00	4085.78	512.73	3909.23	**6380.38**
Cd	*0.32*	0.31	0.14	0.12	0.12	0.32	0.10	0.30	0.24	0.17	0.20	**0.39**
Cr	*0.74*	0.68	0.37	0.42	0.47	0.62	0.35	**0.87**	0.70	0.33	0.68	0.62
Cu	7.84	8.11	6.50	6.85	6.86	**8.43**	6.06	7.41	7.84	4.33	7.40	*8.27*
Fe	329.45	328.17	222.39	319.86	264.04	324.92	182.62	**433.94**	341.86	209.08	*370.15*	322.07
Hg	*0.22*	0.21	0.12	**0.24**	0.16	0.21	0.09	0.19	**0.24**	0.19	0.19	0.14
K	**2838.66**	2363.11	1462.65	1933.63	1341.36	2194.68	979.46	2013.06	2373.76	1341.77	1857.99	*2710.55*
Mg	**759.19**	*562.74*	284.71	441.87	234.18	420.66	256.70	300.76	520.32	299.16	408.38	483.26
Mn	**197.16**	*178.43*	68.42	100.11	41.05	142.83	59.16	33.72	109.19	64.73	123.25	166.87
Na	48.16	36.09	15.93	**55.70**	54.99	50.46	13.76	46.41	*55.27*	37.91	50.44	50.70
Ni	*2.01*	1.65	0.83	0.73	0.92	1.42	0.61	1.86	1.46	0.65	1.56	**2.03**
P	**1110.48**	738.14	434.10	630.09	382.91	697.92	307.60	807.30	902.82	371.21	617.94	*1005.60*
Pb	3.82	4.76	0.86	0.79	0.77	**6.44**	0.81	2.55	*6.14*	0.42	3.10	4.71
S	*1643.11*	1377.11	883.34	994.31	763.08	1487.50	479.46	1171.65	1443.56	987.47	1233.45	**1704.36**
Se	*0.51*	**0.53**	0.20	0.29	0.20	0.49	0.23	0.35	0.49	0.33	0.46	0.46
Ti	11.32	10.39	4.32	11.73	8.57	*14.36*	3.10	13.17	9.12	3.42	10.36	**14.79**
V	1.24	1.18	0.68	0.91	0.78	**1.64**	0.57	*1.48*	1.23	0.62	1.23	1.39
Zn	27.27	**34.00**	18.65	16.64	17.81	*33.26*	17.79	25.08	31.60	29.87	22.08	32.91
Ash	**3.03**	*2.92*	0.75	2.05	1.65	2.17	0.60	2.85	2.00	1.00	2.45	2.60
Number of first and second highs	14	6	0	2	1	5	0	4	3	0	2	10
Number of samples	4	6	2	2	2	6	2	4	6	2	8	4

Table 4. Element means across species grouped by part of park localities occur in Hot Springs National Park. Highest concentrations in each row appear in bold font.

Element	SW	C	NE
Al	**398.36**	342.50	330.91
As	**0.71**	0.69	0.35
B	1.32	**1.98**	1.21
Ca	**4504.91**	3646.77	605.06
Cd	0.25	**0.29**	0.14
Cr	**0.73**	0.60	0.37
Cu	7.60	**7.91**	5.89
Fe	**366.63**	305.01	250.44
Hg	**0.21**	0.18	0.19
K	**2205.15**	2141.53	1579.35
Mg	**483.13**	440.76	341.91
Mn	116.58	**139.77**	77.75
Na	**50.61**	42.98	36.51
Ni	**1.67**	1.48	0.74
P	**819.61**	700.99	478.47
Pb	3.96	**4.46**	0.69
S	**1354.00**	1324.51	955.04
Se	**0.46**	0.44	0.28
Ti	10.71	**11.55**	6.49
V	**1.27**	1.26	0.74
Zn	26.17	**30.32**	21.72
Ash	**2.50**	2.24	1.27
Number of samples	22	20	6

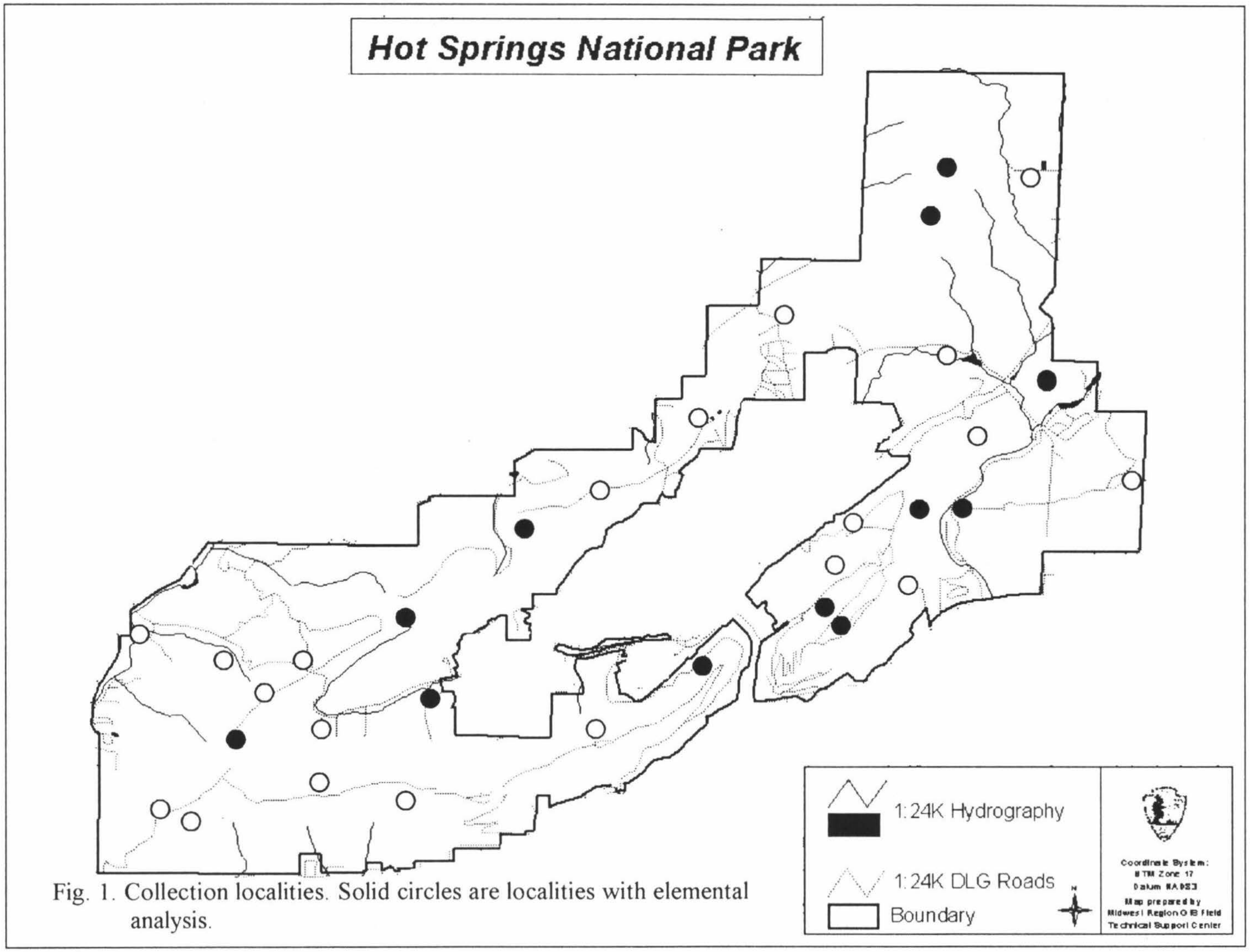


Fig. 1. Collection localities. Solid circles are localities with elemental analysis.

Fig. 2. Twelve lichen chemistry collection localities in Hot Springs National Park, 2001. Localities are assigned to three groups: northeast (NE), central (C), and southwest (SW).

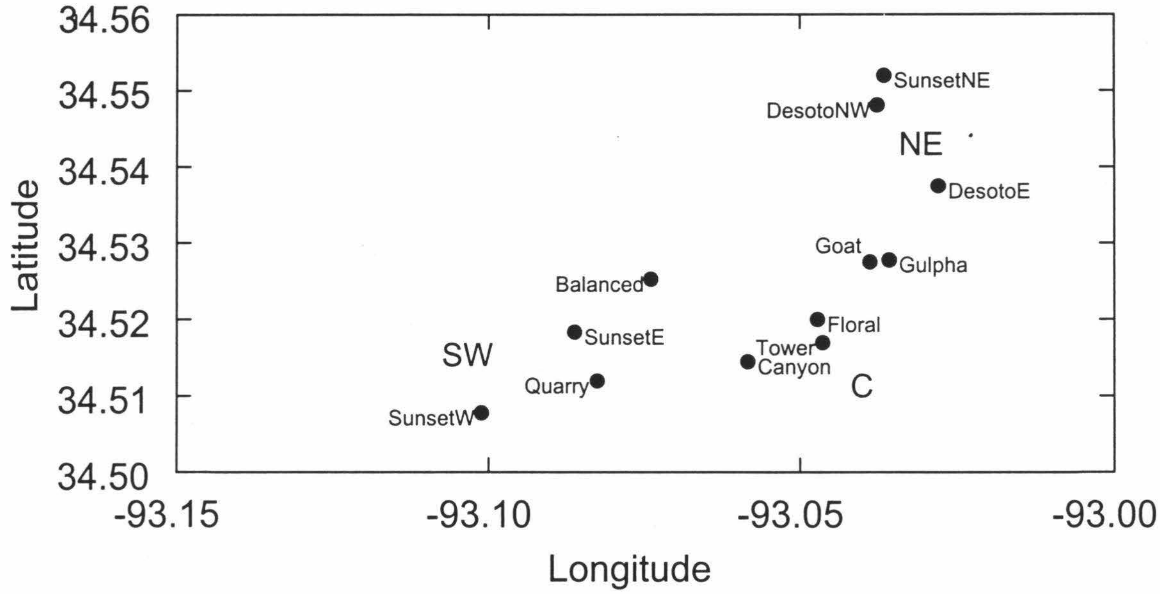


Fig. 3. Laboratory precision expressed as percent difference between two duplicates relative to the mean for 22 elements plus ash for Hot Springs National Park lichens. Elements are arrayed in atomic number order left to right. Number of data points = 24 for each duplicate.

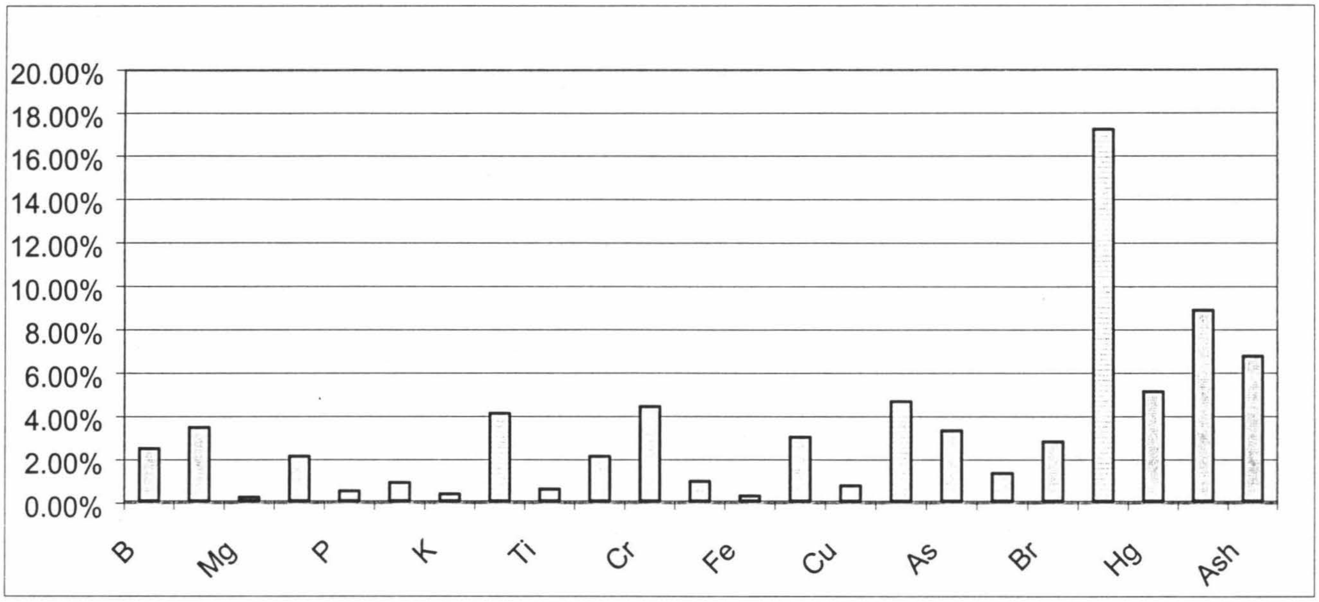
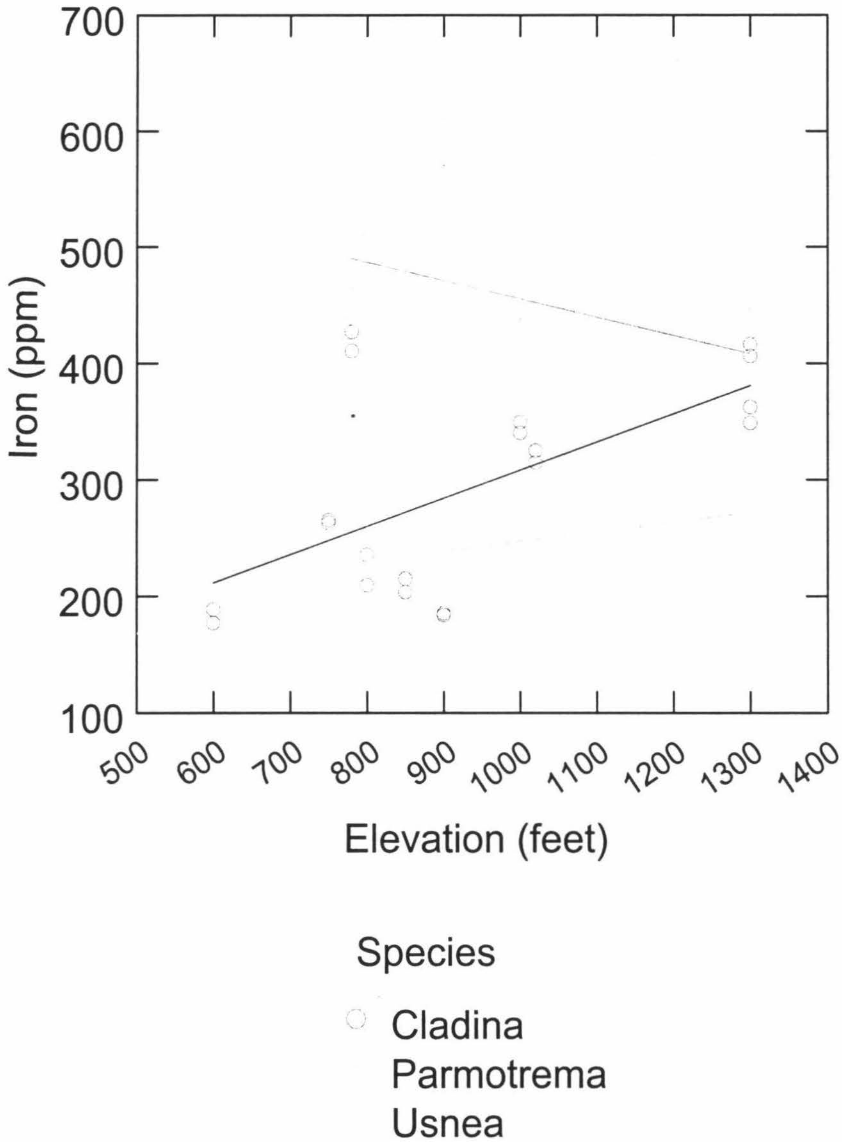


Fig. 4. Effect of elevation on iron concentrations in three lichen species in Hot Springs National Park, 2001.



Appendix I

Hot springs collection localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by number and date of collection. All collections are in Hot Springs National Park, Garland County, Arkansas. Latitude and longitude readings were taken with GPS and rounded to nearest second. Localities where elemental analysis collections were made are indicated by "CHEM".

Loc. 1 - 85429-85475, North of observation tower on Hot Springs Mt. On N side of ridge with oaks, hickory, black cherry, and shortleaf pine, elev. 1000 ft, Sec. 33, T2S, R19W, 16 May 2001, 34°31'01"N, 93°02'47"W CHEM.

Loc. 2 - 85476-85505, Along creek N of observation tower on Hot Springs Mt. In valley with sweetgum, oak, hickory, maple, juniper, and shortleaf pine, elev. 750 ft, Sec. 33, T2S, R19W, 16 May 2001, 34°31'18"N, 93°02'47"W.

Loc. 3 - 85506-85527, Around Goat Rock on North Mountain. On SE facing hillside with shortleaf pine, black cherry, oak, hickory, and rock outcrops, elev. 800 ft., Sec. 32, T2S, R19W, 17 May 2001, 34°31'39"N, 93°02'20"W CHEM.

Loc. 4 - 85528-85567, Upper Floral Trail on Hot Springs Mt. On NW facing slope with oak, hickory, black cherry, shortleaf pine, and rocks, elev. 750 ft., Sec. 33, T2S, R19W, 17 May 2001, 34°31'12"N, 93°02'50"W CHEM.

Loc. 5 - 85568-85610, Below Canyon Trail on NE end of West Mountain. NW facing hillside with oak, hickory, shortleaf pine, and black cherry, elev. 900 ft., Sec. 32 T2S, R19W, 18 May 2001, 34°30'52"N, 93°03'30"W CHEM.

Loc. 6 - 85611-85646, East of Whittington at Graves Quarry. Level area with young shortleaf pines and some hardwoods, redbud, sweetgum, elev. 780 ft., Sec. 31, T2S, R19W, 18 May 2001, 34°30'43"N, 93°04'57"W CHEM.

Loc. 7 - 85647-85686, NW of West Mountain Overlook. On NW facing hillside with shortleaf pine, oak, hickory, black cherry, and rock outcrops, elev. 900 ft., Sec. 32, T2S, R19W, 18 May 2001, 34°30'32"N, 93°04'04"W.

Loc. 8 - 85687-85728, Balanced Rock on Sugarloaf Mountain. Around rocks and N side of ridge with oak, hickory, black cherry, and rock outcrops, elev. 1100 ft., Sec. 30, T2S, R19W, 19 May 2001, 34°31'31"N, 93°04'26"W CHEM.

Loc. 9 - 85729-85770, Half mile E of Black Snake Road on Sunset Trail. N facing hillside with hickory, oak, black cherry, rocks, and few shortleaf pines, elev. 1000 ft., Sec. 31, T2S, R19W, 19 May 2001, 34°31'06"N, 93°05'10"W CHEM.

Loc. 10 - 85771-85801, Ravine N of Black Snake Road at Sunset Trail. N facing ravine with some water seepage, oak, hickory, black cherry, and some shortleaf pines, elev. 900 ft., Sec. 36, T2S, R20W, 19 May 2001, 34°30'53"N, 93°05'33"W.

Loc. 11 - 85802-85836, West of radio towers on Sunset Trail on West Mt. On S facing slope with oak, hickory, black cherry, and few shortleaf pines, elev. 1150 ft., Sec. 6, T3S, R19W, 20 May 2001, 34°30'15"N, 93°05'09"W.

Loc. 12 - 85837-85872, West Mt. on Sunset Trail half mile E of Music Mt. peak. On N facing hillside below saddle with oak, hickory, clack cherry, and few shortleaf pine, elev. 1180 ft., Sec. 1, T3S, R20W, 20 May 2001, 34°30'17"N, 93°05'37"W.

Loc. 13 - 85873-85905, North ridge of Music Mt. peak on Sunset Trail. Rock outcrops near ridgetop with oak, hickory, and some black cherry, elev. 1300 ft., Sec. 1, T3S, R20W, 20 May 2001, 34°30'28"N, 93°06'04"W CHEM.

Loc. 14 - 85906-85955, Peak NW of DeSoto Park on Sunset Trail. Around hilltop with oak, hickory, and some black cherry and shortleaf pine, elev. 1020 ft., Sec. 21, T2S, R19W, 22 May 2001, 34°32'53"N, 93°02'16"W CHEM.

Loc. 15 - 85956-85990, Near NE end of Sunset Trail NW of DeSoto Park. In head of ravine with shortleaf pine, oak, and hickory, elev. 850 ft., Sec. 16, T2S, R19W, 22 May 2001, 34°33'07"N, 93°02'12"W CHEM.

Loc. 16 - 85991-86041, Sunset Trail directly N of Pullman Ave. In ravine on N side of ridge with hickory, oak, elm, and some sweetgum, shortleaf pine, and maple, elev. 800 ft., Sec. 21, T2S, R19W, 22 May 2001, 34°32'25"N, 93°03'07"W.

Loc. 17 - 86042-86080, West of Indian Mt. near E park boudary. On N facing slope with hickory, oak, shortleaf pine, and some juniper and yucca, elev. 1120 ft, Sec. 27, T2S, R19W, 23 May 2001, 34°31'37"N, 93°01'08"W.

Loc. 18 - 86081-86125, Gulpha Gorge N of campground. On E side of creek on steep N facing hillside with rock ledges, oak, hickory, elm, *Carpinus*, and some shortleaf pine, elev. 600 ft., Sec. 27, T2S, R19W, 23 May 2001, 34°31'40"N, 93°02'09"W CHEM.

Loc. 19 - 86126-86163, North end of Rix Pond. Lowland along swamp and stream with oaks, hickory, shortleaf pine, holly, maple, sweetgum, and some magnolia, elev. 620 ft., Sec. 21, T2S, R19W, 23 May 2001, 34°32'16"N, 93°02'16"W.

Loc. 20 - 86164-86212, First peak W of Cedar Glades Road on Sunset Trail. Around peak with hickory, oak, black cherry, and few shortleaf pines, elev. 870 ft., Sec. 29, T2S, R19W, 24 May 2001, 34°31'42"N, 93°04'02"W.

Loc. 21 - 86213-86267, Half mile E of Cedar Glades Rd. on Sunset Trail below water tanks. Valley with elm, maple, oaks, and some shortleaf pines, hickory and magnolia, elev. 750 ft., Sec. 29, T2S, R19W, 24 May 2001, 34°32'00"N, 93°03'34"W.

Loc. 22 - 86268-86305, 1.5 mi E of Whittington on Black Snake Rd. In lowland along stream with elm, maple, hickory, oak, sweetgum, and shortleaf pine, elev. 800 ft. Sec. 36, T2S, R20W, 25 May 2001, 34°30'39"N, 93°05'32"W.

Loc. 23 - 86306-86341, Black Snake Road NW of sharp curves. In ravine on N side of ridge with maple, elm, sweetgum, hickory, and shortleaf pines, elev. 550 ft., Sec. 36, T2S, R20W, Sec. 36, T2S, R20W, 25 May 2001, 34°30'58"N, 93°06'04"W.

Loc. 24 - 86342-86368, Bull Bayou and small side ravine. Along side gully and stream bank with elm, sweetgum, *Carpinus*, hickory, and oak, elev. 450 ft. Sec. 35, T2S, R20W, 25 May 2001, 34°31'01"N, 93°06'32"W.

Loc. 25 - 86369-86425, N slope of SW peak of Music Mt. On N side of peak with oak, hickory, black cherry, and few maple, elev. 1270 ft., Sec. 2, T3S, R20W, 26 May 2001, 34°30'07"N, 93°06'17"W.

Loc. 26 - 86426-86465, SE slope of SW peak of Music Mt. On S facing dry hillside with mostly dead small oak and hickory and some shortleaf pine and elm, elev. 1120 ft., Sec. 1, T3S, R20W, 26 May 2001, 34°30'15"N, 93°06'10"W.

Loc. 27 - 86466-86513, W of Black Snake Rd. on Sunset Trail at level area on ridge. On N facing hillside with oak, hickory, black cherry, and shortleaf pine, elev. 1060 ft., Sec. 36, T2S, R20W, 26 May 2001, 34°30'42"N, 93°05'56"W.

Loc. 28 - 86514-86554, W of Fox Pass Rd. at E side of park. Along stream and on lower N slope with maple, elm, sweetgum, and oaks and some cottonwood, elev. 740 ft., Sec. 22, T2S, R19W, 27 May 2001, 34°33'06"N, 93°01'48"W.

Loc. 29 - 86555-86602, Hill E of DeSoto Park. On N side of hill with hickory, oak, elm, shortleaf pine and many mining exploration pits, elev. 800 ft., Sec. 27, T2S, R19W, 27 May 2001, 34°32'15"N, 93°01'41"W CHEM.

Loc. 30 - 86603-86655, NE of end of hilltop loop on North Mt. On N facing slope below switchback with oak, hickory, shortleaf pine, black cherry, and rocks, elev. 900 ft., Sec. 28, T2S, R19W, 28 May 2001, 34°31'52"N, 93°02'10"W.

Loc. 31 - 86656-86683, N of Upper Dogwood Trail below loop road. On N facing hillside with oak, hickory, big old shortleaf pines, and black cherry, elev. 750 ft., Sec. 28, T2S, R19W, 28 May 2001, 34°31'34"N, 93°02'49"W.

Loc. 32 - 86684-86707, Above Dead Chief Trail near Grand Ave. Trail. On S facing hillside with shortleaf pine, hickory, oak, and black cherry, elev. 700 ft., Sec. 33, T2S, R19W, 29 May 2001, 34°31'07"N, 93°02'26"W.

Appendix II 2001 Elemental analysis data

Rep	Species	Loc	Date	Al	As	B	Br	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg	Mn	Na	Ni	P	Pb	S	Se	Ti	V	Zn	Ash
1	Cladina subtenuis	Floral Trail	5/17/01	324.31	0.26	2.32	22.09	535.88	0.13	0.48	6.56	265.20	0.24	1337.25	234.90	41.89	61.86	0.98	382.65	0.746	731.76	0.20	8.32	0.86	17.14	1.9
2	Cladina subtenuis	Floral Trail	5/17/01	322.24	0.31	3.93	40.93	541.93	0.11	0.46	7.17	262.89	0.07	1345.47	233.46	40.21	48.11	0.87	383.17	0.788	794.39	0.20	8.82	0.70	18.47	1.4
1	Parmotrema perforatum	NW of Mtn Tower	5/16/01	386.61	0.60	3.39	481.09	4112.10	0.31	0.60	8.36	375.10	0.08	2889.88	322.72	51.39	41.85	1.50	1137.90	3.206	1713.29	0.47	16.83	1.61	33.32	2.4
2	Parmotrema perforatum	NW of Mtn Tower	5/16/01	388.89	0.59	3.52	618.67	4422.22	0.32	0.71	8.61	392.83	0.19	2928.28	327.78	51.11	38.38	1.76	1168.69	3.261	1647.47	0.42	16.82	1.65	36.71	2.3
1	Parmotrema perforatum	Goat Rock	5/17/01	602.40	0.80	4.20	550.61	3409.18	0.26	0.88	9.10	514.87	0.13	2552.89	342.51	91.36	34.60	1.65	840.22	4.032	1791.42	0.64	19.51	2.62	41.04	3.4
2	Parmotrema perforatum	Goat Rock	5/17/01	490.34	0.91	3.19	742.65	3517.10	0.24	0.78	9.69	476.16	0.28	2585.51	339.03	94.60	23.49	1.47	861.17	4.187	1779.68	0.50	17.59	2.46	42.67	3.1
1	Cladina subtenuis	Hill NW Desoto Park	5/22/01	373.95	0.46	2.58	553.92	775.95	0.16	0.39	6.73	314.77	0.30	1920.16	440.52	100.50	56.90	0.79	631.64	0.741	1005.99	0.32	11.82	0.92	16.70	1.8
2	Cladina subtenuis	Hill NW Desoto Park	5/22/01	402.30	0.42	3.00	436.87	783.53	0.08	0.45	6.97	324.95	0.19	1947.11	443.21	99.73	54.50	0.67	628.54	0.849	982.63	0.27	11.64	0.89	16.58	2.3
1	Cladina subtenuis	Quarry & log graveyard	5/18/01	442.73	0.37	2.09	256.23	700.69	0.28	0.54	6.30	410.41	0.08	1185.66	277.60	51.63	38.17	0.88	382.71	1.790	749.61	0.20	10.55	1.25	20.95	1.9
2	Cladina subtenuis	Quarry & log graveyard	5/18/01	494.96	0.34	1.75	116.05	673.49	0.16	0.54	6.38	426.81	0.05	1212.70	286.49	52.39	49.82	0.50	388.91	1.798	762.70	0.20	9.58	1.24	22.24	1.9
1	Usnea amblyoclada	Goat Rock	5/17/01	267.27	0.77	1.90	621.72	2198.80	0.41	0.23	7.39	203.82	0.13	1776.10	220.88	23.63	41.51	1.02	534.94	10.077	1036.14	0.34	8.41	0.77	27.48	1.0
2	Usnea amblyoclada	Goat Rock	5/17/01	305.90	0.85	3.17	677.51	2111.00	0.26	0.54	7.90	247.40	0.30	1813.00	235.90	25.86	44.89	0.98	571.10	9.872	1009.00	0.40	8.96	0.82	29.68	1.3
1	Usnea strigosa	NW of Mtn Tower	5/16/01	267.73	1.05	2.71	850.13	8279.88	0.50	0.67	8.03	263.15	0.12	2516.93	643.53	282.77	63.67	2.32	861.95	6.198	1732.07	0.38	8.74	1.18	30.55	2.9
2	Usnea strigosa	NW of Mtn Tower	5/16/01	244.51	1.14	2.74	886.74	8707.32	0.40	0.51	8.10	257.22	0.18	2507.11	639.02	282.22	58.91	2.55	853.86	6.176	1724.59	0.58	17.48	1.14	31.08	2.8
1	Usnea strigosa	Goat Rock	5/17/01	324.02	0.89	2.50	445.28	4006.89	0.44	0.60	8.25	264.17	0.21	2214.57	698.52	309.45	77.87	1.84	688.29	5.264	1640.75	0.56	17.63	1.69	28.86	2.1
2	Usnea strigosa	Goat Rock	5/17/01	299.00	0.76	2.14	530.67	4131.00	0.34	0.66	8.23	243.10	0.22	2226.00	687.10	312.10	80.37	1.54	691.80	5.191	1668.00	0.50	15.26	1.51	29.83	2.1
1	Parmotrema perforatum	Canyon Trail	5/18/01	593.39	0.80	3.34	1016.80	5971.94	0.35	1.05	9.50	570.24	0.29	3240.48	399.90	119.94	31.12	2.01	1159.32	6.003	1735.47	0.73	22.26	1.88	39.68	3.6
2	Parmotrema perforatum	Canyon Trail	5/18/01	634.92	0.95	3.08	1218.09	5824.90	0.14	1.12	9.82	610.22	0.23	3329.96	420.34	126.62	28.69	1.86	1184.21	6.910	1805.67	0.81	21.14	1.92	45.46	3.9
1	Usnea strigosa	Balanced Rock	5/19/01	302.99	0.72	1.92	871.80	5963.07	0.19	0.62	7.35	250.30	0.20	2455.09	1123.75	303.89	63.76	1.94	890.82	4.372	1589.82	0.53	13.56	1.16	25.23	2.4
2	Usnea strigosa	Balanced Rock	5/19/01	275.20	0.67	1.64	1077.12	5685.04	0.30	0.59	7.81	241.04	0.25	2413.39	1097.44	301.38	56.10	2.14	882.87	3.824	1590.55	0.33	12.67	1.08	24.03	2.3
1	Cladina subtenuis	Sunset Trail E of Black Snake Rd	5/19/01	442.46	0.53	1.21	689.68	710.62	0.14	0.32	6.49	349.31	0.16	1764.88	415.87	65.43	45.68	0.49	699.40	9.346	855.16	0.34	6.64	0.95	16.87	1.6
2	Cladina subtenuis	Sunset Trail E of Black Snake Rd	5/19/01	415.31	0.44	1.56	538.08	703.98	0.08	0.45	6.20	340.16	0.16	1788.27	420.08	63.04	38.00	0.66	707.16	11.768	864.51	0.20	9.56	0.86	21.23	0.5
1	Parmotrema perforatum	Quarry & log graveyard	5/18/01	429.62	0.92	2.86	1054.59	9031.81	0.40	1.03	8.60	463.72	0.34	2851.89	324.85	16.99	48.80	2.91	1238.57	2.784	1615.31	0.43	19.89	1.69	28.74	3.7
2	Parmotrema perforatum	Quarry & log graveyard	5/18/01	439.80	0.99	2.33	1276.30	9450.00	0.37	1.36	8.37	434.80	0.28	2802.00	314.10	13.89	48.84	3.15	1219.00	3.829	1559.00	0.57	19.80	1.73	28.41	3.9
1	Cladina subtenuis	Sunset Trail W of Black Snake Rd	5/20/01	450.40	0.48	2.01	481.56	746.90	0.06	0.61	6.55	406.10	0.19	1487.00	403.00	97.64	41.93	0.92	547.90	1.535	894.80	0.35	9.98	1.04	19.98	2.7
2	Cladina subtenuis	Sunset Trail W of Black Snake Rd	5/20/01	476.20	0.54	2.04	360.00	746.08	0.13	0.51	6.80	416.16	0.10	1483.94	404.92	98.66	39.45	0.85	550.20	1.281	901.51	0.35	10.02	1.02	17.33	1.7
1	Usnea strigosa	Sunset Trail W of Black Snake Rd	5/20/01	309.52	0.95	3.26	601.48	6576.15	0.27	0.81	8.13	292.18	0.20	2308.62	622.34	260.02	72.56	2.39	593.49	4.808	1488.98	0.65	19.47	1.41	24.83	2.6
2	Usnea strigosa	Sunset Trail W of Black Snake Rd	5/20/01	299.10	0.76	3.26	690.18	7252.51	0.28	0.73	7.91	269.94	0.25	2095.19	614.83	263.23	71.12	2.23	590.98	6.609	1473.95	0.39	18.18	1.41	23.39	2.4
1	Parmotrema perforatum	Sunset Trail W of Black Snake Rd	5/20/01	441.49	0.73	3.60	1010.28	7277.23	0.34	0.95	9.11	419.60	0.22	2573.27	306.44	55.70	40.42	2.53	838.02	3.153	1694.06	0.70	17.14	1.51	30.04	3.3
2	Parmotrema perforatum	Sunset Trail W of Black Snake Rd	5/20/01	459.98	0.94	2.45	1080.10	7131.42	0.20	0.94	8.16	446.15	0.14	2593.87	315.02	56.56	41.73	2.13	860.77	2.681	1736.17	0.75	17.78	1.42	32.03	3.5
1	Parmotrema perforatum	Balanced Rock	5/19/01	458.95	0.90	3.05	1388.80	5607.36	0.36	0.86	8.16	426.94	0.25	3248.51	412.82	87.14	36.65	2.05	1323.06	3.798	1693.84	0.60	16.65	1.39	29.58	3.5
2	Parmotrema perforatum	Balanced Rock	5/19/01	411.54	1.05	2.44	1557.68	6208.09	0.45	0.87	8.05	399.51	0.19	3237.67	402.76	96.22	36.14	1.89	1345.17	3.302	1698.22	0.56	14.79	1.32	30.25	3.9
1	Parmotrema perforatum	Sunset Trail E of Black Snake Rd	5/19/01	464.47	0.79	2.57	1270.99	6487.85	0.29	1.09	9.04	445.04	0.20	3011.13	363.97	56.96	34.97	2.11	1131.58	3.485	1960.53	0.79	18.35	1.62	42.06	3.1
2	Parmotrema perforatum	Sunset Trail E of Black Snake Rd	5/19/01	463.84	0.92	4.42	1000.68	7319.19	0.33	1.09	9.12	437.88	0.28	3000.00	356.97	56.56	40.21	2.48	1121.21	3.249	1921.21	0.62	17.51	1.64	41.88	3.0
1	Usnea strigosa	Sunset Trail E of Black Snake Rd	5/19/01	253.86	0.99	3.87	952.79	4360.77	0.24	0.60	8.66	248.37	0.31	2348.58	794.11	206.40	91.64	1.59	888.41	4.942	1559.96	0.48	13.71	1.15	32.49	1.6
2	Usnea strigosa	Sunset Trail E of Black Snake Rd	5/19/01	228.09	0.84	3.49	999.62	4932.27	0.36	0.62	7.53	230.38	0.31	2329.68	770.92	206.77	81.09	1.43	869.12	4.071	1500.00	0.53	11.86	1.13	35.08	2.2
1	Cladina subtenuis	Sunset Trail W of Black Snake Rd	5/20/01	418.66	0.36	3.07	472.17	794.01	0.19	0.43	6.35	362.38	0.30	1193.52	308.45	78.51	52.23	0.68	492.83	2.058	916.21	0.20	10.52	0.96	15.39	1.7
2	Cladina subtenuis	Sunset Trail W of Black Snake Rd	5/20/01	384.76	0.33	2.62	473.89	749.50	0.15	0.48	6.17	348.71	0.13	1128.49	292.03	75.68	44.07	0.69	469.32	2.637	761.95	0.31	9.39	1.05	13.65	1.7
1	Usnea strigosa	Canyon Trail	5/18/01	215.11	0.89	1.90	1195.14	6136.18	0.64	0.60	7.79	191.35	0.27	2337.97	949.01	353.88	49.11	2.27	665.81	4.933	1523.86	0.65	11.32	0.99	40.00	4.3
2	Usnea strigosa	Canyon Trail	5/18/01	225.15	0.89	1.90	843.90	6488.07	0.37	0.62	8.81	228.33	0.41	2659.05	978.93	365.51	54.74	2.35	686.58	5.329	1671.97	0.55	12.53	1.07	40.11	
1	Cladina subtenuis	Canyon Trail	5/18/01	236.94	0.34	1.90	569.16	681.17	0.28	0.39	6.21	183.70	0.03	1296.56	312.35	51.58	24.29	0.77	364.68	0.865	756.68	0.20	5.34	0.63	17.49	1.4
2	Cladina subtenuis	Canyon Trail	5/18/01	246.89	0.38	1.50	608.87	630.66	0.09	0.31	6.53	185.17	0.02	1314.63	315.93	53.05	28.60	0.66	368.24	4.492	769.04	0.25	5.23	0.61	21.26	1.4
1	Cladina subtenuis	Gulpha Gorge	5/23/01	234.16	0.25	0.86	535.96	619.42	0.11	0.41	5.98	176.79	0.15	978.09	255.98	59.20	14.88	0.65	306.97	0.789	477.19	0.20	4.76	0.53	19.21	0.8
2	Cladina subtenuis	Gulpha Gorge	5/23/01	240.16	0.38	1.06	638.14	609.74	0.09	0.30	6.13	188.45	0.04	980.82	257.43	59.13	12.63	0.56	308.23	0.825	481.73	0.27	4.70	0.60	16.38	0.4
1	Cladina subtenuis	Hill E of Desoto park	5/27/01	377.32	0.25	1.62	335.96	529.74	0.11	0.32	6.60	235.38	0.07	1478.83	290.42	68.82	15.26	0.75	438.31	0.894	947.08	0.20	5.48	0.73	19.07	1.0
2	Cladina subtenuis	Hill E of Desoto park	5/27/01	299.39	0.20	2.50	452.36	515.66	0.17	0.42	6.39	209.39	0.18	1446.46	278.99	68.01	16.61	0.91	429.90	0.832	819.60	0.21	8.20	0.64	18.22	0.5
1	Cladina subtenuis	NE end of Sunset Trail	5/22/01	276.43	0.36	2.02	506.56	506.02	0.18	0.28	4.39	214.89	0.30	1333.33	298.52	63.88	35.51	0.84	372.58	0.375	1043.39	0.21	5.96	0.62	24.07	0.8
2	Cladina subtenuis	NE end of Sunset Trail	5/22/01	256.05	0.40	2.59	351.44	519.44	0.15	0.38	4.27	203.27	0.09	1350.20	299.80	65.59	40.31	0.46	369.84	0.457	931.55	0.45	5.33	0.62	35.67	1.2