

**LICHENS AND AIR QUALITY
IN
LYE BROOK WILDERNESS
OF THE
GREEN MOUNTAIN NATIONAL FOREST**

Final Report

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by

Clifford M. Wetmore
Plant Biology Department
University of Minnesota
St. Paul, Minnesota

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LICHENS OF LYE BROOK WILDERNESS

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ABSTRACT

This study of the lichens of the Lye Brook Wilderness was designed 1) to collect lichens for a lichen species list, 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. Eighteen localities were studied throughout the wilderness. Samples of three species were collected at four localities for elemental analysis.

The lichen flora is quite diverse. There were 126 species present including six species very sensitive to sulfur dioxide. The distributions of these sensitive species do not show patterns that would suggest directional air quality problems. All of the lichens found were in good health and with normal fertility. The lichens studied by elemental analysis show levels of all elements comparable to other clean areas. ANOVA analysis showed higher levels of thallus accumulation in LBW than in White Mt. Wilderness areas for the 1993 data. There seem to be no indications of threatening air quality problems (mainly sulfur dioxide) in the wilderness.

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. If construction or maintenance activities are planned within the wilderness, a lichenologist should be consulted to prevent loss of species.

PREFACE

Under a contract from the USDA National Forest Service a lichen study was performed in the Lye Brook Wilderness Area (LBW) of the Green Mountain National Forest. The objectives were to survey the lichens of the wilderness area, produce an inventory of the lichen flora, collect and analyze lichens for chemical contents, and evaluate the lichen flora with reference to the air quality. This establishes baseline data to determine the future change in air quality. All work was done at the University of Minnesota with consultation with Mr. Manfred Mielke, and with personnel on the Forest.

The Forest 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 U. S. Forest Service, Green Mountain National Forest and NAS & PF Forest Health Protection. Dave Rugg, statistician with the NCFES did the statistical analysis. I would especially like to acknowledge the able assistance of Zhenfan Wang in the field and the laboratory. 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 $\mu\text{g}/\text{cubic meter}$ (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 $\mu\text{g}/\text{cubic meter}$ (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 sub-lethal but elevated levels in the air.

The Lye Brook Wilderness (LBW) is about 15,680 acres and is located in southern Vermont, about 20 miles north of Bennington. The wilderness is fairly steep and mountainous with some small lakes and streams. The elevations range from 900 to 2880 ft. The ridgetops have red spruce (Picea rubens) mixed with sugar maple (Acer saccharum), birch (Betula). Some of the hillsides have hemlock (Tsuga canadensis), beech (Fagus grandifolia) and sugar maple. In the low and wet areas there are some balsam for (Abies balsamea) and white ash (Fraxinus americana) and red maple (Acer rubrum). Rock outcrops are frequent on the ridges and hillsides and some of low areas have bogs. The Burning is an area that is quite different. It is a large area on the ridge that was burned around 1900 and is now heath with scattered red spruce with some white pines (Pinus strobus).

Most of the forest had been extensively logged prior to 1960 with only limited logging since. The last area to be logged was around Kelly Stand.

There probably has been no lichen collecting in the wilderness prior to this study and no literature references to lichen collections from the wilderness have been found.

METHODS

Field work was done during late July and August, 1993 when 565 collections were made at 18 localities. A complete list of collection localities is given in Appendix I and these are indicated on Fig. 1. Collection localities, about 2 acres in size, were selected first to give a general coverage of the wilderness, second, to sample all vegetational types, and third, to be in localities that should be rich in lichens. Undisturbed as well as disturbed habitats (such as old logging roadsides and trails) were studied. At each locality voucher specimens of all species found were collected to record the total flora for each locality and to avoid missing different species that might appear similar in the field. At some localities additional material of selected species was collected for chemical analysis (see below). While collecting at each locality observations were made about the general health of the lichens. Lichen health was evaluated by looking for damaged or dying lichens on all of the trees where collections were made (at least 100 trees). 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.

LICHEN FLORA

The following list of lichens is based on my 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.

SPECIES LIST

- I Alectoria sarmentosa (Ach.) Ach. :RARE
- Anaptychia palmulata (Michx.) Vain.
- 1 unidentified species of Arthopyrenia
- Bacidia chlorantha (Tuck.) Fink
- Bacidia schweinitzii (Tuck.) Schneid.
- Baeomyces rufus (Huds.) Rebert. :RARE
- S Bryoria furcellata (Fr.) Brodo & Hawksw.
- Bryoria nadvornikiana (Gyeln.) Brodo & Hawksw.
- Buellia arnoldii Serv. & Nadv. :RARE
- I Buellia stillingiana Steiner
- Calicium trabinellum Ach. :RARE
- S-I Candelaria concolor (Dicks.) B. Stein
- Candelariella efflorescens R. Harris & Buck
- Cetraria oakesiana Tuck.
- I Cetraria orbata (Nyl.) Fink
- I Cetraria pinastri (Scop.) Gray
- I Cetraria sepincola (Ehrh.) Ach.
- Cetrelia olivetorum (Nyl.) W. & C. Culb.
- Chaenotheca chrysocephala (Turn. ex Ach.) Th. Fr. :RARE
- Chaenotheca laevigata Nadv. :RARE
- Chaenotheca xyloxena Nadv. :RARE
- Chaenothecopsis lignicola (Nadv.) Schmidt :RARE
- Cladina arbuscula (Wallr.) Hale & W. Culb. :RARE
- Cladina mitis (Sandst.) Hustich
- Cladina rangiferina (L.) Nyl.
- Cladina stellaris (Opiz) Brodo :RARE
- Cladonia bacillaris Nyl. :RARE
- Cladonia caespiticia (Pers.) Flörke
- Cladonia chlorophaea (Flörke ex Somm.) Spreng. :RARE
- Cladonia coccifera (L.) Willd.
- I Cladonia coniocraea (Flörke) Spreng.
- Cladonia cornuta (L.) Hoffm.
- Cladonia crispata (Ach.) Flot.
- I Cladonia cristatella Tuck. :RARE
- Cladonia deformis (L.) Hoffm. :RARE
- Cladonia digitata (L.) Hoffm.
- Cladonia floerkeana (Fr.) Flörke
- Cladonia furcata (Huds.) Schrad.
- Cladonia grayi G. K. Merr. ex Sandst.
- Cladonia merochlorophaea Asah.
- Cladonia squamosa (Scop.) Hoffm.
- Conotrema urceolatum (Ach.) Tuck.
- Diploschistes scruposus (Schreb.) Norm. :RARE
- I Evernia mesomorpha Nyl.

- I Graphis scripta (L.) Ach.
- Haematomma cismonicum Beltr.
- Haematomma elatinum (Ach.) Mass.
- Haematomma pustulatum Brodo & W. Culb.
- Hypocenomyce friesii (Ach. in Lilj.) P. James & G. Schneid. :RARE
- I Hypogymnia physodes (L.) Nyl.
- S Hypogymnia tubulosa (Schaer.) Hav.
- I Imshaugia aleurites (Ach.) S. F. Meyer
- Julella fallaciosa (Stizenb. ex Arn.) R. Harris :RARE
- I Lecanora chlarotera Nyl.
- I Lecanora pulicaris (Pers.) Ach.
- Lecanora thysanophora Harris ined.
- Lecanora wisconsinensis Magn.
- Lecidea helvola (Körb. ex Hellb.) Oliv.
- 2 unidentified species of Lecidea
- Lecidella euphorea (Flörke) Hert.
- Lepraria finkii (B. de Lesd. in Hue) R. Harris
- Lepraria neglecta (Nyl.) Lett.
- 2 unidentified species of Lepraria
- Leptogium cyanescens (Rabenh.) Körb. :RARE
- Leptorhaphis epidermidis (Ach.) Th. Fr. :RARE
- S Lobaria pulmonaria (L.) Hoffm.
- Lobaria quercizans Michx.
- I Lopadium pezizoideum (Ach.) Körb.
- Micarea bauschiana (Körb.) V. Wirth & Vezda :RARE
- 2 unidentified species of Micarea
- I Mycoblastus sanguinarius (L.) Norm.
- Mycocalicium subtile (Pers.) Szat. :RARE
- Ochrolechia pseudopallescens Brodo
- Ochrolechia trochophora (Vain) Oshio :RARE
- Parmelia appalachensis W. Culb. :RARE
- Parmelia aurulenta Tuck.
- Parmelia caperata (L.) Ach.
- Parmelia cumberlandia (Gyeln.) Hale :RARE
- Parmelia galbina Ach. :RARE
- I Parmelia olivacea (L.) Ach. :RARE
- I Parmelia rudecta Ach.
- I Parmelia saxatilis (L.) Ach.
- I Parmelia septentrionalis (Lynge) Ahti
- S Parmelia squarrosa Hale
- S-I Parmelia subaurifera Nyl.
- I Parmelia subrudecta Nyl.
- I-T Parmelia sulcata Tayl.
- 1 unidentified species of Parmelia
- I Parmeliopsis ambigua (Wulf. in Jacq.) Nyl.
- I Parmeliopsis hyperopta (Ach.) Arn.
- Peltigera canina (L.) Willd. :RARE
- I Pertusaria amara (Ach.) Nyl.
- Pertusaria consocians Dibb. :RARE
- Pertusaria macounii (Lamb) Dibb.
- I Pertusaria multipunctoides Dibb. :RARE
- Pertusaria ophthalmiza (Nyl.) Nyl.
- Pertusaria propinqua Müll. Arg. :RARE
- Pertusaria trachythallina Erichs.

- Pertusaria velata (Turn.) Nyl. :RARE
 2 unidentified species of Pertusaria
Phaeocalicium polyporaenum (Nyl.) Tibell
Phaeophyscia chloantha (Ach.) Moberg :RARE
Phaeophyscia pusilloides (Zahlbr.) Essl.
Phaeophyscia rubropulchra (Degel.) Moberg
 I Physcia aipolia (Ehrh. ex Humb.) Fűrnr. :RARE
 I Physcia millegrana Degel.
 I Physcia stellaris (L.) Nyl. :RARE
 I Physconia detersa (Nyl.) Poelt :RARE
Placynthiella icmalea (Ach.) Coppins & James
 I Platismatia glauca (L.) W. & C. Culb.
Platismatia tuckermanii (Oakes) W. & C. Culb.
Porpidia albocaerulescens (Wulf.) Hert. & Knoph
Porpidia crustulata (Ach.) Hert. & Knoph
Porpidia macrocarpa (DC. in Lam. & DC.) Hert. & Schwab :RARE
Pseudevernia cladonia (Tuck.) Hale & W. Culb.
Pseudevernia consocians (Vain.) Hale & W. Culb.
Pyrenula pseudobufonia (Rehm.) R. Harris
Pyxine sorediata (Ach.) Mont. :RARE
Ramalina intermedia (Del. ex Nyl.) Nyl.
 S Ramalina obtusata (Arn.) Bitt. :RARE
Rhizocarpon concentricum (Dav.) Beltram. :RARE
Rhizocarpon hochstetteri (Körb.) Vain.
Rinodina ascociscana Tuck.
Sarea resinae (Fr. ex Fr.) Kuntze :RARE
 I Scoliciosporum chlorococcum (Graewe ex Stenh.) Vezda
Trapeliopsis flexuosa (Fr.) Coppins & James :RARE
Trapeliopsis granulosa (Hoffm.) Lumbsch. :RARE
Trapeliopsis viridescens (Schrad.) Coppins & James
Umbilicaria vellea (L.) Ach. :RARE
 S Usnea filipendula Stirt. :RARE
 S-I Usnea hirta (L.) Weber ex Wigg.
 S-I Usnea subfloridana Stirt.
 1 unidentified species of Verrucaria

DISCUSSION OF FLORA

This list of species presents the first listing of lichens from the Lye Brook Wilderness and includes 126 species found during this study. There are also 11 additional unidentified species, some of which are undescribed. The lichen flora is typical of the eastern deciduous forest. These hardwood forests have fewer lichens than conifer and mixed forests because the dense shade is not favorable to the growth of many species. Some of the most common species are Cetraria oakesiana, Hypogymnia physodes, Parmelia rudecta, P. subaurifera, Phaeophyscia rubropulchra and Graphis scripta.

The lichens of The Burning and in the swamp near Kelly Stand include several species rare in

the LBW. Some of these rare species that are now present may be lost in the future due to natural causes as succession progresses in these areas.

None of the lichen distributions show unexpected patterns. Many of the species prefer wetter areas, such as bogs, and were only found in these bogs. 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 wilderness. The cases of rarity do not necessarily reflect sensitivity damage due from sulfur dioxide.

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 wilderness. There are numerous species with blue-green algae, which are very sensitive to sulfur dioxide. One of the most sensitive lichens, Lobaria pulmonaria, was found twice in the LBW. These observations indicate that there is no air quality degradation in the wilderness due to sulfur dioxide that causes visible damage to the lichen flora.

This study found the following number of species in the different sensitivity categories.

Category	# of Species
Sensitive	6
S/I	4
Intermediate	30
I/T	1
Tolerant	0

Most lichen species are unknown as to sensitivity category. The absence of species in the more tolerant categories in LBW indirectly indicates the lack of sulfur dioxide problems. In areas of high sulfur dioxide these categories would have more species and the most sensitive categories would have fewer species. The RARE species in LBW are not related to air quality (see above). The only way to determine past air quality impacts on the present lichen species inventory is by comparison with historical data (from before the presumed impacts occurred). Since there are no historical species lists from this area it cannot be determined whether the present lichen flora has changed prior to this study.

Another way of analyzing the lichen flora of an area is to study the distributions of the sensitive

species within the wilderness to look for voids in the distributions that might be caused by air pollution. Showman (1975) has described and used this technique in assessing sulfur dioxide levels around a power plant in Ohio. Only the very common species have meaning with such a technique since the rare species may be absent due to other factors. This method of assessing air quality is weak but occasionally is useful in detecting directional effects in an area.

Many of the lichens in the wilderness have known sensitivity to sulfur dioxide according to the list presented in Wetmore (1983). There were six species in the most sensitive category. These species are usually absent when sulfur dioxide levels are above 50 µg per cubic meter average annual concentrations. The species that occur in the LBW in the most sensitive category are as follows.

Bryoria furcellata
Hypogymnia tubulosa
Lobaria pulmonaria
Parmelia squarrosa
Ramalina obtusata
Usnea filipendula

The distributions of these species are shown in Fig. 2-7. Although these species are not found at all localities and most are not common or rare, there is no indication that the voids in the distributions are due to high levels of sulfur dioxide. Some of the localities where collections were made do not have suitable habitats or substrates for some of these species. This is especially true for Lobaria pulmonaria that requires moist habitats.

ELEMENTAL ANALYSIS

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

Four species of lichens were collected for elemental analysis in the LBW. At some localities

not all species were present in quantities needed for the analysis.

METHODS

Lichens were collected in spunbound olefin bags at four localities in different parts of the wilderness for laboratory analysis (Fig. 1). Species collected were Cladina rangiferina, Evernia mesomorpha, Hypogymnia physodes, and Parmelia sulcata. These species were selected because they are locally present in abundance and relatively easy to clean. Cladina rangiferina was present at only two elemental analysis localities and was collected from the ground. Evernia mesomorpha was not present at one locality and was collected from conifer branches. Hypogymnia physodes and Parmelia sulcata were present at all four localities and were collected from conifer bark.

Four localities were selected for elemental analysis and are indicated on the map of collection localities (Fig. 1). These localities are: North of Little Mud Pond (9 Aug. 1993), Hill west of Lye Brook (8 Aug. 1993), West side of Bourn Pond (4 Aug. 1993), and North of Kelly Stand (30 July 1993). Full locality citations are given in Appendix I. Ten to 20 grams of each species were collected at each locality.

Lichens were air dried and cleaned of all bark and detritus under a dissecting microscope but thalli were not washed. Three samples (replicates) of each collection were submitted for analysis. Because of the scarcity of Cladina rangiferina in LBW, these samples were submitted along with lichens from another study, where adequate material was available for parallel analytical splits. Analysis was done for sulfur and multi-element analysis by the Research Analytical Laboratory at the University of Minnesota. In the sulfur analysis, a ground and pelleted 100-150 mg sample was prepared for total sulfur by dry combustion and measurement of evolved sulfur dioxide on a LECO Sulfur Determinator, model no. SC-132, by infra red absorption. Multi-element determination for Ca, Mg, Na, K, P, Fe, Mn, Al, Cu, Zn, Cd, Cr, Ni, Pb, and B were determined simultaneously by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry. For the ICP one gram of dried plant material was dry ashed in a 20 ml high form silica crucible at 485 degrees Celsius for 10-12 hrs. Crucibles

were covered during the ashing as a precaution against contamination. The dry ash was boiled in 2N HCl to improve the recovery of Fe, Al and Cr and followed by transfer of the supernatant to 7 ml plastic disposable tubes for direct determination by ICP.

RESULTS AND DISCUSSION

Table 1 gives the results of the analyses for all three replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. Values for National Bureau Of Standards Peach Leaves (NBS Peach) and a locally used lichen standard (Cladina stellaris) are also given. Lichens collected from hardwood bark sometimes have different accumulations than those collected from conifer bark. To reduce this substrate variable, all tree lichens were collected from conifer bark whenever possible. Different species may accumulate different amounts of elements and this is evident when comparing sulfur levels of the different species. Cladina rangiferina has lower levels of sulfur than the other species. None of the reported values were below the lower detection limits of the instruments.

All of the levels found in the LBW lichens are within typical limits for similar lichens in clean areas and the levels within each species are fairly uniform across all localities. At Kelly Stand two species showed higher accumulations but that may be due to historical effects rather than air quality. This shows that there is no point-source of pollution effecting one part of LBW.

The sulfur levels in lichens tested range from 535 to 1780 ppm for all samples and these values are near background levels as cited by Solberg (1967) Erdman & Gough (1977), Nieboer et al (1977) and Puckett & Finegan (1980) for other species of lichens. Levels may be as low as 200-300 in the arctic (Tomassini et al, 1976) while levels in polluted areas are 4300-5200 ppm (Seaward, 1973) or higher. The sulfur levels in LBW are well within typical levels for clean areas as reported in the literature.

All of the other elements show normal levels for areas with low pollution or relatively clean air. The elemental levels in the same species in the White Mt. Wilderness areas are very similar but slightly lower than those in the LBW. In two species some elements are somewhat higher at the Kelly

**Table 1. Analysis of Lye Brook 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
<u>C. rangiferina</u>	302	1083	207	170	157	173	47.8	54.6	17.1	1.6	0.4	2.9	0.7	0.3	0.1	535	Lye Brook
<u>C. rangiferina</u>	266	976	190	161	166	183	47.2	47.7	16.4	1.5	0.4	3.3	0.6	0.3	0.1	555	Lye Brook
<u>C. rangiferina</u>	269	1001	186	163	159	175	47.9	48.3	16.0	1.7	0.4	3.0	0.9	0.4	0.1	650	Lye Brook
<u>C. rangiferina</u>	312	1446	283	170	206	259	20.8	17.2	24.5	1.8	0.8	3.2	0.6	0.3	0.1	750	Bourn Pond
<u>C. rangiferina</u>	342	1637	235	175	183	229	19.3	15.0	24.6	2.0	0.8	3.1	0.5	0.3	0.1	750	Bourn Pond
<u>C. rangiferina</u>	332	1573	215	174	188	232	20.8	15.5	24.5	1.9	0.8	3.5	0.5	0.3	0.1	530	Bourn Pond
<u>E. mesomorpha</u>	653	2964	668	265	151	186	32.7	43.9	41.5	2.8	2.1	6.0	0.8	0.4	0.2	1330	Little Mud P
<u>E. mesomorpha</u>	646	2985	411	273	164	209	33.5	41.3	41.6	3.0	2.2	6.4	0.9	0.5	0.3	1330	Little Mud P
<u>E. mesomorpha</u>	738	2978	495	292	172	215	47.7	50.4	43.7	3.0	2.3	6.9	0.9	0.5	0.2	1430	Little Mud P
<u>E. mesomorpha</u>	456	1989	417	190	114	138	37.5	79.0	31.9	2.1	1.7	6.6	0.6	0.4	0.2	1070	Lye Brook
<u>E. mesomorpha</u>	449	1936	399	184	107	124	42.2	70.6	29.8	2.0	1.6	6.6	0.7	0.3	0.1	1035	Lye Brook
<u>E. mesomorpha</u>	439	1831	378	184	116	133	45.1	69.9	30.7	2.0	1.4	8.1	0.7	0.4	0.1	1070	Lye Brook
<u>E. mesomorpha</u>	422	1754	623	202	128	135	26.9	27.5	30.3	1.7	1.6	4.7	0.5	0.4	0.2	830	Bourn Pond
<u>E. mesomorpha</u>	463	1750	816	211	110	119	27.8	31.5	30.6	1.6	1.6	3.8	0.5	0.3	0.2	790	Bourn Pond
<u>E. mesomorpha</u>	464	1856	705	231	120	126	29.8	30.8	29.9	1.7	1.5	3.9	0.6	0.4	0.2	790	Bourn Pond
<u>H. physodes</u>	738	3862	8619	576	267	379	22.8	136.2	124.8	4.4	2.1	18.1	1.4	0.7	1.4	1380	Little Mud P
<u>H. physodes</u>	805	4416	5493	512	213	295	24.0	104.5	97.6	4.7	2.0	25.6	1.8	0.7	1.1	1380	Little Mud P
<u>H. physodes</u>	637	3807	8847	495	217	307	23.8	111.0	87.1	4.6	2.0	29.9	1.8	0.6	1.2	1420	Little Mud P
<u>H. physodes</u>	565	2743	7013	489	266	363	33.2	452.3	116.3	3.9	1.2	29.5	1.6	0.8	1.1	950	Lye Brook
<u>H. physodes</u>	694	3070	10832	507	252	322	51.0	506.4	116.7	3.5	1.3	33.7	1.2	0.7	1.4	1000	Lye Brook
<u>H. physodes</u>	619	2790	7764	492	243	322	70.5	508.1	121.4	3.4	1.3	25.8	1.1	0.7	1.2	1025	Lye Brook
<u>H. physodes</u>	813	3165	19606	653	191	229	30.0	281.7	88.1	3.6	2.8	17.5	1.0	0.6	0.9	1080	Bourn Pond
<u>H. physodes</u>	839	3127	21785	670	202	250	29.1	279.6	86.2	3.6	2.8	18.1	1.1	0.6	0.9	990	Bourn Pond
<u>H. physodes</u>	943	3414	17798	726	199	235	30.6	266.4	86.7	3.6	2.8	17.2	1.1	0.5	0.8	1020	Bourn Pond
<u>H. physodes</u>	2405	6348	6706	1008	521	794	57.1	139.8	102.3	6.0	3.1	25.7	2.4	1.1	0.7	1490	Kelly Stand
<u>H. physodes</u>	2037	5771	5686	901	544	814	58.2	110.6	96.4	5.5	2.8	26.1	2.4	1.1	0.5	1440	Kelly Stand
<u>H. physodes</u>	2336	6162	5900	932	542	807	55.5	120.7	100.4	6.4	2.8	43.5	2.3	1.1	0.6	1350	Kelly Stand
<u>P. sulcata</u>	1359	4517	1074	382	309	385	26.9	60.8	93.0	6.6	3.4	22.2	2.0	0.8	0.7	1550	Little Mud P
<u>P. sulcata</u>	1221	4222	1164	368	333	415	26.2	64.3	93.7	6.7	3.6	26.5	2.1	0.8	0.6	1530	Little Mud P
<u>P. sulcata</u>	1298	4442	1096	376	299	378	27.0	63.9	91.0	6.6	3.6	23.9	2.0	0.7	0.7	1780	Little Mud P
<u>P. sulcata</u>	1092	3547	1541	317	271	317	42.3	344.1	115.9	5.1	2.7	21.4	1.4	0.6	0.4	1080	Lye Brook
<u>P. sulcata</u>	664	2024	3587	405	301	326	16.9	181.7	94.5	5.1	2.8	24.1	1.7	0.7	0.4	1020	Bourn Pond
<u>P. sulcata</u>	663	2144	3357	384	326	356	29.2	183.5	96.8	5.0	2.8	23.1	1.8	0.8	0.4	1010	Bourn Pond
<u>P. sulcata</u>	689	2355	3036	357	318	352	18.1	162.2	85.0	4.6	2.6	22.7	1.8	0.8	0.4	1010	Bourn Pond
<u>P. sulcata</u>	1727	4364	2048	606	450	638	48.9	95.2	84.3	5.2	3.2	17.6	1.8	0.9	0.4	1360	Kelly Stand
<u>P. sulcata</u>	1724	4402	2064	599	443	634	40.7	98.9	87.6	5.5	3.4	17.5	1.8	0.9	0.4	1410	Kelly Stand
<u>P. sulcata</u>	1765	4516	2021	636	465	681	44.4	99.7	85.9	5.3	3.3	17.2	1.8	0.9	0.4	1480	Kelly Stand

Standards																	
<u>C. stellaris</u>	195	664	234	264	421	566	74.6	20.4	17.1	2.1	0.9	12.7	1.0	0.8	0.2	410	
<u>C. stellaris</u>	198	664	242	274	435	587	78.9	20.6	18.0	3.0	1.0	13.9	1.1	0.9	0.2	423	
<u>C. stellaris</u>	194	658	234	271	416	551	80.6	20.2	17.1	2.2	1.0	14.1	1.2	1.0	0.2	460	
NBS-Peach	1182	3695	4433	1164	459	177	17.3	686.6	71.3	2.8	17.1	10.8	1.5	1.9	0.2	NA	
NBS-Peach	1210	3718	4523	1199	467	178	24.1	702.1	64.6	3.3	17.5	12.0	1.7	2.1	0.3	NA	
NBS-Peach	1202	3675	4557	1208	459	177	20.0	696.8	66.1	3.2	17.4	12.6	1.9	2.2	0.3	NA	

**Table 2. Summary of Analysis of Lye Brook 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
<hr/>																	
<u>Cladina rangiferina</u>																	
Mean	279	1020	194	165	161	177	47.6	50.2	16.5	1.6	0.4	3.1	0.7	0.3	0.1	580	Lye Brook
Std. dev.	20	56	11	4	4	5	0.4	3.8	0.5	0.1	0.1	0.2	0.1	0.1	<.1	61	Lye Brook
Mean	329	1552	244	173	192	240	20.3	15.9	24.5	1.9	0.8	3.2	0.5	0.3	0.1	677	Bourn Pond
Std. dev.	15	97	35	3	12	17	0.9	1.2	0.1	0.1	<.1	0.2	<.1	<.1	<.1	127	Bourn Pond
<u>Evernia mesomorpha</u>																	
Mean	679	2976	525	277	162	203	38.0	45.2	42.3	2.9	2.2	6.4	0.9	0.5	0.2	1363	Little Mud P
Std. dev.	51	11	131	14	10	15	8.4	4.7	1.2	0.1	0.1	0.5	0.1	<.1	<.1	58	Little Mud P
Mean	448	1919	398	186	113	132	41.6	73.2	30.8	2.0	1.6	7.1	0.7	0.4	0.1	1058	Lye Brook
Std. dev.	9	81	20	3	5	7	3.8	5.1	1.1	0.1	0.2	0.9	<.1	<.1	<.1	20	Lye Brook
Mean	450	1787	715	215	119	126	28.2	29.9	30.3	1.6	1.6	4.1	0.5	0.4	0.2	803	Bourn Pond
Std. dev.	24	60	97	15	9	8	1.5	2.1	0.4	0.1	0.1	0.5	<.1	<.1	<.1	23	Bourn Pond
<u>Hypogymnia physodes</u>																	
Mean	727	4028	7653	527	232	327	23.5	117.2	103.1	4.6	2.0	24.5	1.7	0.6	1.2	1393	Little Mud P
Std. dev.	85	337	1874	43	30	45	0.7	16.8	19.4	0.1	0.1	6.0	0.2	0.1	0.1	23	Little Mud P
Mean	626	2868	8536	496	254	336	51.6	489.0	118.1	3.6	1.2	29.7	1.3	0.7	1.2	992	Lye Brook
Std. dev.	65	177	2023	10	12	24	18.6	31.8	2.8	0.3	<.1	3.9	0.3	0.1	0.2	38	Lye Brook
Mean	865	3235	19730	683	197	238	29.9	275.9	87.0	3.6	2.8	17.6	1.1	0.6	0.9	1030	Bourn Pond
Std. dev.	69	156	1996	38	5	11	0.8	8.3	1.0	<.1	<.1	0.5	<.1	<.1	0.1	46	Bourn Pond
Mean	2259	6094	6098	947	535	805	56.9	123.7	99.7	6.0	2.9	31.8	2.4	1.1	0.6	1427	Kelly Stand
Std. dev.	196	295	538	55	13	11	1.4	14.9	3.0	0.5	0.2	10.1	<.1	<.1	0.1	71	Kelly Stand
<u>Parmelia sulcata</u>																	
Mean	1293	4393	1111	375	314	393	26.7	63.0	92.6	6.6	3.5	24.2	2.1	0.7	0.7	1620	Little Mud P
Std. dev.	69	153	47	7	18	20	0.4	1.9	1.4	0.1	0.1	2.1	<.1	0.1	<.1	139	Little Mud P
Mean	672	2175	3326	382	315	345	21.4	175.8	92.1	4.9	2.7	23.3	1.7	0.7	0.4	1013	Bourn Pond
Std. dev.	15	168	277	25	12	16	6.7	11.8	6.3	0.3	0.1	0.7	0.1	0.1	<.1	6	Bourn Pond
Mean	1739	4427	2044	613	453	651	44.7	97.9	86.0	5.3	3.3	17.5	1.8	0.9	0.4	1417	Kelly Stand
Std. dev.	23	79	22	20	11	26	4.1	2.4	1.7	0.1	0.1	0.2	<.1	<.1	<.1	60	Kelly Stand
Standards																	
<u>Cladina stellaris</u>																	
Mean	196	662	237	270	424	568	78.0	20.4	17.4	2.4	1.0	13.5	1.1	0.9	0.2	431	
Std. dev.	2	3	5	5	10	18	3.1	0.2	0.5	0.5	0.1	0.7	0.1	0.1	<.1	26	
NBS Peach																	
Mean	1198	3696	4504	1190	462	177	20.5	695.2	67.3	3.1	17.3	11.8	1.7	2.1	0.3	NA	
Std. dev.	14	21	64	23	5	1	3.5	7.8	3.5	0.3	0.2	1.0	0.2	0.1	<.1	NA	

Stand.

STATISTICAL ANALYSIS

Introduction

Generally, one bag of lichens was collected from a site, cleaned, separated into groups (with different individuals in the groups), ground, and analyzed for chemical constituents. In approximately 10% of the samples a composite sample was prepared and ground before being subsampled (=analytical splits). The samples from LBW were submitted with those from White Mt. 1993 study. In addition, data from the same species from two relatively clean localities in northern Minnesota (NE of Tofte and Mt. Rose) are included for comparison. This statistical analysis discussion also includes the pertinent parts of the analysis done on the White Mt. study data.

The data were log-transformed to make them more normal, prior to extracting the principal components. The principal components do a good job of describing the data, with the first component explaining 70% of the variability in the data, and the second component explaining an additional 8% of the variability. Only the first two components were used in the analyses. The first component is basically a weighted average of the concentrations of all elements, with a strong downweighting of sodium and a moderate downweighting of manganese. These all vary together. The second component contrasts a weighted average of {**Na, S, B**, P, Fe, Al, K, Cr} to a weighted average of {**Mn, Ca, Cd**, Mg, Pb, Ni, Zn}. The second component includes S and is more meaningful in this air quality study.

LATENT ROOTS (EIGENVALUES)

1	2	3	4	5	6	7	8	9
11.204	1.336	1.069	0.765	0.524	0.377	0.260	0.112	0.098
10	11	12	13	14	15	16		
0.072	0.050	0.040	0.035	0.023	0.021	0.013		

COMPONENT LOADINGS

	1	2	3	4	5	6	7	8
LP	0.777	0.175	-0.479	0.182	-0.114	-0.259	0.036	0.034
LK	0.824	0.114	-0.453	0.235	-0.050	0.023	0.140	0.003
LCA	0.834	-0.406	-0.115	0.045	0.209	0.236	-0.044	-0.031
LMG	0.863	-0.185	-0.351	0.089	0.229	0.045	0.088	-0.081
LAL	0.888	0.144	-0.018	-0.353	0.127	-0.148	-0.107	0.076
LFE	0.897	0.165	-0.015	-0.334	0.160	-0.089	-0.041	0.028
LNA	0.388	0.616	0.380	0.401	0.396	-0.036	0.041	0.043
LMN	0.651	-0.505	0.195	0.405	0.029	-0.177	-0.273	-0.028
LZN	0.950	-0.106	0.154	0.060	-0.147	0.034	-0.037	0.061
LCU	0.971	0.042	0.017	-0.089	-0.095	-0.057	-0.042	0.078
LB	0.837	0.350	-0.141	0.014	-0.221	0.146	-0.239	-0.001
LPB	0.859	-0.185	0.389	-0.027	-0.161	-0.052	0.136	0.049
LNI	0.876	-0.164	0.254	-0.028	-0.124	-0.211	0.215	-0.097
LCR	0.904	0.110	0.095	-0.266	0.125	0.010	-0.044	-0.206
LCD	0.890	-0.268	0.050	-0.064	0.100	0.236	0.109	0.155
LS	0.806	0.360	0.207	0.133	-0.257	0.246	0.029	-0.081

	9	10	11	12	13	14	15	16
LP	0.055	-0.085	0.045	0.068	-0.039	0.028	-0.023	-0.027
LK	0.063	0.057	-0.070	-0.091	0.032	0.030	0.037	0.028
LCA	-0.102	0.002	-0.011	0.009	-0.048	0.089	-0.022	-0.012
LMG	-0.077	0.012	-0.016	0.055	0.050	-0.089	-0.026	0.004
LAL	0.011	0.050	0.002	0.035	0.014	0.024	-0.037	0.073
LFE	0.013	0.098	-0.038	0.032	0.004	0.002	0.066	-0.060
LNA	-0.037	-0.029	0.004	-0.011	-0.008	0.004	0.000	0.001
LMN	0.081	0.051	0.019	-0.005	0.028	-0.005	0.012	-0.001
LZN	-0.010	-0.052	-0.114	0.022	-0.107	-0.048	0.024	0.021
LCU	-0.053	0.038	0.014	-0.116	-0.017	-0.033	-0.076	-0.036
LB	-0.129	-0.068	0.050	-0.007	0.048	-0.004	0.046	0.008
LPB	-0.019	-0.081	-0.073	0.029	0.104	0.033	-0.018	-0.015
LNI	-0.109	0.042	0.088	-0.015	-0.036	0.005	0.038	0.020
LCR	0.122	-0.116	-0.005	-0.050	-0.009	-0.002	-0.006	-0.001
LCD	0.115	-0.041	0.107	-0.005	0.003	-0.022	0.026	0.004
LS	0.082	0.118	0.016	0.063	-0.008	0.004	-0.037	-0.004

VARIANCE EXPLAINED BY COMPONENTS

1	2	3	4	5	6	7	8	9
11.204	1.336	1.069	0.765	0.524	0.377	0.260	0.112	0.098
10	11	12	13	14	15	16		
0.072	0.050	0.040	0.035	0.023	0.021	0.013		

PERCENT OF TOTAL VARIANCE EXPLAINED

1	2	3	4	5	6	7	8	9
70.023	8.351	6.680	4.782	3.275	2.358	1.624	0.703	0.615
10	11	12	13	14	15	16		
0.451	0.311	0.250	0.217	0.146	0.132	0.082		

FACTOR SCORE COEFFICIENTS

	1	2
LP	0.069	0.131
LK	0.074	0.085
LCA	0.074	-0.303
LMG	0.077	-0.138
LAL	0.079	0.108
LFE	0.080	0.124
LNA	0.035	0.461
LMN	0.058	-0.378
LZN	0.085	-0.079
LCU	0.087	0.031
LB	0.075	0.262
LPB	0.077	-0.138
LNI	0.078	-0.123
LCR	0.081	0.082
LCD	0.079	-0.201
LS	0.072	0.269

Question. Are there differences between 1988 and 1993 in White Mt.?

Disregarding localities, principal component 1 shows 1993 to be lower than 1988 (P = 0.004), but principal component 2 shows no difference (P = 0.14). When localities are included as an effect, there are significant differences for both principal components, as well as numerous significant interactions. Averaging over species and localities, PC 1 is again lower in 93 than 88, but for PC 2 93 is higher than 88. Note that the species and localities are somewhat different in the two analyses. Note also that with either analysis perspective, the species effects far outweigh the site or locality effects; this may be related to life history strategies of the lichen species.

TABLE OF YEAR\$ (ROWS) BY SPECIES\$ (COLUMNS)

	C. rang	C. styg	E. meso	H. phys	P. sulc	TOTAL
White88	12	3	3	15	0	33
White93	18	3	15	15	15	66
TOTAL	30	6	18	30	15	99

So P. sulcata is not included in this analysis.

DEP VAR: F1 N: 84 SQUARED MULTIPLE R: 0.956

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR\$	0.3971	1	0.3971	8.8067	0.0040
SPECIES\$	69.7695	3	23.2565	515.7613	0.0000
YEAR*SPP	0.2860	3	0.0953	2.1146	0.1053
ERROR	3.4270	76	0.0451		

	LS MEAN	SE	N
YEAR\$ =White88	-0.4457	0.0480	33
YEAR\$ =White93	-0.6280	0.0384	51

DEP VAR: F2 N: 84 SQUARED MULTIPLE R: 0.770

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR\$	0.5132	1	0.5132	2.2326	0.1393
SPECIES\$	38.3826	3	12.7942	55.6574	0.0000
YEAR*SPP	0.1958	3	0.0653	0.2839	0.8369
ERROR	17.4704	76	0.2299		

	LS MEAN	SE	N
YEAR\$ =White88	-0.4158	0.1083	33
YEAR\$ =White93	-0.2085	0.0866	51

including localities:

TABLE OF SPECIES\$ (ROWS) BY LOCALITY\$ (COLUMNS)
FOR YEAR\$ = White88

	Lows	Ba	Mt. Eis	Mt. Craw	Rky Br	Wamsutta	TOTAL
C. rangi	3	3	3	3	0		12
C. stygi	0	0	0	0	3		3
E. mesom	0	0	3	0	0		3
H. physo	3	3	3	3	3		15
TOTAL	6	6	9	6	6		33

FOR YEAR\$ = White93

	Lows	Ba	Mt. Eis	Mt. Craw	Rky Br	Wamsutta	TOTAL
C. rangi	4	3	4	4	3		18
C. stygi	0	0	0	0	3		3
E. mesom	3	3	3	3	3		15
H. physo	3	3	3	3	3		15
TOTAL	10	9	10	10	12		51

So the Wamsutta Trail locality and C. stygia and E. mesomorpha species will not be included.

DEP VAR: F1 N: 51 SQUARED MULTIPLE R: 0.997
 ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR\$	1.3897	1	1.3897	285.9987	0.0000
SPECIES\$	57.1001	1	57.1001	11750.8963	0.0000
LOCALITY\$	1.1173	3	0.3724	76.6441	0.0000
YEAR*SPP	0.1713	1	0.1713	35.2582	0.0000
YEAR*LOCALITY	0.1659	3	0.0553	11.3814	0.0000
SPP*LOCALITY	0.1233	3	0.0411	8.4610	0.0002
YEAR*SPP*LOCAL	0.1959	3	0.0653	13.4363	0.0000
ERROR	0.1701	35	0.0049		

	LS MEAN	SE	N
YEAR\$ =White88	-0.0610	0.0142	24
YEAR\$ =White93	-0.3932	0.0135	27

DEP VAR: F2 N: 51 SQUARED MULTIPLE R: 0.857
 ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR\$	0.5031	1	0.5031	10.4009	0.0027
SPECIES\$	3.0884	1	3.0884	63.8444	0.0000
LOCALITY\$	0.4121	3	0.1374	2.8395	0.0519
YEAR*SPP	0.0895	1	0.0895	1.8503	0.1825
YEAR*LOCALITY	2.7412	3	0.9137	18.8889	0.0000
SPP*LOCALITY	0.5004	3	0.1668	3.4478	0.0269
YEAR*SPP*LOCAL	2.8067	3	0.9356	19.3405	0.0000
ERROR	1.6931	35	0.0484		

	LS MEAN	SE	N
SITE\$ =White88	-0.8065	0.0449	24
SITE\$ =White93	-0.6066	0.0427	27

Question. Are there differences between Green and White Mts.?

Because differences were found in the previous question, only 1993 data were used in this comparison (and *C. stygia* was not used because it was only sampled in White Mt.). Green Mt. has a higher response than White Mt. for each component ($P < 0.0001$ in each case). These differences do not appear to be affected by which species is being looked at ($P = 0.22$ and $P = 0.55$ for principal components 1 and 2, respectively).

TABLE OF YEAR\$ (ROWS) BY SPECIES\$ (COLUMNS)

	C. rang	C. styg	E. meso	H. phys	P. sulc	TOTAL
Green93	14	0	15	18	16	63
White93	18	3	15	15	15	66
TOTAL	32	3	30	33	31	129

So C. stygia will not be included in the analysis

YEAR\$ Green93 White93

SPECIES\$ C. rangiferina E. mesomorpha H. physodes P. sulcata

DEP VAR: F1 N: 126 SQUARED MULTIPLE R: 0.915

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR\$	1.8198	1	1.8198	20.5992	0.0000
SPECIES\$	106.5286	3	35.5095	401.9508	0.0000
YEAR*SPECIES	0.4022	3	0.1341	1.5174	0.2136
ERROR	10.4245	118	0.0883		

	LS MEAN	SE	N
YEAR\$ =Green93	0.1810	0.0376	63
YEAR\$ =White93	-0.0603	0.0376	63

DEP VAR: F2 N: 126 SQUARED MULTIPLE R: 0.634

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
YEAR\$	8.1904	1	8.1904	24.0951	0.0000
SPECIES\$	61.3694	3	20.4565	60.1807	0.0000
YEAR*SPECIES	0.7252	3	0.2417	0.7112	0.5472
ERROR	40.1103	118	0.3399		

	LS MEAN	SE	N
YEAR\$ =Green93	0.4970	0.0738	63
YEAR\$ =White93	-0.0148	0.0737	63

Question. Does any locality in Green Mt. have significantly higher levels?

Yes. The details are available in the analysis material following this summary.

The first step was figuring out what data could be used. After reviewing the available data, it was determined that the locality comparisons would have to be done in pieces because of the zero counts in many of the design cells. However, it was also determined that a common MSE could be used for each of the principal components. The pooling calculations are given below.

In this analysis data from two relatively clean localities in northern Minnesota (NE of Tofte and Mt. Rose) have been included for comparison with the Green Mt. data.

Principal component 1

Green Mt (no Kelly Stand, no Little Mud Pond, all species): SSE = 0.12775 df = 32 MSE = 0.00399

Principal component 2

Green Mt (no Kelly Stand, no Little Mud Pond, all species): SSE = 1.62988 df = 32 MSE = 0.05093

1993 Green Mt. analyses

TABLE OF SPECIES\$ (ROWS) BY LOCALITY\$ (COLUMNS)

	Bourn P	Kelly	L Mud	Lye Br	Mt. Rose	Tofte	TOTAL
C. rangi	3	0	0	3	4	4	14
E. mesom	3	0	3	3	3	3	15
H. physo	3	3	3	3	3	3	18
P. sulca	3	3	3	1	3	3	16
TOTAL	12	6	9	10	13	13	63

LEVELS ENCOUNTERED DURING PROCESSING ARE:

SPECIES\$ H. physodes P. sulcata

LOCALITY\$ Bourn Pond Kelly Stand L Mud P Lye Brook Mt. Rose Tofte

DEP VAR: F1 N: 34 SQUARED MULTIPLE R: 0.976

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
SPECIES\$	0.01475	1	0.01475	4.87834	0.03792
LOCALITY\$	2.25738	5	0.45148	149.32763	0.00000
SPP*LOCALITY	0.43227	5	0.08645	28.59496	0.00000
ERROR	0.06651	22	0.00302		

DEP VAR: F2 N: 34 SQUARED MULTIPLE R: 0.957

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
SPECIES\$	6.41304	1	6.41304	110.83403	0.00000
LOCALITY\$	18.09785	5	3.61957	62.55561	0.00000
SPP*LOCALITY	2.68571	5	0.53714	9.28322	0.00007
ERROR	1.27296	22	0.05786		

There are significant interactions between species and locality effects. Therefore, will assess locality differences by species.

C. rangiferina

LOCALITY\$ Bourn Pond Lye Brook Mt. Rose NE of Tofte

DEP VAR: F1 N: 14

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 0.38851 3 0.12950 27.07522 0.00000
ERROR 0.43526 91 0.00478

LS MEAN SE N
LOCALITY\$ = Bourn Pond -1.18755 0.04181 3
LOCALITY\$ = Lye Brook -1.32966 0.04181 3
LOCALITY\$ = Mt. Rose -1.05754 0.03621 4
LOCALITY\$ = Tofte -0.87582 0.03621 4

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

Bourn Pond Lye Brook Mt. Rose Tofte
Bourn Pond 1.00000
Lye Brook 0.01360 1.00000
Mt. Rose 0.01573 0.00000 1.00000
NE of Tofte 0.00000 0.00000 0.00035 1.00000

DEP VAR: F2 N: 14

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 3.06925 3 1.02308 19.72326 0.00000
ERROR 4.72035 91 0.05187

LOCALITY\$ = Bourn Pond 0.60388 0.10228 3
LOCALITY\$ = Lye Brook 0.75324 0.10228 3
LOCALITY\$ = Mt. Rose -0.32525 0.08858 4
LOCALITY\$ = Tofte -0.18784 0.08858 4

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

Bourn Pond Lye Brook Mt. Rose Tofte
Bourn Pond 1.00000
Lye Brook 0.42398 1.00000
Mt. Rose 0.00000 0.00000 1.00000
NE of Tofte 0.00002 0.00000 0.39579 1.00000

E. mesomorpha

LOCALITY\$ Bourn Pond Little Mud Pond Lye Brook Mt. Rose NE of Tofte

DEP VAR: F1 N: 15

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 4.50638 4 1.12659 235.53640 0.00000
ERROR 0.43526 91 0.00478

	LS MEAN	SE	N
LOCALITY\$ = Bourn Pond	-0.89592	0.03752	3
LOCALITY\$ = L Mud P	-0.12567	0.03752	3
LOCALITY\$ = Lye Brook	-0.70142	0.03752	3
LOCALITY\$ = Mt. Rose	0.31698	0.03752	3
LOCALITY\$ = Tofte	0.50393	0.03752	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Bourn Pond	L Mud P	Lye Brook	Mt. Rose	Tofte
Bourn Pond	1.00000				
Little Mud P	0.00000	1.00000			
Lye Brook	0.00087	0.00000	1.00000		
Mt. Rose	0.00000	0.00000	0.00000	1.00000	
NE of Tofte	0.00000	0.00000	0.00000	0.00134	1.00000

DEP VAR: F2 N: 15

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
LOCALITY\$	3.55436	4	0.88859	17.13046	0.00000
ERROR	4.72035	91	0.05187		

	LS MEAN	SE	N
LOCALITY\$ = Bourn Pond	0.64152	0.11735	3
LOCALITY\$ = Little Mud P	1.59556	0.11735	3
LOCALITY\$ = Lye Brook	1.15521	0.11735	3
LOCALITY\$ = Mt. Rose	1.89405	0.11735	3
LOCALITY\$ = NE of Tofte	1.92556	0.11735	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Bourn Pond	L Mud P	Lye Brook	Mt. Rose	Tofte
Bourn Pond	1.00000				
Little Mud P	0.00000	1.00000			
Lye Brook	0.00694	0.02000	1.00000		
Mt. Rose	0.00000	0.11192	0.00014	1.00000	
NE of Tofte	0.00000	0.07931	0.00008	0.86584	1.00000

H. physodes

LOCALITY\$ Bourn Pond Kelly Stand Little Mud Pond Lye Brook Mt. Rose NE of Tofte

DEP VAR: F1 N: 18

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
LOCALITY\$	1.79279	5	0.35856	74.96331	0.00000
ERROR	0.43526	91	0.00478		

	LS MEAN	SE	N
LOCALITY\$ = Bourn Pond	0.71642	0.02725	3
LOCALITY\$ = Kelly Stand	1.63222	0.02725	3
LOCALITY\$ = Little Mud P	0.82381	0.02725	3
LOCALITY\$ = Lye Brook	0.77825	0.02725	3
LOCALITY\$ = Mt. Rose	0.90847	0.02725	3
LOCALITY\$ = NE of Tofte	1.17039	0.02725	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

Bourn P Kelly L Mud P Lye Brook Mt. Rose Tofte
 Bourn Pond 1.00000
 Kelly Stand 0.00000 1.00000
 Little Mud P 0.06036 0.00000 1.00000
 Lye Brook 0.27647 0.00000 0.42181 1.00000
 Mt. Rose 0.00100 0.00000 0.13728 0.02337 1.00000
 NE of Tofte 0.00000 0.00000 0.00000 0.00000 0.00001 1.00000

DEP VAR: F2 N: 18

ANALYSIS OF VARIANCE
 SOURCE SS DF MS F P
 LOCALITY\$ 12.58768 5 2.51754 48.53360 0.00000
 ERROR 4.72035 91 0.05187

LS MEAN SE N
 LOCALITY\$ = Bourn Pond -0.91377 0.14557 3
 LOCALITY\$ = Kelly Stand 1.56525 0.14557 3
 LOCALITY\$ = Little Mud P -0.66679 0.14557 3
 LOCALITY\$ = Lye Brook -0.69559 0.14557 3
 LOCALITY\$ = Mt. Rose -0.53926 0.14557 3
 LOCALITY\$ = NE of Tofte -0.32132 0.14557 3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

Bourn P Kelly L Mud P Lye Brook Mt. Rose Tofte
 Bourn Pond 1.00000
 Kelly Stand 0.00000 1.00000
 Little Mud P 0.18746 0.00000 1.00000
 Lye Brook 0.24375 0.00000 0.87728 1.00000
 Mt. Rose 0.04697 0.00000 0.49458 0.40275 1.00000
 NE of Tofte 0.00198 0.00000 0.06643 0.04711 0.24427 1.00000

P. sulcata

LOCALITY\$ Bourn Pond Kelly Stand Little Mud Pond Lye Brook Mt. Rose NE of Tofte

DEP VAR: F1 N: 16

ANALYSIS OF VARIANCE
 SOURCE SS DF MS F P
 LOCALITY\$ 0.94581 5 0.18916 39.54807 0.00000
 ERROR 0.43526 91 0.00478

LS MEAN SE N
 LOCALITY\$ = Bourn Pond 0.56485 0.03641 3
 LOCALITY\$ = Kelly Stand 1.17645 0.03641 3
 LOCALITY\$ = Little Mud P 0.95306 0.03641 3
 LOCALITY\$ = Lye Brook 0.72191 0.06307 1
 LOCALITY\$ = Mt. Rose 1.12243 0.03641 3
 LOCALITY\$ = NE of Tofte 1.22854 0.03641 3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Bourn P	Kelly L	Mud P	Lye Brook	Mt. Rose	Tofte
Bourn Pond	1.00000					
Kelly Stand	0.00000	1.00000				
Little Mud P	0.00000	0.00015	1.00000			
Lye Brook	0.05226	0.00000	0.00475	1.00000		
Mt. Rose	0.00000	0.34130	0.00349	0.00000	1.00000	
NE of Tofte	0.00000	0.35871	0.00000	0.00000	0.06343	1.00000

DEP VAR: F2 N: 16

ANALYSIS OF VARIANCE

SOURCE	SS	DF	MS	F	P
LOCALITY\$	8.49655	5	1.69931	32.75967	0.00000
ERROR	4.72035	91	0.05187		

	LS MEAN	SE	N
LOCALITY\$ = Bourn Pond	-0.64099	0.13039	3
LOCALITY\$ = Kelly Stand	1.65607	0.13039	3
LOCALITY\$ = Little Mud P	1.01513	0.13039	3
LOCALITY\$ = Lye Brook	0.54234	0.22585	1
LOCALITY\$ = Mt. Rose	0.57177	0.13039	3
LOCALITY\$ = NE of Tofte	0.75481	0.13039	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Bourn P	Kelly L	Mud P	Lye Brook	Mt. Rose	Tofte
Bourn Pond	1.00000					
Kelly Stand	0.00000	1.00000				
Little Mud P	0.00000	0.00086	1.00000			
Lye Brook	0.00002	0.00005	0.07553	1.00000		
Mt. Rose	0.00000	0.00000	0.01919	0.91113	1.00000	
NE of Tofte	0.00000	0.00001	0.16494	0.42125	0.32759	1.00000

SIGNIFICANT LOCALITY DIFFERENCES High to low (L to R).05

C. rangiferina

Lye Brook Bourn P Tofte Mt. Rose
Tofte Mt. Rose

E. mesomorpha

Tofte Mt. Rose L Mudd Lye Br Bourn P

H. physodes

Kelly Bourn P Lye Br L Mudd Mt. Rose Tofte
L Mud Mt. Rose Tofte

P. sulcata

Kelly Tofte Mt. Rose L Mud Lye Br Bourn P
L Mud Lye Br Bourn P

Question. Does any locality in White Mt. have high levels?

Yes. The details are available in the analysis material following this summary.

The first step was figuring out what data could be used. After reviewing the available data, it was determined that the locality comparisons would have to be done in pieces because of the zero counts in many of the design cells. However, it was also determined that a common MSE could be used for each of the principal components. The pooling calculations are given below.

Principal component 1

White 88 (no Wamsutta Tr., no C. stygia, no E. mesomorpha): SSE = 0.07713 df = 16 MSE = 0.00482

White 93 (no C. stygia): SSE = 0.23038 df = 43 MSE = 0.00536

Common pooled: SSE = 0.43526 df = 91 MSE = 0.0047831

Principal component 2

White 88 (no Wamsutta Tr., no C. stygia, no E. mesomorpha): SSE = 0.73003 df = 16 MSE = 0.04563

White 93 (no C. stygia): SSE = 2.36044 df = 43 MSE = 0.05489

Common pooled: SSE = 4.72035 df = 91 MSE = 0.051872

1988 White Mt. analyses

TABLE OF SPECIES\$ (ROWS) BY LOCALITY\$ (COLUMNS)						
	Lows	Mt. Eisen	Mt. Craw	Rky Br	Wamsutta	TOTAL
C. rangi	3	3	3	3	0	12
C. stygi	0	0	0	0	3	3
E. mesom	0	0	3	0	0	3
H. physo	3	3	3	3	3	15
TOTAL	6	6	9	6	6	33

So these analyses will focus just on C. rangiferina and H. physodes.

LEVELS ENCOUNTERED DURING PROCESSING ARE:

SPECIES\$ C. rangiferina H. physodes

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge

DEP VAR: F1 N: 24

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
SPP*LOCALITY	0.10263	3	0.03421	7.15231	0.00023
ERROR	0.43526	91	0.00478		

So these analyses will be run by species.

C. rangiferina

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge

DEP VAR: F1 N: 12

ANALYSIS OF VARIANCE

SOURCE	SS	DF	MS	F	P
LOCALITY\$	0.70746	3	0.23582	49.30292	0.00000
ERROR	0.43526	91	0.00478		

	LS MEAN	SE	N	
LOCALITY\$ = Lows Bald Sp	-1.11168	0.04068	3	
LOCALITY\$ = Mt. Eisenhow	-0.66320	0.04068	3	
LOCALITY\$ = NE Mt. Crawf	-1.19428	0.04068	3	
LOCALITY\$ = Rky Br Ridge	-1.30061	0.04068	3	

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhow	Mt. Crawf	Rky Br Ridge
Lows Bald Sp	1.00000			
Mt. Eisenhow	0.00000	1.00000		
NE Mt. Crawf	0.14699	0.00000	1.00000	
Rky Br Ridge	0.00119	0.00000	0.06290	1.00000

DEP VAR: F2 N: 12

ANALYSIS OF VARIANCE

SOURCE	SS	DF	MS	F	P
LOCALITY\$	1.28937	3	0.42979	8.28559	0.00006
ERROR	4.72035	91	0.05187		

	LS MEAN	SE	N	
LOCALITY\$ = Lows Bald Sp	-0.18043	0.08652	3	
LOCALITY\$ = Mt. Eisenhow	-0.83716	0.08652	3	
LOCALITY\$ = NE Mt. Crawf	-0.39317	0.08652	3	
LOCALITY\$ = Rky Br Ridge	-0.99336	0.08652	3	

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhow	Mt. Crawf	Rky Br Ridge
Lows Bald Sp	1.00000			
Mt. Eisenhow	0.00065	1.00000		
NE Mt. Crawf	0.25562	0.01903	1.00000	
Rky Br Ridge	0.00003	0.40316	0.00174	1.00000

H. physodes

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge Wamsutta Trail.

DEP VAR: F1 N: 15

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
LOCALITY\$	0.28975	4	0.07244	15.14453	0.00000
ERROR	0.43526	91	0.00478		

	LS MEAN	SE	N
LOCALITY\$ = Lows Bald Sp	0.82474	0.03750	3
LOCALITY\$ = Mt. Eisenhow	1.17806	0.03750	3
LOCALITY\$ = NE Mt. Crawf	0.90922	0.03750	3
LOCALITY\$ = Rky Br Ridge	0.87010	0.03750	3
LOCALITY\$ = Wamsutta Tr.	0.78383	0.03750	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisen	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.00000	1.00000			
NE Mt. Crawf	0.13813	0.00001	1.00000		
Rky Br Ridge	0.42392	0.00000	0.49027	1.00000	
Wamsutta Tr.	0.47062	0.00000	0.02887	0.13004	1.00000

DEP VAR: F2 N: 15

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
LOCALITY\$	6.34629	4	1.58657	30.58631	0.00000
ERROR	4.72035	91	0.05187		

	LS MEAN	SE	N
LOCALITY\$ = Lows Bald Sp	-0.80865	0.17512	3
LOCALITY\$ = Mt. Eisenhow	-0.64783	0.17512	3
LOCALITY\$ = NE Mt. Crawf	-1.07229	0.17512	3
LOCALITY\$ = Rky Br Ridge	-1.51921	0.17512	3
LOCALITY\$ = Wamsutta Tr.	-2.46138	0.17512	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhow	Mt. Crawf	Rky Br	Wamsutta Tr.
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.38940	1.00000			
NE Mt. Crawf	0.15969	0.02479	1.00000		
Rky Br Ridge	0.00024	0.00001	0.01828	1.00000	
Wamsutta Tr.	0.00000	0.00000	0.00000	0.00000	1.00000

1993 White Mt. analyses

TABLE OF SPECIES\$ (ROWS) BY LOCALITY\$ (COLUMNS)
Lows Mt. Eis Mt. Crawf Rky Br Wamsutta TOTAL

	Lows	Mt. Eis	Mt. Crawf	Rky Br	Wamsutta	TOTAL
C. rangi	4	3	4	4	3	18
C. stygi	0	0	0	0	3	3
E. mesom	3	3	3	3	3	15
H. physo	3	3	3	3	3	15
P. sulca	3	3	3	3	3	15

So these analyses will not include C. stygia.

DEP VAR: F1 N: 63 SQUARED MULTIPLE R: 0.996
ANALYSIS OF VARIANCE
SOURCE SUM-OF-SQUARES DF MEAN-SQUARE F-RATIO P
SPP*LOCAL 1.33297 12 0.11108 20.73334 0.00000
ERROR 0.23038 43 0.00536

So these analyses will be run by species.

C. rangiferina

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge
Wamsutta Trail.

DEP VAR: F1 N: 18
ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 1.21327 4 0.30332 63.41465 0.00000
ERROR 0.43526 91 0.00478

	LS MEAN	SE	N
LOCALITY\$ = Lows Bald Sp	-1.76944	0.03501	4
LOCALITY\$ = Mt. Eisenhow	-1.27615	0.04043	3
LOCALITY\$ = NE Mt. Crawf	-1.64573	0.03501	4
LOCALITY\$ = Rky Br Ridge	-1.37402	0.03501	4
LOCALITY\$ = Wamsutta Tr.	-1.02645	0.04043	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhow	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.00000	1.00000			
NE Mt. Crawf	0.01314	0.00000	1.00000		
Rky Br Ridge	0.00000	0.06715	0.00000	1.00000	
Wamsutta Tr.	0.00000	0.00003	0.00000	0.00000	1.00000

DEP VAR: F2 N: 18

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
LOCALITY\$	3.15226	4	0.78806	15.19247	0.00000
ERROR	4.72035	91	0.05187		

	LS MEAN	SE	N	
LOCALITY\$ = Lows Bald Sp	-0.55868	0.09695	4	
LOCALITY\$ = Mt. Eisenhower	0.32086	0.11195	3	
LOCALITY\$ = NE Mt. Crawford	-0.92272	0.09695	4	
LOCALITY\$ = Rky Br Ridge	-0.10669	0.09695	4	
LOCALITY\$ = Wamsutta Tr.	-0.17998	0.11195	3	

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhower	Mt. Crawford	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhower	0.00000	1.00000			
NE Mt. Crawford	0.02618	0.00000	1.00000		
Rky Br Ridge	0.00612	0.01587	0.00000	1.00000	
Wamsutta Tr.	0.03207	0.00842	0.00005	0.67451	1.00000

E. mesomorpha

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge
Wamsutta Trail.

DEP VAR: F1 N: 15

ANALYSIS OF VARIANCE					
SOURCE	SS	DF	MS	F	P
LOCALITY\$	0.73599	4	0.18400	38.46841	0.00000
ERROR	0.43526	91	0.00478		

	LS MEAN	SE	N	
LOCALITY\$ = Lows Bald Sp	-0.48314	0.04659	3	
LOCALITY\$ = Mt. Eisenhower	-0.08410	0.04659	3	
LOCALITY\$ = NE Mt. Crawford	-0.76552	0.04659	3	
LOCALITY\$ = Rky Br Ridge	-0.54343	0.04659	3	
LOCALITY\$ = Wamsutta Tr.	-0.40270	0.04659	3	

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhower	Mt. Crawford	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhower	0.00000	1.00000			
NE Mt. Crawford	0.00000	0.00000	1.00000		
Rky Br Ridge	0.28853	0.00000	0.00016	1.00000	
Wamsutta Tr.	0.15767	0.00000	0.00000	0.01450	1.00000

DEP VAR: F2 N: 15

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 1.37778 4 0.34444 6.64028 0.00010
ERROR 4.72035 91 0.05187

	LS MEAN	SE	N
LOCALITY\$ =Lows Bald Sp	1.14924	0.16414	3
LOCALITY\$ =Mt. Eisenhower	1.38062	0.16414	3
LOCALITY\$ =NE Mt. Crawford	0.70087	0.16414	3
LOCALITY\$ =Rky Br Ridge	0.73586	0.16414	3
LOCALITY\$ =Wamsutta Tr.	1.39960	0.16414	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhower	Mt. Crawford	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhower	0.21660	1.00000			
NE Mt. Crawford	0.01791	0.00043	1.00000		
Rky Br Ridge	0.02870	0.00080	0.85118	1.00000	
Wamsutta Tr.	0.18154	0.91892	0.00030	0.00057	1.00000

H. physodes

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge
Wamsutta Trail.

DEP VAR: F1 N: 15

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 0.15080 4 0.03770 7.88192 0.00002
ERROR 0.43526 91 0.00478

	LS MEAN	SE	N
LOCALITY\$ = Lows Bald Sp	0.63601	0.04028	3
LOCALITY\$ = Mt. Eisenhower	0.88532	0.04028	3
LOCALITY\$ = NE Mt. Crawford	0.78487	0.04028	3
LOCALITY\$ = Rky Br Ridge	0.61358	0.04028	3
LOCALITY\$ = Wamsutta Tr.	0.69949	0.04028	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhower	Mt. Crawford	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhower	0.00003	1.00000			
NE Mt. Crawford	0.00986	0.07858	1.00000		
Rky Br Ridge	0.69211	0.00001	0.00315	1.00000	
Wamsutta Tr.	0.26389	0.00142	0.13402	0.13162	1.00000

DEP VAR: F2 N: 15

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 1.96850 4 0.49213 9.48730 0.00000
ERROR 4.72035 91 0.05187

LS MEAN SE N
LOCALITY\$ = Lows Bald Sp -1.22367 0.16451 3
LOCALITY\$ = Mt. Eisenhow -1.12244 0.16451 3
LOCALITY\$ = NE Mt. Crawf -0.55828 0.16451 3
LOCALITY\$ = Rky Br Ridge -0.68121 0.16451 3
LOCALITY\$ = Wamsutta Tr. -1.54577 0.16451 3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

Lows Mt. Eisenhow Mt. Crawf Rky Br Wamsutta
Lows Bald Sp 1.00000
Mt. Eisenhow 0.58752 1.00000
NE Mt. Crawf 0.00056 0.00315 1.00000
Rky Br Ridge 0.00445 0.01976 0.51024 1.00000
Wamsutta Tr. 0.08665 0.02517 0.00000 0.00001 1.00000

P. sulcata

LOCALITY\$ Lows Bald Spot Mt. Eisenhower NE Mt. Crawford Rocky Branch Ridge
Wamsutta Trail.

DEP VAR: F1 N: 15

ANALYSIS OF VARIANCE
SOURCE SS DF MS F P
LOCALITY\$ 0.29935 4 0.07484 15.64642 0.00000
ERROR 0.43526 91 0.00478

LS MEAN SE N
LOCALITY\$ = Lows Bald Sp 0.83384 0.04196 3
LOCALITY\$ = Mt. Eisenhow 1.13244 0.04196 3
LOCALITY\$ = NE Mt. Crawf 1.05715 0.04196 3
LOCALITY\$ = Rky Br Ridge 0.92425 0.04196 3
LOCALITY\$ = Wamsutta Tr. 0.74631 0.04196 3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

Lows Mt. Eisenhow Mt. Crawf Rky Br Wamsutta
Lows Bald Sp 1.00000
Mt. Eisenhow 0.00000 1.00000
NE Mt. Crawf 0.00015 0.18575 1.00000
Rky Br Ridge 0.11280 0.00039 0.02075 1.00000
Wamsutta Tr. 0.12464 0.00000 0.00000 0.00220 1.00000

DEP VAR: F2 N: 15

ANALYSIS OF VARIANCE

SOURCE	SS	DF	MS	F	P
LOCALITY\$	1.54351	4	0.38588	7.43903	0.00003
ERROR	4.72035	91	0.05187		

	LS MEAN	SE	N
LOCALITY\$ = Lows Bald Sp	0.37583	0.09156	3
LOCALITY\$ = Mt. Eisenhower	0.22821	0.09156	3
LOCALITY\$ = NE Mt. Crawford	-0.14835	0.09156	3
LOCALITY\$ = Rky Br Ridge	0.73658	0.09156	3
LOCALITY\$ = Wamsutta Tr.	-0.07609	0.09156	3

FISHER'S LSD TEST. MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

	Lows	Mt. Eisenhower	Mt. Crawford	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhower	0.42937	1.00000			
NE Mt. Crawford	0.00591	0.04580	1.00000		
Rky Br Ridge	0.05549	0.00753	0.00001	1.00000	
Wamsutta Tr.	0.01705	0.10521	0.69851	0.00003	1.00000

SIGNIFICANT LOCALITY DIFFERENCES High to low (L to R) P<.05

1988

C. rangiferina

Lows Mt. Crawford Mt. Eisenhower Rky Br
Mt. Eisenhower Rky Br

H. physodes

Mt. Eisenhower Lows Mt. Crawford Rky Br Wamsutta

1993

C. rangiferina

Mt. Eisenhower Rky Br Wamsutta Lows Mt. Crawford

E. mesomorpha

Wamsutta Mt. Eisenhower Lows Rky Br Mt. Crawford
Rky Br Mt. Crawford

H. physodes

Mt. Crawford Rky Br Mt. Eisenhower Lows Wamsutta
Mt. Eisenhower Lows Wamsutta

P. sulcata

Rky Br Lows Mt. Eisenhower Wamsutta Mt. Crawford
Mt. Eisenhower Wamsutta Mt. Crawford
Wamsutta Mt. Crawford

Statistical Analysis Conclusions

The levels of most elements are higher in the LBW than in the White Mt. wilderness areas. When comparing localities with the LBW, Kelly Stand was significantly higher in two species than the other localities. The levels at Bourn Pond were lowest in two species. The higher levels at Kelly stand may be due to historical activities in the area rather than air quality effects. LBW elemental levels are higher than clean areas in northern Minnesota in some species.

CONCLUSIONS

There is no indication that the lichens of LBW are being damaged by sulfur dioxide or the other elements studied. The lichen flora is diverse for such an area and there is no impoverishment of the lichen flora in any part of the wilderness. There are six species in the most sensitive category to sulfur dioxide in the wilderness and most of these are rare. This rarity seems to be due more to ecological and climatic conditions than pollution since these species are quite healthy when present. The maps of the distributions of the more sensitive species do not show any significant voids that are not due to normal ecological conditions. There is no evidence of damaged or dead lichens in any area where healthy ones are not also present. The elemental analyses do not show abnormal accumulations of polluting elements at any locality. There is no geographical gradient of accumulations from north to south. Elemental levels are slightly higher than those in the White Mt. Wilderness areas.

RECOMMENDATIONS

Although there seem to be no sulfur dioxide effects or impacts from other elements monitored in LBW now, periodic restudy is recommended. Elemental analysis should be done every 5 years and compared to the levels reported in this study. A complete floristic restudy should be done every 10-15 years.

If plans are developed to do extensive trail construction or maintenance in the LBW, a lichenologist should be consulted to help design the work so that rare lichens are not lost.

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APPENDIX I

Lye Brook Wilderness collection Localities

Collection numbers are those of Clifford Wetmore. All collections are listed in ascending order by number and date of collection. All localities are in the Green Mountain National Forest, located in Bennington County, Vermont.

Green Mountain National Forest, Lye Brook Wilderness, Bennington County, Vermont

72507-72532 : Up the Lye Brook Falls Trail near talus slopes 3 miles southeast of Manchester Center.

On west facing hillsides with maples, black spruce and some hemlock, elev. 1800 ft. 29 July 1993.

72533-72548 : Along Lye Brook Falls Trail 2 miles south of Manchester Depot. On ridge with maple and hemlock, elev. 1300 ft. 29 July 1993.

72549-72590 : North of Kelly Stand at southern end of wilderness along Branch Pond Brook. Along stream with balsam fir, maples and yellow birch, elev. 2250 ft. 30 July 1993. CHEMICAL ANALYSIS.

72591-72611 : Southeast of Branch Pond Brook in southern end of wilderness. On gentle hillside with beech, sugar maple and yellow birch, elev. 2520 ft. 30 July 1993.

72612-72648 : Four miles south of Manchester Center. In deep gully on north facing slope and ridge with yellow birch and some hemlock and maple, elev. 1700 ft. 31 July 1993.

72649-72676 : Upper part of Lye Brook Hollow below Lye Brook Trail. On banks above stream with maple, birch, red spruce and some balsam fir, elev. 2350 ft. 1 Aug. 1993

72677-72708 : 1.5 miles east of Sunderland. On west facing hillside among overgrown talus with birch, maple, hemlock and some red spruce, elev. 1600 ft. 3 Aug. 1993.

72709-72746 : West side of Bourn Pond. Near lake with balsam fir, red spruce, birch and maple, elev. 2540 ft. 4 Aug. 1993. CHEMICAL ANALYSIS.

72747-72777 : Half mile south of Bourn Pond. At edge of flooded red spruce swamp with some dead balsam fir, elev. 2580 ft. 4 Aug. 1993.

72778-72808 : North of Branch Pond, west of trail to Bourn Pond. On small hill with white and yellow birch, red maple and some young red spruce and balsam fir, elev. 2660 ft. 5 Aug. 1993.

72809-72842 : Northwest corner of Little Mud Pond (4 miles SE of Manchester). Along stream with beaver dams and red maple, red spruce, balsam fir and yellow birch, elev. 2250 ft. 6 Aug. 1993.

72843-72871 : North of Little Mud Pond above shelter. (3 miles of Manchester). In beech-maple woods on gentle slope with sugar maple, beech and some ash and young red spruce and balsam fir, elev. 2260 ft. 6 Aug. 1993.

72872-72910 : Hill west of Lye Brook (3 miles south of Manchester Center). On peak with red spruce, yellow birch and maples, elev. 2200 ft. 8 Aug. 1993. CHEMICAL ANALYSIS.

72911-72941 : North of Little Mud Pond. Near beaver swamps along old logging road with maples, red spruce and balsam fir, elev. 2330 ft. 9 Aug. 1993. CHEMICAL ANALYSIS.

72942-72985 : One mile east of Prospect Rock near trail junction. In beech-maple woods with some yellow birch and ash, elev. 2330 ft. 9 Aug. 1993.

72986-73014 : The Burning at southern end of wilderness (2 miles SE of Sunderland). On ridgetop southeast of pond in heath with red spruce and some white pine, elev. 2475 ft. 10 Aug. 1993.

73015-73046 : On hilltop east of main trail (3.5 miles E of Sunderland). In wet area with red spruce, balsam fir, some red maple and yellow birch, elev. 2600 ft. 13 Aug. 1993.

73047-73071 : Southwest corner of wilderness above Mill Creek. On gentle west slope with hemlock, maples and beech with few ash and oaks, elev. 1050 ft. 14 Aug. 1993.

APPENDIX II

Species Sensitive to Sulfur Dioxide

Based on the list of lichens with known sulfur dioxide sensitivity compiled from the literature, the following species in the Lye Brook Wilderness Area fall within the Sensitive category as listed by Wetmore, 1983. Sensitive species (S) are those present only under 50 µg sulfur dioxide per cubic meter (average annual). Open circles on the maps are localities where the species was not found and solid circles are where it was found. Only the species in the Sensitive category are mapped.

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

Fig. 2 Bryoria furcellata (Fr.) Brodo & Hawksw.

Fig. 3 Hypogymnia tubulosa (Schaer.) Hav.

Fig. 4. Lobaria pulmonaria (L.) Hoffm.

Fig. 5. Parmelia squarrosa Hale

Fig. 6. Ramalina obtusata (Arn.) Bitt.

Fig. 7. Usnea filipendula Stirt.