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1993 ELEMENTAL ANALYSIS OF LICHENS OF THE WHITE MOUNTAIN NATIONAL FOREST WILDERNESS AREAS

Final Report

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by

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ABSTRACT

In the final report on the lichens and air quality in the White Mt. National Forest Wilderness areas (Wetmore, 1989) it was recommended that a restudy of the elemental analysis of lichens be done every five years. This report is on the first restudy done in 1993.

In this study five species of lichens were collected during August, 1993 at the same localities as in the previous study. The methods used were the same as in the previous study.

The results of this study showed similar or slightly lower levels of most elements in most species. ANOVA and pairwise comparisons by statistical analysis showed significantly lower levels in 1993 than 1988. No one locality had consistently higher levels of accumulation. The elemental levels in the White Mt. wilderness areas were lower than in the Lye Brook Wilderness of the Green Mt. National Forest. It is concluded that there probably has been no degradation in the air quality in the wilderness and there might have been a slight improvement in the air quality. The recommendation is made that the periodic five-year restudy of elemental analysis be continued.

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INTRODUCTION

Lichens are able to accumulate chemical elements in the excess of their metabolic needs depending on the levels in the substrate and air and, since lichens are slow growing and long lived, they serve as good summarizers of the environmental conditions in which they are growing. Chemical analysis of the thallus of lichens growing in areas of high fallout of certain elements will show elevated levels in the thallus. Toxic substances (such as sulfur) are also accumulated and determination of the levels of these toxic elements can provide indications of sub-lethal but elevated levels in the air (Wetmore, 1989).

During 1988 a complete study of lichens and air quality was done in the Presidential Dry River and the Great Gulf Wilderness Areas, including a species list and elemental analysis of four species at five localities. The report showed no elevated accumulation of elements at any locality.

During August, 1993 all five of the elemental analysis localities used in the earlier study were revisited for new collections. One lichen species was added in the study for a better comparison with other regional studies (Wetmore, 1984, 1985, 1992, 1995).

METHODS

Methods used in the present study were the same as those of the original study (Wetmore, 1989). All five of the previous localities were again sampled in August, 1993 (Fig.

Table 1. Analysis of White Mt. Lichens - 1993
Values in ppm of thallus dry weight

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
C. rangiferina	508	1516	330	184	145	107	25.7	64.3	16.4	1.3	0.6	1.5	0.4	0.2	0.2	460	Rky. Br. Ridge
C. rangiferina	483	1456	332	177	170	127	25.1	64.6	16.0	1.3	0.5	1.7	0.4	0.3	0.1	520	Rky. Br. Ridge
C. rangiferina	539	1638	329	186	168	122	29.3	57.3	16.6	1.5	0.6	1.8	0.5	0.2	0.1	510	Rky. Br. Ridge
C. rangiferina	547	1586	301	184	154	116	21.9	62.8	16.4	1.4	0.5	1.7	0.4	0.2	0.1	510	Rky. Br. Ridge @
C. rangiferina	535	1562	303	185	152	114	21.4	64.4	15.6	1.4	0.5	1.6	0.4	0.2	0.1	530	Rky. Br. Ridge @
C. rangiferina	590	1679	319	199	166	128	22.8	67.9	16.5	1.5	0.6	1.9	0.5	0.2	0.1	500	Rky. Br. Ridge @
C. rangiferina	305	1364	355	178	80	87	22.2	34.5	14.7	1.4	0.4	1.7	0.4	0.2	0.1	480	Lows Bald Spot
C. rangiferina	266	1208	357	157	84	92	20.2	30.0	13.6	1.3	0.4	1.8	0.5	0.2	0.1	480	Lows Bald Spot
C. rangiferina	332	1445	353	160	78	89	22.0	27.9	14.2	1.4	0.5	1.8	0.4	0.1	0.1	490	Lows Bald Spot
C. rangiferina	309	1379	384	180	86	94	21.2	33.0	15.4	1.5	0.5	1.9	0.5	0.2	0.1	510	Lows Bald Spot @
C. rangiferina	304	1375	376	181	85	93	21.9	32.1	15.2	1.4	0.4	1.8	0.5	0.2	0.1	500	Lows Bald Spot @
C. rangiferina	319	1407	382	182	92	105	22.8	31.4	15.1	1.5	0.5	1.9	0.5	0.2	0.1	550	Lows Bald Spot @
C. rangiferina	283	1139	212	138	134	143	16.2	86.9	13.3	1.3	0.6	3.0	0.5	0.3	0.1	480	NE Mt. Crawford
C. rangiferina	361	1527	309	161	93	96	19.5	142.0	13.9	1.4	0.5	2.1	0.3	0.2	0.1	460	NE Mt. Crawford
C. rangiferina	349	1360	285	151	99	99	19.2	129.7	13.3	1.3	0.5	2.1	0.3	0.2	0.1	450	NE Mt. Crawford
C. rangiferina	324	1328	242	140	119	125	21.6	102.9	13.4	1.3	0.5	2.4	0.4	0.3	0.1	460	NE Mt. Crawford @
C. rangiferina	326	1288	247	144	130	138	24.0	106.0	13.3	1.4	0.5	2.7	0.5	0.3	0.1	430	NE Mt. Crawford @
C. rangiferina	325	1314	254	142	123	129	20.9	102.3	13.4	1.4	0.5	2.6	0.4	0.3	0.1	490	NE Mt. Crawford @
C. rangiferina	327	1320	248	158	162	254	25.8	18.7	16.7	1.4	0.5	3.0	0.7	0.4	0.2	510	Mt. Eisenhower
C. rangiferina	308	1275	226	155	165	258	32.9	16.8	16.8	1.5	0.5	3.5	0.7	0.4	0.2	480	Mt. Eisenhower
C. rangiferina	382	1394	324	157	136	203	23.7	21.8	19.7	1.5	0.5	3.5	0.6	0.4	0.2	525	Mt. Eisenhower
C. rangiferina	524	2439	367	249	124	139	21.7	65.2	22.1	2.0	0.7	2.6	0.6	0.3	0.2	620	Wamsutta Tr.
C. rangiferina	471	2194	304	210	127	144	20.8	44.2	18.9	1.8	0.6	3.1	0.7	0.3	0.2	660	Wamsutta Tr.
C. rangiferina	516	2182	372	241	133	138	26.0	63.9	21.0	1.9	0.6	3.1	0.6	0.3	0.1	610	Wamsutta Tr.
C. stygia	564	2141	444	226	80	85	21.5	54.3	23.3	1.8	0.6	3.4	0.6	0.2	0.1	630	Wamsutta Tr.
C. stygia	642	2425	386	220	73	78	23.1	48.6	22.4	1.7	0.6	2.5	0.5	0.2	0.1	520	Wamsutta Tr.
C. stygia	535	2045	373	207	72	76	19.8	41.2	19.9	1.6	0.5	2.8	0.5	0.2	0.1	560	Wamsutta Tr.
E. mesomorpha	491	2191	649	239	160	166	37.1	74.8	35.3	2.3	1.0	8.0	0.8	0.5	0.3	960	Rky. Br. Ridge
E. mesomorpha	468	1964	510	218	149	153	48.2	72.0	32.1	2.1	0.8	8.0	0.7	0.4	0.2	810	Rky. Br. Ridge
E. mesomorpha	463	2090	625	235	144	150	47.8	93.2	33.5	2.2	0.9	6.6	0.6	0.4	0.2	910	Rky. Br. Ridge
E. mesomorpha	323	1606	349	179	185	202	31.6	29.6	37.1	2.6	1.2	13.9	1.1	0.6	0.2	1130	Lows Bald Spot
E. mesomorpha	327	1540	354	171	201	221	40.3	29.3	37.0	2.5	1.1	18.2	1.1	0.5	0.2	1160	Lows Bald Spot
E. mesomorpha	384	1756	337	187	182	195	36.2	25.2	35.1	2.6	1.3	12.6	1.1	0.5	0.2	1050	Lows Bald Spot
E. mesomorpha	297	1375	238	138	192	212	30.4	38.1	31.4	2.1	1.2	13.3	0.9	0.6	0.2	1050	NE Mt. Crawford
E. mesomorpha	288	1324	298	136	167	183	30.2	53.6	32.8	2.0	1.1	13.7	0.7	0.5	0.1	970	NE Mt. Crawford
E. mesomorpha	293	1328	321	141	157	173	29.6	71.2	34.2	2.1	1.1	11.5	0.7	0.5	0.2	1010	NE Mt. Crawford
E. mesomorpha	453	1654	300	234	323	463	43.0	21.6	42.4	2.9	1.2	19.2	1.3	0.8	0.4	940	Mt. Eisenhower
E. mesomorpha	420	1629	286	230	298	421	42.3	22.4	38.6	2.8	0.9	18.8	1.3	0.8	0.4	970	Mt. Eisenhower
E. mesomorpha	465	1733	323	243	321	403	35.4	20.8	37.9	3.4	1.0	20.6	1.5	0.8	0.4	1040	Mt. Eisenhower
E. mesomorpha	477	1884	802	232	197	212	37.6	44.9	33.2	2.4	1.6	5.9	0.8	0.5	0.3	1000	Wamsutta Tr.
E. mesomorpha	392	1720	728	202	182	187	35.5	28.4	35.5	2.2	1.5	6.4	0.8	0.5	0.2	1020	Wamsutta Tr.
E. mesomorpha	466	1734	333	218	245	275	49.9	22.4	35.3	2.6	1.4	7.1	1.0	0.6	0.3	1060	Wamsutta Tr.

H. physodes	581	3070	5759	474	290	370	33.4	199.3	70.2	4.0	1.3	22.5	1.7	0.6	0.7	1030	Rky. Br. Ridge
H. physodes	774	3824	5357	548	238	294	29.1	201.2	62.3	3.9	1.3	21.3	1.7	0.5	0.9	915	Rky. Br. Ridge
H. physodes	602	3174	6285	527	286	353	35.2	161.4	76.4	3.8	1.3	23.8	1.9	0.6	0.8	1040	Rky. Br. Ridge
H. physodes	757	3173	6868	666	254	319	24.3	223.3	86.9	3.5	1.4	25.7	2.3	0.6	0.7	940	Lows Bald Spot
H. physodes	652	3051	3986	573	265	343	23.5	214.2	74.1	3.7	1.3	26.1	2.4	0.7	0.5	830	Lows Bald Spot
H. physodes	628	3074	4988	548	290	367	25.8	225.2	77.5	4.1	1.4	29.7	2.6	0.7	0.5	960	Lows Bald Spot
H. physodes	548	2647	7256	451	259	345	39.2	334.4	80.2	4.0	1.5	30.3	1.7	0.7	0.7	1050	NE Mt. Crawford
H. physodes	633	2711	7645	447	312	428	34.6	315.7	96.4	4.4	1.8	39.1	1.9	0.7	0.7	1050	NE Mt. Crawford
H. physodes	848	3113	8995	478	277	365	39.5	325.9	85.2	4.0	1.7	31.9	1.9	0.7	0.7	1160	NE Mt. Crawford
H. physodes	719	2846	6721	585	344	474	28.2	173.2	101.5	4.3	1.3	45.8	2.5	0.8	0.9	900	Mt. Eisenhower
H. physodes	485	2183	19947	415	381	561	23.4	179.3	102.8	4.8	1.4	62.0	2.0	1.0	1.2	900	Mt. Eisenhower
H. physodes	910	3476	5707	737	328	440	31.9	166.7	75.6	4.5	1.3	47.5	2.6	0.8	0.7	855	Mt. Eisenhower
H. physodes	384	1606	10563	355	337	427	18.6	201.6	92.6	4.9	1.5	37.1	1.7	0.7	1.6	1020	Wamsutta Tr.
H. physodes	417	1618	10559	333	406	492	24.5	148.0	97.9	5.4	1.6	38.4	1.9	0.8	1.5	1150	Wamsutta Tr.
H. physodes	388	1750	14141	357	380	469	20.1	166.1	92.9	5.0	1.6	44.9	1.9	0.8	2.0	1170	Wamsutta Tr.
P. sulcata	1702	4602	1239	444	365	409	31.5	147.6	87.5	5.4	2.5	24.0	1.8	0.7	0.4	1160	Rky. Br. Ridge
P. sulcata	1332	3848	1149	372	415	462	33.0	114.6	77.0	6.0	2.4	34.5	2.1	0.7	0.5	1110	Rky. Br. Ridge
P. sulcata	1510	4239	1410	441	366	403	34.6	163.6	84.9	5.6	2.7	27.9	1.8	0.7	0.5	1200	Rky. Br. Ridge
P. sulcata	1098	2917	2489	405	349	380	29.0	100.1	118.1	6.0	2.8	38.2	2.1	0.7	0.3	1010	Lows Bald Spot
P. sulcata	878	2509	2639	310	424	446	33.3	71.7	127.0	6.1	2.7	37.9	2.3	0.8	0.3	1080	Lows Bald Spot
P. sulcata	1175	2980	2569	412	411	443	26.5	116.5	115.1	6.2	2.9	37.5	2.3	0.7	0.3	1050	Lows Bald Spot
P. sulcata	1019	3066	1695	348	497	538	26.1	296.7	106.7	6.3	2.2	46.4	2.3	0.9	0.6	1050	NE Mt. Crawford
P. sulcata	942	3068	1647	363	501	540	27.4	297.7	116.8	6.5	2.3	46.1	2.3	0.9	0.6	1150	NE Mt. Crawford
P. sulcata	986	3005	1773	372	546	586	30.8	295.7	105.9	6.4	2.3	48.0	2.4	1.0	0.7	1090	NE Mt. Crawford
P. sulcata	1249	2868	2015	420	430	454	36.0	160.4	125.7	6.4	2.8	32.8	2.1	0.9	0.7	1000	Mt. Eisenhower
P. sulcata	1556	3425	2134	537	442	509	31.8	198.4	120.8	5.9	2.6	35.1	2.1	0.9	0.7	970	Mt. Eisenhower
P. sulcata	1615	3737	2002	547	464	519	32.0	238.2	146.1	6.3	2.6	32.5	2.2	0.9	0.8	1040	Mt. Eisenhower
P. sulcata	743	2288	1919	269	454	490	25.7	114.7	102.4	5.6	2.0	32.5	1.7	0.8	0.6	1040	Wamsutta Tr.
P. sulcata	611	1853	1933	259	526	572	24.9	119.6	103.2	5.9	2.3	35.3	1.9	0.9	0.7	990	Wamsutta Tr.
P. sulcata	616	1902	2165	278	580	616	25.9	160.5	115.7	5.9	2.6	35.1	2.0	1.0	0.8	1070	Wamsutta Tr.

Standards

Species	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
C. stellaris	199	699	250	275	443	597	78.2	20.7	18.2	2.8	1.1	13.1	1.5	1.5	0.2	440	Lichen std.
C. stellaris	190	664	228	262	423	570	74.3	20.0	17.0	2.4	0.9	12.8	1.0	0.8	0.2	450	Lichen std.
C. stellaris	192	669	229	263	421	567	74.0	19.7	17.3	2.4	1.0	13.1	1.1	1.0	0.2	410	Lichen std.
NBS Peach	1202	3734	4378	1174	459	174	17.4	691.8	67.4	2.8	17.3	11.0	1.5	1.8	0.2	NA	NBS Peach
NBS Peach	1191	3728	4406	1182	459	179	18.4	691.5	72.9	2.9	17.3	11.3	1.5	1.9	0.4	NA	NBS Peach
NBS Peach	1219	3753	4447	1199	465	185	18.7	699.9	74.4	3.1	17.8	11.9	1.6	1.9	0.3	NA	NBS Peach

Table 2. Summary of Analysis of White Mt. Lichens - 1993
Values in ppm of thallus dry weight

Cladina rangiferina

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	510	1536	330	182	161	119	26.7	62.1	16.3	1.4	0.6	1.7	0.4	0.2	0.1	497	Rky. Br. Ridge
Std. Dev.	28	93	1	5	14	10	2.2	4.2	0.3	0.1	0.1	0.2	<.1	<.1	<.1	32	Rky. Br. Ridge
Mean	557	1609	308	189	157	119	22.0	65.0	16.2	1.4	0.5	1.8	0.4	0.2	0.1	513	Rky. Br. Ridge @
Std. Dev.	29	62	10	9	8	7	0.7	2.6	0.5	0.1	0.1	0.1	<.1	<.1	<.1	15	Rky. Br. Ridge @
Mean	301	1339	355	165	81	89	21.5	30.8	14.2	1.3	0.4	1.8	0.5	0.2	0.1	483	Lows Bald Spot
Std. Dev.	33	121	2	12	3	3	1.1	3.4	0.5	0.1	<.1	<.1	<.1	<.1	<.1	6	Lows Bald Spot
Mean	311	1387	380	181	88	98	22.0	32.2	15.2	1.5	0.5	1.9	0.5	0.2	0.1	520	Lows Bald Spot @
Std. Dev.	7	18	4	1	4	7	0.8	0.8	0.1	<.1	<.1	0.1	<.1	<.1	<.1	26	Lows Bald Spot @
Mean	331	1342	269	150	109	113	18.3	119.5	13.5	1.3	0.5	2.4	0.4	0.2	0.1	463	NE Mt. Crawford
Std. Dev.	42	194	50	12	22	26	1.8	28.9	0.3	<.1	<.1	0.5	0.1	0.1	<.1	15	NE Mt. Crawford
Mean	325	1310	248	142	124	130	22.2	103.7	13.4	1.4	0.5	2.6	0.4	0.3	0.1	460	NE Mt. Crawford @
Std. Dev.	1	20	6	2	6	7	1.6	2.0	0.1	<.1	<.1	0.1	<.1	<.1	<.1	30	NE Mt. Crawford @
Mean	339	1330	266	157	154	238	27.5	19.1	17.7	1.5	0.5	3.3	0.7	0.4	0.2	505	Mt. Eisenhower
Std. Dev.	38	60	51	2	16	31	4.8	2.5	1.7	<.1	<.1	0.3	<.1	<.1	<.1	23	Mt. Eisenhower
Mean	504	2272	348	233	128	140	22.8	57.8	20.7	1.9	0.7	3.0	0.6	0.3	0.1	630	Wamsutta Tr.
Std. Dev.	29	145	38	21	4	3	2.8	11.8	1.6	0.1	<.1	0.3	0.1	<.1	<.1	26	Wamsutta Tr.

Cladina stygia

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	581	2204	401	218	75	80	21.5	48.0	21.9	1.7	0.6	2.9	0.5	0.2	0.1	570	Wamsutta Tr.
Std. Dev.	55	198	38	10	4	5	1.6	6.6	1.8	0.1	<.1	0.4	<.1	<.1	<.1	56	Wamsutta Tr.

Evernia mesomorpha

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	474	2082	595	231	151	156	44.4	8<.1	33.6	2.2	0.9	7.5	0.7	0.4	0.2	893	Rky. Br. Ridge
Std. Dev.	15	114	74	11	8	8	6.2	11.5	1.6	0.1	0.1	0.8	0.1	<.1	<.1	76	Rky. Br. Ridge
Mean	344	1634	347	179	189	206	36.1	28.0	36.4	2.6	1.2	14.9	1.1	0.5	0.2	1113	Lows Bald Spot
Std. Dev.	34	111	9	8	10	14	4.4	2.4	1.1	<.1	0.1	3.0	<.1	<.1	<.1	57	Lows Bald Spot
Mean	292	1342	286	138	172	189	30.1	54.3	32.8	2.1	1.1	12.8	0.8	0.5	0.1	1010	NE Mt. Crawford
Std. Dev.	4	28	43	2	18	20	0.4	16.6	1.4	0.1	<.1	1.1	0.1	0.1	<.1	40	NE Mt. Crawford
Mean	446	1672	303	236	314	429	40.2	21.6	39.6	3.0	1.0	19.5	1.4	0.8	0.4	983	Mt. Eisenhower
Std. Dev.	23	54	19	6	14	31	4.2	0.8	2.4	0.3	0.2	1.0	0.1	<.1	<.1	51	Mt. Eisenhower
Mean	445	1779	621	217	208	225	41.0	31.9	34.7	2.4	1.5	6.5	0.8	0.5	0.3	1027	Wamsutta Tr.
Std. Dev.	46	91	252	15	33	45	7.8	11.7	1.3	0.2	0.1	0.6	0.1	0.1	<.1	31	Wamsutta Tr.

Hypogymnia physodes

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	652	3356	5800	516	271	339	32.6	187.3	69.6	3.9	1.3	22.5	1.8	0.6	0.8	995	Rky. Br. Ridge
Std. Dev.	106	408	465	38	29	40	3.1	22.4	7.1	0.1	<.1	1.2	0.1	<.1	0.1	69	Rky. Br. Ridge
Mean	679	3099	5281	595	270	343	24.5	220.9	79.5	3.8	1.4	27.2	2.4	0.6	0.6	910	Lows Bald Spot
Std. Dev.	69	65	1463	62	18	24	1.2	5.9	6.6	0.3	0.1	2.2	0.1	0.1	0.1	70	Lows Bald Spot
Mean	676	2824	7965	459	283	379	37.8	325.3	87.3	4.2	1.7	33.8	1.8	0.7	0.7	1087	NE Mt. Crawford
Std. Dev.	155	253	913	17	27	43	2.7	9.4	8.3	0.2	0.1	4.7	0.1	<.1	<.1	64	NE Mt. Crawford
Mean	705	2835	10792	579	351	492	27.8	173.1	93.3	4.5	1.4	51.8	2.4	0.9	0.9	885	Mt. Eisenhower
Std. Dev.	213	647	7945	161	27	62	4.3	6.3	15.3	0.2	0.1	8.9	0.3	0.1	0.2	26	Mt. Eisenhower
Mean	396	1658	11754	348	374	463	21.0	171.9	94.5	5.1	1.5	40.1	1.8	0.8	1.7	1113	Wamsutta Tr.
Std. Dev.	18	80	2067	13	35	33	3.1	27.3	3.0	0.3	0.1	4.2	0.1	0.1	0.3	81	Wamsutta Tr.

Parmelia sulcata

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
Mean	1515	4230	1266	419	382	425	33.0	141.9	83.1	5.7	2.6	28.8	1.9	0.7	0.5	1157	Rky. Br. Ridge
Std. Dev.	185	377	133	41	28	32	1.5	25.0	5.5	0.3	0.1	5.3	0.2	<.1	<.1	45	Rky. Br. Ridge
Mean	1050	2802	2566	375	395	423	29.6	96.1	120.1	6.1	2.8	37.8	2.2	0.7	0.3	1047	Lows Bald Spot
Std. Dev.	154	256	75	57	40	37	3.4	22.7	6.2	0.1	0.1	0.4	0.1	0.1	<.1	35	Lows Bald Spot
Mean	982	3046	1705	361	515	555	28.1	296.7	109.8	6.4	2.3	46.8	2.3	0.9	0.6	1097	NE Mt. Crawford
Std. Dev.	39	36	64	12	27	27	2.4	1.0	6.1	0.1	0.1	1.1	0.1	0.1	<.1	50	NE Mt. Crawford
Mean	1473	3343	2050	501	445	494	33.3	199.0	130.9	6.2	2.7	33.5	2.1	0.9	0.7	1003	Mt. Eisenhower
Std. Dev.	197	440	73	70	18	35	2.3	38.9	13.4	0.3	0.1	1.4	0.1	<.1	0.1	35	Mt. Eisenhower
Mean	657	2014	2006	269	520	559	25.5	131.6	107.1	5.8	2.3	34.3	1.8	0.9	0.7	1033	Wamsutta Tr.
Std. Dev.	75	239	138	10	63	64	0.6	25.2	7.4	0.2	0.3	1.5	0.1	0.1	0.1	40	Wamsutta Tr.

Standards

Cladina stellaris

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S
Mean	193	678	236	267	429	578	75.5	20.1	17.5	2.5	1.0	13.0	1.2	1.1	0.2	433
Std. Dev.	5	19	12	7	12	17	2.4	0.5	0.6	0.2	0.1	0.2	0.3	0.3	<.1	21

NBS Peach Leaves

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S
Mean	1204	3738	4410	1185	461	179	18.2	694.4	71.6	2.9	17.4	11.4	1.5	1.9	0.3	NA
Std. Dev.	14	13	35	13	4	6	0.7	4.7	3.7	0.1	0.3	0.5	0.1	0.1	0.1	NA

Table 3. Comparison of 1988 and 1993 White Mt. Elemental Analyses
Values in ppm of thallus dry weight

Cladina rangiferina

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
1988																	
Mean	466	1395	465	243	103	97	25.4	175.3	12.8	1.6	0.6	2.7	0.9	0.3	0.1	447	Rky. Br. Ridge
Std. dev.	29	99	38	15	7	7	3.3	24.4	0.6	<.1	<.1	0.9	0.1	0.1	0.1	15	
1993																	
Mean	510	1536	330	182	161	119	26.7	62.1	16.3	1.4	0.6	1.7	0.4	0.2	0.1	497	Rky. Br. Ridge
Std. dev.	28	93	1	5	14	10	2.2	4.2	0.3	0.1	0.1	0.2	<.1	<.1	<.1	32	
1988																	
Mean	355	1463	342	206	128	136	25.6	24.2	19.7	2.0	0.6	9.1	1.0	0.3	0.2	560	Lows Bald Spot
Std. dev.	12	5	4	3	<1	3	1.2	0.1	0.8	<.1	<.1	1.3	0.1	0.1	0.1	30	
1993																	
Mean	301	1339	355	165	81	89	21.5	30.8	14.2	1.3	0.4	1.8	0.5	0.2	0.1	483	Lows Bald Spot
Std. dev.	33	121	2	12	3	3	1.1	3.4	0.5	0.1	<.1	<.1	<.1	<.1	<.1	6	
1988																	
Mean	266	1026	251	163	176	187	29.7	69.4	16.6	1.8	0.5	9.1	0.9	0.4	0.2	467	NE Mt. Crawford
Std. dev.	6	30	7	6	19	25	2.9	23.7	0.9	0.1	<.1	1.3	0.2	0.1	<.1	38	
1993																	
Mean	331	1342	269	150	109	113	18.3	119.5	13.5	1.3	0.5	2.4	0.4	0.2	0.1	463	NE Mt. Crawford
Std. dev.	42	194	50	12	22	26	1.8	28.9	0.3	<.1	<.1	0.5	0.1	0.1	<.1	15	
1988																	
Mean	706	1995	457	245	145	187	19.4	91.9	30.6	2.1	0.6	5.9	1.0	0.5	0.2	610	Mt. Eisenhower
Std. dev.	47	98	11	6	4	7	3.2	4.9	1.4	0.1	<.1	0.7	0.1	0.1	<.1	26	
1993																	
Mean	339	1330	266	157	154	238	27.5	19.1	17.7	1.5	0.5	3.3	0.7	0.4	0.2	505	Mt. Eisenhower
Std. dev.	38	60	51	2	16	31	4.8	2.5	1.7	<.1	<.1	0.3	<.1	<.1	<.1	23	
1993																	
Mean	504	2272	348	233	128	140	22.8	57.8	20.7	1.9	0.7	3.0	0.6	0.3	0.1	630	Wamsutta Tr.
Std. dev.	29	145	38	21	4	3	2.8	11.8	1.6	0.1	<.1	0.3	0.1	<.1	<.1	26	

Cladina stygia

	P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
1988																	
Mean	437	1692	352	199	119	122	21.4	53.9	18.9	1.8	0.5	7.2	0.8	0.2	0.2	580	Wamsutta Tr.
Std. dev.	27	76	12	7	10	10	1.7	2.7	0.7	0.1	0.1	1.3	0.2	0.1	<.1	46	
1993																	
Mean	581	2204	401	218	75	80	21.5	48.0	21.9	1.7	0.6	2.9	0.5	0.2	0.1	570	Wamsutta Tr.
Std. dev.	55	198	38	10	4	5	1.6	6.6	1.8	0.1	<.1	0.4	<.1	<.1	<.1	56	

Evernia mesomorpha

		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
	1993																	
Mean		474	2082	595	231	151	156	44.4	8<.1	33.6	2.2	0.9	7.5	0.7	0.4	0.2	893	Rky. Br. Ridge
Std. dev.		15	114	74	11	8	8	6.2	11.5	1.6	0.1	0.1	0.8	0.1	<.1	<.1	76	
	1993																	
Mean		344	1634	347	179	189	206	36.1	28.0	36.4	2.6	1.2	14.9	1.1	0.5	0.2	1113	Lows Bald Spot
Std. dev.		34	111	9	8	10	14	4.4	2.4	1.1	<.1	0.1	3.0	<.1	<.1	<.1	57	
	1993																	
Mean		446	1672	303	236	314	429	40.2	21.6	39.6	3.0	1.0	19.5	1.4	0.8	0.4	983	Mt. Eisenhower
Std. dev.		23	54	19	6	14	31	4.2	0.8	2.4	0.3	0.2	1.0	0.1	<.1	<.1	51	
	1993																	
Mean		445	1779	621	217	208	225	41.0	31.9	34.7	2.4	1.5	6.5	0.8	0.5	0.3	1027	Wamsutta Tr.
Std. dev.		46	91	252	15	33	45	7.8	11.7	1.3	0.2	0.1	0.6	0.1	0.1	<.1	31	
	1988																	
Mean		410	1744	210	183	200	220	33.3	27.0	34.2	2.6	1.1	22.8	1.0	0.6	0.4	1127	NE Mt. Crawford
Std. dev.		18	41	12	7	18	27	0.5	3.9	2.6	0.2	<.1	2.2	0.4	0.1	<.1	125	
	1993																	
Mean		292	1342	286	138	172	189	30.1	54.3	32.8	2.1	1.1	12.8	0.8	0.5	0.1	1010	NE Mt. Crawford
Std. dev.		4	28	43	2	18	20	0.4	16.6	1.4	0.1	<.1	1.1	0.1	0.1	<.1	40	

Hypogymnia physodes

		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
	1988																	
Mean		755	2913	7342	468	346	399	25.5	274.0	104.4	4.6	0.9	59.1	2.3	0.9	1.1	960	Rky. Br. Ridge
Std. dev.		99	378	2315	27	50	67	4.0	34.0	5.3	0.3	0.2	9.0	0.1	0.1	0.2	70	
	1993																	
Mean		652	3356	5800	516	271	339	32.6	187.3	69.6	3.9	1.3	22.5	1.8	0.6	0.8	995	Rky. Br. Ridge
Std. dev.		106	408	465	38	29	40	3.1	22.4	7.1	0.1	<.1	1.2	0.1	<.1	0.1	69	
	1988																	
Mean		761	2890	5386	512	315	384	30.4	165.8	93.2	4.3	1.1	49.8	3.1	0.9	0.7	1047	Lows Bald Spot
Std. dev.		27	53	567	8	13	15	4.1	18.0	4.1	<.1	0.1	2.5	0.2	<.1	0.1	57	
	1993																	
Mean		679	3099	5281	595	270	343	24.5	220.9	79.5	3.8	1.4	27.2	2.4	0.6	0.6	910	Lows Bald Spot
Std. dev.		69	65	1463	62	18	24	1.2	5.9	6.6	0.3	0.1	2.2	0.1	0.1	0.1	70	
	1988																	
Mean		568	2398	8034	410	318	436	30.6	315.0	103.2	5.0	1.3	63.4	2.9	1.0	0.7	1095	NE Mt. Crawford
Std. dev.		25	146	1372	16	9	25	2.2	49.4	4.7	0.2	0.1	1.7	0.5	0.1	0.1	22	
	1993																	
Mean		676	2824	7965	459	283	379	37.8	325.3	87.3	4.2	1.7	33.8	1.8	0.7	0.7	1087	NE Mt. Crawford
Std. dev.		155	253	913	17	27	43	2.7	9.4	8.3	0.2	0.1	4.7	0.1	<.1	<.1	64	

	1988																
Mean		835	2873	7278	571	407	477	34.9	208.3	97.1	6.2	1.5	62.3	3.3	1.1	1.2	1040	Mt. Eisenhower
Std. dev.		136	232	1591	45	8	9	0.1	43.7	1.8	0.4	0.1	1.7	0.2	0.1	0.3	40	
	1993																
Mean		705	2835	10792	579	351	492	27.8	173.1	93.3	4.5	1.4	51.8	2.4	0.9	0.9	885	Mt. Eisenhower
Std. dev.		213	647	7945	161	27	62	4.3	6.3	15.3	0.2	0.1	8.9	0.3	0.1	0.2	26	
	1988																
Mean		676	2568	18603	618	258	291	18.5	365.0	98.8	3.6	1.2	42.6	2.1	0.9	1.4	917	Wamsutta Tr.
Std. dev.		45	143	3537	41	30	26	1.0	53.2	6.2	0.2	0.2	4.5	0.5	0.1	0.2	71	
	1993																
Mean		396	1658	11754	348	374	463	21.0	171.9	94.5	5.1	1.5	40.1	1.8	0.8	1.7	1113	Wamsutta Tr.
Std. dev.		18	80	2067	13	35	33	3.1	27.3	3.0	0.3	0.1	4.2	0.1	0.1	0.3	81	

Parmelia sulcata

		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S	Locality
	1993																	
Mean		1515	4230	1266	419	382	425	33.0	141.9	83.1	5.7	2.6	28.8	1.9	0.7	0.5	1157	Rky. Br. Ridge
Std. dev.		185	377	133	41	28	32	1.5	25.0	5.5	0.3	0.1	5.3	0.2	<.1	<.1	45	
Mean		1050	2802	2566	375	395	423	29.6	96.1	120.1	6.1	2.8	37.8	2.2	0.7	0.3	1047	Lows Bald Spot
Std. dev.		154	256	75	57	40	37	3.4	22.7	6.2	0.1	0.1	0.4	0.1	0.1	<.1	35	
Mean		982	3046	1705	361	515	555	28.1	296.7	109.8	6.4	2.3	46.8	2.3	0.9	0.6	1097	NE Mt. Crawford
Std. dev.		39	36	64	12	27	27	2.4	1.0	6.1	0.1	0.1	1.1	0.1	0.1	<.1	50	
Mean		1473	3343	2050	501	445	494	33.3	199.0	130.9	6.2	2.7	33.5	2.1	0.9	0.7	1003	Mt. Eisenhower
Std. dev.		197	440	73	70	18	35	2.3	38.9	13.4	0.3	0.1	1.4	0.1	<.1	0.1	35	
Mean		657	2014	2006	269	520	559	25.5	131.6	107.1	5.8	2.3	34.3	1.8	0.9	0.7	1033	Wamsutta Tr.
Std. dev.		75	239	138	10	63	64	0.6	25.2	7.4	0.2	0.3	1.5	0.1	0.1	0.1	40	
Green Mt.																		
Mean		975	2914	1680	410	376	489	42.7	89.3	72.0	4.8	2.6	19.6	1.7	0.8	0.4	1120	Green Mt.

Cladina stellaris

		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S
	1988																
Mean		190	655	207	258	363	461	75.7	18.6	16.8	2.3	0.8	13.0	1.6	0.7	0.3	444
Std. dev.		4	28	6	3	16	35	1.9	0.1	0.4	0.1	0.2	1.0	0.1	0.1	<.1	8
	1993																
Mean		193	678	236	267	429	578	75.5	20.1	17.5	2.5	1.0	13.0	1.2	1.1	0.2	433
Std. dev.		5	19	12	7	12	17	2.4	0.5	0.6	0.2	0.1	0.2	0.3	0.3	<.1	21

NBS Peach Leaves

		P	K	Ca	Mg	Al	Fe	Na	Mn	Zn	Cu	B	Pb	Ni	Cr	Cd	S
	1988	NA															
	1993																
Mean		1204	3738	4410	1185	461	179	18.2	694.4	71.6	2.9	17.4	11.4	1.5	1.9	0.3	NA
Std. dev.		14	13	35	13	4	6	0.7	4.7	3.7	0.1	0.3	0.5	0.1	0.1	0.1	NA

1). At each locality a bag of each species was collected from branches of conifers. Lichens were cleaned but not washed. Three replicates were obtained from each bag of each species for each locality. Multi-element analysis was by ICP and sulfur by infra red absorption. In the original study four species were analyzed (Cladina rangiferina, Cladina stygia, Evernia mesomorpha, and Hypogymnia physodes). In the present study Parmelia sulcata was added to provide a better comparison with other regional studies.

RESULTS AND DISCUSSION

Table 1 gives the results of the analysis for all replicates arranged by species. Table 2 gives the means and standard deviations for each set of replicates. All reported values were above the lower detection limits of the instruments. Analytical splits were made from some samples and are indicated by "@" in the tables. In these analytical splits the lichens were ground and mixed before being divided into replicates to determine the instrument error. Table 3 gives the values from the 1988 samples and the 1993 samples arranged by species and locality.

One additional species (Parmelia sulcata) was included in the present study because it has been used in the Green Mt. study and other studies at Isle Royale National Park (Wetmore, 1985), Voyageurs National Park (Wetmore, 1984), and Grand Portage National Monument (Wetmore, 1992). Mean values for this species from the Green Mt. study (Wetmore, 1995) are included in Table 3.

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 an composite sample was prepared and ground before being subsampled (=analytical splits). The samples from Lye Brook Wilderness 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 Green 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

WHITE MT.

At the Wamsutta Trail locality in 1988 only Cladina stygia was found. In 1993 C. rangiferina was also found there. A comparison of the elements of the two species at the same locality provides the possibility of correlating the levels in the two species.

Question. Are there differences between *Cladina rangiferina* and *C. stygia* at same locality in White Mt.?

Wamsutta Tr. is the only shared locality for the two species, and there appears to be a difference between the species at this location. Analyzing the 21 observations from Wamsutta Tr., including 3 *C. rangiferina* and 6 *C. stygia* showed *C. stygia* to have a lower value than *C. rangiferina* for principal component 1 (P = 0.003). Principal component 2 did not show a difference (P = 0.10), but *C. stygia* was again lower than *C. rangiferina*. (Bear in mind that the species sample sizes are rather small to detect anything but large differences.)

```
 LEVELS ENCOUNTERED DURING PROCESSING ARE:
 SPECIES$      C. rangiferina     C. stygia     E. mesomorpha
H.  physodes     P. sulcata

 DEP VAR: F1       N: 21     SQUARED MULTIPLE R: 0.992
                          ANALYSIS OF VARIANCE
 SOURCE    SUM-OF-SQUARES  DF  MEAN-SQUARE  F-RATIO      P
 SPECIES$    17.0039        4     4.2510     477.2545  0.0000
 ERROR        0.1425       16     0.0089

 ROW    SPECIES$
   1    C. rangiferi
   2    C. stygia

 MEAN DIFFERENCE: -0.2439
 FISHER'S LEAST-SIGNIFICANT-DIFFERENCE TEST: P = 0.0021

 DEP VAR: F2       N: 21     SQUARED MULTIPLE R: 0.901
                          ANALYSIS OF VARIANCE
 SOURCE    SUM-OF-SQUARES  DF  MEAN-SQUARE  F-RATIO     P
 SPECIES$     25.2308       4     6.3077     36.5846  0.0000
 ERROR         2.7586      16     0.1724

 MEAN DIFFERENCE: -0.5241
 FISHER'S LEAST-SIGNIFICANT-DIFFERENCE TEST: P = 0.0932
```

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 than 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. 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)

SPECIES$	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
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. Eisenhow	0.32086	0.11195	3
LOCALITY$ = NE Mt. Crawf	-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. Eisenhow	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.00000	1.00000			
NE Mt. Crawf	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. Eisenhow	-0.08410	0.04659	3
LOCALITY$ = NE Mt. Crawf	-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. Eisenhow	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.00000	1.00000			
NE Mt. Crawf	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. Eisenhow	1.38062	0.16414	3
LOCALITY$	=NE Mt. Crawf	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. Eisenhow	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.21660	1.00000			
NE Mt. Crawf	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. Eisenhow	0.88532	0.04028	3
LOCALITY$	= NE Mt. Crawf	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. Eisenhow	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.00003	1.00000			
NE Mt. Crawf	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. Eisenhow	0.22821	0.09156	3
LOCALITY$ = NE Mt. Crawf	-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. Eisenhow	Mt. Crawf	Rky Br	Wamsutta
Lows Bald Sp	1.00000				
Mt. Eisenhow	0.42937	1.00000			
NE Mt. Crawf	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

GREEN MT & WHITE MT.

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

GREEN MT.

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 northen 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

   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 Pond  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

Statistical Analysis Conclusions

The levels of most elements are lower in the White Mt. wildernass areas than in the Lye Brook Wilderness. When comparing localities within the White Mt. wilderness areas, Mt. Eisenhower was significantly higher in two species than the other localities. The levels at Wamsutta Trail were lowest in two species. Elemental levels in the White Mt. wilderness areas have slightly decreased since the 1988 study.

CONCLUSIONS

Most elemental levels in most species show similar or lower levels in 1993 than in 1988. No single locality showed higher levels in all lichen species. The levels in White Mt. lichens are lower than in Green Mt. lichens in 1993. These data show that there is no degradation in the air quality since 1988 and there might have been a slight improvement. Statistical analysis of the data support these conclusions.

RECOMMENDATIONS

The original recommendation that elemental analyses be restudied every five years is again made here. Continued periodic study will help to determine whether the decrease is due to random changes or part of a trend with some significance.

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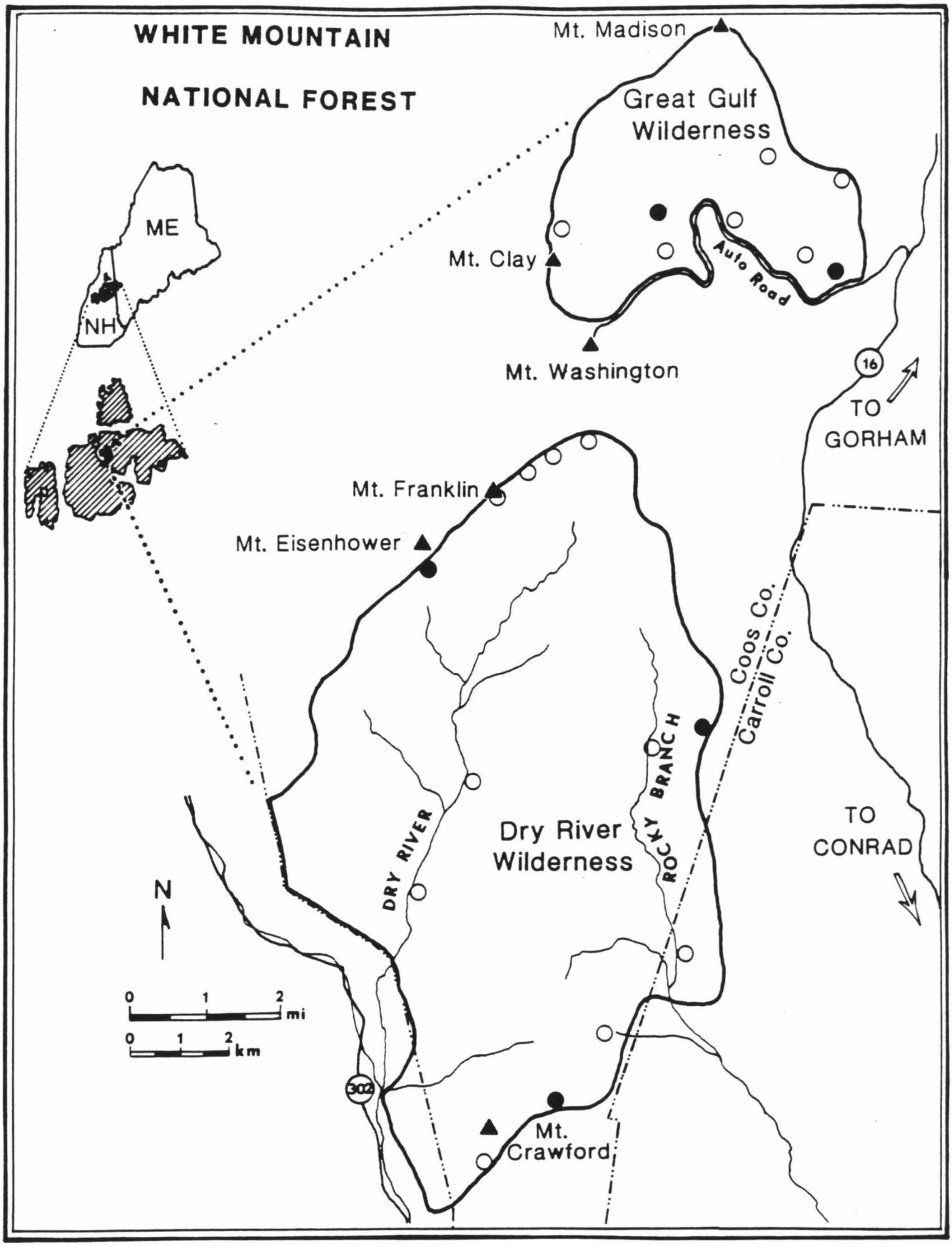

Fig. 1. Open circles are collection localities, solid circles are elemental analysis localities.