FINAL REPORT SUBMITTED TO
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NORTHERN REGION
U.S. DEPARTMENT OF AGRICULTURE
U.S. FOREST SERVICE

COPY

REGARDING:

ESTABLISHMENT OF A LICHEN BIOMONITORING PROGRAM AND AIR QUALITY BASELINE IN THE CABINET MOUNTAINS WILDERNESS AREA

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INTRODUCTION

PROJECT OBJECTIVES:

1. Identify 3 reference sites within the wilderness.

2. Collect, curate, and identify lichen species from various habitats and substrates at each reference site.

3. Identify 3-5 pollution-sensitive lichen species at each reference site. Collect enough tissue of one sensitive indicator species (approximately 6-10 grams dry weight) from each reference site for elemental analyses. Rare species will not be sampled for analysis, but their distribution will be noted.

4. Determine baseline thallus concentrations of 20 potential pollutant elements (including sulfur, selenium, arsenic, copper, bromine, manganese, lead, vanadium, potassium, iron, etc.), using replicate samples of one documented pollution-sensitive species collected at each reference site. Samples will be analyzed using Proton Induced X-Ray Emission (PIXE) techniques.

5. Prepare and submit a draft report by 31 May 1993.

6. Prepare and submit final report details by 31 December 1993.

LICHENS AS BIOLOGICAL INDICATORS OF AIR QUALITY:

Protocol for using lichens as bioindicators of air quality is well-documented (Fields & St.Clair 1984; St.Clair 1989; Richardson 1992). Hale (1983) noted that lichens have been used in three basic ways to monitor the effects of air pollution on biological systems: 1) elemental analysis of lichen tissues, 2) mapping of all (or selected) lichen species found in areas adjacent to pollution sources, and 3) transplant studies. Currently, the most common approach involves a floristic survey along with elemental analyses of tissues from sensitive indicator species (St.Clair 1989; Wetmore 1989).

As lichens accumulate many different pollutants from atmospheric outwash, lichen tissues provide a record of the kinds and relative quantities of air pollutants in any particular airshed (Schutte 1977; Wetmore 1989; Rope & Pearson 1990) Pollutant accumulation patterns for specific elements have been monitored over time by correlating thallus growth rates and pollutant concentrations in excised portions of lichen thalli (Lawrey & Hale 1981). Changes in lichen physiological processes indicate pollution-related damage long before other, more easily detectable changes in thallus color, morphology, or community structure become apparent (Fields & St.Clair 1984).

Lists of pollution-sensitive lichen species have commonly been published in conjunction with floristic and ecological surveys (Rushforth et al. 1982; Wetmore 1989). As certain lichen species are inherently more sensitive to airborne contaminants, air quality can be effectively monitored by occasionally reevaluating lichen community and/or physiological parameters. Pollution-related changes can then be documented by comparing follow-up data to original baseline data.

General Habitat Description for the Cabinet Mountains Wilderness Area:

The Cabinet Mountains Wilderness Area is located in the northeastern corner of Montana and consists of 94,272 acres set in the context of the contiguous Cabinet Mountains Wildlands which includes 186,872 acres. The wilderness occupies the higher elevations of the northern range of the Cabinet Mountains about 15 miles southwest of Libby. The north-south oriented wilderness contains a narrow line of high mountain peaks, glacial lakes, hanging valleys and U-shaped drainages. The mountains of the wilderness are largely comprised of Belt sedimentary rocks which originally formed the bottom of an ancient shallow sea. These sedimentary basins were later thrust upward and subsequently heavily glaciated.

The vascular plant communities of the wilderness include, high elevation alpine tundra, krummholz and small subalpine meadows around glaciated lakes. Downslope are well-developed coniferous forests with some old-growth forests occupying riparian habitats.

LICHEN BIOMONITORING REFERENCE SITES IN THE CABINET MOUNTAINS WILDERNESS AREA:

A total of 3 reference sites were established in the Cabinet Mountains Wilderness Area (figure 1). Specifically, reference sites were established: 1) along the East Fork of the Bull River, along trail #646 (2 August 1992); 2) in the vicinity of Milwaukee Pass and Cliff Lake (3 August 1992); and 3) along trail #926 west of Engle Peak (4 August 1992). Appendix A contains a list of the pollution sensitive indicator species by reference site.

METHODS

COLLECTION, CURATION, IDENTIFICATION, AND DEPOSITION OF LICHEN SPECIES:

Because lichen distribution is directly influenced by substrate, moisture and sunlight, all available substrates and habitats at each reference site were carefully examined. Small amounts of each lichen species were either removed directly from the substrate, or depending on the species, with a small piece of the substrate (bark, wood, soil, or rock).

All specimens were placed in carefully labeled paper sacks and taken back to the BYU Herbarium of Nonvascular Cryptograms, where they were curated, identified, placed in permanent herbarium packets, and labeled with the current epithets and authors' names as well as detailed information about the collection site, habitat, and substrate. Herbarium numbers (BRY C-) were also assigned.

Species were identified using standard lichen keys and taxonomic treatises. Standard chemical spot tests and, where necessary, thin-layer chromatography techniques were used to finalize species identifications.

One set of specimens collected from each reference site will be permanently housed at the BYU Herbarium of Nonvascular Cryptogams in Provo, Utah. A second set of voucher specimens will be sent to any herbarium designated by the Forest Service.

COLLECTION OF LICHEN THALLI FOR LABORATORY ANALYSES:

After careful consideration of species abundance, substrate, growth form, documented/suspected pollution sensitivity and general distribution patterns of the lichens at each reference site, one

species was designated as the sensitive, indicator species and used for all laboratory chemical analyses.

At each reference site sufficient material of at least one sensitive, indicator species was collected for laboratory analyses (6-10 grams dry weight). All lichen material collected for elemental analyses was placed in Hubco cloth bags (to avoid contamination) and transported back to the BYU Herbarium of Nonvascular Cryptogams.

Excess material is permanently stored in Hubco cloth bags in the elemental analysis collection at the BYU Herbarium of Nonvascular Cryptogams. This material is available for additional testing upon request.

DETERMINATION OF ELEMENTAL CONCENTRATIONS IN LICHEN TISSUES:

In the laboratory, surface debris and dust were removed from all samples. Clean, two gram samples of one indicator species from each reference site were delivered to the Elemental Analysis Laboratory at Brigham Young University.

Samples were prepared for PIXE analysis using the methods of Duflou et al. (1987). Lichen samples were placed in Teflon containers with a teflon coated steel ball, cooled to liquid nitrogen temperature, powdered by brittle fracture using a Braun Mikro-Dismemberator II, and then dried in an Imperial IV Microprocessor Over for 14 Hours at 80°C. Subsamples weighing 150 mg were then weighed into teflon containers and spiked with 1 ml of a 360 ppm yttrium solution. The samples were then oven dried again for 14 hours at 80°C. Samples were then homogenized again using the micro-dismemberator. Approximately 1 mg of the powdered lichen was then carefully weighed onto a thin polycarbonate film in an area of 0.5 cm^2. A 1.5% solution of polystyrene in toluene was used to secure the sample to the film.

Samples were analyzed using a 2 MV Van de Graaff accelerator with a 2.28 MeV proton beam which passed through a 1.1 mg/cm^2 pryolytic graphite diffuser foil. The proton beam was collimated to irradiate an area of 0.38 cm^2 on the sample. Typically, 10-100 nA proton beam currents were used. X-rays were detected using a Tracor x-ray spectrometer, model TX-3/48-206, with a 10 mm^2 by 3 mm thick Si(Li) detector positioned at 90° to the proton beam. Samples were analyzed twice using different X-ray absorbers between the samples and the detector. One was a 49 mg/cm^2 Mylar

absorber with a 0.27 mm^2 pinhole (2.8% of detector area). The Mylar was backed with 8.5 mg/cm^2 beryllium foil. A 98 mg/cm^2 Mylar absorber was also used.

To insure adequate quality control, samples of NIST SRM 1571, orchard leaves, and other standards were also prepared and analyzed using the same procedures.

RESULTS AND RECOMMENDATIONS

LICHEN MATERIAL COLLECTED FOR ELEMENTAL ANALYSES:

A total of 5 samples including 3 species from 3 substrates were collected for elemental analyses. Analyses of one species from each reference site was performed using Proton Induced X-Ray Emission (PIXE) technology. Below is a list of the elemental analysis samples by sample number, species, substrate, and collection site (the first number represents the storage drawer and the second number indicates the bag number). All specimens are stored in Hubco cloth bags in the elemental analysis collection at the Herbarium of Nonvascular Cryptograms at Brigham Young University.

Sample#	Taxa	Substrate	Collection Site
21-172	Lobaria pulmonaria	Bark	East Fk. Bull River
21-173	Umbilicaria vellea	Rock	Milwaukee Pass
22-174	Letharia vulpina	Lignum	Milwaukee Pass
22-175	Umbilicaria vellea	Rock	Engle Pk. Trail
22-176	Letharia vulpina	Lignum	Engle Pk. Trail

Elemental analyses have been performed for the following samples:
21-172, 21-173, 22-174, 22-175, 22-176

CHECKLIST OF LICHEN SPECIES FROM SELECTED SITES IN THE CABINET MOUNTAINS WILDERNESS AREA, MONTANA

Acarospora chlorophana (Wahlenb. *ex* Ach.) Massal.
- Growth form: Crustose with effigurate margins
- Substrate: Rock
- Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
- Relative abundance: Rare to locally common
- Pollution sensitivity: Sensitive to sulfur dioxide (Ryan 1990)
- Comments: None
- Deposition of specimens: BYU Herbarium: BRY C-22783, BRY C-23600

Alectoria imshaugii Brodo & D. Hacksw.
- Growth form: Fruticose
- Substrate: Bark
- Site(s): Vicinity of Milwaukee Pass
- Relative abundance: Rare
- Pollution sensitivity: Unknown
- Comments: None
- Deposition of specimens: BYU Herbarium: BRY C-22784

Alectoria sarmentosa (Ach.) Ach.
- Growth form: Fruticose
- Substrate: Conifer branches, Thuja, burnt stump, *Pinus monticola*, dead Birch, Hemlock, conifer bark, *Larix occidentalis*
- Site(s): East Fork of Bull River, vicinity of Milwaukee Pass, Engle Peak Trail
- Relative abundance: Common
- Pollution sensitivity: Sensitive to ozone (Ryan 1990)
- Comments: None
- Deposition of specimens: BYU Herbarium: BRY C-22785 BRY C-23071, BRY C-23135, BRY C-23136, BRY C-23137, BRY C-23138, BRY C-23139, BRY C-23140, BRY C-23141, BRY C-23142, BRY C-23143, BRY C-23233, BRY C-23234, BRY C-23235, BRY C-23236, BRY C-23237

Aspicilia calcarea (L.) Mudd
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22786

Aspicilia cinerea (L.) Körber
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance:
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23601

Baeomyces rufus (Huds.) Rebent.
Growth form: Crustose
Substrate: Mossy soil over
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23238

Bellemerea alpina (Sommerf.) Clauz. & Roux
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common to abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22787, BRY C-23602

Bellemerea cinereorufescens (Ach.) Clauz. & Roux
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22788, BRY C-23603

Biatora vernalis (L.) Fr.
Growth form: Crustose
Substrate: Hemlock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23239, BRY C-23240

Brigantiaea leucoxantha (Sprengel) R. Sant. & Hafellner
Growth form: Crustose
Substrate: Thuja bark
Site(s): East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: This taxon is a new species record for Montana
Deposition of specimens: BYU Herbarium: BRY C-23834

Bryoria abbreviata (Müll. Arg.) Brodo & D. Hacksw.
Growth form: Fruticose
Substrate: Bark, conifer twigs
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Sensitive to ozone (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22789, BRY C-23241

Bryoria capillaris (Ach.) Brodo & D. Hawksw.

Growth form: Fruticose
Substrate: Dead Hemlock, Thuja
Site(s): East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Sensitive to sulfur dioxide; sensitive to fluoride (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23144, BRY C-23145

Bryoria fremontii (Tuck.) Brodo & D. Hawksw.

Growth form: Fruticose
Substrate: Conifer branches, dead Hemlock, dead conifer, Thuja, *Larix occidentalis*, conifer bark, Fir twigs, dead Fir, Hemlock
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Common
Pollution sensitivity: Sensitive to ozone (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-2314446, BRY C-23147, BRY C-23147, BRY C-23148, BRY C-23149, BRY C-23242, BRY C-23243, BRY C-23244, BRY C-23245, BRY C-23246

Bryoria fuscescens (Gyelnik) Brodo & D. Hawksw.

Growth form: Fruticose
Substrate: Dead Hemlock, *Larix occidentalis*
Site(s): East Fork of Bull River
Relative abundance: Rare to locally common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23150, BRY C-23151

Caloplaca cerina (Ehrh. *ex* Hedwig) Th. Fr.
Growth form: Crustose to obsolete
Substrate: Bark
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Sensitive to intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22790

Caloplaca tiroliensis Zahlbr.
Growth form: Crustose to obsolete
Substrate: Detritus
Site(s): Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23247

Catapyrenium lachneum (Ach.) R. Sant.
Growth form: Squamulose
Substrate: Soil
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22791

Catolechia wahlenbergii (Ach.) Körber
Growth form: Squamulose
Substrate: Soil over rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: This taxon is a new species record for Montana
Deposition of specimens: BYU Herbarium: BRY C-22792

Cetraria ericetorum Opiz
Growth form: Foliose, somewhat vagrant
Substrate: Humic soil
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22793

Cetraria hepatizon (Ach.) Vainio
Growth form: Foliose
Substrate: Humic soil over rock, rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23248, BRY C-23249

Chrysothrix chlorina (Ach.) Laundon
Growth form: Leprose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23250

Cladonia chlorophaea (Flörke *ex* Sommerf.) Sprengel
Growth form: Squamulose with podetia
Substrate: Soil, decomposing wood
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23251

Cladonia coniocraea (Flörke) Spreng.
Growth form: Squamulose with podetia
Substrate: Decomposing wood, conifer bark, moss over dead Hemlock, Thuja, soil
Site(s): East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Depostion of specimens: BYU Herbarium: BRY C-23072, BRY C-23152, BRY C-23153, BRY C-23154, BRY C-23155

Cladonia fimbriata (L.) Fr.
Growth form: Squamulose with podetia
Substrate: Soil, decomposing wood, moss over dead Hemlock, Thuja
Site(s): Vicinity of Milwaukee Pass, East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Sensitive to intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22794, BRY C-23156, BRY C-23157

Cladonia pyxidata (L.) Hoffm.
Growth form: Squamulose with podetia
Substrate: Decomposing wood, soil
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23252, BRY C-23253

Cladonia stricta (Nyl.) Nyl.
Growth form: Squamulose with podetia
Substrate: Mossy soil over rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: This taxon is a new species record for Montana
Deposition of specimens: BYU Herbarium: BRY C-223254

Cladonia sulphurina (Michaux) Fr.
Growth form: Squamulose with podetia
Substrate: Thuja, burnt stump, soil
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23158, BRY C-23159, BRY C-23255

Collema polycarpon Hoffm.
Growth form: Foliose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22795

Dermatocarpon intestiniforme (Körber) Hasse
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22796

Dermatocarpon rivulorum (Arnold) Dalla Torre & Sarnth.
Growth form: Foliose, umbilicate
Substrate: Rock (in alpine stream)
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22797

Diploschistes scruposus (Schreber) Norman
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23256

Esslingeriana idahoensis (Essl.) Hale & Lai
Growth form: Foliose
Substrate: Dead conifer, conifer bark, dead hemlock
Site(s): East Fork of Bull River
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23160, BRY C-23161, BRY C-23162

Haematomma lapponicum Räsänen
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23255557

Hypogymnia enteromorpha (Ach.) Nyl.
Growth form: Foliose
Substrate: Conifer branches, Thuja, dead conifer, *Larix occidentalis,* Hemlock, conifer bark
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23073 BRY C-23163, BRY C-23164, BRY C-23165, BRY C-23166, BRY C-23258, BRY C-23259

Hypogymnia imshaugii Krog

Growth form: Foliose

Substrate: Conifer branches, Thuja, dead conifer, dead Birch, Hemlock, *Pinus monticola*

Site(s): East Fork of Bull River, Engle Peak Trail

Relative abundance: Common

Pollution sensitivity: Intermediately sensitive to ozone (Ryan 1990)

Comments: None

Deposition of specimens: BYU Herbarium: BRY C-23167, BRY C-23168, BRY C-23169, BRY C-23170, BRY C-23171, BRY C-23260, BRY C-23261, BRY C-23262, BRY C-23263

Hypogymnia physodes (L.) Nyl.

Growth form: Foliose

Substrate: Decomposing wood, conifer bark, dead conifer, dead Birch, *Larix occidentalis*, Thuja, conifer twigs

Site(s): East Fork of Bull River, Engle Peak Trail

Relative abundance: Locally common to abundant

Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Ryan 1990)

Comments: None

Depostion of specimens: BYU Herbarium: BRY C-23074, BRY C-23172, BRY C-23173, BRY C-23174, BRY C-23174, BRY C-23175, BRY C-23176, BRY C-23264

Hypogymnia tubulosa (Schaerer) Havaas

Growth form: Foliose

Substrate: Conifer bark

Site(s): Engle Peak Trail

Relative abundance: Rare

Pollution sensitivity: Unknown

Comments: None

Deposition of specimens: BYU Herbarium: BRY C-23265

Lecanora argentata (Ach.) Malme
Growth form: Crustose
Substrate: Conifer bark, Hemlock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22798. BRY C-23266

Lecanora impudens Degel.
Growth form: Crustose
Substrate: Conifer bark, Thuja, Hemlock
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23177, BRY C-23178, BRY C-23267, BRY C-23268

Lecanora mellea W. Weber
Growth form: Crustose with effigurate margins
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: This taxon is a new species record for Montana
Deposition of specimens: BYU Herbarium: BRY C-22799

Lecanora novomexicana (B. de Lesd.) Zahlbr.
Growth form: Crustose with effigurate margins
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22800

Lecanora polytropa (Hoffm.) Rabenh.
Growth form: Crustose to obsolete
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22801, BRY C-23604

Lecidea atrobrunnea (Ramond *in* Lam. & DC.) Schaerer
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common to abundant
Pollution sensitivity: Unknown
Comments: This is one of the most common, western saxicolous lichens.
Deposition of specimens: BYU Herbarium: BRY C-22802, BRY C-23605

Lecidoma demissum (Rutstr.) G. Schneider & Hertel
Growth form: Crustose
Substrate: Mossy soil over rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23269

Lepraria neglecta (Nyl.) Lettau
Growth form: Crustose
Substrate: Soil over rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23270, BRY C-23271

Leprocaulon subalbicans (Lamb) Lamb & Ward
Growth form: Sub-fruticose
Substrate: Soil over rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23272

Leproloma membranaceum (Dickson) Vainio
Growth form: Leprose
Substrate: Thuja, dead conifer
Site(s): East Fork of Bull River
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23179, BRY C-23180

Leproloma vouauxii (Hue) Laundon
Growth form: Crustose, leprose
Substrate: Moss
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22803

Letharia vulpina (L.) Hue
Growth form: Fruticose
Substrate: Conifer bark, lignum, dead conifer, Hemlock
Site(s): Vicinity of Milwaukee Pass, East Fork of Bull River, Engle Peak Trail
Relative abundance: Common to locally abundant
Pollution sensitivity: Intermediately sensitive to ozone (Ryan1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22804 BRY C-22991, BRY C-23181, BRY C-23273, BRY C-23274

Lobaria pulmonaria (L.) Hoffm.
Growth form: Foliose
Substrate: Conifer bark, Thuja, Hemlock, dead Birch, dead conifer
Site(s): East Fork of Bull River
Relative abundance: Abundant
Pollution sensitivity: Sensitive to sulfur dioxide (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23075, BRY C-23182, BRY C-23183, BRY C-23184

Lopadium disciforme (Flotow) Kullhem
Growth form: Crustose
Substrate: Thuja
Site(s): East Fork of Bull River
Relative abundance: Locally common to abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23185

Mycoblastus sanguinarius (L.) Norman
Growth form: Crustose
Substrate: Dead conifer, Hemlock, dead Birch
Site(s): East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Sensitive to intermediately sensitive to sulfur dioxide (Ryan1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23186, BRY C-23187, BRY C-23188

Nephroma helveticum Ach.
Growth form: Foliose
Substrate: Hemlock, Thuja, dead conifer
Site(s): East Fork of Bull River
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23189, BRY C-23190, BRY C-23190

Nephroma parile (Ach.) Ach.
Growth form: Foliose
Substrate: Hemlock, dead conifer, moss over rock
Site(s): East Fork of Bull River
Relative abundance: Common to abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23192, BRY C-23193, BRY C-23194

Ochrolechia androgyna (Hoffm.) Arnold
Growth form: Crustose
Substrate: Bark, lignum
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Sensitve to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22805

Ochrolechia montana Brodo
Growth form: Crustose
Substrate: Dead conifer, dead Birch, Hemlock
Site(s): East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23195, BRY C-23196, BRY C-23197

Pannaria conoplea (Ach.) Bory
Growth form: Squamulose
Substrate: Humic soil over rock
Site(s): Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: This taxon is a new species record for Montana
Deposition of specimens: BYU Herbarium: BRY C-23275

Pannaria leucophaea (Vahl) P. Jørg.
Growth form: Squamulose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: This taxon is a new species record for Montana
Deposition of specimens: BYU Herbarium: BRY C-23276

Pannaria pezizoides (Weber) Trevisan
Growth form: Squamulose
Substrate: Soil over rock, humic soil
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23277, BRY C-23278

Parmelia saxatilis (L.) Ach.
Growth form: Foliose
Substrate: Rock, Thuja, dead conifer, moss over rock
Site(s): Vicinity of Milwaukee Pass, East Fork of Bull River, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22806, BRY C-23198, BRY C-23199, BRY C-23279, BRY C-23280

Parmelia sulcata Taylor
Growth form: Foliose
Substrate: Thuja, dead conifer
Site(s): East Fork of Bull River
Relative abundance: Rare to locally common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987); sensitive to intermediately sensitive to ozone; sensitive to fluoride (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23200, BRY C-23201

Parmeliopsis ambigua (Wulfen *in* Jacq.) Nyl.

Growth form: Foliose
Substrate: Lignum, hemlock, conifer bark
Site(s): East Fork of Bull River, Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22807, BRY C-23202, BRY C-232281, BRY C-23282

Parmeliopsis hyperopta (Ach.) Arnold

Growth form: Foliose
Substrate: Lignum, bark, decomposing wood, Thuja, Hemlock, *Pinus monticola*, dead Birch, conifer bark
Site(s): East Fork of Bull River, Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Rare to locally common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22808 BRY C-22992, BRY C-23076, BRY C-23203, BRY C-23204, BRY C-23205, BRY C-23206, BRY C-23283, BRY C-23284

Peltigera canina (L.) Willd.

Growth form: Foliose
Substrate: Soil, moss over rock
Site(s): East Fork of Bull River
Relative abundance: Locally common
Pollution sensitivity: Sensitive to ozone (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23207, BRY C-23208

Peltigera malacea (Ach.) Funck
Growth form: Foliose
Substrate: Soil
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23285

Peltigera polydactyla (Necker) Hoffm.
Growth form: Foliose
Substrate: Decomposing wood
Site(s): East Fork of Bull River
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Depostion of specimens: BYU Herbarium: BRY C-23077

Peltigera venosa (L.) Hoffm.
Growth form: Foliose
Substrate: Soil
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-232286

Pertusaria opthalmiza (Nyl.) Nyl.
Growth form: Crustose
Substrate: Thuja, *Pinus monticola*, dead conifer, Hemlock
Site(s): East Fork of Bull River
Relative abundance: Common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23209, BRY C-23210, BRY C-23211, BRY C-23212

Platismatia glauca (L.) Culb. & C. Culb.

Growth form: Foliose

Substrate: Conifer bark, *Larix occidentalis*, burnt stump, dead Birch, *Pinus monticola*, Birch, dead conifer, Hemlock, conifer twigs

Site(s): East Fork of Bull River, Engle Peak Trail

Relative abundance: Common

Pollution sensitivity: Sensitive to ozone; intermediately sensitive to sulfur dioxide (Ryan 1990)

Comments: None

Deposition of specimens: BYU Herbarium: BRY C-23213, BRY C-23214, BRY C-23215, BRY C-23216, BRY C-23217, BRY C-23218, BRY C-23219, BRY C-23220, BRY C-23287, BRY C-23288, BRY C-23289, BRY C-23290, BRY C-23291

Platismatia herrei (Imsh.) Culb. & C. Culb.

Growth form: Foliose

Substrate: Thuja, burnt stump, conifer bark, Hemlock, dead conifer

Site(s): East Fork of Bull River

Relative abundance: Rare

Pollution sensitivity: Sensitive to ozone; intermediately sensitive to sulfur dioxide (Ryan 1990)

Comments: This taxon is a new species record for Montana

Depostion of specimens: BYU Herbarium: BRY C-23078, BRY C-23221, BRY C-23222, BRY C-23223, BRY C-23224

Platismatia stenophylla (Tuck,) Culb. & C. Culb.

Growth form: Foliose

Substrate: Conifer bark

Site(s): East Fork of Bull River

Relative abundance: Rare

Pollution sensitivity: Unknown

Comments: None

Deposition of specimens: BYU Herbarium: BRY C-23225

Porpidia macrocarpa (DC. in Lam. & DC.) Hertel & Schwab
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22809

Protoparmelia badia (Hoffm.) Hafellner
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare to locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22810

Psoroma hypnorum (Vahl) Gray
Growth form: Squamulose
Substrate: Soil, humic soil, moss over rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22811, BRY C-23292, BRY C-23293

Rhizocarpon badioatrum (Flörke *ex* Sprengel) Th. Fr.
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22812

Rhizocarpon geographicum (L.) DC.
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail, Vicinity of Milwaukee Pass
Relative abundance: Common to abundant
Pollution sensitivity: Sensitive to fluoride (Ryan 1990)
Comments: This is one of the most common western, saxicolous lichens.
Deposition of specimens: BYU Herbarium: BRY C-23606

Solorina crocea (L.) Ach.
Growth form: Foliose
Substrate: Soil, moss over rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23294, BRY C-23295

Sporastatia polyspora (Nyl.) Grumm.
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23607

Sporastatia testudinea (Ach.) Massal.
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Locally common to abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23608

Staurothele fissa (Taylor) Zwackh
Growth form: Crustose
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22813

Tephromela armeniaca (DC.) Hertel & Rambold
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23609

Trapeliopsis granulosa (Hoffm.) Lumbsch.
Growth form: Crustose
Substrate: Humic soil, decomposing wood, lignum
Site(s): Engle Peak Trail
Relative abundance: Locally abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23296, BRY C-23297, BRY C-23298

Tremolecia atrata (Ach.) Hertel
Growth form: Crustose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23610

Tuckermannopsis canadensis (Räsänen) Hale
Growth form: Foliose
Substrate: Dead conifer
Site(s): East Fork of Bull River
Relative abundance: Rare
Pollution sensitivity: Sensitive to ozone (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23226

Tuckermannopsis chlorophylla (Willd. *in* Humb.) Hale
Growth form: Foliose
Substrate: Thuja, conifer bark, Birch, dead conifer, Hemlock, Fir twigs
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Sensitive to sulfur dioxide (Ryan 1990)
Comments: None
Depostion of specimens: BYU Herbarium: BRY C-23079, BRY C-23227, BRY C-23228, BRY C-23229, BRY C-23230, BRY C-23231, BRY C-23299, BRY C-23300, BRY C-23301

Tuckermannopsis platyphylla (Tuck.) Hale
Growth form: Foliose
Substrate: *Larix occidentalis*, Fir twigs, dead Fir
Site(s): East Fork of Bull River, Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23232, BRY C-23302, BRY C-23303, BRY C-23304

Umbilicaria deusta (L.) Baumg.
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23305

Umbilicaria hyperborea (Ach.) Hoffm.
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common to abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22814, BRY C-23306

Umbilicaria phaea Tuck.
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23307

Umbilicaria polyphylla (L.) Baumg.
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Locally common
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Ryan 1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23308

Umbilicaria torrefacta (Lightf.) Schrader
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22815, BRY C-23309

Umbilicaria vellea (L.) Ach.
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22816, BRY C-23310

Umbilicaria virginis Schaerer
Growth form: Foliose, umbilicate
Substrate: Rock
Site(s): Vicinity of Milwaukee Pass, Engle Peak Trail
Relative abundance: Common to locally abundant
Pollution sensitivity: Unknown
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-22817, BRY C-23311

Xanthoria candelaria (L.) Th. Fr.
Growth form: Minutely foliose
Substrate: Rock
Site(s): Engle Peak Trail
Relative abundance: Rare
Pollution sensitivity: Intermediately sensitive to sulfur dioxide (Wetmore 1987); sensitive to ozone (Ryan1990)
Comments: None
Deposition of specimens: BYU Herbarium: BRY C-23611

OBSERVATIONS AND CONCLUSIONS:

1. The lichen flora of the Cabinet Mountains Wilderness Area is diverse and well developed. From our collections at the three reference sites we have identified a total of 94 species in 51 genera including 7 new species records for Montana. All growth forms are well represented; however the flora is dominated by crustose species (40%, 38 species), followed closely by foliose species (38%, 36 species). Fruticose lichens comprise 9% of the flora (8 species) with squamulose species making up 13% (12 species) of the flora. Generally, this growth form pattern seems to be typical of the lichen floras of western Montana and the Pacific Northwest. However, other

Intermountain Area lichen floras are dominated by crustose species (48% in the Bridger Wilderness Area, and 50% in the High Uintas Wilderness Area; with foliose species representing only 28% and 29% of the lichen floras of these wilderness areas).

2. During this study lichens were collected from 4 basic substrates: rocks, lignum/bark, moss/detritus, and soil. A total of 37 species (40% of the flora) were collected from various bark/lignum substrates. Rock substrates were second in importance accounting for 34 species (36% of the flora). Eighteen species (19% of the flora) were collected from soil with only 5 species (5% of the flora) coming from moss/detritus substrates. This substrate pattern is typical of Pacific Northwest lichen communities where bark/lignum species are abundant.

3. High species diversity as well as abundance of all basic growth forms indicates that the lichen communities in the Cabinet Mountains Wilderness Area are healthy and not impacted by air pollutants.

4. The abundance of sensitive indicator species at all reference sites {East Fork of the Bull River (20 spp.), Engle Peak Trail (16 spp.), and vicinity of Milwaukee Pass (11 spp.)} further documents that the lichen flora in the wilderness area is healthy and unimpacted by air pollution.

5. The general absence of necrotic and/or bleached thalli also suggests that the lichen flora is unimpacted.

6. Baseline concentrations of potential pollutant elements were determined by analyzing the tissues of at least one sensitive indicator species from each of the three reference sites. Specifically, *Lobaria pulmonaria* (bark), *Umbilicaria vellea* (rock), and *Letharia vulpina* (bark)were analyzed for pollutant accumulation (table 1). Concentrations of all potential pollutant elements are well within background levels (figure 2). Slightly higher levels of some elements in *Umbilicaria vellea* samples from Milwaukee Pass and Engle Peak Trail are most likely due to substrate uptake. Some of the samples contained moderately high levels of titanium (150-570 ppm) and zinc (231 ppm); however, since both of these elements are common

TABLE #1: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in the Cabinet Mountains Wilderness Area

	Elements (ppm except where indicated)						
	S%	**Cl**	**K%**	**Ca%**	**Ti**	**V**	**Cr**
Lobaria pulmonaria, East Fork Bull River, Sample #172	0.1	440	0.48	0.24	370	*n.d.	n.d.
Umbilicaria vellea, Milwaukee Pass, Sample #173	0.1	200	0.38	0.12	510	n.d.	3.0
Letharia vulpina, Milwaukee Pass, Sample #174	0.08	240	0.23	0.25	150	n.d.	n.d.
Umbilicaria vellea, Engle Peak Trail, Sample #175	0.1	73	0.54	0.15	570	n.d.	n.d.
Letharia vulpina, Engle Peak Trail, Sample #176	0.1	n.d.	0.27	0.50	200	n.d.	n.d.

TABLE #1: Continued

	Elements (ppm except where indicated)						
	Ni	**Cu**	Cu/Zn	**Zn**	**Pb**	**Mn**	**Fe**	**Co**
Lobaria pulmonaria, East Fork Bull River, Sample #172	n.d.	8.0	.267	30	n.d.	49	2400	n.d.
Umbilicaria vellea, Milwaukee Pass, Sample #173	n.d.	9.0	.11	82	18	59	3300	n.d.
Letharia vulpina, Milwaukee Pass, Sample #174	n.d.	20	.417	48	22	73	890	n.d.
Umbilicaria vellea, Engle Peak Trail, Sample #175	n.d.	11	.0476	231	41	104	4000	n.d.
Letharia vulpina, Engle Peak Trail, Sample #176	n.d.	5.0	.125	40	18	210	1010	n.d.

TABLE #1: Continued

	Elements (ppm except where indicated)					
	As	**Se**	**Br**	**Rb**	**Sr**	Fe/Ti
Lobaria pulmonaria, East Fork Bull River, Sample #172	n.d.	n.d.	17	13	18	6.49
Umbilicaria vellea, Milwaukee Pass, Sample #173	2.0	n.d.	11	29	23	6.47
Letharia vulpina, Milwaukee Pass, Sample #174	n.d.	n.d.	11.5	10	14	5.93
Umbilicaria vellea, Engle Peak Trail, Sample #175	n.d.	n.d.	6.0	33	27	7.02
Letharia vulpina, Engle Peak Trail, Sample #176	n.d.	n.d.	10	11	22	5.05

*n.d. = not detectable

Fig. 2 Lichen Biomonitoring Program and Baseline

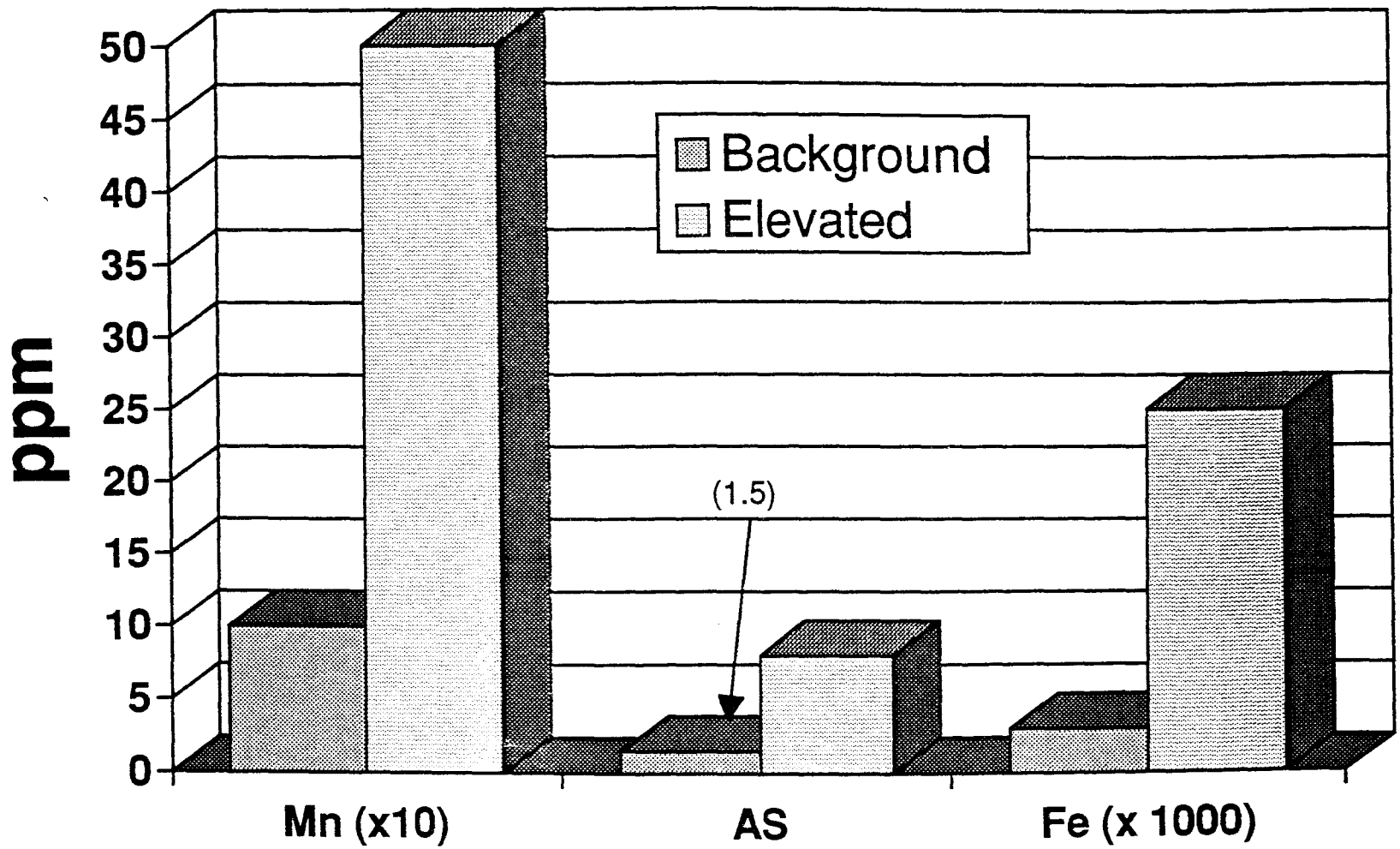
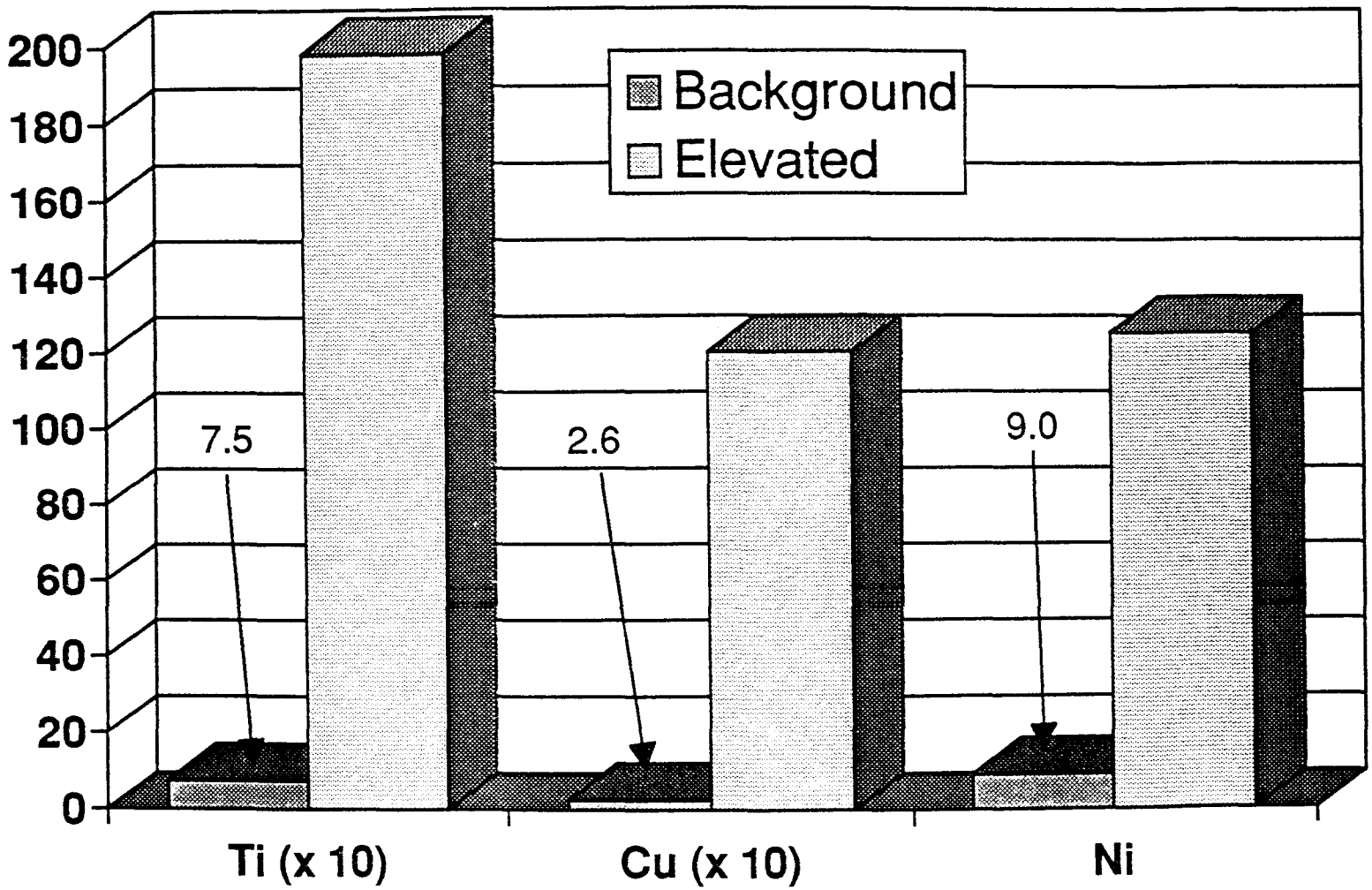
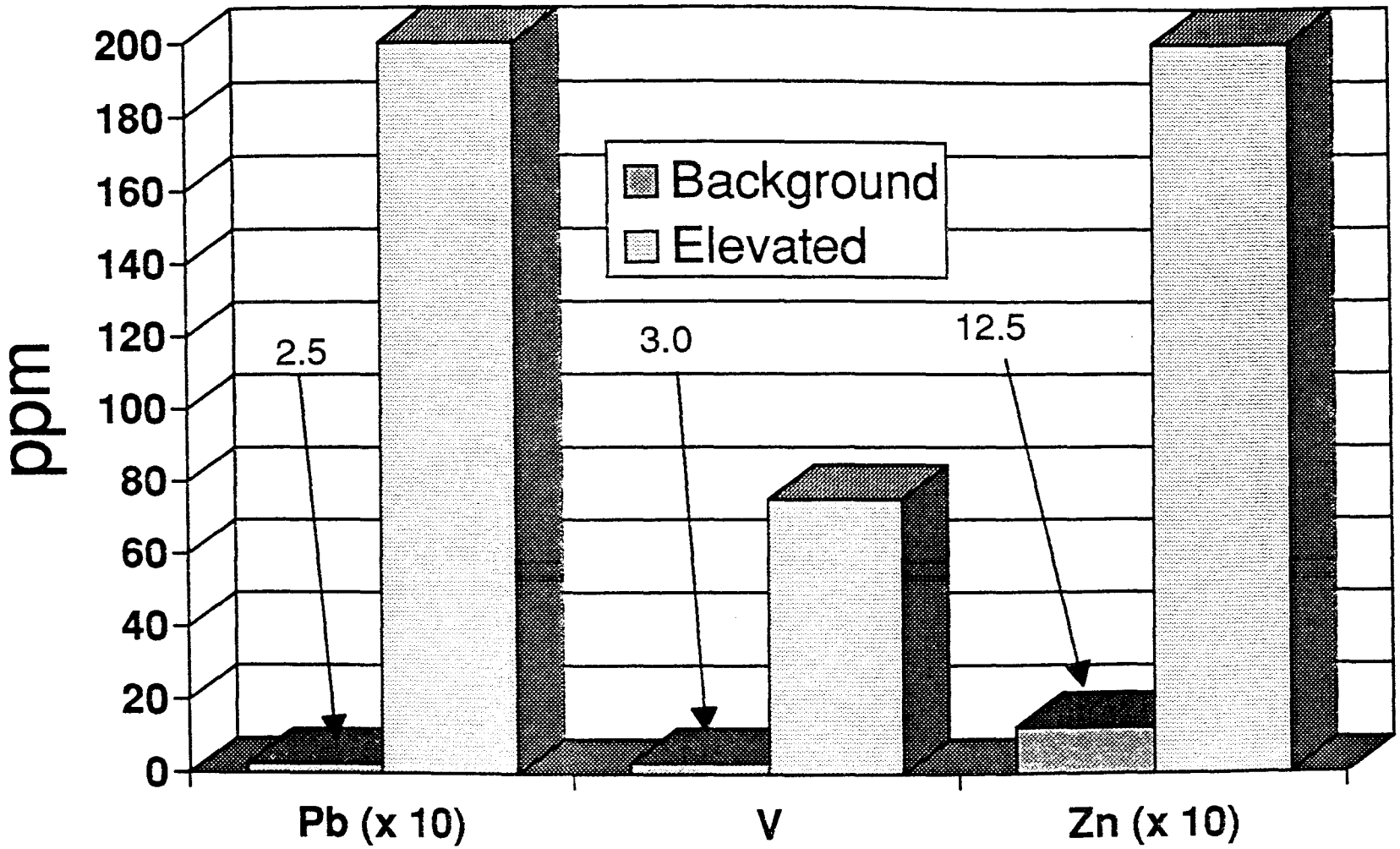


Fig. 2 cont. Lichen Biomonitoring Program and Baseline



Elemental Analysis Data
(background and elevated pollutant levels)

Fig. 2 cont. Lichen Biomonitoring Program and Baseline



components of many soils and rock substrates these values probably represent normal background concentrations. In summary, relatively low concentrations of pollutant elements in the tissues of all sensitive indicator species clearly demonstrates good air quality conditions in the Cabinet Mountains Wilderness Area.

RECOMMENDATIONS:

1. Eventually, reference sites should be established in other parts of the wilderness area. This will provide further information about the lichen flora as well as additional baseline information about the status of sensitive indicator species.

2. Generally, re-evaluation of sensitive indicator species should be performed every 5 to 8 years, depending on significant changes in either local or regional air pollution patterns. The development of new air pollution sources in close proximity to the wilderness area would also be a significant factor in determining the timing of followup surveys.

3. Re-evaluation of the lichen flora at existing reference sites is generally unnecessary, unless sensitive indicator species begin to show either high levels of pollutant elements or significant changes in relative abundance.

4. Eventually, the additional sensitive indicator material should be analyzed in order to strengthen the baseline.

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APPENDIX A

LIST OF POLLUTION SENSITIVE INDICATOR SPECIES BY REFERENCE SITE:

East Fork of Bull River:

Alectoria sarmentosa (sensitive to ozone)
Bryoria capillaris (sensitive to sulfur dioxide; sensitive to fluoride)
Bryoria fremontii (sensitive to ozone)
Bryoria fuscescens (intermediately sensitive to sulfur dioxide)
Cladonia coniocraea (intermediately sensitive to sulfur dioxide)
Cladonia fimbriata (sensitive to intermediately sensitive to sulfur dioxide)
Hypogymnia imshaugii (intermediately sensitive to ozone)
Hypogymnia physodes (intermediately sensitive to sulfur dioxide)
Letharia vulpina (intermediately sensitive to ozone)
Lobaria pulmonaria (sensitive to sulfur dioxide)
Mycoblastus sanguinarius (sensitive to intermediately sensitive to sulfur dioxide)
Parmelia saxatilis (intermediately sensitive to sulfur dioxide)
Parmelia sulcata (intermediately sensitive to sulfur dioxide; sensitive to intermediately sensitive to ozone; sensitive to fluoride)
Parmeliopsis ambigua (intermediately sensitive to sulfur dioxide)
Parmeliopsis hyperopta (intermediately sensitive to sulfur dioxide)
Peltigera canina (sensitive to ozone)
Platismatia glauca (sensitive to ozone; intermediately sensitive to sulfur dioxide
Platismatia herrei (sensitive to ozone; intermediately sensitive to sulfur dioxide)
Tuckermannopsis canadensis (sensitive to ozone)
Tuckermannopsis chlorophylla (sensitive to sulfur dioxide)

Engle Peak Trail:

Acarospora chlorophana (sensitive to sulfur dioxide)
Alectoria sarmentosa (sensitive to ozone)
Bryoria abbreviata (sensitive to ozone)
Bryoria fremontii (sensitive to ozone)
Hypopgymnia imshaugii (intermediately sensitive to ozone)

Hypogymnia physodes (intermediately sensitive to sulfur dioxide)
Letharia columbiana (intermediately sensitive to ozone)
Letharia vulpina (intermediately sensitive to ozone)
Parmelia saxatilis (intermediately sensitive to sulfur dioxide)
Parmeliopsis ambigua (intermediately sensitive to sulfur dioxide)
Parmeliopsis hyperopta (intermediately sensitive to sulfur dioxide)
Platismatia glauca (sensitive to ozone; intermediately sensitive to sulfur dioxide)
Rhizocarpon geographicum (sensitive to fluoride)
Tuckermannopsis chlorophylla (sensitive to sulfur dioxide)
Umbilicaria polyphylla (intermediately sensitive to sulfur dioxide)
Xanthoria candelaria (intermediately sensitive to sulfur dioxide, sensitive to ozone)

Vicinity of Milwaukee Pass:

Acarospora chlorophana (sensitive to sulfur dioxide)
Alectoria sarmentosa (sensitive to ozone)
Bryoria abbreviata (sensitive to ozone)
Caloplaca cerina (sensitive to intermediately sensitive to sulfur dioxide)
Cladonia fimbriata (sensitive to intermediately sensitive to sulfur dioxide)
Letharia vulpina (intermediately sensitive to ozone)
Ochrolechia androgyna (sensitive to sulfur dioxide)
Parmelia saxatilis (intermediately sensitive to sulfur dioxide)
Parmeliopsis ambigua (intermediately sensitive to sulfur dioxide)
Parmeliopsis hyperopta (intermediately sensitive to sulfur dioxide)
Rhizocarpon geographicum (sensitive to fluoride)