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FINAL REPORT COPY

SUBMITTED TO

PETE STEWART & JOHN KRAMER
OF THE
GILA NATIONAL FOREST

REGARDING

ESTABLISHMENT OF A LICHEN AIR QUALITY BIOMONITORING PROGRAM AND BASELINE FOR SELECTED SITES IN THE GILA WILDERNESS AREA, GILA NATIONAL FOREST, NEW MEXICO

SUBMITTED BY

LARRY L. ST. CLAIR Ph.D.
PROFESSOR OF BOTANY AND CURATOR OF NON-VASCULAR CRYPTOGAMS
AND
KIM T. ANDERSON Ph.D., RESEARCH ASSOCIATE
DEPARTMENT OF BOTANY AND RANGE SCIENCE, BRIGHAM YOUNG UNIVERSITY, PROVO, UTAH 84602

1 JULY 1998

Buellia semitensis Tuck.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32442

Buellia spuria (Schaerer) Anzi
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Black Canyon, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32282, 32540

Calicium abietinum Pers.
Growth form: thallus absent
Substrate: bark, lignum
Site(s): Black Canyon, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: this taxon is non-lichenized, however, it is traditionally classified with the lichens. This species is a new state record for the state of New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32226, 32534

Caloplaca cerina (Hedwig) Th. Fr.
Growth form: crustose
Substrate: bark
Site(s): Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: intermediately sensitive to sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32359b

Caloplaca discolor (Willey) Fink
Growth form: crustose
Substrate: bark, lignum, Cactus
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31240, 31245, 31247, 31258, 32177, 32187, 32191, 32248, 32219, 32469, 32474, 32481, 32485, 32493, 32587, 32597, 32606b, 32615, 32626, 32633

Caloplaca durietzii H. Magn.
Growth form: crustose
Substrate: lignum
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: Unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32227

Caloplaca flavovirescens (Wulfen) Dalla Torre & Sarnth.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32511, 32555

Caloplaca fraudans (Th.Fr.) H. Olivier
Growth form: crustose (absent)
Substrate: rock (rhyolite), lignum
Site(s): Railroad Canyon Trail, West Fork of Gila River, Indian Creek Trail, and Rain Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31262, 32178, 32336, 32510a, 32510b, 32571a

Caloplaca holocarpa (Hoffm. *ex* Ach.) M. Wade
Growth form: crustose (absent)
Substrate: bark
Site(s): Indian Creek Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32360, 32533, 32630

Caloplaca microphyllina (Tuck.) Hasse
Growth form: crustose
Substrate: lignum
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: Unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32237

Caloplaca modesta (Zahlbr.) Fink
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): West Fork of Gila River, and Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31297, 31298, 32571b

Caloplaca saxicola (Hoffm.) Nordin
Growth form: crustose (± effigurate margin)
Substrate: rock (rhyolite)
Site(s): Black Canyon Trail, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32266, 32272, 32309, 32346

Candelaria concolor (Dickson) Stein
Growth form: foliose
Substrate: rock (rhyolite), bark
Site(s): Turkey Creek Trail, and Black Canyon
Relative abundance: common
Pollution sensitivity: sensitive to intermediately sensitive to Sulfur dioxide; sensitive to fluoride
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32262, 32471, 32492, 32496, 32524

Candelariella rosulans (Müll. Arg.) Zahlbr.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Railroad Canyon Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31283

Candelariella subdeflexa (Nyl.) Lettau
Growth form: crustose
Substrate: bark, lignum
Site(s): West Fork of the Gila River
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32176

Candelariella vitellina (Hoffm.) Müll. Arg.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail, and Bead Spring Trail
Relative abundance: rare to common
Pollution sensitivity: intermediately sensitive to Sulfur dioxide, sensitive to fluoride
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32338, 32451

Candelina submexicana (de Lesd.) Poelt
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River, Indian Creek Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32203, 32205, 32310, 32342, 32543, 32572

Catapyrenium daedaleum (Kremp.) Stein
Growth form: squamulose
Substrate: soil over rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of speciments: BYU Herbarium: BRY C 32350

Placidium
~~Catapyrenium~~ squamulosum (Ach.) Breuss
Growth form: squamulose
Substrate: soil over rock (rhyolite)
Site(s): Black Canyon, Indian Creek Trail, and Turkey Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of speciments: BYU Herbarium: BRY C 32257, 32277, 32349, 32501

Cladonia cariosa (Ach.) Sprengel
Growth form: squamulose with podetia
Substrate: moss over rock
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32394

Cladonia chlorophaea (Flörke *ex* Sommerf.) Sprengel
Growth form: squamulose with podetia
Substrate: soil over rock
Site(s): Bead Spring Trail, and West Fork of Gila River
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32200

Cladonia coniocraea (Flörke) Sprengel
Growth form: squamulose with podetia
Substrate: lignum, decomposing wood, moss over rock (rhyolite), bark, soil over rock (rhyolite)
Site(s): Bead Spring Trail, and Turkey Creek Trail
Relative abundance: common
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32395, 32402, 32427, 32441, 32447, 32455, 32537

Cladonia pyxidata (L.) Hoffm.
Growth form: squamulose with podetia
Substrate: moss/soil over rock (rhyolite)
Site(s): Bead Spring Trail, and Indian Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32320, 32449

Collema cristatum (L.) F.H. Wigg.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: sensitive to intermediately sensitive to ozone
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32504

Cyphelium tigillare (Ach.) Ach.
Growth form: crustose
Substrate: bark, lignum
Site(s): Railroad Canyon Trail, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31227, 31253, 32372

Dermatocarpon intestiniforme (Körber) Hasse
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32258

PROJECT SUMMARY

During the spring of 1996 a total of 7 lichen air quality biomonitoring reference sites were established in the Gila Wilderness Area of the Gila National Forest. To date 142 lichen species in 67 genera have been identified from our collections, with 52 new species records for the state of New Mexico. Unlike most other sites in the Intermountain Area, the lichen flora of the Gila Wilderness Area is dominated by foliose species (53% or 76 species). During the course of our study lichen specimens were collected from four basic substrates (rocks, bark/lignum, soil, and moss/detritus), with most species occurring on rock substrates (55% or 79 species). A total of 19 elemental analysis samples have been collected from the 7 air quality biomonitoring reference sites in the wilderness. Included in this collection are a total of 3 sensitive indicator species collected from two basic substrates (rock and bark). An average of 11.1 sensitive indicator species were collected from each reference site. This compares with an average of 6.3 along the Wasatch Front; 5.2 in Chiricahua National Monument (southeastern Arizona); and 13.5 in the San Juan-Rio Grande National Forest (southwestern Colorado). Elemental analysis data suggest some areas of concern. Sulfur concentrations in two lichen samples from two sites (Rain Creek and West Fork of the Gila River) were significantly elevated (.28%). In addition, thallus concentrations of arsenic exceeded background levels in 17 out of 19 samples with a range of 1.8-12 ppm. Chromium concentrations in 11 out of 19 samples were moderately evelvated with a range of 3.3 to 19 ppm; and nickel concentrations were somewhat elevated in 2 out of 19 samples (9.2 and 10 ppm from the West Fork of the Gila River and along Indian Creek Trail respectively). Lead concentrations were somewhat elevated in four samples, ranging from 28-55 ppm. Copper to zinc ratios were unusally high in 5 out of 19 samples and marginally high in another 8 samples. The only other area in the intermountain western United States with similar copper/zinc ratios is Chiricahua National Monument (17 out of 21 samples with elevated copper/zinc ratios). Overall, the high species diversity, the general absence of bleached and/or necrotic thalli, and the relatively high average number of sensitive indicator species per site (11.1) suggests that the lichen flora of the Gila Wilderness Area has not been heavily impacted by air pollution. Generally, reevaluation of pollutant levels in tissues of sensitive indicator species should be conducted every 5-8 years. However, some sites with elevated pollutant levels should be reevaluated every 3-5 years. Overtime additional reference sites could be established in other parts of the Wilderness.

INTRODUCTION

PROJECT OBJECTIVES:

1. Identify and establish 7 air quality biomonitoring reference sites in the Gila Wilderness Area of the Gila National Forest.
2. Collect, curate, and identify lichen species from various habitats and substrates at each reference site.
3. Identify 1-3 pollution sensitive lichen species at each reference site. Collect enough tissue of at least one sensitive indicator species (approximately 3-6 grams dry weight) from each reference site for elemental analyses. Rare species will not be collected for analysis, but their distribution will be noted. Excess material will be stored in Hubco cloth bags in the elemental analysis collection in the Herbarium of Non-vascular Cryptogams at Brigham Young University, Provo, Utah.
4. Determine baseline thallus concentrations of 21 potential pollutant elements (including sulfur, selenium, arsenic, copper, bromine, manganese, lead, vanadium, potassium, iron, etc.), using replicate samples of at least 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 transfer to the U.S. Forest Service duplicate herbarium specimens.
6. Prepare and submit an interim report by 31 December 1997.
7. Prepare and submit a final report by 31 January 1998.

LICHENS AS BIOLOGICAL INDICATORS OF AIR QUALITY:

Protocol for using lichens as bioindicators of air quality is well documented (Fields & St. Clair 1984; Richardson 1992). Hale (1983) noted that lichens have been used in three ways to monitor the effects of air pollution on biological communities: 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 and Newberry 1995; Wetmore 1989).

As lichens accumulate a variety of 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 with pollutant concentrations in precisely excised portions of lichen thalli (Lawrey & Hale 1981). Changes in lichen physiological processes indicate pollution-related damage long before other, more easily discernible characteristics such as changes in thallus color, morphology, or community structure become apparent (Fields & St. Clair 1984).

Lists of pollution-sensitive lichen species are frequently 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 biomonitored by occasionally reevaluating lichen community and/or physiological parameters. Pollution-related changes can then be documented by comparing follow up data with original baseline data.

GENERAL HABITAT DESCRIPTION FOR THE GILA WILDERNESS AREA OF THE GILA NATIONAL FOREST, UTAH:

The Gila Wilderness Area is located in the volcanic highlands of southwestern New Mexico (Figure 1). The geologic landscape of the wilderness is dominated by two rather large calderas, the Bursum Caldera located in the western half of the wilderness and the Gila Cliff Dwellings Caldera in the eastern half of the wilderness. Much of the western half of the wilderness is also located in the Mogollon Mountains. Most rock substrates in the wilderness are Tertiary volcanics from the Oligocene and Micocene; consisting mostly of Andesitic and Latitic lava flows (Miocene) and Rhyolite flows of various ages (Oligocene to Miocene). Some Quaternary sedimentary rocks (from the Holocene, Pleistocene, and Pliocene) dominate some locations in the eastern half of the wilderness, especially along the Middle and West forks of the Gila River.

The Western Xeric Evergreen Forest is the dominant plant community type in the Gila Wilderness Area, with some vegetation influence from the Mogollon Plateau. This vegetation type is composed primarily of live oak species, with Quercus emoryi the most prominent member of the live oak group. In addition to the live oaks this community type also contains various conifers including: Cupressus arizonica, Juniperus deppeana, Pinus cembroides, Pinus engelmannii, Pinus leiophylla var. chihuahuana, Pinus ponderosa var. arizonica, and Pinus strobiformis. The southwestern part of New Mexico is floristically somewhat similar to the southeast and east-central portions of Arizona. Riparian habitats in the wilderness include several deciduous angiosperms including, Acer grandidentatum, Acer negundo, Fraxinus velutina, Platanus wrightii, Populus fremontii, and Juglans major. Upper elevation areas of the wilderness contain a mixed conifer community including, Pseudotsuga menziesii, Abies concolor, Pinus ponderosa, and Pinus flexilis. In addition at the higher elevation sites there are several deciduous tree and shrub species including, Acer glabrum, Populus tremuloides, Ribes spp., Robinia neomexicana var. neomexicana, and Physocarpus monogynus.

The mean annual temperature for the wilderness is 53° F; while mean annual precipitation is 15 inches. Average annual precipitation ranges from 13 inches at lower elevations to 30 inches at higher elevations in the wilderness.

GILA WILDERNESS - GILA NATIONAL FOREST, NEW MEXICO

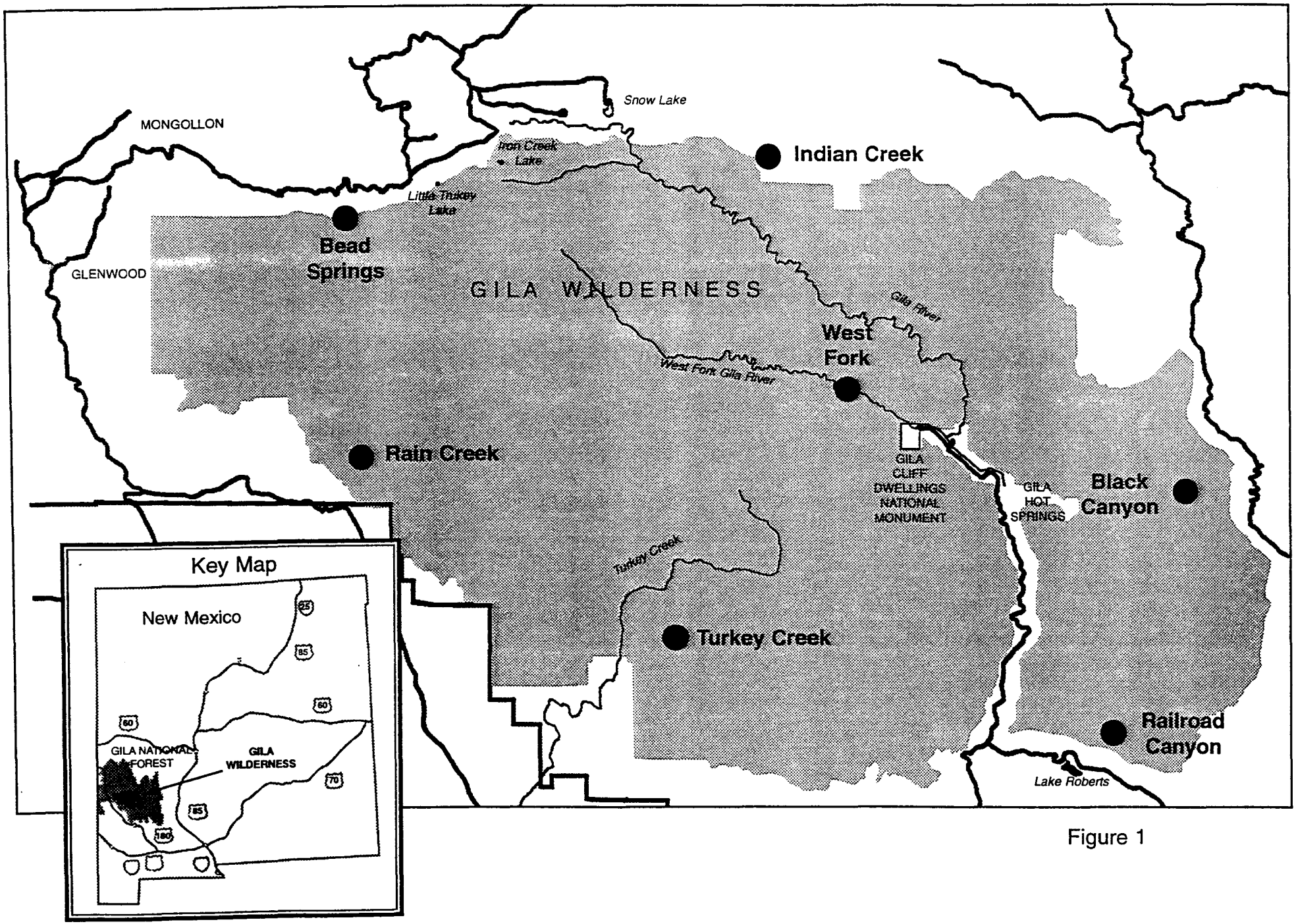


Figure 1

LICHEN BIOMONITORING REFERENCE SITES IN THE GILA WILDERNESS AREA OF THE GILA NATIONAL FOREST, UTAH:

During the spring of 1996 a total of 7 air quality biomonitoring reference sites were established in Gila Wilderness Area, Gila National Forest. Specifically, reference sites have been established at the following locations:

Site #1: 30 April and 1 May 1996. Along West Fork of the Gila River (U.S. Forest Service Trail #151), about 2 km northwest of Gila Cliff Dwellings National Monument, Gila Wilderness Area, Gila National Forest, Catron County, New Mexico. GPS reading: 33° 14.409′ north latitude, 108° 17.265′ west longitude. Elevation: 5800 feet (from topographic map). Collectors: Larry St. Clair, Kim Anderson, and John Kramer (U.S. Forest Service). Herbarium Numbers: 31216-31223; 31290-31299; 32175-32216.

Site #2: 1 May 1996. Along U.S. Forest Service Trail #96 (Railroad Canyon Trail), about 1 km northeast of Trailhead, Gila Wilderness Area, Gila National Forest, Grant County, New Mexico. GPS reading: 33° 02.091′ north latitude, 108° 07.557′ west longitude. Elevation: 6200 feet (from topographic map). Collectors: Larry St. Clair, Kim Anderson, and John Kramer (U.S. Forest Service). Herbarium Numbers: 31224-31289.

Site #3: 2 May 1996. Along U.S. Forest Service Trail #94 (Black Canyon Trail), about 1 km along trail from Trailhead, Gila Wilderness Area, Gila National Forest, Grant County, New Mexico. GPS reading: 33° 10.779′ north latitude, 108° 02.791′ west longitude. Elevation: 6720 feet (from topographic map). Collectors: Larry St. Clair, Kim Anderson, and John Kramer (U.S. Forest Service). Herbarium Numbers: 32217-32302.

Site #4: 3 May 1996. Along Indian Creek Trail, about .3 km south of Double Springs Ranch (Pete Evans), Gila Wilderness Area, Gila National Forest, Catron County, New Mexico. GPS reading: 33° 22.387′ north latitude, 108° 19.014′ west longitude. Elevation: 7360 feet (from topographic map). Collectors: Larry St. Clair, Kim Anderson, John Kramer (U.S. Forest Service). Herbarium Numbers: 32303-32393.

Site#5: 4 May 1996. Along U.S. Forest Service Trail #182 to Bead Spring, Gila Wilderness Area, Gila National Forest, Catron County, New Mexico. GPS reading: 33° 22.195′ north latitude, 108° 41.055′ west longitude. Elevation: 9100 feet (from GPS unit). Collectors: Larry St. Clair and Kim Anderson. Herbarium Numbers: 32394-32462.

Site #6: 6 May 1996. Along U.S. Forest Service Trail #155 (Turkey Creek Trail), Gila Wilderness Area, Gila National Forest, Grant County, New Mexico. GPS reading: 33° 05.919′ north latitude, 108° 29.154′ west longitude. Elevation: 4800 feet (from GPS unit). Collectors: Larry St. Clair, Kim Anderson, and John Kramer. Herbarium Numbers: 32463-32548.

Site #7: 7 May 1996. Along U.S. Forest Service Trail #189 (Rain Creek Trail), Gila Wilderness Area, Gila National Forest, Grant County, New Mexico. GPS reading: 33° 11.487′ north latitude, 108° 40.092′ west longitude. Elevation: 5800 feet (from topographic map). Collectors: Larry St. Clair, Kim Anderson, and John Kramer. Herbarium Numbers: 32549-32647.

METHODS

COLLECTION, CURATION, IDENTIFICATION AND DEPOSITION OF LICHEN SPECIMENS:

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 Cryptogams, 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-) have been assigned to each specimen.

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 set of duplicate voucher specimens will transferred to the U.S. Forest Service for deposition at their discretion.

COLLECTION OF SENSITIVE INDICATOR SPECIES FOR ELEMENTAL ANALYSES:

After carefully reviewing species abundance, local substrates, growth forms, documented/suspected pollution sensitivity and general distribution patterns, one to several pollution sensitive indicator species were collected at each reference site and taken to the Elemental Analysis Laboratory at BYU. PIXE analysis techniques were then used to determine thallus concentrations of 21 potential pollutant elements.

At each reference site sufficient material of at least one sensitive indicator species was collected for elemental analysis (3-6 grams dry weight). Elemental analysis samples were placed in Hubco cloth bags (to avoid contamination) and transported back to the BYU Herbarium of Nonvascular Cryptogams. Excess elemental analysis 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 at least one sensitive 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 Oven for 14 hours at 80°C. Subsamples weighing 150 mg were then weighed in to teflon containers and spiked with 1 ml of a 360 ppm yttrium solution. 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 was passed through a 1.1 mg/cm^2 pyrolytic 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-

Dermatocarpon miniatum (L.) W. Mann
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Black Canyon Trail, Turkey Creek Trail, and West Fork of Gila River
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31290, 32256, 32299a, 32467, 32502b

Dermatocarpon moulinsii (Mont.) Zahlbr.
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Black Canyon, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32299b, 32502a

Dimelaena oreina (Ach.) Norman
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River, Indian Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32199, 32304, 32326, 32557

Diploschistes scruposus (Schreber) Norman
Growth form: crustose
Substrate: rock
Site(s): West Fork of the Gila River, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32198, 32483

Flavoparmelia baltimorensis (Gyelnik & Fóriss) Hale
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32518

Flavoparmelia caperata (L.) Hale
Growth form: foliose
Substrate: bark
Site(s): Indian Creek Trail, and Turkey Creek Trail
Relative abundance: rare to common
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32387, 32521

Flavoparmelia rutidota (Hook. f. & Taylor) Hale
Growth form: foliose
Substrate: bark
Site(s): Railroad Canyon Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31231

Flavopunctelia flaventior (Stirton) Hale
Growth form: foliose
Substrate: rock (rhyolite), bark, Cactus
Site(s): West Fork of the Gila River, Railroad Canyon, Black Canyon, Indian Creek Trail, Bead Spring Trail, Turkey Creek Trail, and Rain Creek Trail.
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31216, 31229, 31242, 32183,32235, 32287, 32296, 32375, 32385, 32523, 32513, 32556, 32608, 32627, 32634

Flavopunctelia praesignis (Nyl.) Hale
Growth form: foliose
Substrate: bark
Site(s): Railroad Canyon Trail, Black Canyon, Rain Creek Trail, and Turkey Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31237, 31289, 32220, 32476, 32495, 32578, 32586, 32593, 32628

Flavopunctelia soredica (Nyl.) Hale
Growth form: foliose
Substrate: bark, rock (rhyolite), Cactus
Site(s): Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Bead Spring Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31228, 31232, 31255, 31271, 32224, 32302, 32356, 32437, 32416, 32472, 32477, 32488, 32494, 32523, 32546, 32580, 32592, 32616, 32640, 32641, 32644

Haematomma subpuniceum (Müll. Arg.) de Lesd.
Growth form: crustose
Substrate: rock
Site(s): West Fork of the Gila River
Relative abundance: common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32192

Heterodermia diademata (Taylor) D.D. Awasthi
Growth form: foliose
Substrate: bark
Site(s): Turkey Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32473

Heterodermia rugulosa (Kurok.) Wetmore
Growth form: foliose
Substrate: bark, Cactus
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Indian Creek Trail, Turkey Creek Trail, Rain Creek Trail, and Black Canyon
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31236, 32184, 32222, 32357, 32378, 32497, 32529, 32589, 32591, 32606a, 32617, 32625

Heterodermia speciosa (Wulfen) Trevisan
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Rain Creek Trail, Black Canyon, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32288, 32520, 32552

Hypotrachyna pseudosinuosa (Asah.) Hale
Growth form: foliose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32436, 32456

Imshaugia aleurites (Ach.) S.F. Meyer
Growth form: foliose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32412

Imshaugia placorodia (Ach.) S.F. Meyer
Growth form: foliose
Substrate: bark
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Bead Spring Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31226, 32182, 32244, 32246, 32369, 32373, 32434, 32619

Lasallia papulosa (Ach.) Llano
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32318

Lecanora argentata (Ach.) Malme
Growth form: crustose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32424, 32433

Lecanora argopholis (Ach.) Ach.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Black Canyon Trail, West Fork of Gila River, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32201, 32270, 32317

Lecanora caesiorubella Ach.
Growth form: crustose
Substrate: lignum
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbaruium: BRY C 32242

Lecanora cenisia Ach.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbaruium: BRY C 32446, 32448

Lecanora muralis (Schreber) Rabenh.
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Rain Creek Trail, and Bead Spring Trail
Relative abundance: rare to common
Pollution sensitivity: sensitive to heavy metals
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31269, 31282, 32209, 32271, 32347, 32410, 32452, 32558, 32560

Lecanora phaedrophthalma Poelt
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32333

Lecanora saligna (Schrader) Zahlbr.
Growth form: crustose
Substrate: lignum
Site(s): Railroad Canyon Trail
Relative abundance: rare
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31254

Lecanora valesiaca (Müll. Arg.) Stizenb.
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): Railroad Canyon Trail, and Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31265, 32561

Lecidea tessellata Flörke
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Black Canyon, Indian Creek Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32263, 32268, 32305, 32327, 32569, 32575

Lecidella euphorea (Flörke) Hertel
Growth form: crustose
Substrate: bark, lignum
Site(s): Bead Spring Trail, Rain Creek Trail, Turkey Creek Trail, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32391, 32536

Lecidella stigmatea (Ach.) Hertel & Leuckert
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Railroad Canyon Trail, Indian Creek Trail, Bead Spring Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Depostition of specimens: BYU Herbarium: BRY C 31263, 31272, 32328, 32340b, 32450, 32542, 32566

Lecidella viridans (Flotow) Körber
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C32567

Leprocaulon albicans (Th. Fr.) Nyl. *ex* Hue
Growth form: minutely fruticose
Substrate: soil over rock (rhyolite)
Site(s): West Fork of the Gila River, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C32193, 32363

Leptogium arsenei Sierk
Growth form: foliose
Substrate: rock (rhyolite), bark, moss/soil over rock (rhyolite)
Site(s): Black Canyon, Rain Creek Trail, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32286b, 32470, 32503b, 32554

Leptogium denticulatum Tuck.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Rain Creek Trail, Black Canyon, and Turkey Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32285a, 32286a, 32503a

Leptogium furfuraceum (Harm.) Sierk
Growth form: foliose
Substrate: rock (rhyolite), bark, lignum
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Indian Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31221, 31239, 31250, 32175, 32186, 32225, 32228, 32230, 32238, 32276, 32359a, 32380, 32499, 32590, 32595, 32612, 32623, 32635

Leptogium hirsutum Sierk
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32285b

Lichinella nigritella (Lettau) Moreno & Egea
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Black Canyon Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32255

Lobothallia alphoplaca (Wahlenb.) Hafellner
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32343

Megaspora verrucosa (Ach.) Hafellner & V. Wirth
Growth form: crustose
Substrate: bark
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Rain Creek Trail, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31243, 31251b, 32188, 32223, 32381, 32594, 32624

Melanelia stygia (L.) Essl.
Growth form: foliose
Substrate: bark, rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32307

Melanelia subolivacea (Nyl.) Essl.
Growth form: foliose
Substrate: bark
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Turkey Creek Trail, Rain Creek Trail, and Bead Spring Trail
Relative abundance: common
Pollution sensitivity: intermediately sensitive to ozone
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32354, 32400, 32418, 32432, 32531, 32577, 32584, 32638

Neofuscelia atticoides (Essl.) Essl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trial, and Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32393, 32507

Neofuscelia brunella (Essl.) Essl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32211

Neofuscelia occidentalis (Essl.) Essl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32637

Neofuscelia subhosseana (Essl.) Essl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32334

Nephroma parile (Ach.) Ach.
Growth form: foliose
Substrate: moss over rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32425

Parmelia sulcata Taylor
Growth form: foliose
Substrate: bark, rock (rhyolite)
Site(s): Indian Creek Trail, and Bead Spring Trail
Relative abundance: rare to common
Pollution sensitivity: sensitive to intermediately sensitive to ozone, intermediately sensitive to sulfur dioxide, sensitive to fluoride
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32384, 32397, 32420, 32460

Parmeliopsis ambigua (Wulfen) Nyl.
Growth form: foliose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32396

Parmotrema ultralucens (Krog) Hale
Growth form: foliose
Substrate: rock
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32465

Peltigera canina (L.) Willd.
Growth form: foliose
Substrate: moss over rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: common
Pollution sensitivity: sensitive to ozone and heavy metals
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32458

Peltigera collina (Ach.) Schrader
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: sensitive to ozone
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32281

Peltigera polydactylon (Necker) Hoffm.
Growth form: foliose
Substrate: moss over rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32426

Peltigera venosa (L.) Hoffm.
Growth form: foliose
Substrate: mossy soil
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32462

Peltula euploca (Ach.) Poelt
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Black Canyon Trail, and West Fork of Gila River
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32194, 32253

Pertusaria saximontana Wetmore
Growth form: crustose
Substrate: bark, lignum
Site(s): Railroad Canyon Trail, and Indian Creek Trial
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31248b, 32383

Pertusaria wulfenioides de Lesd.
Growth form: crustose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32413

Phaeophyscia cernohorskyi (Nádv.) Essl
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32254

Phaeophyscia ciliata (Hoffm.) Moberg
Growth form: foliose
Substrate: bark
Site(s): Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32588

Phaeophyscia endococcinodes (Poelt) Essl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32526

Phaeophyscia hirtella Essl.
Growth form: foliose
Substrate: rock (rhyolite), bark
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Black Canyon, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31238, 32185, 32208, 32221, 32251b, 32482, 32613

Phaeophyscia hispidula (Ach.) Essl.
Growth form: foliose
Substrate: rock (rhyolite), bark, soil/moss over rock
Site(s): Black Canyon, Indian Creek Trail, and Turkey Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32278, 32292, 32295, 32348, 32358, 32366, 32379, 32486, 32500, 32522

Phaeophyscia orbicularis (Necker) Moberg
Growth form: foliose
Substrate: bark, moss over rock (rhyolite)
Site(s): Turkey Creek Trail, Rain Creek Trail, and Black Canyon
Relative abundance: common
Pollution sensitivity: sensitive to ozone and fluoride, intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32284, 32468, 32475, 32486, 32491, 32596

Physcia aipolia (Ehrh. *ex* Humb.) Fürnr.
Growth form: foliose
Substrate: bark
Site(s): Black Canyon Trail, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: intermediately sensitive to sulfur dioxide, sensitive to fluoride.
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32297, 32355

Physcia albinea (Ach.) Nyl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trial, Turkey Creek Trail, Rain Creek Trail, and Black Canyon
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32261, 32345, 32516, 32525

Physcia caesia (Hoffm.) Fürnr.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon, Indian Creek Trail, Turkey Creek Trial, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32259, 32351, 32506, 32570

Physcia callosa Nyl.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32549

Physcia dubia (Hoffm.) Lettau
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon, Bead Spring Trail, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: sensitive to intermediately sensitive to fluoride
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32267, 32364b, 32453

Physcia magnussonii Frey
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C32505

Physcia phaea (Tuck.) J.W. Thomson
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Rain Creek Trail, Turkey Creek Trail, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32325, 32505, 32550

Physcia sorediosa (Vainio) Lynge
Growth form: foliose
Substrate: bark
Site(s): Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32392

Physcia stellaris (L.) Nyl.
Growth form: foliose
Substrate: bark
Site(s): Railroad Canyon Trail, Black Canyon, Bead Spring Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31241, 31251a, 31256, 32250, 32289, 32291, 32399, 32478, 32582

Physciella chloantha (Ach.) Essl.
Growth: foliose
Substrate: bark
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C32480

Pleopsidium flavum (Bellardi) Körber
Growth form: crustose (with effigurate margin)
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32311

Pseudevernia intensa (Nyl.) Hale & Culb.
Growth form: foliose
Substrate: bark
Site(s): Bead Spring Trail, and Rain Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32421, 32431, 32621

Pseudoparmelia sphaerospora (Nyl.) Hale
Growth form: foliose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32435

Psora globifera (Arh.) A. Massal.
Growth form: squamulose
Substrate: soil over rock (rhyolite)
Site(s): Black Canyon, and Indian Creek Trial
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32280, 32330

Psora nipponica (Zahlbr.) Gotth. Schneider
Growth form: squamulose
Substrate: soil over rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32275

Psora tuckermanii R. Anderson *ex* Timdal
Growth form: squamulose
Substrate: soil over rock
Site(s): West Fork of the Gila River
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32214

Punctelia hypoleucites (Nyl.) Krog
Growth form: foliose
Substrate: rock, bark, lignum
Site(s): West Fork of the Gila River, Railroad Canyon Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31230, 32197, 32532, 32547, 32564, 32598, 32632, 32639, 32645

Punctelia semansiana (Culb. & C. Culb.) Krog
Growth form: foliose
Substrate: rock (rhyolite), bark
Site(s): West Fork of the Gila River, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31217, 32479, 32508, 32538, 32545, 32583

Punctelia subrudecta (Nyl.) Krog
Growth form: foliose
Substrate: rock (rhyolite), bark
Site(s): Black Canyon, Indian Creek Trail, and Bead Spring Trail
Relative abundance: common
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32218, 32283, 32324, 32417, 32438, 32439

Ramalina intermedia (Delise *ex* Nyl.) Nyl.
Growth form: fruticose
Substrate: rock (rhyolite)
Site(s): West Fork of Gila River, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32196, 32319

Rhizocarpon disporum (Nägeli *ex* Hepp) Müll. Arg.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River, Indian Creek Trail, Rain Creek Trail, and Bead Spring Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32216, 32339, 32457, 32563

Rhizoplaca chrysoleuca (Sm.) Zopf
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Black Canyon, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensitivity: sensitive to sulfur dioxide and NOx/Pan
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32252, 32312, 32341

Rimelia reticulata (Taylor) Hale & Fletcher
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail, Turkey Creek Trail, and Black Canyon
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32300, 32365, 32519

Rimeliella subtinctoria (Zahlbr.) Kurok.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C32515

Staurothele areolata (Ach.) Lettau
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River
Relative abundance: common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31293

Staurothele drummondii (Tuck.) Tuck
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Railroad Canyon Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31266

Sticta sylvatica (Hudson) Ach.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): West Fork of the Gila River
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31220

Tephromela atra (Hudson) Hafellner
Growth form: crustose
Substrate: lignum, rock (rhyolite), bark
Site(s): Railroad Canyon Trail, Indian Creek Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31248a, 32388, 32484, 32603, 32604, 32610

Thyrea confusa Henssen
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): West Fork of Gila River, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31291, 32344

Trapeliospsis granulosa (Hoffm.) Lumbsch
Growth form: crustose
Substrate: decomposing wood, bark
Site(s): Bead Spring Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32408, 32414, 32461

Tuckermannopsis coralligera (W.A. Weber) W.A. Weber
Growth form: foliose
Substrate: lignum, bark
Site(s): Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31225a, 31246, 31284, 32243, 32390, 32535, 32614, 32631

Tuckermannopsis fendleri (Nyl.) Hale
Growth form: foliose
Substrate: bark
Site(s): Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Bead Spring Trail, Rain Creek Trail, and West Fork of Gila River
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31225, 31233, 32180, 32190,32233, 32247,32294, 32368, 32371, 32377, 32430, 32620, 32622

Umbilicaria americana Poelt & T. Nash
Growth form: foliose (umbilicate)
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32315, 32322

Usnea amblyoclada (Müll. Arg.) Zahlbr.
Growth form: fruticose
Substrate: rock (rhyolite)
Site(s): West Fork of Gila River, Turkey Creek Trail, and Indian Creek Trail
Relative abundance: rare to common
Pollution sensititvity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31219, 32306, 32464, 32541, 32544b

Usnea cirrosa Mot.
Growth form: fruticose
Substrate: bark
Site(s): Black Canyon, Turkey Creek Trail, and Indian Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32229, 32544b

Usnea hirta (L.) F.H. Wigg.
Growth form: fruticose
Substrate: lignum, bark, Cactus, rock (rhyolite)
Site(s): West Fork of the Gila River, Railroad Canyon Trial, Black Canyon, Turkey Creek Trail, Rain Creek Trail, Indian Creek Trail, and Bead Spring Trail
Relative abundance: common to abundant
Pollution sensitivity: intermediately sensitive to sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31224, 31234, 31244, 31252, 32179, 31278, 31286, 31287,32217, 32232, 32245, 32352, 32367, 32370, 32374, 32382, 32419, 32429, 32490, 32498, 32544a, 32576, 32581, 32601, 32609, 32611, 32618, 32629, 32643

Verrucaria hydrela Ach.
Growth form: crustose
Substrate: rock (rhyolite) submerged in stream
Site(s): Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32562

Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai
Growth form: foliose
Substrate: bark
Site(s): Bead Spring Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32428

Xanthoparmelia coloradoënsis (Gyelnik) Hale
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Railroad Canyon, Rain Creek Trail, and Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31264, 32260, 32565

Xanthoparmelia cumberlandia (Gyelnik) Hale
Growth form: foliose
Substrate: rock (rhyolite), bark
Site(s): West Fork of the Gila River, Indian Creek Trail, Bead Spring Trail, Rain Creek Trail, Black Canyon, Turkey Creek Trail, and Railroad Canyon Trail
Relative abundance: common to abundant
Pollution sensitivity: sensitive to sulfur dioxide
Comments: bark is an unusual substrate for this species.
Deposition of specimens: BYU Herbarium: BRY C 31218, 31264, 31267, 31279, 32207, 32213, 32279, 32303, 32335, 32364a, 32404, 32440, 32443, 32509, 32512, 32551

Xanthoparmelia lineola (E.C. Berry) Hale
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32265

Xanthoparmelia plittii (Gyelnik) Hale
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32548, 32642

Xanthoparmelia subdecipiens (Vainio) Hale
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail, and Black Canyon
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32264, 32337

Xanthoparmelia wyomingica (Gyelnik) Hale
Growth form: foliose
Substrate: semi-attached to small rocks on soil
Site(s): Indian Creek Trail
Relative abundance: abundant
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 32361

Xanthoria candelaria (L.) Th. Fr.
Growth form: foliose
Substrate: rock (rhyolite)
Site(s): Black Canyon
Relative abundance: rare
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32262

Xanthoria fallax (Hepp) Arnold
Growth form: foliose
Substrate: bark, rock, Cactus (spines)
Site(s): Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: intermediately sensitive to sensitive to sulfur dioxide, sensitive to NO_X/PAN
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31257, 32249, 32251b, 32290, 32293, 32301, 32353b,32376, 32487, 32489, 32636

Xanthoria polycarpa (Hoffm.) Rieber
Growth form: foliose
Substrate: bark
Site(s): Railroad Canyon Trail, Black Canyon, Indian Creek Trail, Bead Spring Trail, and Turkey Creek Trail
Relative abundance: common
Pollution sensitivity: intermediately sensitive to sensitive to sulfur dioxide
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31288, 32251a, 32298, 32353a, 32398

OBSERVATIONS AND CONCLUSIONS:

1. Lichen species collected at selected reference sites in the Gila Widerness Area of the Gila National Forest make up a diverse and well developed flora. From our collections at the 7 air quality biomonitoring reference sites we have identified a total of 142 species in 67 genera, with 52 new state records for New Mexico. All growth forms are represented; however the flora is clearly dominated by foliose species (53%, 76 species), followed by crustose species (36%, 51 species). Squamulose lichens make up 7% of the flora (10 species); while fruticose species comprise 4% of the flora with 5 species. This growth form distribution pattern departs from other more northerly Intermountain Area lichen floras which are characteristically dominated by crustose species (e.g. 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 flora in those wilderness areas). A similar study conducted at several sites along the Wasatch Front yielded an even higher percentage of crustose species (60%, 91 out of 155 total species). The abundance of crustose species along the Wasatch Front (a growth form generally thought to be more tolerant of air pollution) suggests that other more sensitive growth forms (especially fruticose and foliose species) may have over time been reduced in numbers due to declining air quality. The proximity of some of the Gila Wilderness Area reference sites to local and regional copper extracting and smelting activity suggests the need for careful monitoring of sensitive indicator species.

2. Lichen specimens were collected from 4 basic substrates: rocks, bark/lignum, moss/detritus, and soil. A total of 79 species (55% of the flora) were collected from rocks. Species on bark and lignum substrates were next in abundance, totaling 49 species (35% of the flora). Eight species (6% of the flora) were collected from the soil, while 6 species (4% of the flora) were collected from moss/detritus substrates. Intermountain Area lichen floras are typically dominated by saxicolous (rock) species. For example, 37% (67 species) of the lichen flora from the High Uintas Wilderness Area (northeastern Utah) are from rock substrates with only 23% (41 species) from corticolous (bark and lignum) substrates. The Bridger Wilderness Area, in western Wyoming, shows a similar pattern with 51% (76 species) reported from rock substrates and only 23% (35 species) from bark and lignum. One significant difference in the Gila Wilderness Area lichen flora, when compared with other Intermountain Area floras, is the unusually high number of large foliose species on rock substrates. Similar patterns have also been noted for southeastern Arizona (Chiricahua National Monument) and southwestern Colorado (the San Juan-Rio Grande National Forest). Likely, unusual substrate and growth form distribution patterns for this region is related to mild winters and summer monsoonal rains.

3. Total species diversity (142 species in 67 genera) suggests that the lichen communities in the Gila Wilderness Area have not been heavily impacted by air pollution. Furthermore, the high average number of sensitive indicator species per reference site (11.1 species) also suggests limited air pollution-related impact in the Gila Wilderness Area. This compares to 13.5 for the San Juan-Rio Grande National Forest, Colorado; 10.3 for the High Uintas Wilderness Area, Utah; 8.8 for the Bridger Wilderness Area, Wyoming; 6.3 for sites along the Wasatch Front, Utah; and 5.2 for Chiricahua National Monument, Arizona.

4. Necrotic and/or bleached thalli (typical signs of air pollution-related impact) were absent.

5. Baseline concentrations of potential pollutant elements were determined by analyzing the tissues of at least one sensitive indicator species from each reference site (Table 1). Thallus concentrations of several pollutants exceeded background levels (Figure 2). For example, two samples (from Rain Creek and the West Fork of the Gila River) showed elevated levels of sulfur (.28%)(Table 1). It is generally thought that thallus sulfur concentrations of .2% or higher indicate significant sulfur accumulation, and may interfere with sensitive metabolic activities such as photosynthesis, cellular respiration and nitrogen fixation. Most of the samples (17 out of 19) showed elevated concentrations of arsenic (1.8 ppm to 12 ppm). Nickel concentrations were elevated in 2 out of 19 samples (9.2 ppm and 10 ppm); and chromium values were moderately high in 11 out of 19 samples, ranging from 3.3 to 19 ppm. Lead was somewhat elevated (28 to 55 ppm) in four samples. Finally, copper to zinc ratios were significantly elevated in 5 out of 19 samples and moderately elevated in another 8 samples. Copper to zinc ratios in lichen tissues at clean air sites range between 1/3 and 1/10. The best copper to zinc ratio from the Gila samples was 1 to 2.9. A similar pattern for copper to zinc ratios has been detected at Chiricahua National Monument in southeastern Arizona where 17 out 21 samples showed significantly elevated ratios (ranging between 1:1 and 2:1). Specifically, this pattern of unusually high copper to zinc ratios in the Gila Wilderness Area is most likely related to regional air quality problems. Overall the pattern of element accumulation by sensitive indicator species in the Wilderness suggests that at least some of the reference sites in the Gila Wilderness Area are experiencing some air pollution-related impact.

TABLE 1: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in Gila Wilderness Area, New Mexico.

Species, Collection Site, Sample Number, and Substrate	Elements (ppm except where indicated)									
	P	S%	CL	K%	Ca%	Ti	Ba	V	Cr	Mn
Usnea hirta, Turkey Creek, Sample #498 (bark)	1500	0.0630	190	0.3300	0.3200	54	ND	ND	ND	70
Xanthoparmelia cumberlandia, Turkey Creek, Sample #503 (rock)	1750	0.1200	300	0.4000	1.5200	500	60	13	12	200
Usnea hirta, Indian Creek, Sample #499 (bark)	840	0.0830	250	0.2600	0.2300	38	34	ND	ND	36
Rhizoplaca chrysoleuca, Indian Creek, Sample #500 (rock)	1490	0.0840	47	0.2600	0.3300	240	ND	ND	4.1	34
Usnea hirta, Indian Creek, Sample #502 (bark)	760	0.0780	180	0.2400	1.1000	122	ND	ND	3.3	37
Usnea hirta, Indian Creek, Sample #520 (rock)	1210	0.0910	81	0.2800	0.1410	118	63	ND	ND	55
Xanthoparmelia cumberlandia, Indian Creek, Sample #521 (rock)	1020	0.0770	164	0.3700	1.8100	1190	108	25	5.0	119
✓ *Usnea hirta*, Black Canyon, Sample #501 (bark)	1050	0.1140	150	0.2900	0.3700	74	47.6	ND	ND	54
✓ *Rhizoplaca chrysoleuca*, Black Canyon, Sample #518 (rock)	1360	0.1100	210	0.3300	1.4700	540	120	15	ND	57
✓ *Xanthoparmelia cumberlandia*, Black Canyon, Sample #519 (rock)	1670	0.1560	770	1.3300	2.0000	31	55	ND	4.0	105

TABLE 1 cont.: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in Gila Wilderness Area, New Mexico.

Species, Collection Site, Sample Number, and Substrate	Elements (ppm except where indicated)										
	Fe	Co	Ni	Cu	Zn	Pb	As	Se	Br	Rb	Sr
Usnea hirta, Turkey Creek, Sample #498 (bark)	380	3	0.9	13	34	8.1	2.6	ND	8.5	4.3	24
Xanthoparmelia cumberlandia, Turkey Creek, Sample #503 (rock)	4100	13	7.2	174	66	30	4.5	ND	21	24.7	52
Usnea hirta, Indian Creek, Sample #499 (bark)	400	ND	2.1	16	37	6	3	ND	6.3	3.7	19
Rhizoplaca chrysoleuca, Indian Creek, Sample #500 (rock)	1600	ND	2	24	64	17	3	ND	4	10	17.4
Usnea hirta, Indian Creek, Sample #502 (bark)	880	ND	1.5	20	21	10	3	ND	12	3.8	47
Usnea hirta, Indian Creek, Sample #520 (rock)	1100	ND	2.3	19.1	24	7.9	3.4	ND	5.8	7.6	23
Xanthoparmelia cumberlandia, Indian Creek, Sample #521 (rock)	8300	ND	9.2	53	63	28	3.6	ND	17	15	77.7
Usnea hirta, Black Canyon, Sample #501 (bark)	600	4.7	2.6	20	26	8	3	ND	8	7	30
Rhizoplaca chrysoleuca, Black Canyon, Sample #518 (rock)	3800	ND	5.4	18	27	5.3	1.9	ND	7	10	71
Xanthoparmelia cumberlandia, Black Canyon, Sample #519 (rock)	330	ND	2.7	13	32	55	11	ND	13	16	46

TABLE 1: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in Gila Wilderness Area, New Mexico.

Species, Collection Site, Sample Number, and Substrate	Elements (ppm except where indicated)									
	P	S%	CL	K%	Ca%	Ti	Ba	V	Cr	Mn
Xanthoparmelia cumberlandia, Rain Creek, Sample #504 (rock)	1500	0.1051	250	0.4200	1.9000	570	68	ND	3.8	189
Usnea hirta, Rain Creek, Sample #512 (bark)	7300	0.2800	1260	0.9800	6.3800	220	220	ND	ND	240
Usnea hirta, Bead Spring, Sample #507 (bark)	1300	0.0700	134	0.3000	0.4900	44	30	ND	ND	53
Xanthoparmelia cumberlandia, Bead Spring, Sample #522 (rock)	2200	0.0930	420	0.3800	1.2200	440	89	ND	9.6	85
Xanthoparmelia cumberlandia, West fork of Gila River, Sample #513 (rock)	4300	0.2800	1080	0.9400	6.3000	950	240	ND	19	370
Usnea hirta, West Fork of Gila River, Sample #514 (rock)	1850	0.0530	144	0.1400	0.5300	165	ND	ND	5.0	60
Usnea hirta, West Fork of Gila River, Sample #517 (bark)	830	0.0970	270	0.1600	1.1500	50	45	ND	ND	114
Xanthoparmelia cumberlandia, Railroad Canyon, Sample #515 (rock)	860	0.0650	200	0.5600	3.4000	1150	163	26	15.4	159
Usnea hirta, Railroad Canyon, Sample #516 (bark)	770	0.0920	200	0.1980	0.9000	63	123.0	ND	6.1	41

TABLE 1 cont.: Mean concentrations of potential pollutant elements in sensitive indicator species from air quality biomonitoring reference sites in Gila Wilderness Area, New Mexico.

Species, Collection Site, Sample Number, and Substrate	Elements (ppm except where indicated)										
	Fe	Co	Ni	Cu	Zn	Pb	As	Se	Br	Rb	Sr
Xanthoparmelia cumberlandia, Rain Creek, Sample #504 (rock)	4000	16.9	2.9	98	49	13.7	5.5	2.3	16.9	14	72
Usnea hirta, Rain Creek, Sample #512 (bark)	2330	ND	6.0	72	210	16	12	ND	38	7.7	94
Usnea hirta, Bead Spring, Sample #507 (bark)	280	ND	1.16	16	39	9	2.22	ND	7.5	3.6	32.3
Xanthoparmelia cumberlandia, Bead Spring, Sample #522 (rock)	3300	ND	5.9	83	84	23	ND	ND	25	33	50
Xanthoparmelia cumberlandia, West fork of Gila River, Sample #513 (rock)	7400	ND	10	160	133	45	6.3	ND	32	52	160
Usnea hirta, West Fork of Gila River, Sample #514 (rock)	1170	ND	2.4	17	22	11	ND	1.53	6.7	6	26
Usnea hirta, West Fork of Gila River, Sample #517 (bark)	520	4.1	1.70	11	18	ND	1.8	ND	5.1	7.6	28
Xanthoparmelia cumberlandia, Railroad Canyon, Sample #515 (rock)	8800	ND	7.5	46	59	17.8	6	ND	12.9	45	250
Usnea hirta, Railroad Canyon, Sample #516 (bark)	1050	6.3	3.2	17	23	14.2	3.1	ND	5	6.4	9

Fig. 2 Lichen Biomonitoring Program and Baseline

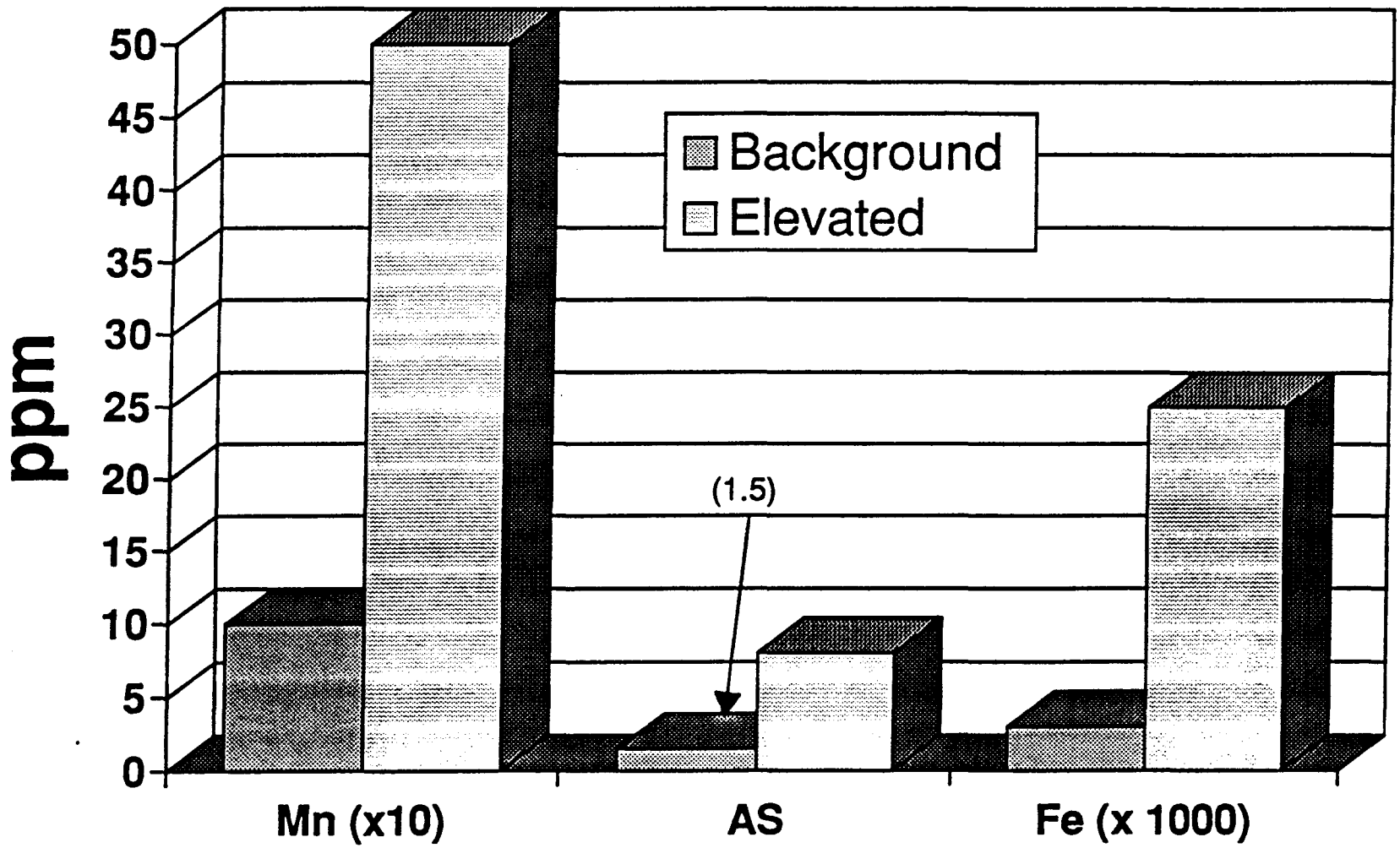


Fig. 2 cont. Lichen Biomonitoring Program and Baseline

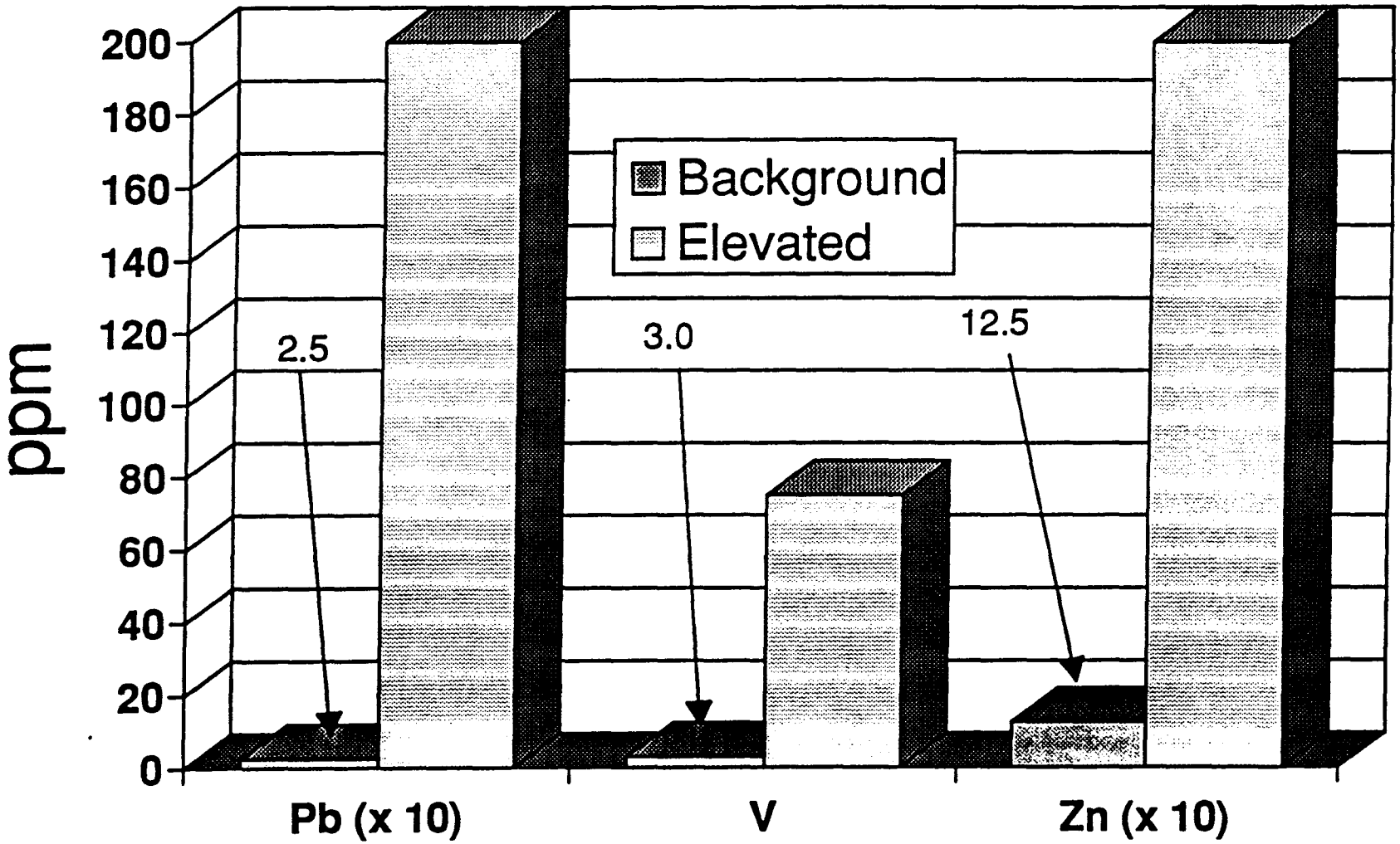
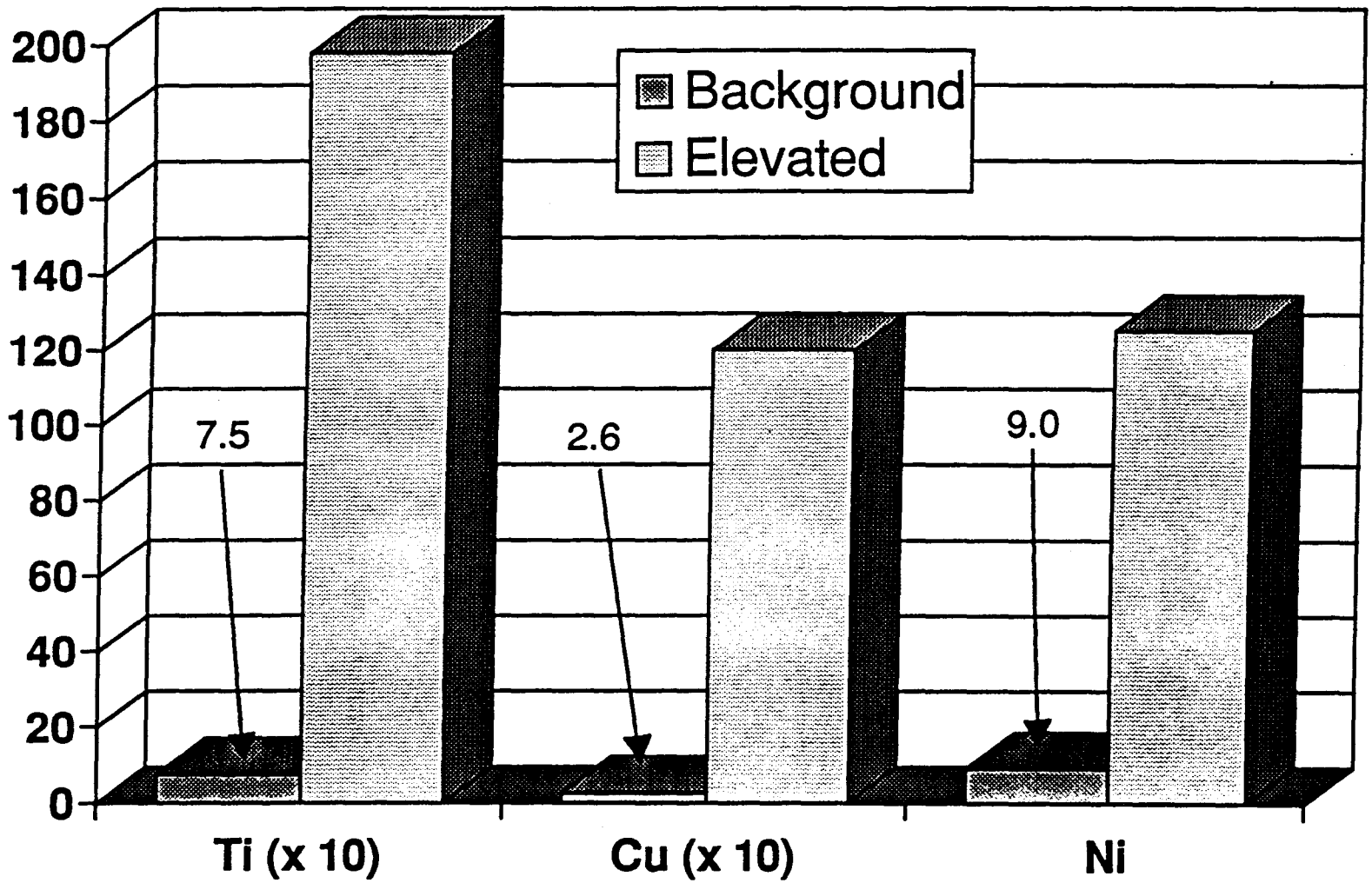


Fig. 2 cont. Lichen Biomonitoring Program and Baseline



Elemental Analysis Data
(background and elevated pollutant levels)

6. Ambient air samples, based on data from the direct air sampling program in the Wilderness, also show some areas of potential concern (Table 2). Concentrations of several heavy metals appear to be somewhat elevated. Specifically, ambient air concentrations of arsenic, lead and copper are moderately high especially during the spring (lead = 285-475 ppm; arsenic = 241-431 ppm; and copper = 381-738 ppm). These values are generally lower than concentrations reported for Chiricahua National Monument (southeastern Arizona), but higher than values reported for Mesa Verde National Park (southwest Colorado). Overall, data from the ambient air sampling program is accurately reflected in the elemental analysis data from the lichen samples.

RECOMMENDATIONS:

1. Usually, review of pollutant concentrations in sensitive indicator species should be performed every 5 to 8 years. However, because thallus concentrations of several critical pollutants exceed background levels, sensitive indicator species from at least some of the reference sites should probably be reevaluated on a three to five year schedule.

2. Reevaluation of the lichen flora at existing reference sites is generally unnecessary, unless over time sensitive indicator species begin to show either increasing levels of pollutant elements or significant changes in relative abundance. At this point reevaluation of the lichen communities at the reference sites in the Gila Wilderness Area does not appear to be necessary.

3. Over time additional reference sites could be established in other parts of the Wilderness. These should be set up to reflect the range of habitat types across the Wilderness, as well as general proximity to potential air pollution sources.

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Table 2. Mean concentrations for 7 elements in ambient air samples from Gila Wilderness Area, Chiricahua National Monument and Mesa Verde National Park over a 4 year period (1993-1996). Spring values were selected to correspond with the time when elemental analysis samples were collected in Gila Wilderness Area.

Element (ppm)	1993	1994	1995	1996
Gila Wilderness Area				
Nickel	no data	15.71	22.31	33.85
Arsenic	no data	328.57	430.77	241.15
Lead	no data	285	396.54	474.61
Sulfur	no data	66425	73398.46	59220
Titanium	no data	1481.43	1638.46	2242.69
Copper	no data	381.42	509.61	737.69
Zinc	no data	1192.14	878.46	647.67
Chiricahua National Monument				
Nickel	22.31	30.4	37.92	37.31
Arsenic	784.85	954.4	985.83	308.38
Lead	363.85	631.2	493.33	353.85
Sulfur	83256.92	80550.8	71674.17	59716.92
Titanium	1382.69	1546.4	1774.58	2280.39
Copper	761.92	944	814.58	476.92
Zinc	690	3447.2	1240	696.15
Mesa Verde National Park				
Nickel	22.73	18.4	29.23	195.77
Arsenic	70.91	99.58	112.69	47.31
Lead	203.64	161.67	304.61	212.31
Sulfur	93392.27	77829.58	88763.85	48606.92
Titanium	1370.91	1828.4	2177.69	2739.23
Copper	80.77	106.8	111.15	93.08
Zinc	198.85	246.4	372.31	662.31

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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 an 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 prepared and analyzed using the same procedures.

RESULTS, OBSERVATIONS AND RECOMMENDATIONS

LICHEN MATERIAL COLLECTED FOR ELEMENTAL ANALYSES:

A total of 19 samples including 3 species from 2 basic substrates (rock and bark) were collected for elemental analysis. Analysis of at least one species from each reference site has been 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 in the Herbarium of Nonvascular Cryptogams at Brigham Young University. Reference site numbers correspond to the numbers listed in the site description section of this report.

Sample #	Taxa	Substrate	Reference Site
48-498	Usnea hirta	bark	6
48-499	Usnea hirta	bark	4
48-500	Rhizoplaca chrysoleuca	rock	4
48-501	Usnea hirta	bark	3
48-502	Usnea hirta	bark	4
48-503	Xanthoparmelia cumberlandia	rock	6
48-504	Xanthoparmelia cumberlandia	rock	7
48-507	Usnea hirta	bark	5
49-512	Usnea hirta	bark	7
49-513	Xanthoparmelia cumberlandia	rock	1
49-514	Usnea hirta	rock	1
49-515	Xanthoparmelia cumberlandia	rock	2
49-516	Usnea hirta	bark	2
49-517	Usnea hirta	bark	1
49-518	Rhizoplaca chrysoleuca	rock	3
49-519	Xanthoparmelia cumberlandia	rock	3
49-520	Usnea hirta	rock	4
49-521	Xanthoparmelia cumberlandia	rock	4
49-522	Xanthoparmelia cumberlandia	rock	5

LIST OF POLLUTION SENSITIVE INDICATOR SPECIES BY REFERENCE SITE:

BEAD SPRING TRAIL

Amandinea punctata	intermediately sensitive to sulfur dioxide
Candelariella vitellina	intermediately sensitive to sulfur dioxide, sensitive to fluoride
Cladonia coniocraea	intermediately sensitive to sulfur dioxide
Imshaugia aleurites	intermediately sensitive to sulfur dioxide
Lecanora muralis	sensitive to heavy metals
Melanelia subolivacea	intermediately sensitive to ozone

BEAD SPRING TRAIL cont.

Parmelia sulcata	intermediately sensitive to ozone, intermediately sensitive to sulfur dioxide, sensitive to fluoride
Parmeliopsis ambigua	intermediately sensitive to sulfur dioxide
Peltigera canina	sensitive to ozone and heavy metals
Physcia dubia	sensitive to intermediately sensitive to fluoride
Physcia stellaris	intermediately sensitive to sulfur dioxide
Punctelia subrudecta	intermediately sensitive to sulfur dioxide
Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide
Xanthoria polycarpa	intermediately sensitive to sensitive to sulfur dioxide

BLACK CANYON

Amandinea punctata	intermediately sensitive to sulfur dioxide
Candelaria concolor	intermediately sensitive to sensitive to sulfur dioxide
Lecanora muralis	sensitive to heavy metals
Peltigera collina	sensitive to ozone
Phaeophyscia orbicularis	sensitive to ozone and fluoride, intermediately sensitive to sulfur dioxide
Physcia aipolia	intermediately sensitive to sulfur dioxide, sensitive to fluoride
Physcia caesia	intermediately sensitive to sulfur dioxide
Physcia dubia	sensitive to intermediately sensitive to fluoride
Physcia stellaris	intermediately sensitive to sulfur dioxide
Punctelia subrudecta	intermediately sensitive to sulfur dioxide
Rhizoplaca chrysoleuca	sensitive to sulfur dioxide and NO_X/PAN
Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide
Xanthoria fallax	intermediately sensitive to sulfur dioxide; sensitive to NO_X/PAN
Xanthoria polycarpa	intermediately sensitive to sensitive to sulfur dioxide

INDIAN CREEK TRAIL

Caloplaca cerina	intermediately sensitive to sensitive to sulfur dioxide
Caloplaca holocarpa	intermediately sensitive to sulfur dioxide
Candelariella vitellina	intermediately sensitive to sulfur dioxide, sensitive to fluoride
Flavoparmelia caperata	intermediately sensitive to sulfur dioxide
Lecanora muralis	sensitive to heavy metals
Melanelia subolivacea	intermediately sensitive to ozone
Parmelia sulcata	intermediately sensitive to sensitive to ozone, intermediately sensitive to sulfur dioxide, sensitive to fluoride
Physcia aipolia	intermediately sensitive to sulfur dioxide, sensitive to fluoride
Physcia caesia	intermediately sensitive to sulfur dioxide
Physcia dubia	sensitive to intermediately sensitive to fluoride
Punctelia subrudecta	intermediately sensitive to sulfur dioxide
Rhizoplaca chrysoleuca	sensitive to sulfur dioxide and NO_X/PAN
Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide
Xanthoria fallax	intermediately sensitive to sulfur dioxide; sensitive to NO_X/PAN
Xanthoria polycarpa	intermediately sensitive to sensitive to sulfur dioxide

RAILROAD CANYON

Physcia stellaris	intermediately sensitive to sulfur dioxide
Lecanora muralis	sensitive to heavy metals
Lecanora saligna	intermediately sensitive to sulfur dioxide

RAILROAD CANYON cont.

Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide
Xanthoria fallax	intermediately sensitive to sulfur dioxide; sensitive to NO_X/PAN
Xanthoria polycarpa	intermediately sensitive to sensitive to sulfur dioxide

RAIN CREEK TRAIL

Amandinea punctata	intermediately sensitive to sulfur dioxide
Caloplaca holocarpa	intermediately sensitive to sulfur dioxide
Lecanora muralis	sensitive to heavy metals
Melanelia subolivacea	intermediately sensitive to ozone
Phaeophyscia orbicularis	sensitive to ozone and fluoride; intermediately sensitive to sulfur dioxide
Physcia caesia	intermediately sensitive to sulfur dioxide
Physcia stellaris	intermediately sensitive to sulfur dioxide
Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide
Xanthoria fallax	intermediately sensitive to sulfur dioxide; sensitive to NO_X/PAN

TURKEY CREEK TRAIL

Caloplaca holocarpa	intermediately sensitive to sulfur dioxide
Candelaria concolor	intermediately sensitive to sensitive to sulfur dioxide
Cladonia coniocraea	intermediately sensitive to sulfur dioxide
Flavoparmelia caperata	intermediately sensitive to sulfur dioxide
Melanelia subolivacea	intermediately sensitive to ozone
Phaeophyscia orbicularis	sensitive to ozone and fluoride; intermediately sensitive to sulfur dioxide
Physcia caesia	intermediately sensitive to sulfur dioxide
Physcia stellaris	intermediately sensitive to sulfur dioxide
Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide
Xanthoria fallax	intermediately sensitive to sulfur dioxide; sensitive to NO_X/PAN

WEST FORK OF THE GILA RIVER

Amandinea punctata	intermediately sensitive to sulfur dioxide
Lecanora muralis	sensitive to heavy metals
Usnea hirta	intermediately sensitive to sensitive to sulfur dioxide
Xanthoparmelia cumberlandia	sensitive to sulfur dioxide

CHECKLIST OF LICHEN SPECIES FROM SELECTED SITES IN THE GILA WILDERNESS AREA, GILA NATIONAL FOREST, NEW MEXICO

Information for each species includes: Growth form, substrate(s), collection sites, relative abundance, pollution sensitivity (if known), and location of herbarium specimens. The scale of relative abundance is rare<common<abundant. Assignment of relative abundance categories is based on the following criteria: rare = 1-2 encounters, common = 3-9 encounters, and abundant ≥ 10 encounters.

Acarospora fuscata (Schrader) Arnold
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Railroad Canyon Trail, and Rain Creek Trail
Relative abundance: common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31281, 32574

Acarospora glaucocarpa (Ach.) Körber
Growth form: squamulose
Substrate: rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32411

Acarospora schleicheri (Ach.). A. Massal.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): West Fork of Gila River, Indian Creek Trail, and Rain Creek Trail
Relative abundance: common to abundant
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32202, 32215, 32323, 32573

Acarospora strigata (Nyl.) Jatta
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Railroad Canyon Trail
Relative abundance: rare
Pollution sensititvity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 31268

Amandinea punctata (Hoffm.) Coppins & Scheid.
Growth form: crustose
Substrate: bark
Site(s): West Fork of Gila River, Black Canyon, Bead Spring Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: intermediately sensitive to sulfur dioxide
Comments: none
Depostition of specimens: BYU Herbarium: BRY C 32181, 32234, 32401, 32422, 32579, 32585

Aspicilia cinerea (L.) Körber
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Indian Creek Trail, Bead Spring Trail, Turkey Creek Trail, and Rain Creek Trail
Relative abundance: rare to common
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32362, 32403, 32444, 32445, 32527, 32539, 32568

Biatora vernalis (L.) Fr.
Growth form: crustose
Substrate: lignum
Site(s): Black Canyon, and Rain Creek Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32239, 32600

Buellia erubescens Arnold
Growth form: crustose
Substrate: bark, lignum
Site(s): Railroad Canyon Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: This species is a new state record for New Mexico.
Deposition of specimens: BYU Herbarium: BRY C 31235, 31249

Buellia retrovertens Tuck.
Growth form: crustose
Substrate: rock (rhyolite)
Site(s): Bead Spring Trail
Relative abundance: rare
Pollution sensitivity: unknown
Comments: none
Deposition of specimens: BYU Herbarium: BRY C 32454