

**REPORT
SUBMITTED**

**TO
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USDA FOREST SERVICE – SOUTHWEST REGION
ALBUQUERQUE, NEW MEXICO**

REGARDING

**FIELD REVIEW OF THE LICHEN AIR QUALITY BIO-MONITORING PROGRAM
AND BASELINE AT SELECTED SITES IN THE GILA WILDERNESS AREA, GILA
NATIONAL FOREST, NEW MEXICO**

BASED ON COLLECTIONS MADE DURING THE 2013 FIELD SEASON

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Introduction: In order to more effectively monitor potential air pollution-related issues in the Gila Wilderness Area, Gila National Forest – a lichen air quality bio-monitoring program and baseline was established during the spring of 1996. A review of 4 of the 7 original lichen air quality bio-monitoring reference sites was conducted in the summer of 2013. Using lichens as bio-monitors of air quality effectively complements other air quality monitoring technologies including visibility monitoring and direct air sampling. Monitoring of sensitive indicator species (in this case lichens) provides an early indication of impending air pollution-related damage to other less sensitive but essential community components. Initial establishment of the program constitutes a baseline against which all subsequent reviews are compared. Therefore, in order to maintain the integrity of the bio-monitoring program periodic review of each reference site is essential.

Project Goals: This project involved a field review of 4 of the 7 original baseline sites in addition to resampling and elemental analysis of the same sensitive indicator species collected during the baseline study in 1996. The number and location of the original reference sites was pre-determined in consultation with USDA Forest Service personnel. **Note:** Unfortunately, 2 of the original 1996 reference sites were subsequently destroyed by fire. However, during the 2014 field season USDA Forest Service personnel collected the same sensitive indicator species for elemental analysis from adjacent intact sites. The protocol for establishing each of the 7 original reference sites included the following:

1. Document lichen species diversity at each reference site – by collecting voucher specimens for deposition in the Herbarium of Nonvascular Cryptogams at the M.L. Bean Life Science Museum on the campus of Brigham Young University, Provo, Utah. **Note:** A few additional voucher specimens were collected during the 2013 field season (see this report for details).
2. Compile from the overall species lists for each reference site a sub-list of documented air pollution sensitive indicator species, including information about the specific air pollutant sensitivities of each species. **Note:** An important part of the site review process involves a careful review of the air pollution sensitive indicator species at each reference site.
3. Collection of at least one (where possible 2) sensitive indicator species from each reference site and analysis of three sub-samples from each collection to determine concentrations of 25 potential air pollutant elements using ICP technology. In addition, percent Nitrogen was also determined for three replicate samples using a Nitrogen analyzer following the Dumas method. Residual elemental analysis material is deposited in the archival elemental analysis collection housed in the Herbarium of Nonvascular Cryptogams in the M.L. Bean Life Science Museum at Brigham Young University. **Note:** Residual elemental analysis material from the 2013 collections has also been deposited in the BYU archival elemental analysis collection in the Herbarium of Nonvascular Cryptogams.
4. Examine the sensitive indicator species at each reference site for patterns of upper surface discoloration, bleaching, erosion, and/or necrosis (potential visual indications of air pollution-related damage). **Note:** Part of the 2013 reference site review process involved examination of the upper surfaces of sensitive indicator species for visual signs of air-pollution-related damage.
5. Analyze general growth form and substrate patterns for the lichen flora at each reference site. **Note:** Part of the 2013 reference site review process also included a re-evaluation of the substrate and growth form distribution patterns at each reference site.

**GILA WILDERNESS AREA
LICHEN BIO-MONITORING PROGRAM
(2013 FIELD REVIEW)**

RESULTS

REFERENCE SITES – Gila Wilderness Area: During the 2013 summer field season, 4 of the original 7 lichen air quality bio-monitoring reference sites (established in 1996) were visited and reevaluated. In 2013 a limited number of voucher specimens were also collected and have now been identified – as documented in this report. In addition, elemental analysis samples of 2-3 documented air pollution sensitive indicator species were re-collected at each reference site.

Note: In each case the same sensitive indicator species collected for elemental analysis in 1996 were re-collected during the 2013 field season. All 2013 samples have been analyzed for 25 potential pollutant elements, including percent Nitrogen (Table 1). Specifically, the following reference sites were revisited in the summer of 2013:

Site No. 1: 17 July 2013 (originally collected 2 May 1996). New Mexico, Grant County, Gila National Forest, Gila Wilderness Area, along USFS Trail No. 94 (Black Canyon Trail) **GPS reading:** 33° 10.779' north latitude, 108° 02.791' west longitude; elevation 2048 m. **Elemental analysis samples** collected: *Usnea hirta* from Gray oak bark (106-1440) and *Xanthoparmelia* sp. from local rock substrates (106-1441). **Collectors:** Larry L. St. Clair and Steven D. Leavitt. **Voucher Collections –** Herbarium numbers: BRYC-56161-56163 and Collection numbers: St. Clair-20461-20463. **Original Collection Information:** Field Book No. 2 page 49. **Note:** 17 July 2013 an exsiccata collection of *Pseudevernia intensa* from dead *Pinus ponderosa* branches was collected along USFS Road No. 150. New Mexico, Grant County, Gila National Forest at 33° 07.814' north latitude, 108° 00.410' west longitude, elevation 2347 m. Herbarium number: BRYC-56165 and Collection number: St. Clair-20465.

Site No. 2: 17 July 2013 (originally collected 1 May 1996). New Mexico, Grant County, Gila National Forest, Gila Wilderness Area, along USFS Trail No. 96 (Railroad Canyon) **GPS reading:** 33° 02.091' north latitude, 108° 07.557' west longitude; elevation 1890 m. **Elemental analysis samples** collected: *Xanthoparmelia* sp. from local rock substrates (106-1439) and *Usnea hirta* from Gray oak bark (106-1438). **Collectors:** Larry L. St. Clair and Steven D. Leavitt. **Voucher Collection –** Herbarium number: BRYC-56164 and Collection number: St. Clair-20464. **Original Collection Information:** Field Book No. 2 page 48

Site No. 3: 18 July 2013 (originally collected 30 April and 1 May 1996). New Mexico, Catron County, Gila National Forest, Gila Wilderness Area, along USFS Trail No. 151 (along West Fork of Gila River). **GPS reading:** 33° 14.409' north latitude, 108° 17.265' west longitude; elevation 1768 m. **Elemental analysis samples** collected: *Xanthoparmelia* sp. from local rock substrates (106-1444), *Usnea* sp. from local rock substrates (106-1443), and *Usnea* sp. from Gambel oak bark (106-1442). **Collectors:** Larry L. St. Clair and Steven D. Leavitt. **Voucher Collections –** Herbarium

numbers: BRYC-56166- 56171 and Collection numbers: St. Clair-20466-20471.

Original Collection Information: Field Book No. 2 page 47

Site No. 4: 18 July 2013. New Mexico, Grant County, Gila National Forest, Gila Wilderness Area, along USFS Trail No.189 (Rain Creek Trail – at creek). **GPS Reading:** 33° 11.487' north latitude, 108° 40.092' west longitude; elevation 1768 m. **Elemental analysis samples** collected: *Xanthoparmelia* sp. from local rock substrates (106-1446) and *Usnea* sp. from Pinyon pine bark (106-1445). **Collectors:** Larry L. St. Clair and Steven D. Leavitt. **Voucher Collections** – Herbarium numbers: BRYC-56172- 56179 and Collection numbers: St. Clair-20472-20479. **Original Collection Information:** Field Book No. 2 page 53

**GILA WILDERNESS AREA, GILA NATIONAL FOREST
AIR QUALITY BIO-MONITORING REFERENCE SITES (Review visits)**

**ALONG USFS TRAIL NO. 94 (BLACK CANYON TRAIL)
REFERENCE SITE NO. 1
17 JULY 2013**

ADDITIONAL VOUCHER COLLECTIONS – 2013 FIELD SEASON

Identified by Larry St. Clair

Taxa	Substrate	Growth Form	BRYC- No.	Collection No.
^x <i>Peltigera canina</i>	Moss over soil	Fo	56162	St. Clair-20462
^x <i>Phaeophyscia ciliata</i>	Moss over rock	Fo	56163	St. Clair-20463
^x <i>Usnea intermedia</i>	Bark	Fr	56161	St. Clair-20461

^xNew species reports for this site (not collected in 1996)

ELEMENTAL ANALYSIS COLLECTIONS

Taxa	Substrate	EA Collection Number
<i>Usnea hirta</i>	Bark	106-1440
<i>Xanthoparmelia</i> sp.	Rock	106-1441

**ALONG USFS TRAIL NO. 96 (RAILROAD CANYON)
REFERENCE SITE NO. 2
17 JULY 2013**

ADDITIONAL VOUCHER COLLECTIONS – 2013 FIELD SEASON

Identified by Larry St. Clair

Taxa	Substrate	Growth Form	BRYC	Collection Number
^x <i>Caloplaca arizonica</i>	Bark	Cr	56164	St. Clair-20464

^xNew species report for this site (not collected in 1996)

ELEMENTAL ANALYSIS COLLECTIONS

Taxa	Substrate	EA Collection Number
<i>Usnea hirta</i>	Bark	106-1438
<i>Xanthoparmelia</i> sp.	Rock	106-1439

**ALONG USFS TRAIL NO. 151 (ALONG WEST FORK OF GILA RIVER)
REFERENCE SITE NO. 3
18 JULY 2013**

ADDITIONAL VOUCHER COLLECTIONS – 2013 FIELD SEASON

Identified by Larry St. Clair

Taxa	Substrate	Growth Form	BRYC	Collection Number
^x <i>Flavopunctelia soledica</i>	Bark	Fo	56166	St. Clair-20466
^x <i>Nephroma helveticum</i>	Rock	Fo	56167	St. Clair-20467
^x <i>Peltigera rufescens</i>	Soil	Fo	56171	St. Clair-20471
<i>Ramalina intermedia</i>	Rock	Fr	56169	St. Clair-20469
^x <i>Xanthoparmelia wyomingica</i>	Lichens over rock	Fo	56170	St. Clair-20470

^xNew species reports for this site (not collected in 1996)

ELEMENTAL ANALYSIS COLLECTIONS

Taxa	Substrate	EA Collection Number
<i>Usnea</i> sp.	Bark	106-1442
<i>Usnea</i> sp.	Rock	106-1443
<i>Xanthoparmelia</i> sp.	Rock	106-1444

**ALONG USFS TRAIL NO.189 (RAIN CREEK TRAIL)
REFERENCE SITE NO. 4
18 JULY 2013**

ADDITIONAL VOUCHER COLLECTIONS – 2013 FIELD SEASON

Identified by Larry St. Clair

Taxa	Substrate	Growth Form	BRYC	Collection Number
^x <i>Cladonia chlorophaea</i>	Bark	Sq	56179	St. Clair-20479
^x <i>Cladonia ecmocyna</i>	Bark	Sq	56178	St. Clair-20478
^x <i>Flavoplaca citrina</i>	Bark	Cr	56177	St. Clair-20477
^x <i>Heterodermia diademata</i>	Bark	Fo	56172	St. Clair-20472
<i>Pseudevernia intensa</i>	Bark	Fr	56175	St. Clair-20475
^x <i>Punctelia bolliana</i>	Rock	Fo	56173	St. Clair-20473
^x <i>Rhizoplaca chrysocoma</i>	Rock	Fo	56174	St. Clair-20474
<i>Tuckermanella coralligera</i>	Lignum	Fo	56176	St. Clair-20476

^xNew species reports for this site (not collected in 1996)

ELEMENTAL ANALYSIS COLLECTIONS

Taxa	Substrate	EA Collection Number
<i>Usnea</i> sp.	Bark	106-1445

SITE REVIEWS GILA WILDERNESS AREA, CARSON NATIONAL FOREST OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

1. Four of the original 7 lichen air quality bio-monitoring reference sites, established in the Gila Wilderness Area in 1996, were reviewed during the summer of 2013. Overall, each of the 4 sites reviewed still demonstrate significant species diversity with differences in species numbers between the reference sites is most likely due to local habitat variation. Likewise, the total number and abundance of air pollution sensitive indicator species at each site has not changed – indicating that the lichen communities at these four sites are still intact and generally free from air pollution-related damage. **Note:** Much of the area between the trailhead and the reference site along the West Fork of the Gila River (along USFS Trail No. 151 – Site No. 3) has been burned; however, the area immediately around the original 1996 reference site is still intact. The long term impact of the adjacent burned area on the intact lichen community at this reference site should be monitored over time.
2. Similarly, growth form and substrate distribution patterns at each of the 4 original reference sites reviewed during the summer of 2013 have not changed. Based on our field review, the lichen flora at each site is still rich with significant numbers of the more air pollution sensitive foliose and fruticose species. In addition, species diversity on both rock and bark substrates remains high. These observations also support the general conclusion that the lichen communities at each of the 4 sites reviewed during the summer of 2013 are still healthy and relatively free from air pollution-related impact. Any variation in substrate and growth form distribution patterns between the four reference sites is most likely due to basic habitat differences.
3. A careful field check of the sensitive indicator species at each reference site did not reveal any upper surface bleaching, discoloration, erosion, and/or necrosis (potential visual indications of air pollution-related damage).
4. **Elemental analysis data (Table 1)** – Based on the collection and analysis of sensitive indicator species from the four reference site reviewed – there appear to be some potential areas of concern. Specifically, at least one sensitive indicator species at each of the four sites reviewed in 2013 had elevated (>1.50%) Nitrogen levels with 7 out of the 9 samples analyzed showing at least somewhat elevated levels of Nitrogen ($\geq 1.0\%$). **Note:** The 1996 sensitive indicator species samples were not analyzed for percent Nitrogen – consequently, a baseline comparison is not available. In 1996, Manganese concentrations in 6 of 9 sensitive indicator samples (across all four reference sites) were elevated (>90 ppm); however, only four samples, from two sites (Black Canyon Trail and along the West Fork of the Gila River) had elevated concentrations of Mn in 2013. In 1996, Sulfur levels in 2 samples from two reference sites (along West Fork of the Gila River and Rain Creek Trail) were elevated ($\geq 0.20\%$); however, Sulfur concentrations in all of the 2013 samples were well within background levels. Elevated levels of Arsenic (≥ 2.4 ppm) and Nickel (≥ 6 ppm) are reported for both the 1996 and 2013 samples. In 1996 six samples, from 3 of 4 reference sites, showed elevated levels of Arsenic; however, only the two 2013 samples from the West Fork of the Gila River had elevated Arsenic. Nickel was also elevated in two of the 2013 elemental analysis samples (West Fork of the Gila River and Black Canyon). Overall,

comparison of the elemental analysis data from the 1996 and 2013 samples suggests that pollutant element loads have generally improved at the four review sites. However, concentrations of some pollutant elements (N, Mn, As, and Ni) continue to be elevated at some sites. Nitrogen concentrations are of particular concern and deserve further consideration. Likewise, the elevated levels of Ni and As at the West Fork of Gila River site may merit further examination.

5. In light of the elevated levels of several critical pollutant elements we recommend that the lichen air quality bio-monitoring program in the Gila Wilderness Area be reevaluated every 5 years. More frequently if point sources of pollution are developed in the general vicinity of this wilderness area. **Notes:** 1) In order to more effectively track long term percent Nitrogen patterns in the Gila Wilderness Area – archival samples from all 7 of the original (1996) reference sites, available in the BYU Herbarium of Nonvascular Cryptogams, should be analyzed for percent Nitrogen, 2) In light of the combined size and proximity of the Gila and Aldo Leopold wilderness areas, we recommend that additional lichen air quality reference sites be established, and 3) Consistent reviews of the air quality bio-monitoring program for the Gila Wilderness area is essential to maintaining the integrity of the program.

Table 1. Mean concentrations of potential pollutant elements in sensitive indicator species from air quality bio-monitoring reference sites in the Gila Wilderness Area, Gila National Forest. Element values are based on 1996 and 2013 field collections. Note: ~ = somewhat elevated and ↑ = elevated.

Species and Collection Site	Elements (ppm except where indicated)																							
	%N		%Ca		Cu		Fe		%K		%Mg		Mn		Na		%P		%S		Zn		As	
	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013
<i>Usnea</i> sp., Railroad Canyon. Sample #516 (bark), 1438	n.s.	1.51↑	0.9	1.04	17	14.15	1050	999	0.198	0.8	n.s.	0.13	41	84	n.s.	113.5	0.077	0.13	0.092	0.13	23	22.9	3.1↑	1.48↓
<i>Xanthoparmelia</i> sp., Railroad Canyon. Sample #515 (rock), 1439	n.s.	0.87	3.4	3.67	46↑	20.01↓	8800	3973	0.56	0.59	n.s.	0.2	159↑	74.8↓	n.s.	417.1	0.086	0.08	0.065	0.07	59	31.6	6↑	1.27↓
<i>Usnea</i> sp., along Black Canyon Trail. Sample #501 (bark), 1440	n.s.	1.55↑	0.37	1.24	20	9.18	600	574	0.29	0.95	n.s.	0.19	54	146↑	n.s.	84.2	0.105	0.18	0.114	0.1	26	17.9	3	1.53
<i>Xanthoparmelia</i> sp., along Black Canyon Trail. Sample #519 (rock), 1441	n.s.	~1.25	2	2.85	13	22.94	330	4239	1.33	0.94	n.s.	0.21	105↑	91.7↓	n.s.	132.2	0.167	0.18	0.156	0.1	32	117.9	11↑	0.07↓
<i>Usnea</i> sp., along USFS Trail No. 151. Sample #517 (bark), 1442 (bark)	n.s.	1.53↑	1.15	0.7	11	13.28	520	632	0.16	0.79	n.s.	0.16	114↑	128.4↑	n.s.	132.9	0.083	0.1	0.097	0.12	18	51.1	1.8	3.75↑
<i>Usnea</i> sp., along USFS Trail No. 151. Sample #514 (rock), 1443 (rock)	n.s.	0.87	0.53	0.49	17	12.38	1170	536	0.14	0.44	n.s.	0.08	60	71.5	n.s.	92.9	0.185	0.08	0.053	0.08	22	82.4	n.d.	4.18↑
<i>Xanthoparmelia</i> sp., along USFS Trail No. 151. Sample #513 (rock), 1444	n.s.	~1.19	6.3	2.5	160↑	23.47↓	7400	2056	0.94	0.74	n.s.	0.11	370↑	95.3↓	n.s.	122.5	0.43	0.14	0.28↑	0.1↓	133	57.2	6.3↑	1.18↓
<i>Usnea</i> sp., along Rain Creek Trail. Sample #512 (bark), 1445	n.s.	1.54↑	6.38	1.06	72↑	13.18↓	2330	417	0.98	0.8	n.s.	0.12	240↑	63.9↓	n.s.	77.2	0.73	0.12	0.28↑	0.12↓	210	28.6	12↑	0.1↓
<i>Xanthoparmelia</i> sp., along Rain Creek Trail. Sample #504 (rock), 1446	n.s.	~1.24	1.9	3.83	98↑	38.19↓	4000	1911	0.42	0.9	n.s.	0.09	189↑	70.7↓	n.s.	107.9	0.15	0.14	0.105	0.11	49	47.3	5.5↑	1.52↓

n.d. = element not detected, n.s. = element not sampled, n.a. = sample not available

Table 1 (cont.). Mean concentrations of potential pollutant elements in sensitive indicator species from air quality bio-monitoring reference sites in the Gila Wilderness Area, Gila National Forest. Element values are based on 1996 and 2013 field collections. Note: ~ = somewhat elevated and ↑ = elevated.

Species and Collection Site	Elements (ppm except where indicated)																									
	B		Ba		Cd		Co		Cr		Mo		Ni		Pb		Se		Si		Sr		Ti		V	
	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013	1996	2013
<i>Usnea</i> sp., Railroad Canyon. Sample #516 (bark), 1438	n.s.	8.29	123	12.43	n.s.	0.39	6.3	0.71	6.1	2.55	n.s.	n.d.	3.2	1.99	14.2	4.46	n.d.	n.d.	n.s.	43.2	9	25	63	55.89	n.d.	n.d.
<i>Xanthoparmelia</i> sp., Railroad Canyon. Sample #515 (rock), 1439	n.s.	8.33	163	45.86	n.s.	0.76	n.d.	1.6	15.4↑	3.61↓	n.s.	n.d.	7.5↑	1.72↓	17.8	5.17	n.d.	n.d.	n.s.	18.5	250	77.8	1150	220.9	26	n.d.
<i>Usnea</i> sp., along Black Canyon Trail. Sample #501 (bark), 1440	n.s.	15.98	47.6	29.26	n.s.	0.31	4.7	0.43	n.d.	1.81	n.s.	n.d.	2.6	1.69	8	3.13	n.d.	n.d.	n.s.	34.1	30	76.2	74	36.49	n.d.	n.d.
<i>Xanthoparmelia</i> sp., along Black Canyon Trail. Sample #519 (rock), 1441	n.s.	10.04	55	29.61	n.s.	0.95	n.d.	2.41	4	9.54↑	n.s.	n.d.	2.7	6.38↑	~55	4.35↓	n.d.	n.d.	n.s.	64.8	46	73.8	31	265.5	n.d.	n.d.
<i>Usnea</i> sp., along USFS Trail No. 151. Sample #517 (bark), 1442 (bark)	n.s.	19.31	45	22.65	n.s.	2.54	4.1	2.76	n.d.	4	n.s.	2.86	1.7	6.19↑	n.d.	6.07	n.d.	2.18	n.s.	57.6	28	43.6	50	38.58	n.d.	n.d.
<i>Usnea</i> sp., along USFS Trail No. 151. Sample #514 (rock), 1443 (rock)	n.s.	15.73	n.d.	11.74	n.s.	1.23	n.d.	1.27	5	2.51	n.s.	0.99	2.4	2.58	11	4.66	1.53	n.d.	n.s.	44.8	26	31.3	165	23.29	n.d.	n.d.
<i>Xanthoparmelia</i> sp., along USFS Trail No. 151. Sample #513 (rock), 1444	n.s.	3.53	240	24.09	n.s.	1.13	n.d.	1.07	19↑	1.93↓	n.s.	n.d.	10↑	2.22↓	~45	8.91↓	n.d.	n.d.	n.s.	65.8	160	55.8	950	95.46	n.d.	n.d.
<i>Usnea</i> sp., along Rain Creek Trail. Sample #512 (bark), 1445	n.s.	7.96	220	7.83	n.s.	0.61	n.d.	0.43	n.d.	1.11	n.s.	0.13	6	0.68	16	3	n.d.	0.91	n.s.	68.8	94	31.5	220	14.33	n.d.	n.d.
<i>Xanthoparmelia</i> sp., along Rain Creek Trail. Sample #504 (rock), 1446	n.s.	8.36	68	15.18	n.s.	0.85	16.9	0.79	3.8	1.98	n.s.	n.d.	2.9	0.33	13.7	14.78	2.3	n.d.	n.s.	113.2	72	63.4	570	84.33	n.d.	n.d.