WESTERN AIRBORNE CONTAMINANTS ASSESSMENT PROJECT FINAL REPORT: VOLUME II

The Fate, Transport, and Ecological Impacts of Airborne Contaminants in Western National Parks (USA)

Appendices

Burial Lake, Noatak National Preserve
Photo: Adam Schwindt

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EPA/600/R-07/138
January 2008

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This report is the final report for the Western Airborne Contaminants Assessment Project (WACAP), and is available online at http://www.nature.nps.gov/air/studies/air_toxics/wacap.cfm and http://www.epa.gov/nheerl/wacap

Proper citation of this document is:

Landers, D.H., S.L. Simonich, D.A. Jaffe, L.H. Geiser, D.H. Campbell, A.R. Schwindt, C.B. Schreck, M.L. Kent, W.D. Hafner, H.E. Taylor, K.J. Hageman, S. Usenko, L.K. Ackerman, J.E. Schrlau, N.L. Rose, T.F. Blett, and M.M. Erway. 2008. *The Fate, Transport, and Ecological Impacts of Airborne Contaminants in Western National Parks (USA)*. EPA/600/R-07/138. U.S. Environmental Protection Agency, Office of Research and Development, NHEERL, Western Ecology Division, Corvallis, Oregon.

APPENDIX 1A

Summary of Site Characteristics in Core and Secondary Parks

Table 1A-1. Summary of Physical Attributes of the Lake Catchments in Core Parks

Park	Site	Latitude (dd)	Longitude (dd)	Bathymetry Source	Elevation (m) (from NPS)	Lake Elevation (m) (from drg*)	Lake Surface Area (ha)	Lake Volume (m^3)	Lake Max Depth (m)	Mean Depth (volume/ surface area)	Shoreline length (km)	Shoreline Development*	Watershed Area (ha)	Watershed Elevation - lowest (m) (from drg*)	Watershed Elevation - highest (m) (from drg*)	Watershed Area/ Lake Volume (m^2/m^3)	Annual HRT* Based on ET* (y)	Fish Species
NOAT	Burial	68.43	159.18	vaga/j605	427	429.8	65.5	5297945.2	24.1	8.1	3.1	1.07	264.9	429.8	535.2	0.50	24.559	Lake Trout
GAAR	Matcharak	67.75	156.21	vaga/j605	488	502.3	300.7	21889008.3	20.4	7.3	10.7	1.74	2388.3	502.3	1162.2	1.09	7.643	Lake Trout
DENA	Wonder	63.48	150.88	scan	610	605.0	265.6	77653853.3	70	29.2	9.7	1.68	3212.4	605.0	876.3	0.41	6.836	Lake Trout
DENA	McLeod	63.38	151.07	vaga/j605	609	563.9	35.9	1847704.4	13.5	5.2	3.2	1.53	236.8	563.9	731.5	1.28	4.131	Burbot, Round Whitefish
GLAC	Snyder	48.62	113.79	landers/j700	1600	1597.2	2.6	38297.5	3.5	1.5	0.7	1.24	303.7	1597.2	2761.5	79.30	0.005	Westslope Cutthroat Trout
GLAC	Oldman	48.5	113.46	landers/j663	2026	2025.7	18.2	1266062.9	17	7.0	1.8	1.17	230.3	2025.7	2811.8	1.82	0.235	Westslope Cutthroat Trout
OLYM	PJ	47.95	123.42	landers/j663	1433	1383.8	0.8	19099.3	6.4	2.5	0.3	1.08	56.2	1383.8	1904.1	29.41	0.003	Brook Trout
OLYM	Hoh	47.9	123.79	vaga/j605	1384	1379.2	7.7	396198.1	14.9	5.2	1.1	1.09	43.9	1379.2	1684.0	1.11	0.107	Brook Trout
MORA	Golden	46.89	121.9	scan	1372	1368.6	6.6	689577.5	23.9	10.4	1.0	1.07	106.1	1368.6	1720.6	1.54	0.067	Brook Trout
MORA	LP19	46.82	121.89	scan	1372	1371.6	1.8	99878.6	12.1	5.4	0.5	1.11	44.9	1371.6	1652.0	4.49	0.024	Brook Trout
ROMO	Mills	40.29	105.64	landers/j597	3030	3029.7	6.1	78251.1	9	1.3	1.3	1.46	1208.9	3029.7	4344.9	154.49	0.009	Rainbow, Cutthroat Trout
ROMO	Lone Pine	40.22	105.73	vaga/j605	3024	3017.5	4.9	128324.6	9.7	2.6	0.8	1.07	1830.0	3017.5	3998.4	142.61	0.012	Brook Trout
SEKI	Pear	36.6	118.67	scan	2904	2907.8	7.3	578000	27	7.9	1.3	1.31	142.0	2907.8	3453.1	2.46	0.251	Brook Trout
SEKI	Emerald	36.58	118.67	scan	2800	2810.3	2.5	160000	10	6.3	0.6	1.12	121.3	2810.3	3439.4	7.58	0.087	Brook Trout

Notes:

*drg (digital raster graphic) lake boundaries used for calculations; except lake volume for Pear and Emerald from Sickman and Melack, 1989

*shoreline length/2*square root of (pi * surface area)

***HRT** = Hydraulic Residence Time of lake based on **ET** = Evapotranspiration in % of precipitation

Table 1A-2. Summary of Chemical Attributes of the Lake Catchments in Core Parks

Park	Site	WACAP No	Date Collected	pH Value	Specific Conductance (µS/cm)	ANC Value (µeq/L)	Turbidity (NTU)	Total Suspended Solids (mg/L)	Color (APHA Pt-Co Units)	DOC (mg/L)	DIC (mg/L)	NH_4-N (mg/L)	SiO_2 (mg/L)	Total N (mg/L)	Total P (µg/L)	Cl (mg/L)	NO_3 (mg N/L)	SO_4 (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Zn (mg/L)	Se (µg/L)	Chl-*a* (µg/L)
NOAT	Burial	46003	8/04/2004	7.57	35.08	272.98	0.32	1.4	10	3.32	3.27	0.01	0.28	0.23	9.06	0.18	0.00	1.46	4.50	1.15	0.36	0.40	0.03	-0.38	0.81
GAAR	Matcharak	46000	8/2/2004	8.31	248.10	1967.03	0.35	72.2	10	4.71	23.18	0.01	3.39	0.28	1.09	0.87	0.00	27.02	37.30	6.37	4.14	0.52	0.03	0.86	0.96
DENA	Wonder	46005	8/14/2004	8.18	190.10	1693.60	0.34	0.5	15	2.10	20.29	0.00	2.95	0.11	0.50	0.12	0.00	14.31	32.00	4.24	1.08	0.71	0.01	-0.04	0.49
DENA	McLeod	46008	8/10/2004	7.24	8.41	51.02	0.29	-0.6	5	2.25	0.90	0.01	0.17	0.13	1.04	0.11	0.01	0.26	0.95	0.16	0.15	0.31	0.03	0.11	0.61
GLAC	Snyder	56009	8/25/2005	6.42	16.80	162.08	0.64	1.7	10	0.65	4.41	0.01	1.41	0.10	2.67	0.06	0.02	0.51	1.85	0.74	0.36	0.13	0.01	-0.24	4.73
GLAC	Oldman	56006	8/21/2005	8.24	159.10	1573.73	0.35	-0.8	2	0.70	19.98	0.01	1.88	0.07	0.55	0.09	0.00	3.65	21.17	8.00	0.26	0.21	0.00	-0.53	0.77
OLYM	PJ	56014	9/14/2005	8.14	127.40	1092.95	0.36	1.2	5	1.05	12.18	0.02	4.24	0.09	2.78	0.31	0.00	9.03	21.33	1.84	1.61	0.32	0.00	-0.08	1.77
OLYM	Hoh	56011	9/11/2005	7.52	63.69	512.45	0.39	0.8	7	0.74	5.71	0.01	2.57	0.06	1.16	0.67	0.02	4.15	10.50	0.70	1.15	0.12	0.00	0.13	0.83
MORA	Golden	56004	8/14/2005	6.47	10.08	69.05	0.52	0.2	4	1.88	1.18	0.01	5.51	0.07	0.60	0.63	0.02	0.38	0.64	0.17	0.85	0.14	0.01	-0.55	0.35
MORA	LP19	56001	8/10/2005	6.63	10.72	80.14	0.31	0.0	8	1.37	1.32	0.01	6.61	0.07	0.92	0.55	0.00	0.38	0.91	0.17	0.91	0.26	0.00	-0.43	0.60
ROMO	Mills	36004	9/11/2003	6.61	12.04	50.81	0.55	0.2	5	1.55	1.01	0.01	1.84	0.38	3.33	0.18	0.23	1.00	1.27	0.15	0.51	0.13	0.04	-2.13	3.02
ROMO	LonePine	36006	9/14/2003	6.67	14.02	91.52	0.31	0.2	5	1.74	1.44	0.01	2.95	0.17	2.70	0.16	0.06	1.40	1.74	0.19	0.64	0.14	0.02	-2.13	1.95
SEKI	Pear	36003	8/26/2003	6.10	4.02	23.99	0.23	0.0	0	0.82	1.13	0.02	1.43	0.11	0.59	0.18	0.05	0.33	0.34	0.02	0.21	0.11	0.03	-1.97	0.64
SEKI	Emerald	36001	8/25/2003	6.22	5.42	26.34	0.26	0.3	0	0.94	1.04	0.01	2.28	0.17	1.47	0.18	0.07	0.31	0.39	0.04	0.38	0.13	0.05	-1.95	0.62

Table 1A-3. Summary Characteristics of Vegetation and Air Sampling Sites in Core and Secondary Parks (for key, see last page)

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (°C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
Park: Bandelier National Monument, New Mexico (BAND) **Ag Intensity Index:** 2.5 ; **IMPROVE AmmNO3:** 0.25 μg/m^3; **IMPROVE AmmSO4**: 1.00 μg/m^3 **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Southern Rockies													
BAND1	Vegetation	35.7279	-106.2745	1854	10.5	34	43	Flatland	1.79	*Xanthoparmelia*	*Pinus edulis*	S terminus of mesa between Lummis and White Rock Canyon, where Burro Trail descends into Lummis Canyon.	One-seed juniper woodland with scattered oak and two-needle piñon on a moderately steep W-facing slope. Ground is rocky with some large outcrops. Almost all piñon were dead along mesa on hike in (cause could be drought and/or bark beetles).
BAND2	Vegetation	35.7989	-106.2846	2076	9.9	39	34	Flatland	1.58	*Usnea*	*Pinus edulis*	On the mesa just NW of Juniper Campground	One-seed juniper woodland with oaks and two-needle piñon on a mesa. Most of the pines were dead as a result of past drought and bark beetles. *Usnea* and *Xanthoparmelia* are abundant here. Nitrophilous lichens abundant on some trees.
BAND3	Vegetation	35.8241	-106.3611	2348	8.1	47	36	Toe slope	1.58	*Xanthoparmelia*	*Pinus ponderosa*	On the lower e slopes of Frijoles Peak ~ 1.6 km along trail from Ponderosa group camp.	*Pinus ponderosa* stand with Oregon white oak and low-growing *Ceanothus* species in the understory. Fire came through within the last few decades (fire scars on bark and an open canopy). Ground cover is grassy with open gravel/mineral soils.
BAND4	Vegetation	35.8262	-106.3893	2576	6.4	55	72	Mid-slope	1.26	*Usnea*	*Pinus ponderosa*	Lower SW slope of Cerro Grande, accessed from 1.6 km hike on Apache Spring trail.	Ponderosa pine/Douglas-fir stand on the edge of a SE-facing drainage. Fire came through recently (burn scars on bark and little vegetation in understory). Mostly duff and gravelly soil.
BAND5	Air, vegetation	35.8642	-106.4178	2926	5.4	62	36	Upper slope	1.56	*Usnea*	*Pinus ponderosa*	On the saddle SW of Cerro Grande Peak at the W edge of the meadow.	On the edge of a Douglas-fir forest with some ponderosa pine, Engelmann spruce, and quaking aspen bordered by a large open meadow. Nitrophilous lichens were observed.
Park: Big Bend National Park, Texas (BIBE) **Ag Intensity Index:** 0.5; **IMPROVE AmmNO3:** 0.26 μg/m^3; **IMPROVE AmmSO4**: 2.82 μg/m^3 **North American Biome: EPA Ecoregion 3** – North American Deserts: Southern Deserts													
BIBE1	Air, vegetation	29.1870	-102.9718	560	21	26	3	Valley				Rio Grande Village in cottonwood/ grass area near hot springs trailhead; ~60 m from picnic area parking lot and 60 m from the hot springs road.	Cottonwood woodland bordered by dense mesquite shrublands.
BIBE2	Air, vegetation	29.3079	-103.1828	1067	18.6	34	0	Flatland				76 m at 354° from the water tank along the road to K-Bar Camp near Panther Junction.	Desert shrubland with honey mesquite, yucca, and cacti.
BIBE3	Air, vegetation	29.2850	-103.2799	1608	17.5	47	23	Mid-slope			*Pinus cembroides*	N side of Panther Pass along Chisos Basin Rd. (~90 m E of road) in Green Gulch Creek drainage basin.	Mexican piñon/oak woodland on a low-grade N-facing slope. The ground is rocky and the cover is mostly bunch-grass.
BIBE4	Air, vegetation	29.2534	-103.2979	1920	16.7	52	65	Mid-slope	1.40	*Usnea*	*Pinus cembroides*	Pinnacles campground	Mixed Mexican piñon/drooping juniper/juniper/oak stand; on a bench on the NW mountain slope. Dry, many large boulders; deciduous and evergreen oaks in understory.
BIBE5	Vegetation	29.2465	-103.3049	2316	16.7	52	59	Upper slope	1.56	*Usnea*	*Pinus cembroides*	On the N slope of Emory Peak on saddle below peak.	On a steep N-facing slope bordering the ridge top. Vegetation is dominated by Mexican piñon and evergreen oak. The nitrophilous lichen, *Teloschistes,* is abundant on oaks.
Park: Crater Lake National Park, Oregon (CRLA) **Ag Intensity Index: 4.2; IMPROVE AmmNO3:** 0.11 μg/m^3; **IMPROVE AmmSO4**: 0.43 μg/m^3 **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Cascades													
CRLA1	Vegetation	42.8364	-122.1459	1798	4.2	155	74	Toe slope	0.66	*Letharia vulpina*	*Abies magnifica*	W of the Lodgepole picnic areas and just SE of Bear Bluff on SW side of Rd. 62, ~122 m from the road.	Lodgepole pine stand; regeneration layer is almost entirely fir (esp. red fir) and mountain hemlock. The ground is mineral soil with pumice stones and a thin layer of pine needle duff. Lupine dominates herb layer.
CRLA2	Vegetation	42.8821	-122.1914	1859	3.5	160	49	Mid-slope	0.59	*Letharia vulpina*	*Abies concolor*	~120 m NW of Rd. 62 and NE of Whitehorse Pond.	Mixed conifer stand (white fir, lodgepole pine and mountain hemlock) of multiple age classes. The site is a bench on rocky ground; ground cover is mostly bearberry manzanita and grouse huckleberry.
CRLA3	Vegetation	42.9346	-122.1776	2043	3.4	164	31	Upper slope	0.62	*Letharia vulpina*	*Abies magnifica*	Meadow bench just off Lightning Springs trail, ~0.4 km W of Rim Drive.	Meadow with clumps of old Shasta fir and mountain hemlock. The landform is a W-facing flat bench; the soil is sandy and dry; cover is mostly grass and buckwheat.
CRLA4	Vegetation	42.9194	-122.0289	2423	3.5	108	21	Upper slope	0.62	*Letharia vulpina*	*Pinus albicaulis*	On the SW side of Mt. Scott, ~1.6 km up Mt. Scott trail, on downhill side of trail.	Whitebark pine stand with some mountain hemlock and red fir. Slopes are steep and rocky with very little vegetation.
CRLA5	Air, vegetation	42.9233	-122.0162	2713	3.5	108	0	Ridgetop			*Pinus albicaulis*	Top of Mt. Scott on NE side of fire lookout.	Gently sloping rocky summit ridge vegetated by clumps of small whitebark pine and some high-elevation herbs (pasque flower, paintbrush, *Penstemon* and bunch grasses).
Park: Denali National Park and Preserve, Alaska (DENA) **Ag Intensity Index:** 0 **IMPROVE AmmNO3:** 0.042 μg/m^3 **IMPROVE AmmSO4**: 0.36 μg/m^3 **North American Biome: EPA Ecoregion 3** – Taiga: Interior Forested Lowlands and Uplands (DENA1); Northwestern Forested Mountains: Alaska Range (DENA2-6)													
DENA1	Vegetation	63.7740	-151.0194	221	-2.6	41	0	Flatland	0.41	*Flavocetraria cucullata*	*Picea mariana*	Moose Creek, ~ 23 km N of Wonder Lake.	Black-spruce dominated taiga and peatlands.
DENA2: Wonder	Air (2), fish, lake water, snow, sediments, vegetation	63.4538	-150.8720	655	-2.6	66	69	Toe slope	0.44	*Flavocetraria cucullata/ Masonhalea richardsonii*	*Picea mariana*	SW end of Wonder Lake on hillslope facing lake ~ 60 m downhill from water tower.	Black and white spruce woodland on gentle, NE-facing hillslope. Ground cover is matted blueberry, dwarf birch, grass, bryophytes, and lichens interspersed with willows and alder. Trees are open-grown with branches to ground level.

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (^{o}C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
DENA3: McLeod	Fish, lake water, snow, sediments, vegetation	63.3696	-151.1003	579	-2.4	70	16	Flatland	0.36	*Flavocetraria cucullata/ Masonhalea richardsonii*	*Picea mariana*	S side of McLeod Lake, ~ 15 km sw of Wonder Lake.	Black spruce peatland/taiga sloping to shoreline. Trees are open grown, most to 4.5 m tall, others to 9 m.
DENA4	Vegetation	63.5520	-150.9670	975	-2.9	68	5	Upper slope	0.43	*Masonhalea richardsonii*	*Picea mariana*	On ridge W of Wickersham dome.	Transition zone from black spruce forest; tundra on a S-facing slope near ridgetop. Small clumps of willow shrubs and a few scattered spruce trees; mostly dwarf willows, crowberry, other heaths, and lichens.
DENA5	Vegetation	63.1648	-151.3599	1296	-4.7	122	0	Upper slope	0.43	*Flavocetraria cucullata/ Masonhalea richardsonii*		Upper Birch Creek, NW footslopes of the Alaska Range below Peters Dome glacier.	Riparian zone above tree line above Birch Creek, a stony, braided stream. 1.2 m high willows along stream bank, most browsed but not this year (new growth > 2.5 cm long and untouched). Above stream is tundra on gentle hillslope, with dwarf willow.
DENA6	Vegetation	63.1386	-151.3221	1753	-6.9	178	0	Ridgetop	0.29	*Thamnolia*		NW side of Alaska Range on plateau at foot of Westermere Glacier on Peter's Dome; ~ 18 km NW of Mt. McKinley Peak.	High-elevation, graveled plateau, ~ 50% vegetated (~4 in. tall) and 50% gravels. Mostly sedges and moss, with trace amounts of other tundra plants. *Thamnolia* and sparse amounts of other lichens (mainly *Stereocaulon*) present.
Park: Gates of the Arctic National Park and Preserve, Alaska (GAAR) **Ag Intensity Index:** 0; **IMPROVE AmmNO3:** 0.05 $\mu g/m^3$; **IMPROVE AmmSO4**: 0.42 $\mu g/m^3$ **North American Biome: EPA Ecoregion 3** – Tundra: Brooks Range													
GAAR1: Matcharak	Air, fish, lake water, snow, sediments, vegetation	67.7529	-156.2323	505	-8.6	43	0	Flatland	0.48	*Flavocetraria cucullata/ Masonhalea richardsonii*		Matcharak Lake, birch-covered side slope, W side of lake.	Small side slope with dwarf birch and bryophytes.
Park: Glacier National Park, Montana (GLAC) **Ag Intensity Index:** 21.6; **IMPROVE AmmNO3:** 0.29 $\mu g/m^3$ **IMPROVE AmmSO4**: 0.84 $\mu g/m^3$ **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Canadian Rockies													
GLAC1	Vegetation	48.6208	-113.9058	961	5.4	74	128	Lake basin	1.26	*Platismatia glauca*	*Tsuga heterophylla*	W side Continental Divide, past McDonald Ranger Station to trailhead at end of road; lake is SE of trail, ~ 0.2 km from trailhead.	Area on other side of trail away from lake was burned 1-2 years ago; trail acted as fire line, preventing burning along lake edge. Plot was downslope from trail, toward lake, and was not affected by the fire.
GLAC2	Vegetation	48.6757	-113.8096	1089	2.9	85	164	Toe slope	0.94	*Platismatia glauca*	*Tsuga heterophylla*	W side Continental Divide, ~ 0.6 km on Avalanche Lake Trail from trailhead at Avalanche Campground on NE side of Avalanche Creek.	On NE edge of creek, with areas of full exposure along creek edge, and partly shaded areas in forest.
GLAC3: Snyder	Air, fish, lake water, snow, sediments, vegetation	48.6261	-113.8031	1609	2.5	178	31	Lake basin	0.82	*Platismatia glauca/Alectoria sarmentosa*	*Picea engelmanii*	W side Continental Divide, Snyder Lake trail to Snyder Lake; in forest on SW edge of lake across from food preparation area.	In a lake valley, mid-valley slope.
GLAC4: Oldman	Air, fish, lake water, snow, sediments, vegetation	48.5104	-113.4552	2024	2.9	85	34	High elevation lake basin	0.97	*Letharia vulpina*	*Picea engelmanii*	E side Continental Divide, trail from Two Medicine Campground to Oldman Lake; site is S of trail where it meets the lake and along the stream from the lake.	Lake surrounded by many small, little-used foot trails. Stream flowing from lake.
GLAC5	Vegetation	48.6924	-113.5170	1353	2.9	121	114	Valley	1.16	*Letharia vulpina/ Hypogymnia physodes*	*Pseudotsuga menziesii*	E side Continental Divide, St. Mary Lake; road across from Rising Sun campground to picnic area; site is 100 m SW toward stream and along lake.	Abundant quaking aspen along stream and lake, with sparse lichens and Douglas-fir.
Park: Glacier Bay National Park, Alaska (GLBA) **Ag Intensity Index:** 0 **IMPROVE AmmNO3:** 0.04 $\mu g/m^3$ **IMPROVE AmmSO4**: 0.46 $\mu g/m^3$ (2005 Data from PETE1 in Petersburg, SE AK) **North American Biome: EPA Ecoregion 3** – Marine West Coast Forest: Coastal Western Hemlock-Sitka Spruce Forests													
GLBA1	Air, vegetation	58.6022	-135.8831	8	4	261	79	Toe slope	0.79	*Platismatia glauca*	*Picea sitchensis*	In forest near shore of N end of Beartrack Cove at toe-slope of SW ridge.	Sitka spruce stand near the beach. The forest floor is entirely covered in moss with 5-leaf bramble mixed in. Some devilsclub and *Aruncus* shrubs in understory, and western hemlock in the regenerating stand.
GLBA2	Vegetation	58.6061	-135.8801	168	4	261	106	Mid-slope bench	0.51	*Sphaerophorus globosus*	*Picea sitchensis*	On first knob on SW ridge of Beartrack Mountain.	Sitka spruce stand that appears ~ 100-150 years old. The regenerating stand is almost entirely western hemlock. The ground is covered in a dense thick carpet of moss. Some huckleberry, *Aruncus*, and strawberry-leaf raspberry.
GLBA3	Vegetation	58.6093	-135.8724	457	4	261	117	Mid-slope	0.57	*Sphaerophorus globosus*	*Picea sitchensis*	On SW slope of Beartrack Mountain ~200 m E of first major stream. Just below glacial trim line.	Late-seral mountain hemlock/Sitka spruce stand on a steep SW-facing slope. The forest is dense and the understory has a high cover of huckleberry; the ground is mossy.
GLBA4	Vegetation	58.6121	-135.8714	625	4	261	18	Upper slope	0.39	*Alectoria sarmentosa*	*Picea sitchensis*	Treeline at the headwaters of first major creek W of Beartrack Mountain's SW ridge.	Krumoltz mountain hemlock with a few Sitka spruce with high cover of heather, copperbush, and deer cabbage. Some ferns and *Sphagnum*.

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (°C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
Park: Great Sand dunes National Park and Preserve, Alaska (GRSA) **Ag Intensity Index: IMPROVE AmmNO3:** 0.20 μg/m³ **IMPROVE AmmSO4**: 0.82 μg/m³ **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Southern Deserts (GRSA1); Northwestern Forested Mountains: Southern Rockies (GRSA2-5)													
GRSA1	Vegetation	37.7258	-105.5323	2469	5.3	32	18	Valley			*Pinus edulis*	Near park headquarters, ~ 60 m SW of autoshop	Two-needle piñon/Rocky Mountain juniper woodland on valley floor bordering a large grassland. Grass dominates the ground cover with scattered but abundant prickly-pear cactus. Very windy.
GRSA2	Vegetation	37.7308	-105.4874	2774	4.3	48	5	Mid-slope	1.46	*Xanthoparmelia*	*Pinus edulis*	Mosca Pass trail, midway to pass on a steep slope on the N side of the trail.	Two-needle piñon/alderleaf mountain mahogany woodland. Steep SW-facing slope with many rocks and rocky outcroppings.
GRSA3	Vegetation	37.7338	-105.4602	2941	3.9	58	46	Upper slope			*Pinus flexilis*	Mosca Pass, just down-slope from radar tower.	Meadow dominated by quaking aspen with some limber and ponderosa pines.
GRSA4	Vegetation	37.7223	-105.4699	3109	4.3	48	59	Mid-slope	0.77	*Xanthoparmelia*	*Pinus flexilis*	On the N slope of Carbonate Mtn ~ 0.8 km upslope; use the drainage ~1.6 km W of Mosca Pass for access.	NW-facing slope in a quaking aspen/ Engelmann spruce forest with yellow lupine and branch litter. High cover of nitrophilous lichens, esp. *Xanthoria*.
GRSA5	Air, vegetation	37.7149	-105.4704	3338	4.3	48	36	Ridgetop			*Pinus flexilis*	On N-facing ridge of Carbonate Mtn; grassy bench just below snag-ringed knob, benchmark 3,435 m.	NE-facing slope bordering the ridgetop in a grassy opening with patchy Engelmann spruce/quaking aspen forest with some limber pine. Very windy with winds blowing up the W-NW slope. High nitrophilous lichen (*Xanthoria*) cover on spruce.
Park: Grand Teton National Park, Wyoming (GRTE) **Ag Intensity Index:** 10.2 **IMPROVE AmmNO3:** 0.22 μg/m³ **IMPROVE AmmSO4**: 0.58 μg/m³ **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Middle Rockies													
GRTE1	Vegetation	43.7307	-110.7389	2073	2.2	80	36	Valley	0.99	*Usnea*	*Pinus contorta*	W edge of Lupine Meadows, just off trail; ~ 0.53 km from Lupine Meadows trailhead.	On valley floor at edge of a subalpine meadow. Lodgepole pine is dominant tree with subalpine fir, quaking aspen, and Engelmann spruce. Many snags and dying trees. Some nitrophilous lichens (esp. *Xanthoria*).
GRTE2	Vegetation	43.7256	-110.7601	2362	2.2	80	76	Mid-slope	0.99	*Letharia vulpina*	*Abies lasiocarpa*	Slope above Bradley Lake on trail to Amphitheatre Lake; off second switchback.	Subalpine forest dominated by subalpine fir and Douglas-fir. S-facing slope with dense herb groundcover.
GRTE3	Vegetation	43.7264	-110.7657	2591	1.1	106	66	Mid-slope	0.88		*Pinus flexilis*	On the SE-facing slope below Amphitheater Lake; mid-slope half-way between Amphitheater Lake and Valley floor just up trail from the Garnet Canyon Junction.	SE-facing slope in subalpine forest dominated by subalpine fir. Ground cover mostly grasses with some heaths and a few large boulders (lots of marmot scat on boulders).
GRTE4	Vegetation	43.7276	-110.7713	2804	1.1	106	47	Mid-slope			*Pinus flexilis*	~0.5 km E of Surprise Lake, just off trail where the slope steepens and switchbacks shorten.	On a steep E-facing slope in a mixed conifer stand. Ground has a high cover of thinleaf huckleberry and grouse whortleberry and large granite outcrops.
GRTE5	Air, vegetation	43.1300	-110.7800	3048	2.2	68	21	Ridgetop			*Pinus albicaulis*	S rim above Amphitheater Lake.	On an E-facing ridge above a glacial cirque. Trees are patchy mixed pine, fir, and spruce. On a glacier cut and mostly all granite with some alpine herbs. No lichens, a few crusts.
Park: Katmai National Park and Preserve, Alaska (KATM) **Ag Intensity Index:** 0 **IMPROVE AmmNO3:** 0.10 μg/m³ **IMPROVE AmmSO4**: 0.50 μg/m³ (Data from monitor at Tuxedni Wilderness, USFWS) **North American Biome: EPA Ecoregion 3** – Tundra: Bristol Bay-Nushagak Lowlands (KATM1-5); Marine West Coast Forest: Alaska Peninsula Mountains (KATM6)													
KATM1	Vegetation	58.5459	-155.7836	36	2.2	50	16	Flatland	0.52	*Hypogymnia physodes*	*Picea glauca*	~ 2 km from Brooks camp on road to Three Forks Overlook.	Forest uneven age with fallen conifers interspaced hardwoods. Height of dominant trees is 18-21 m.
KATM2	Vegetation	58.5686	-155.7937	213	1.9	54	107	Toe slope	0.71	*Hypogymnia physodes*	*Picea glauca*	Dumpling Mountain trail on small knoll facing Naknek Lake.	Scattered white spruce 6-12 m tall on steep sloped knob with Sitka alder and deep moss mats. Oldest trees probably 100-200 years old. Collected over larger area, including a meadow and slope on far side of the meadow. Meadow had black cottonwood and *Calamagrostis*.
KATM3	Air, vegetation	58.5711	-155.8036	370	1.9	54	16	Mid-slope	0.97	*Hypogymnia physodes*	*Picea glauca*	Dumpling Mountain at 370 m.	Vegetation dominated by 3 m Sitka alder, heavily infested and defoliated by inch worms.
KATM4	Vegetation	58.5718	-155.8421	563	1.4	68	3	Upper slope	0.46	*Flavocetraria cucullata*	*Picea glauca*	On S face of Dumpling Mountain 180 m below peak, downhill from trail overlooking Naknek Lake, Brooks River, and Brooks Lake.	At tree line, scattered short spruce (up to 1.2 m tall) among tundra vegetation, dominated by crowberry and other heaths.
KATM5	Vegetation	58.5793	-155.8558	724	1.4	68	3	Ridgetop	0.44	*Flavocetraria cucullata*	*Picea glauca*	Top of Dumpling Mountain; SE-facing slope	Tundra on gently sloping top of Dumpling Mountain. Spruce needles were collected from very short trees (up to 0.4 m) widely scattered on mountain top.
KATM6	Vegetation	58.4715	-155.4901	1112	0.1	83	0	Upper slope	0.52	*Flavocetraria cucullata*		W slopes of Mt. Katolinat, accessed from Iliuk Arm of Naknek Lake, ~ 610 m below peak.	Alpine tundra, gently stone and gravel slope with thin soils near uppermost NW slopes of Mt. Katolinat.
Park: Lassen Volcanic National Park, California (LAVO) **Ag Intensity Index: 7.4; IMPROVE AmmNO3:** 0.20 μg/m³; **IMPROVE AmmSO4**: 0.61 μg/m³ **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Sierra Nevada													
LAVO1	Vegetation	40.5568	-121.5315	1829	7.4	103	3	Mid-slope	0.59	*Letharia vulpina*	*Abies concolor*	At Sunflower Flat ~120 m SW of main park road.	A nearly flat ponderosa pine, western white fir woodland with some shrubby manzanita and chinquapin. Some boulders from adjacent rocky slope; ground cover mostly grasses. Several downed trees in various decay states.
LAVO2	Vegetation	40.5314	-121.5342	2012	6.6	109	62	Upper slope	0.51	*Letharia vulpina*	*Abies concolor*	~2.4 km on Chaos Crags trail from trailhead.	Late-seral, mixed pine and white fir woodland. W-facing rocky slope with a dense covering of bearberry manzanita, and older fir trees have dense cover of the wolf-lichen, *Letharia*.
LAVO3	Vegetation	40.4550	-121.5399	2271	4.1	303	76	Upper slope	0.85	*Letharia columbiana*	*Abies magnifica*	Just below the Ridge Lakes Basin ~ 0.8 km up Ridge Lakes Trail.	In a California red fir/mountain hemlock stand bordered by a creek and wet meadow on the N side and dry meadow (lily and waterleaf) on the S side. Very little ground vegetation in the forested section, mostly duff and branch litter with some lupine.

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (°C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
LAVO4	Vegetation	40.4392	-121.5576	2499	4.8	254	18	Upper slope	0.87	*Letharia vulpina*	*Abies magnifica*	On S slope of Brokeoff Top Mtn, ~3.2 km up trail.	In a mountain hemlock stand on a mild sloping rocky bench. The herb layer is almost all lupine and wolf-lichens (*Letharia* spp.) are abundant.
LAVO5	Air, vegetation	40.4476	-121.5662	2713	4.8	254	21	Ridgetop	0.94	*Letharia vulpina*	*Abies magnifica*	Near summit of Brokeoff Top Mtn, on NW ridge.	On a mountain top with nearly krumholtz mountain hemlock and some California red fir. The slope is W-facing and rocky with some bearberry and manzanita. The lichen community consisted of mostly of the wolf lichens, *Letharia vulpina* and *L. columbiana*.
Park: Mount Rainier National Park, Washington (MORA) **Ag Intensity Index:** 6; **IMPROVE AmmNO3:** 0.20 µg/m^3; **IMPROVE AmmSO4**: 1.11 µg/m^3 **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Cascades													
MORA1	Vegetation	46.7433	-121.8915	654	6.4	197	77	Valley	0.63	*Alectoria sarmentosa*	*Tsuga heterophylla*	Along Tahoma Creek, off Rd. 706.	Silver fir/western hemlock/Douglas-fir stand along creek. Average dbh <53 cm, age 200+ years, but some young trees (1.5 m) present also.
MORA2	Vegetation	46.7697	-121.7893	985	3.5	244	91	Mid-slope	0.47	*Alectoria sarmentosa*	*Tsuga heterophylla*	Ricksecker Point Picnic Area; trail from rear of parking lot, past restrooms, towards river behind outhouse.	Woodland/riparian area, with old Douglas-fir (200+ years) and an understory of mostly Pacific silver fir, western hemlock, mountain hemlock, and a few pines. Many paths through site to river edge.
MORA3: LP19	Air, fish, lake water, snow, sediments, vegetation	46.8239	-121.8953	1372	4	222	85	Lake basin	0.42	*Alectoria sarmentosa*	*Abies amabilis*	Unnamed lake LP19 vicinity; 80-90 degrees up steep slope above St. Andrews Creek drainage, NE of Puyallup Lakes.	Stand 300+ years old, with mature Douglas-fir, 10-100-year-old Pacific silver fir. Fir most abundant, but 100-200-year-old western and mountain hemlock also present in low abundance. Red huckleberry and oval-leaf blueberry cover 50-75% of forest floor.
MORA4: Golden	Air, fish, lake water, snow, sediments, vegetation	46.8878	-121.8987	1369	4.6	220	36	Lake basin	0.54	*Alectoria sarmentosa*	*Abies amabilis*	N side Golden Lake.	Site is on a bench on high mountain. Woodland, age 150+ years, with tall Douglas-fir and Pacific silver fir in understory. Much *Vaccinium* in understory, and lots of moss near lake. *Alectoria* dominant lichen at site.
MORA5	Vegetation	46.8006	-121.7831	1809	2.4	260	36	Upper slope			*Abies procera*	Mildred Point; in middle of flat area.	Flat bench at base of Mt. Rainier glacier overlooking steep and deep glacial drainage. Stand has noble fir and Alaskan yellow cedar with very few lichens. Pacific silver fir and mountain hemlock also present in low abundance.
Park: Noatak National Preserve, Alaska (NOAT) **Ag Intensity Index:** 0 ; **IMPROVE AmmNO3:** NA µg/m^3; **IMPROVE AmmSO4**: NA µg/m^3 **North American Biome: EPA Ecoregion 3** – Tundra: Arctic Foothills (NOAT1, NOAT3); Tundra: Brooks Range (NOAT5)													
NOAT1	Vegetation	68.2847	-161.4657	227	-7.4	41	0	Toe slope	0.38	*Masonhalea richardsonii*		Knoll above Middle Kugururok River.	Dwarf birch on tundra-covered knoll.
NOAT3: Burial	Air, fish, lake water, snow, sediments, vegetation	68.4063	-159.2223	388	-8.8	39	0	Flatland	0.53	*Masonhalea richardsonii/ Flavocetraria cucullata*		Burial Lake; gravel drainage to lake.	Dwarf birch in well-drained area.
NOAT5	Vegetation	68.4625	-161.4612	675	-8.8	50	0	Upper slope	0.35	*Masonhalea richardsonii*		SW of Copter Peak.	Alpine *Dryas* tundra with mountain heather.
Park: North Cascades National Park, Washington (NOCA) **Ag Intensity Index:** 3.7; **IMPROVE AmmNO3:** 0.13 µg/m^3; **IMPROVE AmmSO4**: 0.78 µg/m^3 **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: North Cascades													
NOCA1	Vegetation	48.6493	-121.3070	198	8.6	207	74	Toe slope	0.34	*Alectoria sarmentosa*	*Pseudotsuga menziesii*	On Thornton Creek, just below single-lane bridge (off dirt road to Thornton Lake trailhead), 60 m from road.	Steep, granite outcrop on the E side of a major perrenial creek. Forest is dominated by Douglas-fir and regeneration is mostly red cedar. Ground vegetation is almost all salal.
NOCA2	Vegetation	48.6420	-121.3370	614	8.6	206	84	Mid-slope	0.52	*Platismatia glauca*	*Tsuga heterophylla*	Lower S slope of Mt. Triumph, 4 km up Thornton Lake Rd., 90 m N of road.	E slope in a western hemlock forest which was logged <100 years ago; oldest stand found at this elevation in area. Ground is mossy with some scattered herbs and shrubs.
NOCA3	Vegetation	48.6641	-121.3266	945	8.3	243	92	Mid-slope	0.50	*Alectoria sarmentosa*	*Abies amabilis*	SE slope of Mt. Triumph ~ 4 km up the Thornton Lakes trail.	SE slope in a western hemlock forest with Pacific silver fir as the regeneration stand. Ground is mossy; thinleaf huckleberry and beard lichens abundant.
NOCA4	Vegetation	48.6716	-121.3187	1228	8.7	205	97	Upper slope	0.37	*Alectoria sarmentosa*	*Abies amabilis*	Upper SE slope of Mt. Triumph, off Thornton Lakes trail just below the park boundary sign.	SE slope in an old-growth, mixed-conifer stand (western hemlock, Alaska yellow cedar and Pacific silver fir). Ground is mossy; thinleaf huckleberry and beard lichens abundant.
NOCA5	Air, vegetation	48.6824	-121.3217	1600	8.2	205	47	Ridgetop	0.48	*Alectoria sarmentosa*	*Abies amabilis*	S ridge of Trappers Peak, near treeline, above lower Thornton Lake.	Site is on a S-facing ridgeline (rim of glacial cirque) and at tree-line. Forest of Alaska yellow cedar, mountain hemlock and Pacific silver fir. Slope is steep and rocky with open soil, alpine herbs and thinleaf huckleberry.

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (°C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
Park: Olympic National Park, Washington (OLYM) **Ag Intensity Index:** 2.2; **IMPROVE AmmNO3:** 0.39 μg/m^3; **IMPROVE AmmSO4**: 0.99 μg/m^3 **North American Biome: EPA Ecoregion 3** – Marine West Coast Forest: Puget Lowlands (OLYM1); Marine West Coast Forest: Coast Range (OLYM2), Northwestern Forested Mountains: North Cascades (OLYM3-5)													
OLYM1	Vegetation	48.0926	-123.4338	137	9.4	92	85	Valley		*Lobaria oregana*	*Tsuga heterophylla*	Outskirts of Port Angeles; Peabody Creek Loop Trail, along w side of creek, ~ 2/3 way around the loop.	Mature mixed conifer/deciduous forest bordering urban area. Douglas-fir dominant, with western hemlock in understory.
OLYM2	Vegetation	47.9535	-123.8381	518	6.7	360	94	Valley		*Alectoria sarmentosa*	*Tsuga heterophylla*	~ 3.2 km SE of Sol Duc Hot Spgs Resort on N side of Sol Duc River, ~0.4 km from junction with Canyon Creek.	Old-growth western hemlock forest along Sol Duc River. Floodplain of river is approximately 61 m wide with mainly rounded stones and small boulders with islands of alder and willow. Forest understory has low moss cover, and some blueberry, ferns.
OLYM3: Hoh	Air, fish, lake water, snow, sediments, vegetation	47.8973	-123.7831	1448	6.9	458	31	Upper slope	0.36	*Alectoria sarmentosa/ Bryoria fuscescens*	*Abies lasiocarpa*	NW slope above Hoh Lake.	NW-facing slope above a subalpine lake. Stand is mixed mountain hemlock and subalpine fir with a high cover of blueberry.
OLYM4: PJ	Air, fish, lake water, snow, sediments, vegetation	47.9463	-123.4136	1392	4.9	216	101	Lake basin	0.44	*Platismatia glauca/ Bryoria fuscescens*	*Abies amabilis*	SW side of PJ Lake; ~0.8 km e of Hurricane Ridge Rd. to Obstruction Point, and 0.8 km N of Eagle Point.	Mixed fir/red cedar old-growth forest adjacent to meadow with willow. Willow also present along lake shore. Little understory, site has deep snow cover in winter. Lake has significant algal growth.
OLYM5	Vegetation	47.9307	-123.4105	1850	4.9	216	38	Ridgetop	0.63	*Alectoria sarmentosa/ Bryoria*	*Abies lasiocarpa*	Ridgetop approximately 100 m E of Hurricane Ridge Rd. to Observation Point, and ~ 1 km S of Eagle Point.	Ridgetop with mature old-growth stand of subalpine fir in subalpine habitat. Site is wind-blasted from the E and W, high cover of lichens on large trees in most sheltered areas.
Park: Rocky Mountain National Park, Colorado (ROMO) **Ag Intensity Index:** 14.4; **IMPROVE AmmNO3:** 0.35 μg/m^3; **IMPROVE AmmSO4**: 0.83 μg/m^3 **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Southern Rockies													
ROMO1	Air, vegetation	40.2381	-105.7995	2560	1.7	65	92	Valley			*Picea engelmanii*	W side of Continental Divide, S of East Inlet trailhead, near creek.	Flat floodplain forested with lodgepole pine and Engelmann spruce. Much willow and some aspen in understory. Grasses abundant; most herbs have withered. Evidence of moose in area: lots of browsed willow and pellets.
ROMO2	Air, vegetation	40.2305	-105.7611	2720	1.2	79	36	Mid-slope			*Abies lasiocarpa*	W side of Continental Divide, halfway between Cats Lair Camp and Lower East Inlet Camp; East Inlet Trail, on slope above falls.	Steep, dry, rocky slope with a lodgepole pine dominated stand. Quaking aspen is dominant hardwood, a few willow shrubs present.
ROMO3: Lone Pine	Air, fish, lake water, snow, sediments, vegetation	40.2310	-105.7310	3018	0.1	104	21	High elevation lake basin			*Abies lasiocarpa*	W side of Continental Divide, on S shore of Lone Pine Lake.	Meadow on the s shore of a subalpine lake with a few large groves of willow; bordered by an Engelmann spruce forest.
ROMO4	Air, vegetation	40.2300	-105.7130	3232	-0.4	116	18	Mid-slope			*Abies lasiocarpa*	W side of Continental Divide, on S-facing rock outcrop plateau above Lake Verna.	Rock outcrop plateau with sparse forest of subalpine fir and Engelmann spruce. No other vegetation, only rock.
ROMO5	Vegetation	40.3916	-105.6867	3451	1.4	92	16	Ridgetop			*Abies lasiocarpa*	W side of Continental Divide, near Ute Crossing on Sundance Mountain.	Rocky ridgetop with patchy forest of subalpine fir; some krumholtz and small patches of willow.
ROMO6: Mills	Air, fish, lake water, snow, sediments, vegetation	40.2916	-105.6438	3042	1.3	113	62	High elevation lake basin	1.2	*Xanthoparmelia*	*Picea engelmanii*	E side of Continental Divide, on NW corner of Mills Lake, on large flat rock at outlet.	High-elevation Engelmann spruce/subalpine fir with limber pine. Large, smooth, rocky outcrops covered with crustose lichens. Krumholtz conifers present.
Park: Sequoia and Kings Canyon National Parks, California (SEKI) **Ag Intensity Index:** 16.6; **IMPROVE AmmNO3:** 2.19 μg/m^3; **IMPROVE AmmSO4**: 1.98 μg/m^3 **North American Biome: EPA Ecoregion 3** – Mediterranean California: Southern and Central Chaparral and Oak Woodlands (SEKI2); Northwestern Forested Mountains: Sierra Nevada (SEKI3-7)													
SEKI2	Air, vegetation	36.5762	-118.7862	1573	16.9	36	88	Valley	2.23	*Letharia vulpina*	*Abies concolor*	Marble Fork of the Kaweah River, just upstream from Crystal Cove Drive overpass.	Mature forest of pine, incense cedar, and California red fir along boulder-filled, granite riverbed ~ 25 m wide bordered by willow.
SEKI3	Vegetation	36.5536	-118.7492	2071	10.3	100	78	Mid-slope bench	1.59	*Letharia vulpina*	*Abies concolor*	Crescent Meadow.	Meadow and nearby stand along Crescent Creek. Vegetation is diverse and in good condition. Tree cover is clumped.
SEKI4	Air, vegetation	36.5985	-118.7212	2332	5.3	108	31	Mid-slope bench	1.56	*Letharia vulpina*	*Abies magnifica*	Wolverton Creek Meadow.	Meadow of sedges surrounded by tall California red fir and open-grown lodgepole pine encroaching on meadow. Vegetation appears healthy. Site is on a bench on a mid-slope.
SEKI5: Emerald	Air, fish, lake water, snow, sediments, vegetation	36.6005	118.6789	2816	3.4	89	47	High elevation lake basin	1.53	*Letharia vulpina*	*Abies magnifica*	Emerald Lake Basin, Topokah valley watershed.	Mixed red fir/pine stand with Labrador tea understory; many granite boulders.

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (°C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
SEKI6: Pear	Air, fish, lake water, snow, sediments, vegetation	36.6040	-118.6690	2911	2.4	75	34	High elevation lake basin			*Pinus contorta*	Outflow area of Pear Lake.	Drainage area for alpine lake, but currently dry. Pine stand with willow on granite slabs. Algal and aquatic moss lines indicate that the lake floods widely over the granite slabs in some places.
SEKI7	Air, vegetation	36.5165	-118.8017	630	14.5	76	49	Valley				Potwisha Campground n of highway on Deep Canyon Creek.	Creek with one main channel and granite boulders on either side. Tree canopy overhangs river and provides intermittent shade.
Park: Stikine-LeConte Wilderness, Tongass National Forest, Alaska (STLE) **Ag Intensity Index:** 0.1; **IMPROVE AmmNO3:** 0.04 μg/m³; **IMPROVE AmmSO4**: 0.46 μg/m³ (2005 IMPROVE data from PETE1, Petersburg SE AK). **North American Biome: EPA Ecoregion 3** – Marine West Coast Forest: Pacific Coastal Mountains													
STLE1	Air, vegetation	56.7910	-132.5110	0	4.5	318	31	Marine beach	0.49	*Platismatia glauca/ Alectoria sarmentosa*	*Picea sitchensis*	Bussy Creek outlet NE side of creek in upper beach meadow 60 -75 m from inter-tidal flats.	Upper beach meadows with scattered Sitka spruce. Vegetation samples were collected from open-grown spruce and along forest edge.
STLE2	Air, vegetation	56.8047	-132.5317	254	3.6	378	119	Mid-slope	0.49	*Platismatia glauca/Lobaria oregana*	*Picea sitchensis*	Bussy Creek drainage on lower slopes at 254 m following ridge line between the N and S main tributaries.	Old growth mixed coniferous forest of Alaska yellow cedar and western hemlock. Canopy cover ~80%. Understory of mixed forms and shrubs with high moss ground cover. Area slopes steeply facing Bussy Creek drainage.
STLE3	Air, vegetation	56.8095	-132.5407	567	3.6	378	34	Mid-slope	0.39	*Alectoria sarmentosa*	*Picea sitchensis*	SE of small lake above Bussy Creek. In long, narrow Muskeg bench parallel to and overlooking drainage on long edge.	Muskeg bench with scattered shorepine (*Pinus contorta*) on SE-facing slope of Thunder Mountain overlooking Bussy Creek drainage.
STLE4	Air, vegetation	56.8250	-132.5715	815	2.7	488	3	Ridgetop	0.37	*Platismatia glauca/ Alectoria sarmentosa*	*Picea sitchensis*	Ridgetop knob on Wilderness boundary ~ 0.4 km NW of Bussy Lake and 0.4 km due W of small lake beside Wilderness. To NW a prominent cliff face overlooks headwaters of the Muddy River.	Small knob with several scattered ponds. Subalpine heath with clumps of old mountain hemlock.
STLE5	Vegetation	56.8180	-132.6090	1064	3.6	431	5	Ridgetop	0.45	*Platismatia glauca/ Cladina arbuscula*	*Picea sitchensis*	Top of Thunder Mountain.	Alpine mountain peak dominated by sedges, avues, and dwarf heath.
Park: Wrangell-St. Elias National Park and Preserve, Alaska (WRST) **Ag Intensity Index:** 0; **IMPROVE AmmNO3:** 0.04 μg/m³; **IMPROVE AmmSO4**: 0.46 μg/m³ (2005 data from PETE1, Petersburg SE AK) **North American Biome: EPA Ecoregion 3** – Marine West Coast Forest: Pacific Coastal Mountains (WRST1); Northwestern Forested Mountains: Copper Plateau (WRST2-3); Northwestern Forested Mountains: Interior Highlands (WRST4-5)													
WRST1	Vegetation	60.0476	-141.3066	7	3.1	312	101	Marine beach	0.51	*Hypogymnia apinnata*	*Picea sitchensis*	Kageets Point on E shore of Icy Bay, ~ 0.4 km S of landing strip, in Sitka spruce/alder forest at shoreline.	Oblong collection area along beach fringe. Recently deglaciated (50-100 years ago) forelands, ~ 30 m into the Sitka spruce forest from the beach. Age class of trees varying depending on distance from the shore and isostatic rebound.
WRST2	Vegetation	61.5219	-144.4002	219	-1.9	31	16	Valley			*Picea glauca*	S side of McCarthy Rd. along silt bluffs over looking confluence of Chintina and Copper Rivers ~0.8 km from road and campground.	Edge of forest along river bluff, multiple age class of white spruce. Many old dead trees of possibly black spruce. Collected along forest edge at bluff.
WRST3	Air, vegetation	61.3856	-143.6014	648	-1.7	62	85	Toe slope			*Picea glauca*	From highest point along Crystalline Hills trail on N side McCarthy Rd., just E of marble grotto, take uphill side trail ~23 m to highest point, scale small cliff, and go uphill another 60 m.	Steep, mostly treeless slope with scattered clumps of quaking aspen and white spruce.
WRST3B	Vegetation	61.3844	-143.6063	607	-1.7	62	31	Toe slope	0.60	*Hypogymnia physodes*		Crystalline Hills loop trail at 607 m.	White spruce/quaking aspen woodland regenerating from fire.
WRST4	Vegetation	61.4964	-142.8684	1020	-2.2	85	43	Mid-slope			*Picea glauca*	Trail to Bonanza Mine from Kennicott, W side of trail at 1,020 m; exposed to the Kennicott Valley, glaciers.	Conifers from 2 to 12 m tall, declining in health. Area gets 2.5 - 3 m snow in winter. Exposed to Kennicott glacier and Kennicott, Nizina, and Chitna River valleys with views to Chugach Mountains ~80 km distant.
WRST5	Vegetation	61.5014	-142.8381	1421	-2.7	127	3	Upper slope	0.49	*Flavocetraria cucullata/ Cladina arbuscula-mitis*	*Picea glauca*	On trail to Bonanza Mine below pass between Bonanza ridge and Porphyry Mountain, ~2.5 km E of Kennicott.	Dwarf ericaceous vegetation with *Dryas*, moss and willow. Slope is exposed to Kennicot glacier, river headwaters, and basin.
Park: Yosemite National Park, California (YOSE) **Ag Intensity Index:** 13.8; **IMPROVE AmmNO3:** 0.46 μg/m³; **IMPROVE AmmSO4**: 0.98 μg/m³ **North American Biome: EPA Ecoregion 3** – Northwestern Forested Mountains: Sierra Nevada													
YOSE1	Vegetation	37.6783	-119.7541	661	12.1	82	36	Valley	1.35	*Xanthoparmelia*	*Pinus sabiniana*	Yosemite National Park on Hwy. 140 at turnout on left side of road just inside SW park boundary on N bank of river.	Large boulders with canyon live oak and poison oak; a few foothill and ponderosa pines present.
YOSE2	Vegetation	37.7150	-119.6801	1433	10.7	86	39	Mid-slope	0.98	*Letharia vulpina*	*Pinus ponderosa*	On N-facing slope of Turtleback Dome.	Dry, rocky slope; mixed conifer forest (pine, cedar, and Douglas-fir), with abundant manzanita in the understory. All conifer species in the regeneration layer. Wolf -lichen (*Letharia vulpina)* abundant; some nitrophilous lichens (*Xanthoria)* on oaks.
YOSE3	Vegetation	37.7237	-119.5336	1829	10.3	98	77	Mid-slope	1.12	*Letharia vulpina*	*Pinus lambertiana*	On top of Nevada Falls on the Merced River ~30 m S of falls off trail.	Incense cedar-dominated stand with multiple conifer species present. Gentle NW-facing slope with branch litter, a thin layer of duff, and two herbs (western rattlesnake plantain and Pacific Rhododendron).

Site Name	Media	Lat.	Long.	Elev. (m)	Ann. Temp. (°C)	nn. Ppt. (cm)	Canopy Cover (%)	Landform	Lichen N % dw	Lichens collected	Conifers collected	Location	Habitat
YOSE4	Vegetation	37.7506	-119.3631	2713	4.2	110	21	Mid-slope			*Pinus contorta*	On Lewis Creek near confluence with trail around Cony Crags into the Lyell Forte Basin.	Lodgepole pine woodland on slab granite; a few young western hemlock and California red fir and scattered shrubby chinquapin and western brackenfern. Some pines with charred trunk bases.
YOSE5	Air, vegetation	37.7744	-119.3371	3048	3.1	108	16	Upper slope			*Pinus contorta*	Valley at head of Lewis Creek watershed at the confluence of Gallison Lake Outlet Creek.	Alpine meadow with pine woodland; willow-lined creek runs through site center.

Key to Table:

Park = name, state and acronym of the park or wilderness.

Ag Intensity = agricultural intensity in a 150 km radius around the park, see methods section for more details.

IMPROVE AmmNO3 and **AmmSO4** = mean annual nitrate and ammonium sulfate concentrations in micrograms per cubic meter in ambient fine particulates under 2.5 um in diameter sampled for 24 hours, air is sampled every 3rd day at IMPROVE monitors located in WACAP parks and wilderness, if no IMPROVE site exists for the park then data is from the nearest IMPROVE site and the name of that site is given, value is the 1998-2004 mean for annual data that meets IMPROVE quality assurance criteria, see methods section for more details.

Biome = Level three US EPA ecological region in which the site is located, see http://www.epa.gov/wed/pages/ecoregions/ecoregions.htm for general information.

Long. = latitude and longitude of site center in decimal degrees, mapping datum WGS84, sites were approximately 1 ha.

Elev. (m) = elevation in meters, derived from site location on USGS topographic 15' quadrangles.

Ann. Temp. and **Ann. Ppt.** = mean annual temperature in degrees Celsius and mean annual precipitation in centimeters estimated from the PRISM climate model—see Chapter 3 for details.

Canopy Cover (%) = field ocular estimate of the canopy cover of dominant and co-dominant trees on the site as a percentage of total site area.

Landform = physiographical feature on which the site was located, determined from USGS 15' topographic quadrangles.

Lichen N % dw = mean nitrogen concentration in lichen thalli collected on the site as percent of dry weight, if more than one species was collected, species N concentrations were averaged after averaging laboratory and field replicates.

Lichens collected = lichens collected for nitrogen, sulfur, metals and SOC analysis.

Conifers collected = conifer species collected for SOC analysis. If vegetation was collected, but both "conifers collected" and "lichens collected" fields are blank, then leaves or bark of deciduous shrubs were collected and results are not reported.

Location = site location description.

Habitat = ecological characteristics of the collection site.

APPENDIX 3A

Summary of Sampling and Analysis Plan by Environmental Medium

Medium	SNOW					
Purpose	Measure of direct atmospheric contaminant loading, and in many cases, 90% of the annual precipitation, interannual variability					
Frequency	Annually; 14 sites in 8 core parks, and additional snow-only sites for elevational transect					
Samples	**Inorganic** Integrated vertical snowpack profile Single Teflon Bag, 6 liters of snow = 2 liters of water; Shipped with dry ice and blue ice to USGS-CO					**Organic** Integrated vertical snowpack profile 6 Teflon Bags, 20 liters of snow each = 42 liters of water; Shipped with dry ice and blue ice to WRS
Sample Processing	Filtration thru 0.45µm	Unfiltered, acidified	Unfiltered	Filtered thru GF/C (1.2µm)	Filtration thru GF/F (0.7µm)	Sorbant ASE
Analytes	Filtered, acidified: Ca, Mg, Na, K (IC) Filtered: NO_3, SO_4, Cl, NH_4 (IC) DOC (IR) Unfiltered: specific conductance, pH, ANC	Metals: Cd, Cu, Pb, Ni, V, Zn, plus additional metals listed in Table 2.2.1 (ICP-MS)	Hg (oxidation, purge and trap; CVAFS)	Spheroidal carbonaceous particle analysis	Total particulate C and N (EPA Method 440.0)	Target SOC analytes (GC/MS)
Laboratory	USGS-CWSC	USGS-NRP Boulder	USGS-WWSC	ECRC	CBL	SEC

Medium	FISH					
Purpose	Direct measure of food web impacts, bioaccumulation and link to the terrestrial component; evaluation of health and condition effects					
Frequency	Once per site: 4 to 6 sites (2 to 3 core parks) per year					
Samples	~30 fish/lake (3 fish from each of 5 age classes, from both sexes, from a single species); samples frozen on dry ice in field, shipped to WRS, then distributed to appropriate lab.					
	Condition factors	Hematology/ Physiology	Histopathology (gills, kidney, liver, spleen, gonads)	Whole fish tissue		Livers and fillets (from up to 10 additional fish collected for metals analysis)
Sample Processing		Blood obtained by caudal vein puncture, plasma collected and frozen in the field	Organs preserved in 10% neutral buffered formalin	Liquid N_2 homogenization; subsample solvent extracted (ASE) for SOC analyses		Homogenization, freeze drying, microwave digestion
Analytes	Weight, fork length, Macroscopic health index; ages from scales and otoliths	Hematocrits, plasma, cortisol, glucose, sex hormones, and vitellogenin	Evaluation of pathological changes, macrophage aggregate analysis; and reproductive state	Hg (Direct Hg Analyzer)	Target SOC analyses (GC/MS)	Metals: Cd, Cu, Pb, Ni, V, Zn (ICP/MS)
Laboratory	In field, and OSU-Fish	In field, and OSU-Fish	OSU-Fish	WRS	SEC	USGS-NRP Boulder

Medium	LICHENS			CONIFER NEEDLES and LICHENS		SUBSISTENCE NATIVE FOOD (MOOSE)		
Purpose	Direct measure of food web impacts and bioaccumulation; used primarily to evaluate N, S, and heavy metal impacts			Measure of ecosystem exposure, large "n" for statistical comparisons within and among sites, parks, regions, and elevations		Direct measure of food sources (moose) used by native people		
Frequency	Once per site: from 12 sites in 8 core parks in 2004			Once per site: Elevational transects (~5 sites/park) from 8 core (2004) and 12 secondary parks (2005). Pilot study (4 sites) in SEKI in 2003		Once: Alaska only, 3 moose collected		
Samples	6 lichen samples collected per site (3 samples each of 2 species); ~20 g dry weight of material for each sample; Shipped with ice to WRS			One lichen species and second-year needles from one conifer species at 5 sites at different elevations per park; 3 samples collected at each core park site, 1 sample collected at each secondary park site; Shipped with ice to WRS		Samples provided to Parks by native hunters; Shipped with dry ice to WRS		
Sample Processing	Ground thru 20 mesh, then oven dried at 65°C to constant weight			SOCs: Extraction using ASE N: Ground thru 20 mesh, then oven dried at 65°C to constant weight		Hg & SOCs: Liquid N_2 homogenization; subsample solvent extracted (ASE) for SOC analyses Metals: Homogenization, freeze drying, microwave digestion		
Analytes	S	Metals: Cd, Cu, Pb, Ni, V, Zn (ICP-MS)	Hg (Direct Hg Analyzer)	N	Target SOC analytes (GC/MS)	Hg (Direct Hg Analyzer)	Target SOC analytes (GC/MS)	Metals: Cd, Cu, Pb, Ni, V, Zn (ICP-MS)
Laboratory	UMNRAL	USGS-NRP Boulder	WRS	UMNRAL	SEC	WRS	SEC	USGS-NRP Boulder

Medium	WATER		LAKE SEDIMENT				
Purpose	System characterization; standard water quality information	Hydrophilic current-use chemicals and SOCs	Historic trends (~150 years) of contaminant loading to catchments				
Frequency	Once per site: 4 to 6 sites (2 to 3 core parks) per year	Once per site: 4 to 6 sites (2 to 3 core parks) per year	Once per site: 4 to 6 sites (2 to 3 core parks) per year				
Samples	**Inorganic** 2 L water sample, 2 60-ml syringe samples; shipped with ice to WRS	**Organic** ~50 L water sample filtered *in situ*; filters shipped with dry ice to WRS	Sediment cores, sectioned in 0.5 cm intervals to 10 cm, then 1.0 cm intervals to 30 cm.; shipped with ice packs to WRS				
Analytes	*In situ:* specific conductance, DO, temperature, turbidity Filtered: Ca, Mg, Na, K, Zn, Se (AAS), NO3, SO4, Cl, (IC) SiO2, NH4 (AA), DOC (IR), color Unfiltered: TN, TP (FIA), ANC, TSS Syringe "closed system" samples: pH, DIC	Target SOC analytes, particulate and dissolved phases (GC/MS)	Dating profiles (^{210}Pb, ^{137}Cs, ^{241}Am)	Spheroidal carbonaceous particle analysis	%moisture, Ash-free dry weight (loss-on-ignition) or total organic carbon Hg (Direct Hg Analyzer)	Target SOC analytes (GC/MS)	Metals: Cd, Cu, Pb, Ni, V, Zn (ICP-MS)
Laboratory	WRS	SEC	ERRC	ECRC	WRS	SEC	USGS-NRP Boulder

Abbreviations:

AAS	Atomic absorption spectrophotometry
ASE	Accelerated solvent extraction
CVAFS	Cold vapor atomic fluorescence spectrometry
FIA	Flow injection analysis
GC/MS	Gas chromatography with mass spectrometry
IC	Ion chromatography
ICP-AES	Inductively coupled plasma with atomic emission spectrometry
ICP-MS	Inductively coupled plasma with mass spectrometry
IR	Infrared detection

Laboratories:

Laboratory Abbreviation	**Laboratory**
CBL	Chesapeake Biological Laboratory, Univ. of Maryland, Solomons, MD
ECRC	Environmental Change Research Centre, University College London, London, UK
ERRC	University Environmental Radioactivity Research Centre, University of Liverpool, Liverpool, UK
OSU-Fish	OSU Kent Laboratory, Corvallis, OR
SEC	Simonich Environmental Chemistry Laboratory, OSU, Corvallis, OR
UMNRAL	University of Minnesota Research Analytical Laboratory, St. Paul, MN
USGS-NRP Boulder	National Research Program Laboratory, Boulder, CO
USGS-CWSC	USGS Colorado Water Science Center, Alpine Hydrologic Research Team, Lakewood, CO
USGS-WWSC	USGS Wisconsin Water Science Center, Mercury Research Laboratory, Middleton, WI
WRS	Willamette Research Station Analytical Laboratory, USEPS, Corvallis, OR

APPENDIX 3B

Sampling Information, Methods, and Data Quality

The WACAP Quality Assurance Project Plan (QAPP), May 2004, outlines the quality assurance and quality control objectives for WACAP.

Snow QA/QC

Field

Quality assurance and quality control procedures for handling US Geological Survey (USGS) snow chemistry samples were well established, with annual regional surveys dating back to 1993. A detailed description of sampling protocols was contained in each field kit, and experienced personnel led each site visit. Information about snowpack physical characteristics was recorded on prepared data sheets. All original data sheets were carried as personal baggage during transit and were photocopied and kept in separate locations, as soon as facilities permitted.

Approximately 10% of the total number of samples were field processing blanks and field replicates. Field blanks were collected to detect possible contamination from collection methods, laboratory processing, DI rinse water, filtering apparatus, and Teflon collection bags. Field replicates were also useful for this purpose, but in addition to contamination, they also reflect the natural variability in snow chemistry and the precision of analytical techniques.

Laboratory

Detailed laboratory QA/QC procedures are specified in the WACAP QAPP. Quality control at the USGS Colorado District laboratory involves systematically analyzing blanks, an internal reference sample, USGS standard reference water samples, and certified nutrient standards from High Purity Standards, Inc. International blind audit samples from Environment Canada were analyzed twice per year. Approximately 40% of sample batch run time for the analytical instrumentation was dedicated to analyzing blanks, duplicates, reference samples, and standards. Calibration verifications were made with standards at the beginning and end of each batch of sample analyses on the ion chromatograph.

Quality control at the USGS National Research Program laboratory involves systematic analysis of blanks, standard reference materials, and spike addition samples. Details, results, and figures are described in the Quality Assurance/Quality Control section of the database.

Ionic charge balance was calculated as the sum of cations (hydrogen ion, calcium, magnesium, sodium, potassium, and ammonium) minus the sum of anions (alkalinity, chloride, nitrate, and sulfate) divided by the total cations and anions in solution. Alkalinities were predominantly negative for snow samples; only positive values for alkalinity were included with the sum of anions in charge-balance calculations. Analytical results and charge balance values were examined and outliers for the snow sample database and rerun were performed as necessary.

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. The analyte recovery over the entire analytical method and the estimated method detection limits for snow is given in Table 3B-1.

Metals

Detailed laboratory QA/QC procedures are specified in the WACAP QAPP. Quality control at the USGS Colorado District laboratory involves systematically analyzing blanks, an internal reference sample, USGS standard reference water samples, and certified nutrient standards from High Purity Standards, Inc. International blind audit samples from Environment Canada were analyzed twice per year. Approximately 40% of sample batch run time for the analytical instrumentation was dedicated to analyzing blanks, duplicates, reference samples, and standards. Calibration verifications were made with standards at the beginning and end of each batch of sample analyses on the ion chromatograph.

Quality control at the USGS National Research Program laboratory involves systematic analysis of blanks, standard reference materials, and spike addition samples. Details, results and figures are described in the Quality Assurance/Quality Control Section of the database (Table 3B-2).

Ionic charge balance was calculated as the sum of cations (hydrogen ion, calcium, magnesium, sodium, potassium, and ammonium) minus the sum of anions (alkalinity, chloride, nitrate, and sulfate) divided by the total cations and anions in solution. Alkalinities were predominantly negative for snow samples; only positive values for alkalinity were included with the sum of anions in charge-balance calculations. Analytical results and charge balance values were examined and outliers for the snow sample database and rerun were performed as necessary.

Passive Air Sampler QA/QC

Passive Air Sampler Deployment Summary

Table 3B-3 lists the latitude, longitude, and elevation of each site where a PASD was deployed.

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. The analyte recovery over the entire analytical method and the estimated method detection limits for PASDs is given in Table 3B-4.

Table 3B-1. SOC Recovery and EDLs in Snow Over the Entire Analytical Method (Usenko et al., 2005).

Chemical Class / Compounds	log K_{ow}	50 L Melted Snow[2] Avg. % Rec	% RSD	EDL[3] pg/L
Amide Pesticides				
Propachlor	2.4	139.5	19.5	3.7
Alachlor	2.6	79.7	1.0	43.4
Acetochlor	3.03[1]	65.6	6.9	25.2
Metolachlor	3.1	89.0	1.4	13.8
Organochlorines Pesticides and Metabolites				
HCH, gamma	3.8	87.9	6.3	12.3
HCH, alpha	3.8	71.7	7.4	18.2
HCH, beta	4.0	100.7	7.2	32.1
HCH, delta	4.1	111.8	5.2	20.7
Methoxychlor	4.5	59.1	20.9	16.4
Heptachlor epoxide	4.6	31.8	32.0	14.7
Endrin aldehyde	4.8	40.6	13.8	23.2
Endrin	5.2	90.2	26.8	47.6
Heptachlor	5.2	49.9	19.6	121.7
o,p'-DDE	5.5	55.3	12.9	24.7
Chlordane, oxy	5.5	28.1	31.5	9.4
Dieldrin	5.5	109.1	23.5	105.6
Chlordane, cis	5.9	32.7	29.1	16.3
p,p'-DDD	5.9	66.5	14.6	44.0
Nonachlor, trans	6.1	56.4	16.7	0.9
o,p'-DDD	6.1	41.5	25.7	24.7
Chlordane, trans	6.1	60.9	15.3	0.4
Nonachlor, cis	6.1	30.2	27.3	0.6
Aldrin	6.4	43.7	25.9	107.6
o,p'-DDT	6.5	36.4	5.6	23.4
p,p'-DDE	6.8	50.1	19.6	10.3
Mirex	6.9	51.5	10.6	27.1
p,p'-DDT	6.9	61.9	24.3	26.2
Organochlorine Sulfides and Metabolites				
Endosulfan sulfate	3.7	65.4	17.3	1.0
Endosulfan I	4.7	51.3	17.7	4.9
Endosulfan II	4.8	53.3	18.1	2.0
Phosphorothioate Pesticides				
Methyl parathion	2.7	74.6	1.0	52.0
Malathion	2.9	54.8	13.6	8.4
Diazinon	3.7	75.0	11.7	9.1
Parathion	3.8	56.9	9.6	3.2
Ethion	5.1	46.7	30.0	6.2
Chlorpyrifos	5.1	59.7	22.5	6.9
Thiocarbamate Pesticides				
EPTC	3.2	64.8	25.2	45.0
Pebulate	3.8	99.9	33.2	63.8
Triallate	4.6	73.6	18.5	10.1

Chemical Class / Compounds	log K_{ow}	50 L Melted Snow[2] Avg. % Rec	% RSD	EDL[3] pg/L
Triazine Herbicides and Metabolites				
Atrazine desisopropyl	1.36[1]	nd[5]	nd[5]	na[6]
Atrazine desethyl	1.78[1]	nd[5]	nd[5]	na[6]
Simazine	2.2	nd[5]	nd[5]	na[6]
Cyanazine	2.2	107.8	2.3	26.2
Atrazine	2.3	105.8	4.2	11.5
Prometon	2.7	62.8	15.6	34.6
Miscellaneous Pesticides				
Metribuzin	1.70[1]	77.4	2.1	24.5
Etridiazole	2.6	206.2	26.1	22.5
Dacthal	4.3	109.9	10.5	1.7
Trifluralin	5.3	47.6	30.2	0.7
Hexachlorobenzene	5.5	55.3	14.6	0.2
Polycyclic Aromatic Hydrocarbons				
Acenaphthylene	3.9	52.7	1.8	19.8
Acenaphthene	4.0	101.3	2.1	11.3
Fluorene	4.2	93.2	4.7	8.3
Anthracene	4.5	73.0	7.3	19.9
Phenanthrene	4.5	82.7	5.1	8.8
Pyrene	5.1	74.4	10.5	4.9
Fluoranthene	5.2	77.9	10.7	4.0
Chrysene + Triphenylene	5.7	71.2	11.2	13.3
Benzo(a)anthracene	5.9	70.5	11.1	14.6
Retene	6.4	61.0	4.0	33.4
Benzo(k)fluoranthene	6.5	66.7	10.3	5.0
Benzo(a)pyrene	6.5	59.3	10.9	7.9
Benzo(b)fluoranthene	6.6	68.4	11.4	6.9
Indeno(1,2,3-cd)pyrene	6.7	61.5	9.1	31.5
Dibenz(a,h)anthracene	6.8	62.9	8.5	28.9
Benzo(e)pyrene	6.9	59.3	10.9	8.9
Benzo(ghi)perylene	7.0	59.2	9.4	16.5
Polychlorinated Biphenyls (PCBs)				
PCB 74	6.3	45.5	23.2	124.8
PCB 101	6.4	48.5	21.4	31.0
PCB 138	6.7	53.3	18.1	2.8
PCB 153	6.9	51.3	17.7	1.3
PCB 118	7.0	52.8	21.8	1.3
PCB 187	7.2	56.0	18.1	0.9
PCB 183	8.3	55.1	17.8	1.2
Average Recoveries and Standard Deviations[4]				
Average		68.3	14.8	21.9
Max		206.2	33.2	124.8
Min		28.1	1.0	0.2

[1]Estimated log K_{ow}. [2]Recoveries validated at 6 ng/L and were corrected for background concentrations of SOCs in snow. [3]Sample-Specific Estimated Method Detection Limits. [4]Average recoveries and percent relative standard deviations do not include compounds that were not detected or not applicable. [5]Not Detected (nd) due to lost during silica cleanup. [6]Not Applicable (na) due to lost during silica cleanup.

Table 3B-2. Trace Metals and Detection Limits for Snow Sample Analyses at the USGS National Research Program Laboratory, Boulder, Colorado. Concentrations are in µg/L.

Analyte	Detection Limit	Analyte	Detection Limit
Al	< 0.2	Nd	< 0.0006
As	< 0.02	Ni	< 0.02
B	< 3	Pb	< 0.004
Ba	<0.005	Pr	< 0.0003
Be	< 0.005	Rb	< 0.0006
Bi	< 0.0009	Re	< 0.0002
Cd	< 0.002	Sb	< 0.001
Ce	< 0.0002	Se	< 0.05
Co	< 0.002	Sm	< 0.0002
Cr	< 0.2	Sr	< 0.03
Cs	< 0.009	Tb	< 0.0001
Cu	< 0.04	Te	< 0.005
Dy	< 0.0004	Th	< 0.0004
Er	< 0.0002	Tl	< 0.001
Eu	< 0.0002	Tm	< 0.0001
Gd	< 0.0002	U	< 0.0004
Ho	< 0.0001	V	< 0.07
La	< 0.0002	W	< 0.001
Li	< 0.008	Y	< 0.0002
Lu	< 0.0001	Yb	< 0.0002
Mn	< 0.01	Zn	< 0.04
Mo	< 0.03	Zr	< 0.0008

Table 3B-3. Extended Details of Passive Sampling Device (PASD) Locations. Mapping datum is WGS84.

Park Code	# of PSDs	Target Watershed	Latitude	Longitude	Elev (m)	Veg Site
BAND	1		35.8642	-106.4178	2926	BAND5
BIBE *Elevational Gradient*	4		29.1870	-102.9718	560	BIBE1
			29.3079	-103.1828	1067	BIBE2
			29.2534	-103.2979	1920	BIBE4
			29.2465	-103.3049	2316	BIBE5
CRLA	1		42.9233	-122.0162	2713	CRLA5
DENA	2	Wonder N	63.5421	-150.9781	564	DENA2
		Wonder S	63.4549	-150.8761	686	DENA2
GAAR	1	Matcharak	67.7500	-156.2300	505	GAAR1
GLAC	2	Snyder	48.6264	-113.8050	1609	GLAC3
		Oldman	48.5126	-113.4564	2036	GLAC4
GLBA	1		58.6022	-135.8831	8	GLBA1
GRSA	1		37.7149	-105.4704	3338	GRSA5
GRTE	1		43.1300	-110.7800	3048	GRTE5
KATM	1		58.5711	-155.8036	370	KATM3
LAVO	1		40.4476	-121.5662	2713	LAVO5
MORA	2	Golden	46.8866	-121.9002	1369	MORA4
		LP19	46.8226	-121.8963	1372	MORA3
NOAT	1	Burial	68.4100	-159.2200	388	NOAT3
NOCA	1		48.6824	-121.3217	1600	NOCA5
OLYM	2	PJ	47.9500	-123.4200	1392	OLYM4
		Hoh	47.9000	-123.7900	1433	OLYM3
ROMO *Elevational Gradient*	5		40.2368	-105.7992	2560	ROMO1
		Lone Pine	40.2203	-105.7582	2720	ROMO2
			40.2303	-105.7335	3018	ROMO3
		Mills	40.2922	-105.6420	3042	ROMO6
			40.2290	-105.7117	3536	ROMO4
SEKI *Elevational Gradient*	4		36.5176	-118.8003	658	None (Potwisha)
			36.5762	-118.7862	1573	SEKI2
		Emerald	36.5985	-118.7212	2332	SEKI4
			36.6005	-118.6789	2816	SEKI05
STLE *Elevational Gradient*	4		56.7910	-132.5110	1	STLE1
			56.8047	-132.5317	254	STLE2
			56.8095	-132.5407	567	STLE3
			56.8250	-132.5715	815	STLE4
WRST	1		61.3856	-143.6014	648	WRST3
YOSE	1		37.7744	-119.3371	3048	YOSE5

Table 3B-4. SOC Recovery and EDLs in Passive Air Sampling Devices Over the Entire Analytical Method.

	XAD[a]		EDL[b]		XAD[a]		EDL[b]
	Avg. % Rec	% RSD	ng/g dw		Avg. %Rec	%RSD	ng/g dw
			Amide Pesticides				
Propachlor	100.7	3.8	0.05	Acetochlor	87.9	3.1	0.1
Alachlor	97.0	2.1	0.1	Metolachlor	102.6	1.9	0.02
			Organochlorine Pesticides and Metabolites				
HCH, gamma[c]	92.2	0.4	0.01	Chlordane, cis	82.6	3.7	0.02
HCH, alpha[c]	89.9	1.0	0.01	p,p'-DDD[e]	106.3	3.2	0.05
HCH, beta[c]	94.5	1.1	0.00	Nonachlor, trans	99.3	1.6	0.00
HCH, delta[c]	102.9	0.8	0.02	o,p'-DDD[e]	94.9	1.7	0.02
Methoxychlor	110.0	1.4	0.01	Chlordane, trans	104.1	1.1	0.001
Heptachlor epoxide	122.4	1.3	0.03	Nonachlor, cis	93.9	2.5	0.001
Endrin aldehyde	92.9	1.4	0.003	Aldrin	99.2	1.3	0.01
Endrin	107.3	2.2	0.03	o,p'-DDT[f]	67.5	8.8	0.04
Heptachlor	111.6	2.6	0.01	p,p'-DDE[d]	91.0	1.8	0.01
o,p'-DDE[d]	104.2	7.7	0.02	Mirex	86.5	2.5	0.004
Chlordane, oxy	118.2	1.4	0.03	p,p'-DDT[f]	94.4	1.5	0.01
Dieldrin	95.2	1.8	0.02				
			Organochlorine Sulfide Pesticides and Metabolites				
Endosulfan sulfate	94.7	3.6	0.0002	Endosulfan II	97.8	2.3	0.003
Endosulfan I	102.0	1.1	0.003				
			Phosphorothioate Pesticides				
Methyl parathion	80.7	1.4	0.1	Ethion	100.4	8.5	0.1
Malathion	74.0	5.8	0.1	Chlorpyrifos	81.8	2.6	0.003
Diazinon	81.2	2.2	0.04	Chlorpyrifos oxon	150.6	9.9	0.2
Parathion	77.1	3.4	0.1				
			Triazine Herbicides and Metabolites				
Simazine	102.7	1.3	0.1	Atrazine desethyl	107.7	3.4	0.1
Cyanazine	210.0	2.0	0.1	Atrazine desisoproply	102.7	1.4	0.02
Atrazine	90.2	1.0	0.04				
			Miscellaneous Pesticides				
Metribuzin	90.8	7.0	0.02	Trifluralin	82.6	4.5	0.001
Etridiazole	116.5	0.7	0.1	Hexachlorobenzene	93.3	1.0	0.0002
Triallate	91.9	2.2	0.01	EPTC	83.8	1.4	0.2
Dacthal	95.4	3.7	0.002	Pebulate	88.8	1.3	0.1
			Polycyclic Aromatic Hydrocarbons				
Acenaphthylene	48.4	25.6	0.03	Benzo[k]fluoranthene (BkF)	79.6	2.4	0.01
Acenaphthene	81.2	4.4	0.04	Benzo[a]pyrene (BaP)[g]	88.2	0.0	0.02
Fluorene	92.1	2.2	0.04	Benzo[b]fluoranthene (BbF)	99.2	0.7	0.007
Anthracene	20.9	154.8	0.1	Indeno[1,2,3-cd]pyrene (Ind)	93.7	1.4	0.01
Phenanthrene	99.4	2.2	0.1	Dibenz[a,h]anthracene	89.9	2.4	0.02
Pyrene (Pyr)	89.4	2.7	0.01	Benzo[e]pyrene (BeP)	101.8	3.6	0.009
Fluoranthene (Fla)	92.2	3.0	0.01	Benzo[ghi]perylene (BghiP)	88.9	2.5	0.01
Chrysene/Triphenylene	87.5	1.9	0.005	Retene	114.2	3.0	0.02
Benzo[a]anthracene	63.8	44.8	0.01				
			Polychlorinated Biphenyls				
PCB 74	93.5	0.6	0.1	PCB 118	70.9	4.6	0.001
PCB 101	88.7	3.1	0.003	PCB 187	91.0	1.5	0.001
PCB 138	111.8	1.7	0.001	PCB 183	91.9	1.6	0.0002
PCB 153	103.9	1.6	0.001				
			Averages and % RSD				
average	93.7	5.6	0.03	max	210.0	154.8	0.2
				min	20.9	0.0	0.00

[a] Recoveries were corrected for background concentrations of SOCs in needles. [b]Sample-specific estimated method detection limits calculated from a sample taken from Hoh Lake in Olymic National Park. [c]Hexachlorocyclohexane. [d]Dichlorodiphenyldichloroethylene. [e]Dichlorodiphenyldichloroethane. [f]Dichlorodiphenyltrichloroethane. [g]Data obtained from one sample.

Vegetation QA/QC

Vegetation Sample Summary

Table 3B-5. Vegetation Sample Summary by Park.

Park Type	Park	Sampling Month	# Sites	# Conifer samples	# Lichen samples
Core	DENA	8/2004	6	12	29
	GAAR	7/2004	1	0	7
	GLAC	8/2004	5	15	25
	MORA	8/2004	5	18	19
	NOAT	6/2004	3	0	15
	OLYM	9/2004	5	15	21
	ROMO	9/2004	5	18	6
	SEKI*	10/2004	8	32	26
Secondary	BAND	6/2005	5	6	6
	BIBE	6/2005	5	5	2
	CRLA	8/2005	5	6	5
	GLBA	7/2005	4	4	4
	GRSA	6/2005	5	5	2
	GRTE	7/2005	5	6	3
	KATM	6/2005	6	5	6
	LAVO	8/2005	5	5	5
	NOCA	7/2005	5	5	5
	STLE	7/2005	5	6	10
	WRST	7/2005	5	7	7
	YOSE	8/2005	5	6	4
Total:	**20**	**8**	**98**	**176**	**207**

Table 3B-6. Vegetation Sample Summary. Species collected at each site are recorded in Appendix 1A-3.

Sample type	Genus	Scientific name	Common name	Parks where samples were collected	SOC samples	N samples	N, S & metals samples
Conifer needles	*Abies*	*Abies amabilis*	Pacific silver fir	MORA, NOCA, OLYM, ROMO, SEKI	13	0	0
		Abies concolor	white fir	CRLA, LAVO	9	0	0
		Abies lasiocarpa	subalpine fir	GLAC, GRTE, OLYM	22	0	0
		Abies magnifica	Red fir	CRLA, LAVO, SEKI	12	0	0
		Abies procera	Noble fir	MORA	4	0	0
	Picea	*Picea engelmanii*	Engelmann spruce	GLAC, ROMO	9	0	0
		Picea glauca	white spruce	KATM, WRST	10	0	0
		Picea mariana	black spruce	DENA	12	0	0
		Picea sitchenis	Sitka spruce	GLBA, STLE, WRST	12	0	0
	Pinus	*Pinus albicaulis*	white pine	CRLA, GRTE	3	0	0
		Pinus cembroides	Mexican pinyon	BIBE	3	0	0
		Pinus contorta	lodgepole pine	GRTE, SEKI, YOSE	7	0	0
		Pinus edulis	twoneedle pine	BAND, GRSA	5	0	0
		Pinus flexiilis	limber pine	GRSA, GRTE	5	0	0
		Pinus lambertiana	sugar pine	YOSE	1	0	0
		Pinus ponderosa	ponderosa pine	BAND, YOSE	5	0	0
		Pinus sabiniana	California foothill pine	YOSE	1	0	0
	Psuedotsuga	*Pseudotsuga menziesii*	Douglas-fir	GLAC, NOCA	4	0	0
	Tsuga	*Tsuga heterophylla*	western hemlock	GLAC, MORA, NOCA, OLYM	20	0	0
Lichens	*Alectoria*	*A. sarmentosa*	old man's beard lichen	GLAC, GLBA, MORA, NOCA, OLYM, STLE	26	11	15
	Bryoria	*Bryoria spp.*	horsehair lichen	OLYM	6	6	0
	Cladina	*C. arbuscula*	reindeer lichen	STLE, WRST	2	2	0
	Flavocetraria	*F. cucullata*	reindeer lichen	DENA, GAAR, KATM, NOAT, WRST	8	0	11
	Hypogymnia	*H. apinnata*	tube lichen	WRST	3	3	0
		H. physodes	tube lichen	GLAC, KATM, WRST	7	7	0
	Letharia	*L. columbiana*	wolf lichen	LAVO	1	1	0
		L. vulpina	wolf lichen	CRLA, GLAC, GRTE, LAVO, SEKI, YOSE	29	23	6
	Lobaria	*Lobaria oregana*	Oregon lung lichen	OLYM, STLE	4	4	0
	Masonhalea	*M. richardsonii*	Mason Hale's lichen	DENA, GAAR, NOAT	23	11	12
	Platismatia	*P. glauca*	ragged lichen	GLAC, GLBA, NOCA, OLYM, STLE, WRST	15	10	5
	Sphaerophorus	*S. globosus*	globe ball lichen	GLBA	2	2	0
	Thamnolia	*Thamnolia sp.*	whiteworm lichen	DENA	1	1	0
	Usnea	*Usnea spp.*	beard lichen	BAND, BIBE, GRTE	8	8	0
	Xanthoparmelia	*Xanthoparmelia spp.*	xanthoparmelia lichen	BAND, GRSA, ROMO, YOSE	8	5	3
Needles Count:	***5***		**19**		**157**	**0**	**0**
Lichens Count:	***13***		**16**		**143**	**94**	**52**
Total Count:	***19***		***36***		***300***	***94***	***52***

Figure 3B-1. Vegetation Sampling. First row: lichen sampling from tundra, rocks and trees; second row: conifer needle sampling from mid and alpine elevations; third row: lichen and conifer samples in Kapak bags; fourth row: weighing and sealing vegetation samples.

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. The analyte recovery over the entire analytical method and the estimated method detection limits for conifer needles are given in Table 3B-7 and for lichen in Table 3B-8.

Table 3B-7. SOC Recovery and EDLs in Conifer Needles Over the Entire Analytical Method.

	Local Conifer Needles[a]		EDL[b]		Local Conifer Needles[a]		EDL[b]
	Avg. % Rec	% RSD	ng/g dw		Avg. %Rec	%RSD	ng/g dw
			Organochlorine Pesticides and Metabolites				
HCH, gamma[c]	79.1	1.7	1.9	Chlordane, cis	57.6	0.9	0.6
HCH, alpha[c]	80.2	2.1	1.5	p,p'-DDD[e]	71.7	4.8	6.0
HCH, beta[c]	74.8	1.3	1.7	Nonachlor, trans	58.9	3.1	0.2
HCH, delta[c]	91.5	2.1	3.1	o,p'-DDD[e]	71.8	0.5	5.4
Methoxychlor	84.9	2.4	5.3	Chlordane, trans	82.8	4.6	0.05
Heptachlor epoxide	75.4	6.7	1.2	Nonachlor, cis	30.5	1.8	0.1
Endrin aldehyde	24.6	3.7	0.9	Aldrin	72.6	3.8	2.2
Endrin	79.5	5.4	14.6	o,p'-DDT[f]	57.7	1.8	1.7
Heptachlor	85.6	3.2	3.3	p,p'-DDE[d]	81.1	1.2	1.8
o,p'-DDE[d]	67.0	1.0	3.6	Mirex	87.9	0.9	0.4
Chlordane, oxy	78.8	7.1	1.6	p,p'-DDT[f]	66.8	0.9	2.5
Dieldrin	75.1	9.5	5.8				
			Organochlorine Sulfide Pesticides and Metabolites				
Endosulfan sulfate	80.6	4.6	0.6	Endosulfan II	63.8	1.0	0.7
Endosulfan I	62.4	2.6	0.2				
			Phosphorothioate Pesticides				
Chlorpyrifos	68.8	0.6	0.4	Methyl parathion	51.1	44.4	72.3
			Miscellaneous Pesticides				
Dacthal	83.2	3.9	0.1	Triallate	92.8	11.2	1.7
Hexachlorobenzene	71.0	1.5	0.0	Trifluralin	77.2	0.3	0.1
			Polycyclic Aromatic Hydrocarbons				
Acenaphthylene	53.2	2.5	2.3	Benzo[a]anthracene	78.2	2.7	13.0
Acenaphthene	80.4	9.5	7.1	Benzo[k]fluoranthene (BkF)	71.9	2.7	6.5
Fluorene	66.3	10.7	3.2	Benzo[a]pyrene (BaP)	92.6	0.8	8.4
Anthracene	79.1	1.2	10.4	Benzo[b]fluoranthene (BbF)	76.3	2.9	7.9
Phenanthrene	51.2	5.8	4.8	Indeno[1,2,3-cd]pyrene (Ind)	84.3	1.0	16.4
Pyrene (Pyr)	79.7	3.1	0.6	Dibenz[a,h]anthracene	62.5	3.0	58.5
Fluoranthene (Fla)	85.6	5.3	3.7	Benzo[e]pyrene (BeP)	81.7	2.7	9.4
Chrysene/Triphenylene	86.6	2.3	4.3	Benzo[ghi]perylene (BghiP)	87.7	1.8	3.0
			Polychlorinated Biphenyls				
PCB 74	97.3	2.3	16.7	PCB 118	89.2	0.8	0.2
PCB 101	81.3	2.4	2.2	PCB 187	85.7	0.9	0.04
PCB 138	78.8	1.9	0.2	PCB 183	79.8	1.1	0.04
PCB 153	81.2	1.7	0.05				
			Averages, % RSD, and PD[c]				
average	73.2	3.7	5.7	max	97.3	44.4	72.3
				min	24.6	0.3	0.01

[a]Samples collected at Walnut Park located in Corvallis, OR, USA. Recoveries were corrected for background concentrations of SOCs in needles.
[b]Sample-specific estimated method detection limits calculated from a sample taken from Mount Rainier National Park. [c]Hexachlorocyclohexane.
[d]Dichlorodiphenyldichloroethylene. [e]Dichlorodiphenyldichloroethane. [f]Dichlorodiphenyltrichloroethane.

Table 3B-8. SOC Recovery and EDLs in Lichen Over the Entire Analytical Method.

	Wolverton Creek[a]		EDL[b]		Wolverton Creek[a]		EDL[b]
	Avg. % Rec	% RSD	ng/g lipid		Avg. %Rec	%RSD	ng/g lipid
			Organochlorine Pesticides and Metabolites				
HCH, gamma[c]	73.8	5.6	1.0	Chlordane, cis	62.4	13.2	2.7
HCH, alpha[c]	81.6	4.8	0.9	p,p'-DDD[e]	76.8	7.2	5.3
HCH, beta[c]	80.9	0.6	1.9	Nonachlor, trans	56.9	16.8	0.4
HCH, delta[c]	88.9	6.5	1.0	o,p'-DDD[e]	79.5	0.7	7.3
Methoxychlor	71.3	28.4	7.3	Chlordane, trans	59.0	15.9	0.21
Heptachlor epoxide	58.7	13.2	4.6	Nonachlor, cis	31.3	6.8	0.2
Endrin aldehyde	52.0	9.7	0.5	Aldrin	76.0	4.0	2.6
Endrin	93.8	13.6	6.9	o,p'-DDT[f]	52.4	25.9	13.5
Heptachlor	81.8	3.3	1.5	p,p'-DDE[d]	77.3	1.6	6.4
o,p'-DDE[d]	68.0	1.0	7.1	Mirex	139.5	7.6	1.0
Chlordane, oxy	57.5	12.0	1.7	p,p'-DDT[f]	90.8	40.0	6.3
Dieldrin	120.4	10.0	8.0				
			Organochlorine Sulfide Pesticides and Metabolites				
Endosulfan sulfate	38.4	22.6	0.4	Endosulfan II	64.8	5.9	0.2
Endosulfan I	62.0	10.9	1.1				
			Phosphorothioate Pesticides				
Chlorpyrifos	92.7	1.6	0.2	Methyl parathion	80.0	3.7	54.3
			Miscellaneous Pesticides				
Dacthal	68.6	20.0	0.2	Triallate	99.8	37.2	0.9
Hexachlorobenzene	72.8	1.7	0.01	Trifluralin	94.1	2.0	0.1
			Polycyclic Aromatic Hydrocarbons				
Acenaphthylene	50.3	14.5	13.7	Benzo[a]anthracene	87.3	2.4	2.4
Acenaphthene	68.5	19.2	6.3	Benzo[k]fluoranthene (BkF)	54.8	87.3	9.2
Fluorene	74.6	6.2	2.7	Benzo[a]pyrene (BaP)	71.4	30.0	5.3
Anthracene	82.9	0.4	4.9	Benzo[b]fluoranthene (BbF)	55.7	90.5	9.1
Phenanthrene	67.1	17.8	2.3	Indeno[1,2,3-cd]pyrene (Ind)	82.4	2.9	5.9
Pyrene (Pyr)	75.5	2.0	1.7	Dibenz[a,h]anthracene	80.5	6.7	23.0
Fluoranthene (Fla)	77.7	2.8	1.7	Benzo[e]pyrene (BeP)	70.0	16.1	7.0
Chrysene/Triphenylene	87.6	1.3	1.8	Benzo[ghi]perylene (BghiP)	90.2	3.1	2.4
			Polychlorinated Biphenyls				
PCB 74	89.0	2.3	9.1	PCB 118	89.9	0.8	0.3
PCB 101	77.3	2.0	3.7	PCB 187	75.7	4.5	0.11
PCB 138	76.2	5.6	0.2	PCB 183	75.9	10.7	0.09
PCB 153	75.5	3.3	0.12				
			Averages and % RSD				
average	73.9	12.3	4.6	max	139.5	90.5	54.3
				min	31.3	0.4	0.01

[a]Samples collected at Wolverton Creek in Sequoia and Kings Canyon National Park, CA in 2003. Recoveries were corrected for background concentrations of SOCs in lichen. [b]Sample-specific estimated method detection limits calculated from a sample taken from Mount Rainier National Park. [c]Hexachlorocyclohexane. [d]Dichlorodiphenyldichloroethylene. [e]Dichlorodiphenyldichloroethane. [f]Dichlorodiphenyltrichloroethane.

Metals (Lichen)

Detailed laboratory QA/QC procedures are specified in the WACAP QAPP. Quality control at the USGS National Research Program laboratory in Boulder, Colorado (see Table 3B-9), involves systematic analysis of blanks, replicates, standard reference materials, and spike addition samples. Standard Reference Materials used for the quality control of lichen analysis included Commission of European Communities CRM 482 Trace Elements in Lichen and International Atomic Energy Agency IAEA-336 Trace and Minor Elements in Lichen. Details, results and figures are described in the Quality Assurance/Quality Control Section of the database.

Table 3B-9. Metals and Detection Limits for Lichen Sample Analyses Performed at the USGS National Research Program Laboratory, Boulder, Colorado. Concentrations in dry weight, assuming a 0.2 g sample size (1:10 dilution).

Analyte	Units	Detection Limit	Analyte	Units	Detection Limit
Al	µg/g	< 1	Mn	µg/g	< 0.2
As	µg/g	< 0.05	Mo	µg/g	< 0.3
B	µg/g	<14	Na	Wt%	< 0.0008
Ba	µg/g	<0.03	Nd	µg/g	< 0.004
Be	µg/g	< 0.03	Ni	µg/g	< 0.1
Bi	µg/g	< 0.01	Pb	µg/g	< 0.04
Ca	Wt%	<0.001	Pr	µg/g	< 0.001
Cd	µg/g	< 0.01	Rb	µg/g	< 0.02
Ce	µg/g	< 0.001	Re	µg/g	< 0.002
Co	µg/g	< 0.01	Sb	µg/g	< 0.01
Cr	µg/g	< 0.5	Se	µg/g	< 0.2
Cs	µg/g	<2	Sm	µg/g	< 0.005
Cu	µg/g	< 0.1	Sr	µg/g	< 0.08
Dy	µg/g	< 0.003	Tb	µg/g	< 0.0007
Er	µg/g	< 0.004	Te	µg/g	< 0.04
Eu	µg/g	< 0.001	Tl	µg/g	< 0.02
Fe	µg/g	<20	Tm	µg/g	< 0.0007
Gd	µg/g	< 0.003	U	µg/g	< 0.004
Ho	µg/g	< 0.001	V	µg/g	< 0.1
K	Wt%	<0.006	W	µg/g	< 0.01
La	µg/g	< 0.001	Y	µg/g	< 0.001
Li	µg/g	< 0.04	Yb	µg/g	< 0.003
Lu	µg/g	< 0.0007	Zn	µg/g	< 0.9
Mg	Wt%	< 0.0003	Zr	µg/g	< 0.09

Nitrogen and Sulfur (Lichen)

As macronutrients, nitrogen and sulfur are used in relatively large quantities by lichens in cellular metabolism and in the production of biomolecules. Even in geographic areas with low nitrogen and sulfur deposition, these elements occur in relatively high concentrations in lichen thalli (~ 1 and 0.1 % dry weight, respectively), and therefore, compared to other contaminants analyzed by WACAP, their quantification is relatively easy. Four types of quality control checks were employed:

1. *Randomization of samples*. Samples were analyzed in random order before analysis to prevent unintentional bias within and between batches.
2. *Field triplicates*. Triplicate samples of each lichen species were collected at each collection site in the core parks as an indicator of error due to field methodology. Triplicate samples that are truly representative of the lichen population at a site will have low variability.
3. *Laboratory replicates*. Duplicate measurements were made of every 10th sample to assess precision of laboratory measurements.
4. *Standard Reference Materials*. NIST 1515 Apple Leaves and NIST 1547 Peach Leaves to assess accuracy of laboratory measurements.
5. *Lichen reference materials*. A 1998 US Forest Service bulk collection of *Alectoria sarmentosa* from Willamette Pass, Oregon, dried, ground and stored in air tight container at UMRAL. This lichen has a relatively low N and S content compared to most lichen species and all NIST SRMS and therefore is more challenging to analyze. An aliquot of the bulk collection was analyzed every 10 samples to assess worst-case precision of laboratory measurements and to compare to laboratory performance to prior years.

Table 3B-10 shows that variability in N and S concentrations between sites (WACAP lichens), measured either as the standard deviation or as the size of the standard deviation relative to the mean (100* sd/mean), was greater than that of the field triplicates, which was in turn, greater than variability among laboratory and AlesarWIL replicates. Laboratory precision of nitrogen analyses was excellent, with most values for individual replicates falling within 1% of means; precision of sulfur analyses was good, most individual values were <5% of means. UMRAL measurements of NIST SRMs fell within certified ranges for N. UMRAL values were close to non-certified values for S (NIST does not certify means or ranges for S).

Table 3B-10. Statistical Summary of Quality Control Measures for Total Nitrogen and Sulfur (% dw) in Lichen Samples from the WACAP Core Parks.

Element	Material	Count	UMRAL Mean	UMRAL sd	100 * (sd/mean)	NIST Mean	NIST Certified Range
N	WACAP lichens	58	0.567	0.303	53.44	NA	NA
	Field triplicates	17	0.585	0.096	16.33	NA	NA
	Lab replicate pairs	5	0.456	0.003	0.76	NA	NA
	AlesarWIL	7	0.423	0.012	2.84	NA	NA
	NIST 1515	3	2.313	0.012	0.50	2.25	2.06-2.44
	NIST 1547	4	3.010	0.022	0.72	2.94	2.82-3.06
S	WACAP lichens	56	0.044	0.030	68.28	NA	NA
	Field triplicates	17	0.045	0.005	11.49	NA	NA
	Lab replicate pairs	8	0.028	0.001	4.57	NA	NA
	AlesarWIL	6	0.034	0.004	10.87	NA	NA
	NIST 1515	5	0.193	0.011	5.60	0.180	NA
	NIST 1547	5	0.163	0.019	11.54	0.200	NA

Lake Water QA/QC

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. The analyte recovery over the entire analytical method and the estimated method detection limits for water are given in Table 3B-11.

Table 3B-11. SOC Recovery and EDLs in Water Over the Entire Analytical Method (Usenko et al., 2005).

Chemical Class	log K_{ow}	1 L RO Water[3]		50 L RO Water[3]	
Compounds		Avg. % Rec	% RSD	Avg. % Rec	% RSD
Amide Pesticides					
Propachlor[2]	2.4	110.2	7.0	111.3	1.9
Alachlor[2]	2.6	101.5	4.0	104.6	0.8
Acetochlor[2]	3.03[1]	96.9	2.9	102.4	2.7
Metolachlor[2]	3.1	109.9	4.8	114.7	1.0
Organochlorines Pesticides and Metabolites					
HCH, gamma[2,4]	3.8	99.2	3.5	103.5	1.0
HCH, alpha[2]	3.8	105.1	7.8	115.9	1.4
HCH, beta[2]	4.0	103.0	5.7	113.8	2.2
HCH, delta[2]	4.1	108.4	4.9	118.9	2.0
Methoxychlor[2]	4.5	127.7	21.3	158.8	2.4
Heptachlor epoxide[2]	4.6	57.5	19.2	72.1	6.3
Endrin aldehyde[2]	4.8	78.3	15.1	74.4	32.0
Endrin[2]	5.2	147.2	30.1	138.6	3.8
Heptachlor[2]	5.2	132.3	28.0	157.4	4.0
o,p'-DDE[2,5]	5.5	86.4	14.9	101.9	0.8
Chlordane, oxy[2]	5.5	55.1	21.7	71.8	4.2
Dieldrin[2]	5.5	100.8	12.6	74.5	3.5
Chlordane, cis[2]	5.9	44.5	18.4	60.6	3.3
p,p'-DDD[2,6]	5.9	105.1	20.8	122.0	3.7
Nonachlor, trans	6.1	49.4	14.1	66.3	2.6
o,p'-DDD[2]	6.1	91.5	18.3	110.1	2.0
Chlordane, trans	6.1	42.4	12.4	55.5	3.0
Nonachlor, cis[2]	6.4	62.5	18.8	75.7	1.4
Aldrin[2]	6.5	57.7	21.0	70.6	1.7
o,p'-DDT[7]	6.8	73.4	3.1	91.5	3.5
p,p'-DDE[2]	6.9	83.2	11.5	97.9	0.8
Mirex[2]	6.9	110.3	10.2	118.3	5.5
p,p'-DDT[2]	6.9	82.3	11.6	97.5	0.4
Organochlorine Sulfide Pesticides and Metabolites					
Endosulfan sulfate[2]	3.7	88.4	19.8	93.3	5.2
Endosulfan I[2]	4.7	55.8	17.8	69.0	6.8
Endosulfan II[2]	4.8	88.1	19.2	98.7	2.8
Phosphorothioate Pesticides					
Methyl parathion[2]	2.7	107.9	5.2	114.4	2.4
Malathion[2]	2.9	97.5	4.9	111.2	4.7
Diazinon[2]	3.7	100.9	9.5	114.5	3.0
Parathion[2]	3.8	97.3	7.3	106.1	4.1
Ethion[2]	5.1	99.6	24.4	115.4	3.8
Chlorpyrifos[2]	5.1	81.9	20.4	96.2	4.3
Thiocarbamate Pesticides					
EPTC[2]	3.2	100.6	1.3	104.2	1.9
Pebulate[2]	3.8	125.3	4.6	128.9	3.2
Triallate[2]	4.6	61.1	20.0	79.7	7.4

Chemical Class	log K_{ow}	1 L RO Water[3]		50 L RO Water[3]	
Compounds		Avg. % Rec	% RSD	Avg. % Rec	% RSD
Triazine Herbicides and Metabolites					
Atrazine desisopropyl	1.36[1]	106.0	6.3	89.3	2.4
Atrazine desethyl	1.78[1]	62.8	7.3	82.8	2.7
Simazine[2]	2.2	115.2	3.6	117.8	0.6
Cyanazine[2]	2.2	60.5	10.9	62.7	4.6
Atrazine[2]	2.3	102.1	2.1	104.6	0.7
Prometon[2]	2.7	68.7	42.7	90.5	8.9
Miscellaneous Pesticides					
Metribuzin[2]	1.70[1]	86.3	14.7	96.1	4.3
Etridiazole[2]	2.6	124.6	4.1	127.7	2.0
Dacthal[2]	4.3	98.7	8.6	104.1	2.9
Trifluralin[2]	5.3	71.2	5.0	62.9	7.8
Hexachlorobenzene[2]	5.5	81.0	13.8	89.1	3.3
Polycyclic Aromatic Hydrocarbons					
Acenaphthylene[2]	3.9	60.3	9.0	63.8	10.9
Acenaphthene[2]	4.0	86.1	5.6	91.9	1.6
Fluorene[2]	4.2	96.9	0.4	102.2	2.5
Anthracene[2]	4.5	41.1	73.6	24.7	69.5
Phenanthrene	4.5	118.3	3.5	104.8	1.3
Pyrene[2]	5.1	84.5	8.6	89.3	1.3
Fluoranthene[2]	5.2	101.2	9.3	105.1	2.7
Chrysene + Triphenylene[2]	5.7	92.1	11.5	106.0	0.9
Benzo(a)anthracene[2]	5.9	76.7	22.3	76.8	20.1
Retene[2]	6.4	121.9	9.6	142.0	3.4
Benzo(k)fluoranthene[2]	6.5	84.6	11.8	100.8	5.3
Benzo(a)pyrene[2]	6.5	98.6	9.1	117.4	5.7
Benzo(b)fluoranthene[2]	6.6	99.9	14.2	117.2	7.4
Indeno(1,2,3-cd)pyrene[2]	6.7	87.9	15.7	103.4	0.5
Dibenz(a,h)anthracene[2]	6.8	102.4	9.4	113.2	2.7
Benzo(e)pyrene[2]	6.9	112.4	19.9	126.4	9.2
Benzo(ghi)perylene[2]	7.0	87.1	9.1	96.9	3.0
Polychlorinated Biphenyls					
PCB 74[2]	6.3	74.5	21.8	106.6	0.9
PCB 101[2]	6.4	66.2	22.3	95.1	1.2
PCB 138[2]	6.7	94.9	3.6	105.1	3.4
PCB 153[2]	6.9	99.3	4.3	110.0	3.5
PCB 118[2]	7.0	57.1	24.8	82.6	0.9
PCB 187[2]	7.2	80.5	5.3	88.5	3.5
PCB 183[2]	8.3	85.3	4.5	94.1	3.9
Average Recoveries and %RSD					
		89.4	13.1	99.0	4.8
Max		147.2	73.6	158.8	69.5
Min		41.1	0.4	24.7	0.4

[1]Estimated log Kow. [2]Recoveries not statistically different: two sided t-test (p<0.01). [3]Recoveries determined at 300 ng total of each compound (300 ng/L for 1 L experiment and 6 ng/L for 50 L experiment). [4]Hexachlorocyclohexane. [5]Dichlorodiphenyldichloroethylene. [6]Dichlorodiphenyldichloroethane. [7]Dichlorodiphenyltrichloroethane

Inorganic Compounds

Table 3B-12. Inorganic Lake Water Analytes, Methods, and Detection Limits

Analyte	Method[1]	Detection Limit[2]
Specific Conductance	EPA 120.6; USEPA (1987)	NA
Temperature	USEPA (1987)	NA
Dissolved Oxygen (DO)	USEPA (1987), YSI Model 6920 Datasonde	NA
Turbidity	YSI Model 6920 Datasonde	0.1 NTU
pH (syringe, closed system)	USEPA (1987)	NA
Acid Neutralizing Capacity (ANC)	EPA 310.1 (modified), USEPA (1987)	NA
Chlorophyll a	APHA (1989)	1 µg/L
Total Suspended Solids (Residue)	EPA 160.2; APHA (1989)	0.1 mg/L
True Color	APHA (1989), EPA 100.2 (modified), USEPA (1987)	NA
Dissolved Organic Carbon (DOC)	EPA 415.2, USEPA (1987)	0.1 mg/L
Dissolved Inorganic Carbon (DIC), syringe, closed system	USEPA (1987)	0.1 mg/L
Ammonium (NH_4)	Lachat 10-107-06-3-D	2 µg/L
Nitrate + Nitrite Nitrogen	EPA 353.2	1 µg/L
Silica (SiO2)	EPA 370.1 (modified), U.S. EPA (1987)	5 µg/L
Total Nitrogen (TN)	EPA 353.2 (modified), USEPA (1987)	10 µg/L
Total Phosphorus (TP)	EPA 365.1 (modified), USEPA (1987)	2 µg/L
Chloride (Cl)	EPA 300.6; USEPA (1987)	0.03 mg/L
Nitrate (NO_3)	EPA 300.6; USEPA (1987)	0.03 mg/L
Sulfate (SO_4)	EPA 300.6; USEPA (1987)	0.05 mg/L
Calcium (Ca)	EPA 215.1; USEPA (1987)	0.02 mg/L
Sodium (Na)	EPA 273.1; USEPA (1987)	0.02 mg/L
Potassium (K)	EPA 258.1; USEPA (1987)	0.04 mg/L
Magnesium (Mg)	EPA 242.1; USEPA (1987)	0.01 mg/L

[1] American Public Health Association. 1989. Standard Methods for the Examination of Water and Wastewater. Seventeenth Edition. American Public Health Association, Washington, D.C.

U.S. EPA. 1983. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory. EPA/600/4-79/020, U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati.

U.S. EPA. 1987. Handbook of Methods for Acid Deposition Studies: Laboratory Analyses for Surface Water Chemistry. EPA 600/4-87/026. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

[2] The method detection limit is determined as a one-sided 99% confidence interval from repeated measurements of a low-level standard across several calibration curves.

Sediment QA/QC

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. The analyte recovery over the entire analytical method and the estimated method detection limits for sediment are given in Table 3B-13.

Table 3B-13. SOC Recovery and EDLs in Sediment Over the Entire Analytical Method.

	Waldo Lake[a]		EDL[b]	SRM1941b				Waldo Lake[a]		EDL[b]	SRM1941b		
	Avg. % Rec	% RSD	ng/g dw	ng/g dw	PD[c]	% RSD		Avg. %Rec	%RSD	ng/g dw	ng/g dw	PD[c]	% RSD
Amide Pesticides													
Propachlor	49.8	3.3	7.8				Acetochlor	46.1	9.3	9.3			
Alachlor	53.1	12.2	13.3				Metolachlor	58.6	12.2	14.2			
Organochlorine Pesticides and Metabolites													
HCH, gamma[d]	29.6	9.4	117.5				Chlordane, cis	45.7	14.7	18.4	0.7	10.0	29.5
HCH, alpha[d]	50.8	9.0	133.3				p,p'-DDD[f]	60.3	10.2	16.5	5.1	0.0	40.0
HCH, beta[d]	36.2	9.1	175.7				Nonachlor, trans	46.8	17.2	3.7	0.1	53.2	32.8
HCH, delta[d]	51.8	9.4	59.5				o,p'-DDD[f]	55.6	10.8	4.3	1.1		
Methoxychlor	67.4	14.8	18.6	1.0			Chlordane, trans	46.8	15.2	2.0	0.4	5.8	28.2
Heptachlor epoxide	46.8	13.8	89.4				Nonachlor, cis	53.6	13.0	1.5	0.1	55.4	24.2
Endrin aldehyde	51.8	7.9	19.6				Aldrin	29.0	12.5	83.2			
Endrin	70.4	11.5	204.7				o,p'-DDT[g]	44.4	12.0	23.6			
Heptachlor	32.5	12.4	111.9				p,p'-DDE[e]	55.9	12.7	3.4	3.1	0.0	15.8
o,p'-DDE[e]	57.7	11.2	11.3				Mirex	56.3	6.3	41.4			
Chlordane, oxy	43.7	14.8	12.2				p,p'-DDT[g]	54.7	13.5	37.9			
Dieldrin	74.0	13.1	114.8	0.3									
Organochlorine Sulfide Pesticides and Metabolites													
Endosulfan sulfate	61.4	9.6	4.4				Endosulfan II	58.5	10.3	9.0			
Endosulfan I	50.2	13.2	8.1										
Phosphorothioate Pesticides													
Methyl parathion	49.9	5.1	33.0				Parathion	54.0	6.5	15.7			
Malathion	48.3	7.9	65.8				Ethion	60.0	10.4	10.8			
Diazinon	47.9	5.4	5.1				Chlorpyrifos	45.3	9.7	1.2			
Triazine Herbicides and Metabolites													
Simazine	63.2	3.4	58.3				Atrazine	57.6	6.3	9.5			
Cyanazine	136.0	19.3	171.2										
Miscellaneous Pesticides													
Metribuzin	43.6	20.6	30.0				Dacthal	55.5	11.5	6.4			
Etridiazole	21.6	13.9	29.1				Trifluralin	32.9	10.8	1.7			
Triallate	41.1	8.6	24.2				Hexachlorobenzene	33.5	8.0	1.0	7.6	24.1	22.8
Polycyclic Aromatic Hydrocarbons													
Acenaphthylene	20.9	14.7	13.3	138.8			Benzo[a]anthracene	64.5	10.2	11.4	250.4	17.8	17.2
Acenaphthene	33.5	13.5	11.2	51.6			Benzo[k]fluoranthene (BkF)	68.5	10.0	3.3	205.6	0.6	21.6
Fluorene	25.5	12.7	7.2	59.2	12.7	22.3	Benzo[a]pyrene (BaP)	46.7	9.3	2.1	220.7	33.6	23.7
Anthracene	34.8	8.0	24.6	163.3	1.5	13.6	Benzo[b]fluoranthene (BbF)	64.8	9.5	4.0	468.2	0.0	18.7
Phenanthrene	26.0	20.0	13.0	382.6	0.0	18.6	Indeno[1,2,3-cd]pyrene (Ind)	60.1	9.5	29.0	239.9	12.9	17.3
Pyrene (Pyr)	50.6	5.7	1.0	402.8	24.0	22.1	Dibenz[a,h]anthracene	58.2	9.8	23.7	76.4	25.3	22.9
Fluoranthene (Fla)	50.5	5.1	1.1	442.6	24.3	20.8	Benzo[e]pyrene (BeP)	64.6	9.1	6.5	285.5	4.5	22.4
Chrysene/Triphenylene	59.9	9.2	0.8	171.2	48.1	22.3	Benzo[ghi]perylene (BghiP)	55.0	11.1	5.1	227.2	11.3	22.0
Polychlorinated Biphenyls													
PCB 101	70.7	14.2	129.1	4.1	13.2	29.9	PCB 118	74.2	11.6	10.2	3.3	17.2	34.5
PCB 138	74.9	11.7	9.7	4.3	12.3	30.4	PCB 187	76.1	13.1	3.9	2.0	0.0	22.1
PCB 153	73.2	11.8	3.5	4.0	21.6	20.1	PCB 183	76.5	13.1	3.7	0.7	23.0	20.4
Polybrominated Diphenyl Ethers													
BDE 7	58.6	3.0	0.2				BDE 85/155	73.0	2.0	1.8			
BDE 8	77.8	2.2	0.1				BDE 99	75.5	2.4	27.2	0.6		
BDE 10	42.7	6.9	0.2				BDE 100	74.1	2.3	9.4	0.9		
BDE 17	78.1	3.6	0.4				BDE 116	72.8	3.2	1.8			
BDE 25	83.3	3.3	0.8				BDE 118	76.5	4.8	15.1			
BDE 28	70.5	4.7	4.1				BDE 119	75.0	2.9	3.3			
BDE 30	70.6	3.9	0.6				BDE 126	69.2	1.7	2.1			
BDE 32	77.2	1.7	0.7				BDE 138	76.0	1.2	3.3			
BDE 35	82.6	3.2	0.7				BDE 153	76.7	1.3	26.0			
BDE 37	80.3	4.0	1.3				BDE 154	84.8	0.8	0.9			
BDE 49	69.4	5.4	1.3				BDE 155	101.6	0.9	15.6			
BDE 47	71.9	4.5	15.6	1.3			BDE 166	72.4	2.0	2.8			
BDE 66	75.2	5.1	0.6				BDE 181	99.9	2.3	5.8			
BDE 71	67.7	4.8	1.3				BDE 183	73.3	2.3	31.3			
BDE 75	70.0	5.4	4.9				BDE 190	104.4	2.1	5.7			
BDE 77	70.5	6.1	0.8										
Averages, % RSD, and PD[c]													
average	60.3	8.5	23.8	109.3	16.8	23.6	max	136.0	20.6	204.7	468.2	55.4	40.0
							min	20.9	0.8	0.1	0.1	0.0	13.6

[a]Recoveries validated at 26 ng/g wet wt and were corrected for background concentrations of SOCs in sediment. [b]Sample-specific estimated method detection limits. [c]Percent Difference from SRM 1941b certified values n=5. [d]Hexachlorocyclohexane. [e]Dichlorodiphenyldichloroethylene. [f]Dichlorodiphenyldichloroethane. [g]Dichlorodiphenyltrichloroethane.

Metals

Detailed laboratory QA/QC procedures are specified in the WACAP QAPP. Quality control at the USGS National Research Program laboratory in Boulder, Colorado, involves systematic analysis of blanks, replicates, standard reference materials, and spike addition samples (see Table 3B-14). Standard reference materials used for the quality control of sediment analysis included National Institute of Standards and Technology SRM 2704 and 8704 Buffalo River Sediment; and SRM 2702 Inorganics in Marine Sediment. Details, results and figures are described in the Quality Assurance/Quality Control Section of the database.

Table 3B-14. Metals and Detection Limits for Sediment Sample Analyses Performed at the USGS National Research Program Laboratory, Boulder, Colorado. Concentrations in dry weight, assuming a 0.1-g sample size (1:10 dilution).

Analyte	Units	Detection Limit	Analyte	Units	Detection Limit
Al	Wt%	< 0.0008	Mo	µg/g	< 0.2
As	µg/g	< 0.07	Na	Wt%	< 0.003
B	µg/g	< 4	Nd	µg/g	< 0.01
Ba	µg/g	<0.08	Ni	µg/g	< 0.06
Be	µg/g	< 0.07	Pb	µg/g	< 0.03
Bi	µg/g	< 0.01	Pr	µg/g	< 0.002
Ca	Wt%	<0.002	Rb	µg/g	< 0.09
Cd	µg/g	< 0.01	Re	µg/g	< 0.003
Ce	µg/g	< 0.01	Sb	µg/g	< 0.01
Co	µg/g	< 0.01	Se	µg/g	< 0.6
Cr	µg/g	< 0.5	Sm	µg/g	< 0.009
Cs	µg/g	<0.02	Sr	µg/g	< 0.1
Cu	µg/g	< 0.1	Tb	µg/g	< 0.001
Dy	µg/g	< 0.005	Te	µg/g	< 0.05
Er	µg/g	< 0.007	Th	µg/g	< 0.01
Eu	µg/g	< 0.003	Ti	Wt%	<0.0001
Fe	Wt%	<0.009	Tl	µg/g	< 0.06
Ga	µg/g	< 0.01	Tm	µg/g	< 0.001
Gd	µg/g	< 0.005	U	µg/g	< 0.007
Ho	µg/g	< 0.002	V	µg/g	< 0.4
K	Wt%	<0.009	W	µg/g	< 0.01
La	µg/g	< 0.007	Y	µg/g	< 0.006
Li	µg/g	< 0.1	Yb	µg/g	< 0.004
Lu	µg/g	< 0.001	Zn	µg/g	< 0.7
Mg	Wt%	< 0.0005	Zr	µg/g	< 0.01
Mn	µg/g	< 0.1			

Fish QA/QC

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. The analyte recovery over the entire analytical method and the estimated method detection limits for fish are given in Table 3B-15.

Table 3B-15. SOC Recovery and EDLs in Fish Over the Entire Analytical Method.

Compounds	Log K_{ow}	Method Recovery[1] (%)		Estimated Method Detection Limit[2] (pg/g ww)		Determined Values for NIST SRM 1946 (ng/g ww)		Deviation from Certified Values[3]
		Avg.	SD	Avg.	%RSD	Avg.	%RSD	% Diff
HCH[4], gamma	3.8	38.2	1.6	17	7.5	1.0	46	0
HCH[4], alpha	3.8	37.6	1.6	0.2	8.1	5.4	6.5	0
HCH4, beta	4.0	44.3	1.7	7.8	1.7	0.46	34	
HCH4, delta	4.1	42.2	1.7	0.6	3.0			
Methoxychlor	4.5	62.1	1.8	99	73			
Heptachlor epoxide	4.6	33.6	2.0	14	2.2	5.3	1.1	0
Endrin	5.2	89.1	2.2	170	26	4.7	0.22	
Heptachlor	5.2	48.5	1.3	1.6	1.42	0.38	37	
Hexachlorobenzene	5.5	37.8	1.9	5.0	1.9	6.6	2.7	0
o,p'-DDE[5]	5.5	53.8	2.1	58	23	0.91	15	0
Chlordane, oxy	5.5	35.1	1.9	5.5	1.9	16	7.9	15
Dieldrin	5.5	95.3	3.6	8.4	21	34	4.8	0
Chlordane, cis	5.9	32.6	1.0	16	6.8	31	8.9	0
p,p'-DDD[6]	5.9	67.8	1.0	99	39	12	9.0	30
Nonachlor, trans	6.1	32.0	1.0	2.9	1.3	90	7.1	9.5
o,p'-DDD6	6.1	55.2	2.1	68	16	1.8	25	17
Chlordane, trans	6.1	31.4	1.0	1.6	0.96	9.7	66	16
Nonachlor, cis	6.4	40.3	1.5	5.0	1.0	49	5.9	16
Aldrin	6.5	39.4	1.6	21	3.5			
o,p'-DDT[7]	6.8	61.1	4.8	97	63	16	20	28
p,p'-DDE[5]	6.9	63.7	4.7	98	12	350	9.3	0
Mirex	6.9	54.0	3.3	6.8	1.5	6.1	3.2	0
p,p'-DDT[7]	6.9	68.1	2.1	94	50	34	6.1	0
Endosulfan sulfate	3.7	46.4	4.0	3.7	0.83	0.44	12	
Endosulfan I	4.7	36.0	3.2	4.9	2.46	0.10	10	
Endosulfan II	4.8	49.0	3.5	8.9	5.8			
Parathion	3.8	44.4	9.6	9.1	1.0			
Ethion	5.1	48.8	10.5	1.9	2.59			
Chlorpyrifos	5.1	45.5	8.9	5.5	0.88			
Etridiazole	2.6	34.8	1.8	15	2.2			

Table 3B-15. SOC Recovery and EDLs in Fish Over the Entire Analytical Method.

Compounds	Log K_{ow}	Method Recovery[1] (%)		Estimated Method Detection Limit[2] (pg/g ww)		Determined Values for NIST SRM 1946 (ng/g ww)		Deviation from Certified Values[3]
		Avg.	SD	Avg.	%RSD	Avg.	%RSD	% Diff
Dacthal	4.3	62.2	2.2	2.6	1.6	4.6	11	
Triallate	4.6	88.0	2.3	11	1.80			
Trifluralin	5.3	42.9	3.4	7.2	0.89			
PCB 74	6.3	78.9	1.2	48	15	4.1	20	15
PCB 101	6.4	66.5	4.5	1.1	2.6	28	29	20
PCB 138	6.7	77.3	5.7	2.6	2.9	134	33	21
PCB 153	6.9	65.0	4.6	2.2	0.87	110	30	0
PCB 118	7.0	74.5	6.1	2.2	0.96	51	6.2	0
PCB 183	8.3	75.9	5.3	0.84	3.7	23	8.6	0
PCB 187	7.2	77.3	5.0	1.4	2.2	54	13	0
Average	6.1	61.4	4.1	79	11	30	15	7
Min	2.6	31.4	0.3	0.2	0.83	0.10	0.22	0
Max	9.4	98.3	12	920	86	350	66	30
Polycyclic Aromatic Hydrocarbons								
Acenaphthylene	3.9	36.0	2.5	38	4.1			
Acenaphthene	4.0	54.4	5.5	50	2.5			
Fluorene	4.2	41.7	1.6	16	1.7			
Anthracene	4.5	51.8	5.4	59	6.8			
Phenanthrene	4.5	56.3	3.8	56	10			
Pyrene	5.1	63.7	5.4	6.7	3.5			
Fluoranthene	5.2	58.4	4.0	7.6	1.8			
Chrysene /Triphenylene	5.7	59.3	0.9	20	12			
Benzo(a)anthracene	5.9	59.4	2.3	26	0.96			
Retene	6.4	55.3	5.8	44	14			
Benzo(k)fluoranthene	6.5	64.6	0.3	23	0.9			
Benzo(a)pyrene	6.5	43.4	5.2	17	1.7			
Benzo(b)fluoranthene	6.6	64.4	0.9	20	1.6			
Indeno(1,,3-cd)pyrene	6.7	60.5	0.3	18	3.33			
Dibenz(a,h)anthracene	6.8	58.0	1.6	19	8.9			
Benzo(e)pyrene	6.9	57.8	0.7	100	34			
Benzo(ghi)perylene	7.0	60.1	0.7	6.3	1.3			
PolyBrominated Diphenyl Ethers[8]								
BDE 10	5.0	64.2	6.4	920	26			
BDE 7	5.0	49.7	2.4	120	43			
BDE 8	5.0	52.0	5.3	710	23			
BDE 12	5.8	45.2	2.3	880	18			

Table 3B-15. SOC Recovery and EDLs in Fish Over the Entire Analytical Method.

Compounds	Log K_{ow}	Method Recovery[1] (%)		Estimated Method Detection Limit[2] (pg/g ww)		Determined Values for NIST SRM 1946 (ng/g ww)		Deviation from Certified Values[3]
		Avg.	SD	Avg.	%RSD	Avg.	%RSD	% Diff
BDE 13	5.8	50.4	2.7	910	21			
BDE 15	5.8	82.2	6.3	860	15			
BDE 30	5.9	47.2	6.6	240	37			
BDE 32	5.9	46.9	2.2	38	7.6			
BDE 17	5.8	55.7	2.4	32	8.4			
BDE 25	5.9	55.9	2.3	43	7.1			
BDE 28	5.9	51.1	2.1	23	2.8	0.94	1.9	26
BDE 35	6.7	52.6	2.0	57	3.8			
BDE 37	6.7	52.3	2.1	40	8.1			
BDE 75	6.8	86.9	6.7	24	5.3			
BDE 49	6.8	94.1	7.1	30	3.6			
BDE 71	6.8	84.8	5.2	22	1.9			
BDE 47	6.8	91.1	7.5	14	1.1	29	10	0
BDE 66	6.8	83.6	8.5	120	26			n/a[9]
BDE 77	7.6	93.6	8.0	83	24			
BDE 100	7.7	79.0	8.4	6.7	1.1	8.4	2.7	0
BDE 119	7.7	78.9	7.2	19	14			
BDE 99	7.7	85.7	6.3	23	1.95	18	5.4	0
BDE 116	7.7	75.6	7.9	91	48			
BDE 85/155	7.7 / 8.6	91.8	8.3	37	10			
BDE 126	8.5	88.6	9.2	36	9.2			
BDE 118	7.7	75.0	11.9	200	86			
BDE 155	8.6	80.8	7.0	2.3	1.0	0.68	11	
BDE 154	8.6	79.7	7.4	8.3	2.7	6.2	18	0
BDE 153	8.6	78.6	6.7	6.5	3.1	2.9	9.3	0
BDE 138	8.6	81.6	7.1	1.1	1.1			
BDE 166	8.6	98.3	7.8	1.9	1.7			
BDE 183	9.4	81.5	5.8	1.6	0.95	0.23	14	
BDE 181	9.4	76.8	4.1	3.5	3.14			
BDE 190	9.4	72.4	5.0	5.0	2.5			

[1] Triplicate recoveries across entire method of ~8 ng/g ww tissue spikes. Blank and sample background corrected.

[2] 3:1 S:N of IS normalized response factors in three separate fish from Denali, Sequoia, and Rocky Mountain National Parks according to EPA Method 8280A

[3] Percentage difference between this method and NIST certified values for SRM # 1946 LakeTrout, 0% difference when method average is within certified confidence interval, n=5

Table 3B-15. SOC Recovery and EDLs in Fish Over the Entire Analytical Method.

Compounds	Log K_{ow}	Method Recovery[1] (%)		Estimated Method Detection Limit[2] (pg/g ww)		Determined Values for NIST SRM 1946 (ng/g ww)		Deviation from Certified Values[3]
		Avg.	SD	Avg.	%RSD	Avg.	%RSD	% Diff

[4] HexachloroCycloHexane

[5] DichloroDiphenyldichloroEthylene

[6] DichloroDiphenylDichloroethane

[7] DichloroDiphenylTrichloroethane

[8] Log K_{ow} Estimated by EPI Suite

[9] Interferant prohibited quantitation

Blank Cells indicate no certified, or refernce value for the SRM, and/or not detected here.

Metals

Detailed laboratory QA/QC procedures are specified in the WACAP QAPP. Quality control at the USGS National Research Program Laboratory in Boulder, Colorado, involves systematic analysis of blanks, replicates, standard reference materials, and spike addition samples (see Tables 3B-16 and 3B-17). Standard Reference Materials used for the quality control of fish tissue analysis included National Research Council of Canada SRM DOLT-1 Dogfish Liver, DORM-1 Dogfish Muscle, TORT-1 Lobster hepatopancreas, and National Institute of Standards and Technology Standard Reference Materials SRM 2976 Bivalve Tissue. Details, results and figures are described in the Quality Assurance/Quality Control Section of the database.

Table 3B-16. Metals and Detection Limits for Fish Fillet Tissue Analyses Performed at the USGS National Research Program Laboratory, Boulder, Colorado. Concentrations in dry weight, assuming a 0.2-g sample size (1:2 dilution).

Analyte	Units	Detection Limit
Al	µg/g	< 0.9
As	µg/g	< 0.03
B	µg/g	<1
Ba	µg/g	<0.008
Be	µg/g	< 0.02
Bi	µg/g	< 0.002
Ca	Wt%	<0.0008
Cd	µg/g	< 0.005
Ce	µg/g	< 0.001
Co	µg/g	< 0.009
Cr	µg/g	< 0.3
Cs	µg/g	<0.02
Cu	µg/g	< 0.03
Dy	µg/g	< 0.002
Er	µg/g	< 0.002
Eu	µg/g	< 0.0005
Fe	µg/g	<11
Gd	µg/g	< 0.001
Ho	µg/g	< 0.0003
K	Wt%	<0.002
La	µg/g	< 0.0006
Li	µg/g	< 0.03
Lu	µg/g	< 0.0004
Mg	Wt%	< 0.0008

Analyte	Units	Detection Limit
Mn	µg/g	< 0.2
Mo	µg/g	< 0..02
Na	Wt%	< 0.002
Nd	µg/g	< 0.001
Ni	µg/g	< 0.05
Pb	µg/g	< 0.01
Pr	µg/g	< 0.0003
Rb	µg/g	< 0.007
Re	µg/g	< 0.0009
Sb	µg/g	< 0.003
Se	µg/g	< 0.2
Sm	µg/g	< 0.001
Sr	µg/g	< 0.03
Tb	µg/g	< 0.0002
Te	µg/g	< 0.01
Tl	µg/g	< 0.006
Tm	µg/g	< 0.0004
U	µg/g	< 0.0009
V	µg/g	< 0.05
W	µg/g	< 0.001
Y	µg/g	< 0.0003
Yb	µg/g	< 0.009
Zn	µg/g	< 0.4
Zr	µg/g	< 0.002

Table 3B-17. Metals and Detection Limits for Fish Liver Tissue Analyses Performed at the USGS National Research Program Laboratory, Boulder, Colorado. Concentrations in dry weight, assuming a 0.1-g sample size (1:2 dilution).

Analyte	Units	Detection Limit	Analyte	Units	Detection Limit
Al	µg/g	< 0.6	Mn	µg/g	< 0.5
As	µg/g	< 0.1	Mo	µg/g	< 0..04
B	µg/g	<5	Na	Wt%	< 0.004
Ba	µg/g	<0.03	Nd	µg/g	< 0.002
Be	µg/g	< 0.02	Ni	µg/g	< 0.06
Bi	µg/g	< 0.005	Pb	µg/g	< 0.009
Ca	Wt%	<0.003	Pr	µg/g	< 0.0005
Cd	µg/g	< 0.01	Rb	µg/g	< 0.01
Ce	µg/g	< 0.002	Re	µg/g	< 0.001
Co	µg/g	< 0.01	Sb	µg/g	< 0.005
Cr	µg/g	< 0.4	Se	µg/g	< 0.3
Cs	µg/g	<0.1	Sm	µg/g	< 0.003
Cu	µg/g	< 0.1	Sr	µg/g	< 0.04
Dy	µg/g	< 0.002	Tb	µg/g	< 0.0005
Er	µg/g	< 0.003	Te	µg/g	< 0.02
Eu	µg/g	< 0.0009	Tl	µg/g	< 0.03
Fe	µg/g	<16	Tm	µg/g	< 0.0004
Gd	µg/g	< 0.002	U	µg/g	< 0.001
Ho	µg/g	< 0.0005	V	µg/g	< 0.05
K	Wt%	<0.004	W	µg/g	< 0.004
La	µg/g	< 0.0008	Y	µg/g	< 0.0006
Li	µg/g	< 0.04	Yb	µg/g	< 0.002
Lu	µg/g	< 0.0005	Zn	µg/g	< 0.5
Mg	Wt%	< 0.001	Zr	µg/g	< 0.01

Moose QA/QC

SOCs

Detailed laboratory QA/QC procedures for SOCs are specified in the WACAP QAPP. Because so few moose samples were analyzed for SOCs, detailed recovery and estimated method detection limits experiments for moose were not conducted. However, the SOC recoveries and estimated method detection limits were similar to those for fish (see Table 3B-15).

Metals

Detailed laboratory QA/QC procedures are specified in the WACAP QAPP. Quality control at the USGS National Research Program laboratory in Boulder, Colorado, involves systematic analysis of blanks, replicates, standard reference materials, and spike addition samples (see Table 3B-18). Standard reference materials used for the quality control of moose tissue analysis included National Institute of Standards and Technology SRM 8414 Bovine Muscle Powder and SRM 1577b Bovine Liver. Details, results, and figures are described in the Quality Assurance/Quality Control Section of the database.

Table 3B-18. Metals and Detection Limits for Moose Tissue Analyses Performed at the USGS National Research Program Laboratory, Boulder, Colorado. Concentrations in dry weight, assuming a 0.2-g sample size (1:2 dilution).

Analyte	Units	Detection Limit	Analyte	Units	Detection Limit
Al	µg/g	< 7	Mn	µg/g	< 0.03
As	µg/g	< 0.007	Mo	µg/g	< 0..006
B	µg/g	<9	Na	Wt%	< 0.0002
Ba	µg/g	<0.03	Nd	µg/g	< 0.0006
Be	µg/g	< 0.006	Ni	µg/g	< 0.03
Bi	µg/g	< 0.004	Pb	µg/g	< 0.006
Ca	Wt%	<0.001	Pr	µg/g	< 0.0002
Cd	µg/g	< 0.004	Rb	µg/g	< 0.003
Ce	µg/g	< 0.002	Re	µg/g	< 0.0004
Co	µg/g	< 0.004	Sb	µg/g	< 0.01
Cr	µg/g	< 0.04	Se	µg/g	< 0.04
Cs	µg/g	<03	Sm	µg/g	< 0.0003
Cu	µg/g	< 0.02	Sr	µg/g	< 0.01
Dy	µg/g	< 0.0003	Tb	µg/g	< 0.0001
Er	µg/g	< 0.0004	Te	µg/g	< 0.006
Eu	µg/g	< 0.0002	Tl	µg/g	< 0.003
Fe	µg/g	<1	Tm	µg/g	< 0.0001
Gd	µg/g	< 0.0005	U	µg/g	< 0.0001
Ho	µg/g	< 0.0001	V	µg/g	< 0.005
K	Wt%	<0.0005	W	µg/g	< 0.003

Analyte	Units	Detection Limit
La	µg/g	< 0.0008
Li	µg/g	< 0.009
Lu	µg/g	< 0.0001
Mg	Wt%	< 0.002

Analyte	Units	Detection Limit
Y	µg/g	< 0.0003
Yb	µg/g	< 0.0003
Zn	µg/g	< 0.9
Zr	µg/g	< 0.002

APPENDIX 4A

Detailed Information on Contaminants in Vegetation, Including Elevation Trends

Appendix 4A.1. Comparison of Mean SOC Concentrations in Different Lichen Species Sampled from the Same Sites.

Notes

Standard error uses a pooled estimate of variance.
One way analysis of variance by site and SOC was conducted for all sites where more than one species of lichen was sampled.
If no values for a site were > EDLs, then no data was used for that SOC.
If any value for a site was > EDLs, then 1/2 EDLS were used for samples below EDLS.

DENA5

Flavocetraria cucullata had 7-50X higher concentrations than *Masonhalea richardsonii* of all SOCs but dacthal

One-way Analysis of Dacthal by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Increase (fold)
Species	1	0.01020833	0.010208	0.075	0.8099	NA
Error	2	0.27226667	0.136133			
C. Total	3	0.282475				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	0.77	0.36896	-0.8175	2.3575
Masonhalea richardsonii	3	0.886667	0.21302	-0.0299	1.8032

One-way Analysis of Endosulfans by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	76.608533	76.6085	898.8095	**0.0011**	6.7
Error	2	0.170467	0.0852			
C. Total	3	76.779				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	11.87	0.29195	10.614	13.126

Masonhalea richardsonii	3	1.7633	0.16856	1.038	2.489	

One-way Analysis of HCB by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	219.85707	219.857	22434.39	**0.0043**	22.6
Error	1	0.0098	0.01			
C. Total	2	219.86687				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	19	0.09899	17.74	20.258
Masonhalea richardsonii	2	0.84	0.07	-0.05	1.729

One-way Analysis of a-HCH by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	111.2643	111.264	4295.919	**0.0002**	15.9
Error	2	0.0518	0.026			
C. Total	3	111.3161				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	13	0.16093	12.308	13.692
Masonhalea richardsonii	3	0.82	0.09292	0.42	1.22

One-way Analysis of g-HCH by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	18.0075	18.0075	720300	**<.0001**	50.0
Error	2	0.00005	0			
C. Total	3	18.00755				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	5	0.005	4.9785	5.0215
Masonhalea richardsonii	3	0.1	0.00289	0.0876	0.1124

One-way Analysis of PAHs by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	81870.642	81870.6	1062.527	**0.0009**	48.2
Error	2	154.106	77.1			
C. Total	3	82024.748				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	337.4	8.778	299.6	375.17
Masonhalea richardsonii	3	7.005	5.068	-14.8	28.81

One-way Analysis of Total Current Use by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	74.850075	74.8501	290.4543	**0.0034**	4.8
Error	2	0.5154	0.2577			
C. Total	3	75.365475				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	12.64	0.50764	10.456	14.824
Masonhalea richardsonii	3	2.65	0.29309	1.389	3.911

One-way Analysis of Total Historic Use by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	946.2528	946.253	2344.096	**0.0004**	25.0
Error	2	0.80735	0.404			
C. Total	3	947.06015				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	37	0.63535	34.27	39.734
Masonhalea richardsonii	3	1.48	0.36682	-0.1	3.058

One-way Analysis of Total Pesticides by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	1553.3701	1553.37	1189.615	**0.0008**	12.0
Error	2	2.6115	1.31			
C. Total	3	1555.9816				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	49.64	1.1427	44.723	54.557
Masonhalea richardsonii	3	4.13	0.6597	1.291	6.969

One-way Analysis of % Current Use by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	0.11955714	0.119557	26.5354	**0.0357**	26.5
Error	2	0.00901114	0.004506			
C. Total	3	0.12856828				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Flavocetraria cucullata	1	0.254633	0.06712	-0.0342	0.54344
Masonhalea richardsonii	3	0.653895	0.03875	0.4872	0.82064

WRST1

Platismatia glauca has 2.5x higher HCBs and PAHs compared to *Hypogymnia apinnata.*

One-way Analysis of Dacthal ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Increase (fold)
Species	1	1.7066667	1.70667	21.3333	0.1357	NA
Error	1	0.08	0.08			
C. Total	2	1.7866667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	1.8	0.2	-0.7412	4.3412
Platismatia glauca	1	3.4	0.28284	-0.1939	6.9939

One-way Analysis of Endosulfans ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	NA
Species	1	1.706667	1.7067	0.0386	0.8765	
Error	1	44.18	44.18			
C. Total	2	45.886667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	50.8	4.7	-8.92	110.52
Platismatia glauca	1	52.4	6.6468	-32.06	136.86

One-way Analysis of HCB ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	5280.6667	5280.67	293.3704	**0.0371**	2.5
Error	1	18	18			
C. Total	2	5298.6667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	61	3	22.881	99.12
Platismatia glauca	1	150	4.2426	96.092	203.91

One-way Analysis of a-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	682.66667	682.667	13.6533	0.1683	NA
Error	1	50	50			
C. Total	2	732.66667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	22	5	-41.53	85.53

Platismatia glauca	1	54	7.0711	-35.85	143.85	

One-way Analysis of g-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	26.46	26.46	10.9339	0.187	NA
Error	1	2.42	2.42			
C. Total	2	28.88				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	7.7	1.1	-6.277	21.677
Platismatia glauca	1	14	1.5556	-5.766	33.766

One-way Analysis of Chlordanes ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	1.0250667	1.02507	0.4394	0.6273	NA
Error	1	2.3328	2.3328			
C. Total	2	3.3578667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	2.81	1.08	-10.91	16.533
Platismatia glauca	1	4.05	1.5274	-15.36	23.457

One-way Analysis of PCBs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	0.7280167	0.72802	0.4648	0.6191	NA
Error	1	1.56645	1.56645			
C. Total	2	2.2944667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	3.455	0.885	-7.79	14.7
Platismatia glauca	1	4.5	1.2516	-11.4	20.403

One-way Analysis of PAHs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	4676368.2	4676368	660.4573	**0.0248**	2.6
Error	1	7080.5	7081			
C. Total	2	4683448.7				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia apinnata	2	1697.5	59.5	941.5	2453.5
Platismatia glauca	1	4346	84.146	3276.8	5415.2

WRST5

Platismatia glauca has 5-17X higher dacthal, endosulfans, HCBs, a-HCH, g-HCH, chlordanes, pcbs, & PAHs compared to *Alectoria sarmentosa*

One-way Analysis of Dacthal ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Increase (fold)
Species	1	7.3704167	7.37042	510.0634	**0.0282**	9.9
Error	1	0.01445	0.01445			
C. Total	2	7.3848667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	0.375	0.085	-0.705	1.455
Platismatia glauca	1	3.7	0.12021	2.173	5.2274

One-way Analysis of Endosulfans ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	3952.41	3952.41	20899.78	**0.0044**	17.1
Error	1	0.1891	0.19			
C. Total	2	3952.5991				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	4.7825	0.3075	0.875	8.69
Platismatia glauca	1	81.78	0.43487	76.254	87.306

One-way Analysis of HCB ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	1713.66	1713.66	1338.797	**0.0174**	10.6
Error	1	1.28	1.28			
C. Total	2	1714.94				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	5.3	0.8	-4.86	15.465
Platismatia glauca	1	56	1.1314	41.62	70.375

One-way Analysis of a-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	468.16667	468.167	477.7211	**0.0291**	8.6
Error	1	0.98	0.98			
C. Total	2	469.14667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	3.5	0.7	-5.39	12.394
Platismatia glauca	1	30	0.98995	17.42	42.579

One-way Analysis of g-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	18.235267	18.2353	83.7248	**0.0693**	5.9
Error	1	0.2178	0.2178			
C. Total	2	18.453067				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	1.07	0.33	-3.123	5.263
Platismatia glauca	1	6.3	0.46669	0.37	12.23

One-way Analysis of Chlordanes ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	2.57415	2.57415	142.6122	**0.0532**	5.1
Error	1	0.01805	0.01805			
C. Total	2	2.5922				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	0.485	0.095	-0.7221	1.6921
Platismatia glauca	1	2.45	0.13435	0.7429	4.1571

One-way Analysis of PCBs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	4.2909127	4.29091	709.2418	**0.0239**	5.6
Error	1	0.00605	0.00605			
C. Total	2	4.2969627				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	0.553	0.055	-0.146	1.2518
Platismatia glauca	1	3.09	0.07778	2.102	4.0783

One-way Analysis of PAHs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	2623046.5	2623047	62660.49	**0.0025**	8.4
Error	1	41.9	42			
C. Total	2	2623088.4				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2	267.43	4.575	209.3	325.6
Platismatia glauca	1	2251	6.47	2168.8	2333.2

STLE1

Platismatia glauca has 3.4 to 17.1x higher concentrations of dacthal, endosulfans,HCB, a-HCH, chlordanes, PCBs and PAHs than *Alectoria sarmentosa*

One-way Analysis of Dacthal by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Increase (fold)
Species	1.00	7.37	7.37	510.06	**0.03**	9.9
Error	1.00	0.01	0.01			
C. Total	2.00	7.38				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	0.38	0.09	-0.71	1.46
Platismatia glauca	1.00	3.70	0.12	2.17	5.23

One-way Analysis of Endosulfans by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1.00	3952.41	3952.41	20899.78	**0.00**	17.1
Error	1.00	0.19	0.19			
C. Total	2.00	3952.60				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	4.78	0.31	0.88	8.69
Platismatia glauca	1.00	81.78	0.43	76.25	87.31

One-way Analysis of HCB by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1.00	1713.66	1713.66	1338.80	**0.02**	10.6
Error	1.00	1.28	1.28			
C. Total	2.00	1714.94				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	5.30	0.80	-4.86	15.47
Platismatia glauca	1.00	56.00	1.13	41.62	70.38

One-way Analysis of a-HCH by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F

Species	1.00	468.17	468.17	477.72	**0.03**	8.6
Error	1.00	0.98	0.98			
C. Total	2.00	469.15				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	3.50	0.70	-5.39	12.39
Platismatia glauca	1.00	30.00	0.99	17.42	42.58

One-way Analysis of g-HCH by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1.00	18.24	18.24	83.72	0.07	5.9
Error	1.00	0.22	0.22			
C. Total	2.00	18.45				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	1.07	0.33	-3.12	5.26
Platismatia glauca	1.00	6.30	0.47	0.37	12.23

One-way Analysis of Chlordanes by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1.00	2.57	2.57	142.61	**0.05**	5.1
Error	1.00	0.02	0.02			
C. Total	2.00	2.59				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	0.49	0.10	-0.72	1.69
Platismatia glauca	1.00	2.45	0.13	0.74	4.16

One-way Analysis of PCBs by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1.00	1.19	1.19	196.98	**0.05**	3.4

Error	1.00	0.01	0.01
C. Total	2.00	1.20	

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	0.55	0.06	-0.15	1.25
Platismatia glauca	1.00	1.89	0.08	0.90	2.88

One-way Analysis of PAHs by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1.00	2623046.50	2623047.00	62660.49	**0.00**	8.4
Error	1.00	41.90	42.00			
C. Total	2.00	2623088.40				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	2.00	267.43	4.58	209.30	325.60
Platismatia glauca	1.00	2251.00	6.47	2168.80	2333.20

OLYM5

Bryoria has 2.5-5x higher concentrations of dacthal, endosulfans, and pcbs compared to *Alectoria sarmentosa*

One-way Analysis of Trifluralin ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Increase (fold)
Species	0	0	.	.	.	NA
Error	2	5.2866667	2.64333			
C. Total	2	5.2866667				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Bryoria	3	2.23333	0.93868	-1.805	6.2721

One-way Analysis of Chlorpyrifos ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	10.120033	10.12	2.5664	0.2503	NA
Error	2	7.886667	3.9433			
C. Total	3	18.0067				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	0.16	1.9858	-8.384	8.7041
Bryoria	3	3.83333	1.1465	-1.1	8.7663

One-way Analysis of Dacthal ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	280.33333	280.333	9.2418	**0.0933**	2.5
Error	2	60.66667	30.333			
C. Total	3	341				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	13	5.5076	-10.7	36.697
Bryoria	3	32.3333	3.1798	18.65	46.015

One-way Analysis of Endosulfans ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	60847.521	60847.5	24.1044	**0.0391**	5.4
Error	2	5048.667	2524.3			
C. Total	3	65896.188				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	64.5	50.243	-151.7	280.68
Bryoria	3	349.333	29.008	224.5	474.14

One-way Analysis of HCB ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	4.083333	4.0833	0.1012	0.7805	NA

Error	2	80.666667	40.3333			
C. Total	3	84.75				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	35	6.3509	7.674	62.326
Bryoria	3	32.6667	3.6667	16.89	48.443

One-way Analysis of a-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	2581.3333	2581.33	5.2644	0.1487	NA
Error	2	980.6667	490.33			
C. Total	3	3562				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	36	22.143	-59.28	131.28
Bryoria	3	94.6667	12.785	39.66	149.67

One-way Analysis of g-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	918.75	918.75	6.25	0.1296	NA
Error	2	294	147			
C. Total	3	1212.75				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	11	12.124	-41.17	63.167
Bryoria	3	46	7	15.88	76.119

One-way Analysis of Chlordanes ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	7.061002	7.061	1.4601	0.3504	NA
Error	2	9.671667	4.83583			
C. Total	3	16.732669				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	1.765	2.1991	-7.697	11.227
Bryoria	3	4.83333	1.2696	-0.629	10.296

One-way Analysis of PCBs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	195.8592	195.859	18.7684	**0.0494**	5.1
Error	2	20.8712	10.436			
C. Total	3	216.7304				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	3.94	3.2304	-9.96	17.839
Bryoria	3	20.1	1.8651	12.08	28.125

One-way Analysis of PAHs ng/g Lipid by Species

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	15624.083	15624.1	0.6356	0.5089	NA
Error	2	49162.167	24581.1			
C. Total	3	64786.25				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Alectoria sarmentosa	1	3841.5	156.78	3166.9	4516.1
Bryoria	3	3697.17	90.52	3307.7	4086.6

GLAC5

Letharia vulpina has higher concentrations of 50 x more chlorpyrifos and 2x more g-HCH than *Hypogymnia physodes.*

H. physodes has higher concentrations of 2-10X higher HCB, a-HCH ($p > F$ =0.06), chlordanes, ddts, PCBs and PAHs than *L. vulpina.*

One-way Analysis of Triallate ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	Increase (fold)
Species	1	0.440833	0.44083	0.0476	0.8475	
Error	2	18.526667	9.26333			
C. Total	3	18.9675				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	12.7667	1.7572	5.206	20.327
Letharia vulpina	1	12	3.0436	-1.095	25.095

One-way Analysis of Chlorpyrifos ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	161.48003	161.48	15514.49	**<.0001**	45.9
Error	2	0.02082	0.01			
C. Total	3	161.50085				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	0.3267	0.0589	0.073	0.58
Letharia vulpina	1	15	0.10202	14.561	15.439

One-way Analysis of Dacthal ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	2700	2700	3.8571	0.1885	NA
Error	2	1400	700			
C. Total	3	4100				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	220	15.275	154.28	285.72
Letharia vulpina	1	160	26.458	46.16	273.84

One-way Analysis of Endosulfans ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	3104.0833	3104.08	1.5081	0.3443	NA

Error	2	4116.6667	2058.33			
C. Total	3	7220.75				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	814.333	26.194	701.63	927.04
Letharia vulpina	1	750	45.369	554.79	945.21

One-way Analysis of HCB ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	752.08333	752.083	33.6754	**0.0284**	2.4
Error	2	44.66667	22.333			
C. Total	3	796.75				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	53.6667	2.7285	41.927	65.406
Letharia vulpina	1	22	4.7258	1.666	42.334

One-way Analysis of a-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	690.08333	690.083	13.1863	**0.0682**	2.7
Error	2	104.66667	52.333			
C. Total	3	794.75				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	48.3333	4.1767	30.36	66.304
Letharia vulpina	1	18	7.2342	-13.13	49.126

One-way Analysis of g-HCH ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	1656.75	1656.75	33.8112	**0.0283**	1.7
Error	2	98	49			
C. Total	3	1754.75				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	63	4.0415	45.611	80.39
Letharia vulpina	1	110	7	79.881	140.12

One-way Analysis of Chlordanes ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	48.400833	48.4008	104.4622	**0.0094**	2.1
Error	2	0.926667	0.4633			
C. Total	3	49.3275				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	15.2333	0.39299	13.542	16.924
Letharia vulpina	1	7.2	0.68069	4.271	10.129

One-way Analysis of DDTs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	13722.803	13722.8	541.6896	**0.0018**	9.8
Error	2	50.667	25.3			
C. Total	3	13773.47				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	150.667	2.9059	138.2	163.17
Letharia vulpina	1	15.4	5.0332	-6.3	37.06

One-way Analysis of PCBs ng/g Lipid by Species

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	25.172033	25.172	49.315	**0.0197**	1.8
Error	2	1.020867	0.5104			
C. Total	3	26.1929				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	12.7533	0.41249	10.979	14.528
Letharia vulpina	1	6.96	0.71445	3.886	10.034

One-way Analysis of PAHs ng/g Lipid by Species

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F	
Species	1	387129488	387129488	91.4526	0.0108	3.1
Error	2	8466232	4233116.1			
C. Total	3	395595720				

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Hypogymnia physodes	3	33464.3	1187.9	28353	38575
Letharia vulpina	1	10744.9	2057.5	1892	19597

Appendix 4A.2. Mean Total Pesticide Burdens (ng/g lipid) in WACAP Parks by Lichen Genus. Parks not connected by the same letter are significantly different. Levels not connected by same letter are significantly different.

Park Within Genus		Total Pesticides (ng/g lipid)	Notes
Alectoria			
Park		*Mean*	
MORA	A	168.23	**MORA > STLE**
OLYM	A B	139.68	OLYM = NOCA = GLBA = STLE
NOCA	A B	102.88	
GLBA	A B	74.98	
STLE	B	23.97	
Flavocetraria			
Park		*Mean*	
KATM	A	37.30	KATM = WRST= DENA
WRST	A	25.80	
DENA	A	18.94	
Hypogymnia			
Park		*Mean*	
GLAC	A	1378.33	**GLAC > WRST , KATM**
WRST	B	108.44	WRST = KATM
KATM	B	82.97	
Letharia			
Park		*Mean*	
GLAC	A	947.20	**GLAC, SEKI > CRLA, LAVO**
SEKI	A	899.59	GLAC = SEKI = YOSE = GRTE
YOSE	A B	615.57	CRLA = LAVO = GRTE = YOSE
CRLA	B	306.51	
GRTE	A B	264.44	
LAVO	B	218.42	
Lobaria			
Park		*Mean*	
OLYM	A	58.33	OLYM = STLE
STLE	A	46.33	
Masonhalea			
Park		*Mean*	
NOAT	A	3.88	**GAAR > NOAT**
DENA	A B	3.08	DENA = NOAT
GAAR	B	1.96	DENA = GAAR
Platismatia			
Park		*Mean*	
GLAC	A	1504.40	**GLAC > STLE**
NOCA	A B	485.10	GLAC =NOCA = WRST= GLBA
STLE	B	327.78	
WRST	A B	277.85	
GLBA	A B	258.80	
Usnea			
Park		*Mean*	
BAND	A	257.95	BAND = BIBE = GRTE
BIBE	A	222.89	
GRTE	A	212.61	
Xanthoparmelia			
Park		*Mean*	
GRSA	A	899.95	**GRSA > ROMO**
BAND	A B	179.29	BAND = YOSE = ROMO
YOSE	A B	173.04	
ROMO	B	28.45	

Appendix 4A.3. Comparisons of SOC Concentrations in the Epiphytic Lichen, *Hypogymnia physodes*, and the Tundra Lichen, *Flavocetraria cucullata*, from Three Sites Each in Katmai National Park. Comparisons provide evidence that concentrations of endosulfans, HCB, HCHs, PCBs and PAHs were 1.5- to 4.6-fold higher in *H. physodes* than in *F. cucullata* (t-tests, assuming equal variances, $p < 0.05$).

SOC	***H. physodes*** **Park Mean (ng/g lipid)**	***F. cucullata*** **Park Mean (ng/g lipid)**	***H. ph./F. cu.*** **Ratio**	**Significant? (p < 0.05)**
Endosulfan	32.30	7.10	4.55	Y
HCB	30.30	20.00	1.52	Y
a-HCH	12.30	6.70	1.84	Y
g-HCH	3.50	1.72	2.03	Y
PCBs	2.91	0.67	4.34	Y
PAHs	406.00	118.00	3.44	Y
Chlordanes	3.75	1.08	3.47	N
Dacthal	0.72	0.44	1.64	N

Appendix 4A.4. Comparisons of SOC Concentrations in the Epiphytic Lichens, *Platismatia glauca* and *Alectoria sarmentosa*, from Three Sites Each in the Stikine LeConte Wilderness. Comparisons provide evidence that concentrations of dacthal, endosulfans, HCB, HCHs, PCBs and PAHs were 3.8 to 22.2 fold higher in *P. glauca* than *A. sarmentosa* (t-tests, assuming equal variances, $p < 0.05$).

SOC	***P. glauca*** **Park Mean (ng/g lipid)**	***A. sarmentosa*** **Park Mean (ng/g lipid)**	**P. gl./A. sa. Ratio**	**Significant? (p < 0.05)**
Endosulfan	12.67	0.70	18.10	Y
HCB	156.16	7.03	22.21	Y
a-HCH	81.50	6.32	12.90	Y
g-HCH	58.75	7.20	8.16	Y
PCBs	14.07	2.01	7.00	Y
PAHs	4.62	0.71	6.51	N
Chlordanes	4.45	1.15	3.87	Y
Dacthal	1648.00	156.00	10.56	Y

Appendix 4A.5. Mean Total Pesticide Burdens (ng/g lipid) in WACAP Parks by Conifer Genus. Parks not connected by the same letter are significantly different. Levels not connected by same letter are significantly different

Park within Genus		Total Pesticides (ng/g lipid)	Notes
True fir *(Abies)*			
Park		*Mean*	
SEKI	A	472.46	SEKI > CRLA, MORA, GLAC, NOCA, ROMO, OLYM
LAVO	A B	270.61	
CRLA	B	180.19	
MORA	B	173.29	
GLAC	B	136.23	
NOCA	B	118.82	
GRTE	A B	86.12	
ROMO	B	73.70	
OLYM	B	67.93	
Spruce *(Picea)*			
Park		*Mean*	
GLAC	A	103.67	GLAC > GLBA, ROMO, STLE, WRST, KATM, DENA
GLBA	B	48.88	GLBA > KATM, DENA
ROMO	B C	42.52	
STLE	B C D	35.97	
WRST	B C D	19.46	
KATM	C D	15.17	
DENA	D	11.18	
Pine *(Pinus)*			
Park		*Mean*	
YOSE	A	118.64	YOSE > GRSA, BAND
SEKI	A B	94.27	
GRTE	A B	25.19	
BIBE	A B	23.88	
CRLA	A B	21.94	
GRSA	B	15.01	
BAND	B	12.60	
Douglas-fir *(Pseudotsuga)*			
Park		*Mean*	
GLAC	A	155.59	GLAC > NOCA
NOCA	B	70.52	
Western hemlock *(Tsuga)*			
Park		*Mean*	
GLAC	A	550.92	GLAC > MORA, OLYM
MORA	B	193.50	MORA = NOCA = OLYM
NOCA	A B	178.94	
OLYM	B	119.19	

Appendix 4A.6. Comparison of Inter-generic Differences among Conifer SOC Concentrations (ng SOC/g conifer needle lipid) within WACAP Parks Where More than One Genus of Conifer Was Sampled. Within park and contaminant, genera sharing a common letter do not have different mean concentrations (Tukey-Kramer multiple means comparison test, α = 0.05). Results show that: (1) concentrations of many SOCs in pine (*Pinus*) were significantly lower than concentrations in true fir (*Abies*) from the same parks, (2) western hemlock (*Tsuga*) SOC concentrations were similar to or higher than true firs, Douglas fir (*Pseudotsuga*), and spruce (*Picea*), and (3) spruce (*Picea*) and true firs were similar*.

		Trifluralin	Triallate	Chlorpyrifos	Endosulfans	Dacthal	Current Use	g-HCH	a-HCH	HCB	Historic Use	PCBs	PAHs
	Genus	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
GRTE	*Abies*	5.80 A		1.10 A	30.3 A	20.0 A	57.2 A		14.0 A	14.0 A	28.9 A	0.56 A	870 A
	Pinus	4.13 A		1.12 A	3.4 B	7.9 B	16.5 B		3.50 B	4.9 B	8.7 B	0.60 A	16 B
SEKI	*Abies*			2.63 A	309.6 A	75.8 A	388.0 A	8.36 A	16.6 A	15.7 A	84.5 A	4.66 A	3960 A
	Pinus			2.00 A	29.9 B	38.3 A	70.3 B	2.90 A	5.3 A	5.8 A	24.0 A	0.38 B	1140 B
CRLA	*Abies*	0.34 A			77.7 A	33.7 A	111.8 A	5.80 A	26.2 A	33.8 A	68.4 A	1.39 A	1825 A
	Pinus	0.18 B			4.3 A	6.1 A	10.5 A	0.63 B	4.20 B	6.40 A	11.4 B	0.06 B	48 A
OLYM	*Tsuga*			5.33 A	21.6 A	2.9 A	29.3 A	8.3 A	47.5 A	29.0 A	89.9 A	2.76 A	5787 A
	Abies			0.39 B	18.9 A	3.7 A	23.0 B	3.4 B	25.3 B	15.3 B	45.0 B	1.12 A	245 B
MORA	*Tsuga*				96.2 A	12.7 A	110.6 A	8.0 A	39.7 A	24.2 A	83.0 A	2.54 A	4129 A
	Abies				91.8 A	6.7 B	98.6 A	5.8 A	31.7 A	23.3 A	74.7 A	3.44 A	506 B
NOCA	*Tsuga*				62.0 A	13.0 A	75.0 A	11.0 A	49.0 A	35.0 A	103.9 A	2.27 A	4265 A
	Abies				42.1 B	9.5 B	51.6 B	5.2 B	31.0 B	25.3 A	67.2 A	1.30 A	2542 A
	Pseud.				24.4 C	5.2 C	29.6 C	2.0 B	17.0 B	19.0 A	40.9 A	0.50 A	241 A
GLACE	*Abies*		5.1 B	0.77 B	84.8 A	18.7 B	109.3 A	6.0 A	11.7 A	7.1 A	26.9 A	0.87 A	2345 A
	Pseud.		17.3 A	3.50 A	83.9 A	25.3 A	130.0 A	5.9 A	8.7 A	8.2 A	25.6 A	0.79 A	2209 A
ROMO	*Abies*			0.31 A	29.8 A	20.5 A	50.4 A	3.4 A	9.2 A	8.2 A	23.4 A	1.09 A	382 A
	Picea			1.05 A	5.6 B	12.7 A	19.4 A	16.2 A	2.8 A	2.1 A	23.2 A	0.49 A	88 A
GLACW	*Tsuga*		22.7 A	3.70 A	231.8 A	112.3 A	370.6 A	41.2 A	67.7 A	50.5 A	180.4 A	3.23 B	47312 A
	Picea		0.7 A	0.29 A	28.3 B	22.3 A	51.4 B	43.0 A	3.2 A	4.3 A	52.3 A	6.90 A	1043 B

Notes: The analysis ignores site effects within parks but sites on different sides of the continental divide (GLACeast, GLACwest) were not compared and sites influenced by local sources (OLYM1) were excluded.

* Contaminant concentrations in *Abies* was generally substantially higher than *Pinus*: especially in endosulfans ~ 10 x higher, dacthal 2-5X higher, historic use g- and a-HCH, and HCB ~ 3-5x higher: *Tsuga* was usually somewhat higher than Abies by 1/3 to 3x. *Pseudotsuga* was similar to *Abies* but could be 2-3x lower in endosulfans and dacthal. *Picea* was similar to *Abies* and *Tsuga* but 5 (*Abies*) to 10 (*Tsuga*) x lower in endosulfans.

Appendix 4A.7. Comparison of Lichen and Conifer SOC Concentrations. Results are given of paired t-tests from sites within the 20 WACAP parks at which both vegetation types were collected. Lichen concentrations were 2- to 9-fold higher, or not different than, conifer needle concentrations. N, number of sites, varies with detection frequency among sites. Bold-faced SOCs indicate lichen and conifer concentrations were significantly different (Prob > t < 0.05).

SOC	Statistic	ng/g lipid	T-test Parameter	T-test result	Notes
Trifluralin	Lichen mean		t-Ratio		No difference, but only one pair
	Conifer mean		DF	0	
	Mean Difference	-0.25	Prob > |t|	-2.0000	
	% Difference		Prob > t	2.0000	
	Std Error		Prob < t	-1.0000	
	Upper95%		N	1	
	Lower95%		Correlation		
Triallate	Lichen mean	6.24	t-Ratio	-1.1972	No difference; but only 7 pairs
	Conifer mean	11.46	DF	6	
	Mean Difference	-5.22	Prob > |t|	0.2764	
	% Difference	*54*	Prob > t	0.8618	
	Std Error	4.36	Prob < t	0.1382	
	Upper95%	5.45	N	7	
	Lower95%	-15.90	Correlation	0.33	
Chlorpyrifos	Lichen mean	8.47	t-Ratio	3.6789	Lichens 3x higher
	Conifer mean	2.80	DF	15	
	Mean Difference	5.67	Prob > |t|	0.0022	
	% Difference	*302*	Prob > t	0.0011	
	Std Error	1.54	Prob < t	0.9989	
	Upper95%	8.96	N	16	
	Lower95%	2.39	Correlation	0.67	
Dacthal	Lichen mean	63.73	t-Ratio	4.0682	Lichens 3x higher
	Conifer mean	22.38	DF	59	
	Mean Difference	41.35	Prob > |t|	0.0001	

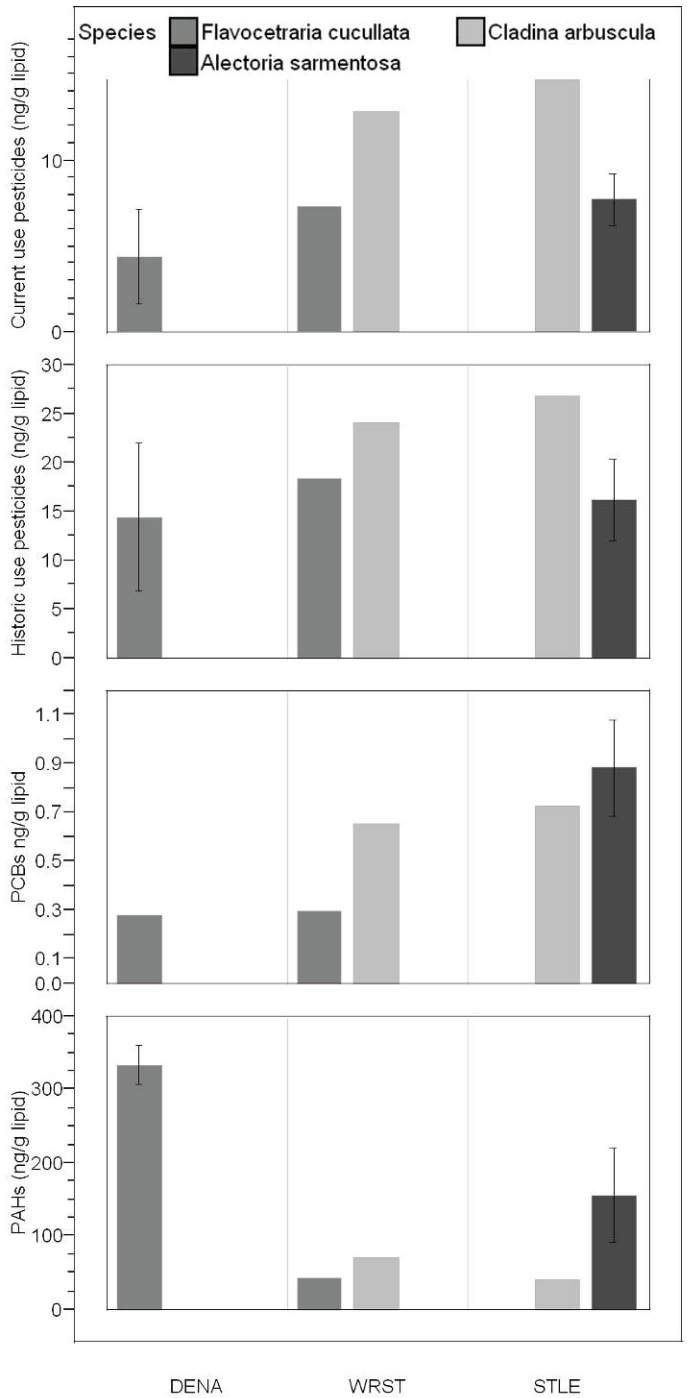
	% Difference	*285*	Prob > t	0.0001	
	Std Error	10.16	Prob < t	0.9999	
	Upper95%	61.69	N	60	
	Lower95%	21.01	Correlation	0.59	
Endosulfans	Lichen mean	188.36	t-Ratio	5.2249	Lichens 4x higher
	Conifer mean	51.38	DF	65	
	Mean Difference	136.98	Prob > |t|	0.0000	
	% Difference	*367*	Prob > t	0.0000	
	Std Error	26.22	Prob < t	1.0000	
	Upper95%	189.34	N	66	
	Lower95%	84.62	Correlation	0.45	
HCB	Lichen mean	24.66	t-Ratio	2.9045	Lichens 2x higher; no correlation between veg types
	Conifer mean	14.40	DF	62	
	Mean Difference	10.26	Prob > |t|	0.0051	
	% Difference	*171*	Prob > t	0.0025	
	Std Error	3.53	Prob < t	0.9975	
	Upper95%	17.33	N	63	
	Lower95%	3.20	Correlation	0.01	
a-HCH	Lichen mean	18.60	t-Ratio	1.0468	Many pairs, no difference; poor correlation between veg types
	Conifer mean	15.45	DF	63	
	Mean Difference	3.15	Prob > |t|	0.2992	
	% Difference	*120*	Prob > t	0.1496	
	Std Error	3.00	Prob < t	0.8504	
	Upper95%	9.15	N	64	
	Lower95%	-2.86	Correlation	0.10	
g-HCH	Lichen mean	13.21	t-Ratio	0.4303	Many pairs, no difference; poor correlation between veg types
	Conifer mean	11.86	DF	46	
	Mean Difference	1.35	Prob > |t|	0.6690	

	% Difference	*111*	Prob > t	0.3345	
	Std Error	3.13	Prob < t	0.6655	
	Upper95%	7.64	N	47	
	Lower95%	-4.95	Correlation	0.27	
Chlordanes	Lichen mean	6.59	t-Ratio	5.0010	Lichens 2x higher
	Conifer mean	2.69	DF	57	
	Mean Difference	3.90	Prob > |t|	0.0000	
	% Difference	*245*	Prob > t	0.0000	
	Std Error	0.78	Prob < t	1.0000	
	Upper95%	5.46	N	58	
	Lower95%	2.34	Correlation	0.46	
Dieldrin	Lichen mean	7.27	t-Ratio	2.1543	No difference, but only 3 pairs
	Conifer mean	4.51	DF	2	
	Mean Difference	2.76	Prob > |t|	0.1640	
	% Difference	*161*	Prob > t	0.0820	
	Std Error	1.28	Prob < t	0.9180	
	Upper95%	8.26	N	3	
	Lower95%	-2.75	Correlation	0.85	
DDTs	Lichen mean	77.73	t-Ratio	3.6962	Lichens 9X higher
	Conifer mean	8.60	DF	15	
	Mean Difference	69.13	Prob > |t|	0.0022	
	% Difference	*904*	Prob > t	0.0011	
	Std Error	18.70	Prob < t	0.9989	
	Upper95%	108.99	N	16	
	Lower95%	29.26	Correlation	0.33	
PCBs	Lichen mean	4.92	t-Ratio	6.8672	Lichens 3X higher
	Conifer mean	1.75	DF	46	

	Mean Difference	3.17	Prob > |t|	0.0000	
	% Difference	*281*	Prob > t	0.0000	
	Std Error	0.46	Prob < t	1.0000	
	Upper95%	4.10	N	47	
	Lower95%	2.24	Correlation	0.44	
PAHs	Lichen mean	7294.10	t-Ratio	1.7279	Lichens 3X higher, strong correlation between veg types
	Conifer mean	2711.62	DF	63	
	Mean Difference	4582.48	Prob > |t|	0.0889	
	% Difference	*269*	Prob > t	0.0444	
	Std Error	2651.98	Prob < t	0.9556	
	Upper95%	9882.05	N	64	
	Lower95%	-717.09	Correlation	0.87	

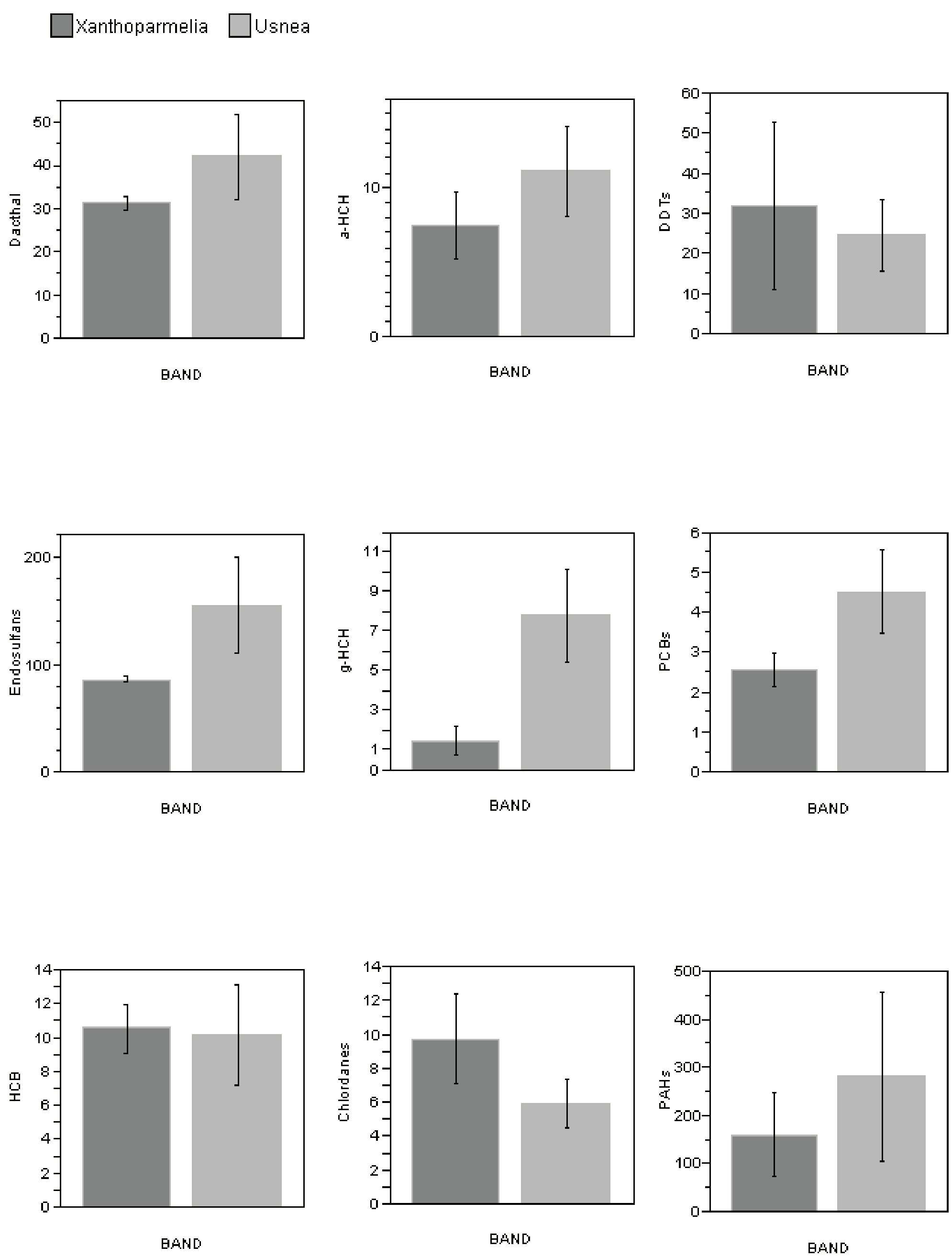
Appendix 4A.8. SOC Concentrations in Lichens

In general, lichens growing on trees accumulated higher concentrations of SOCs than lichens growing on the ground, but there was much variability among species. For example, pesticide concentrations in the best accumulators among the tundra lichens, *F. cucullata* and *C. arbuscula* (grays), were comparable to or higher than those of the poorest epiphytic accumulator, *A. sarmentosa* (black). Smoke from a forest fire in DENA during sampling could have boosted PAHs at this park. Bars indicate one standard error.



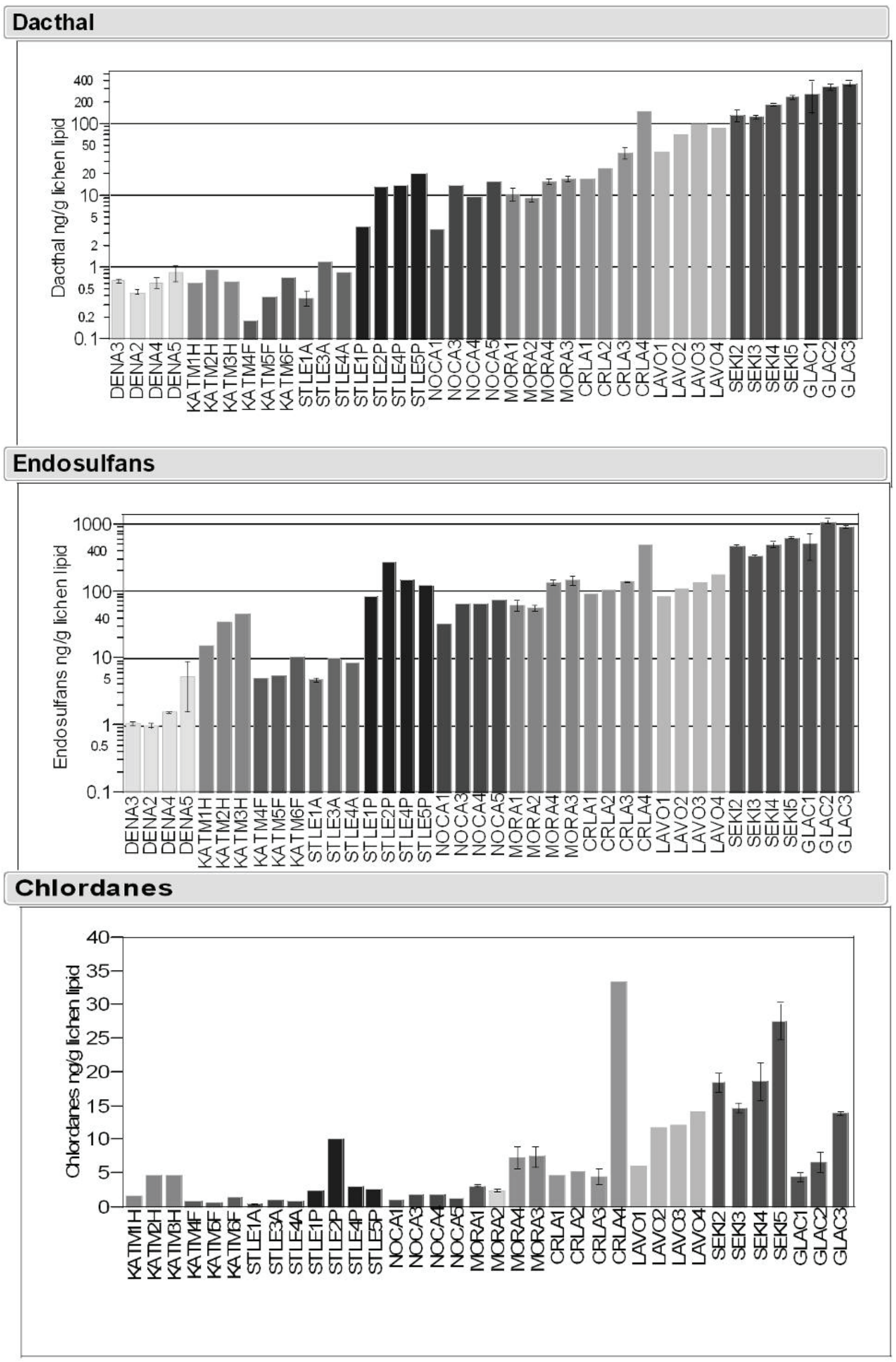
Appendix 4A.9. SOC Concentrations in Lichens *Xanthoparmelia* and *Usnea* from BAND

Despite major differences in growth habit and form, the lichens *Xanthoparmelia* and *Usnea* from BAND accumulated similar concentrations of many SOCs. *Xanthoparelia* is a flat, leafy lichen that adheres closely to its rock substrates; *Usnea* is a hair-like or filamentous lichen that hangs from trees; they were sampled at the two lowest and three highest elevations, respectively. Snow burial was not expected to limit exposure period at any of the sites. Bars indicate one standard error.

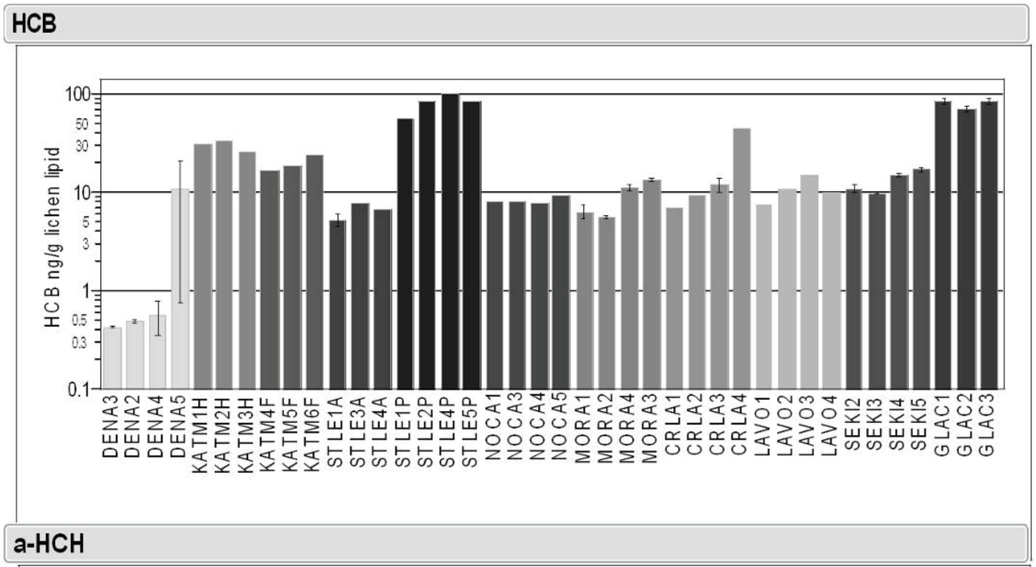


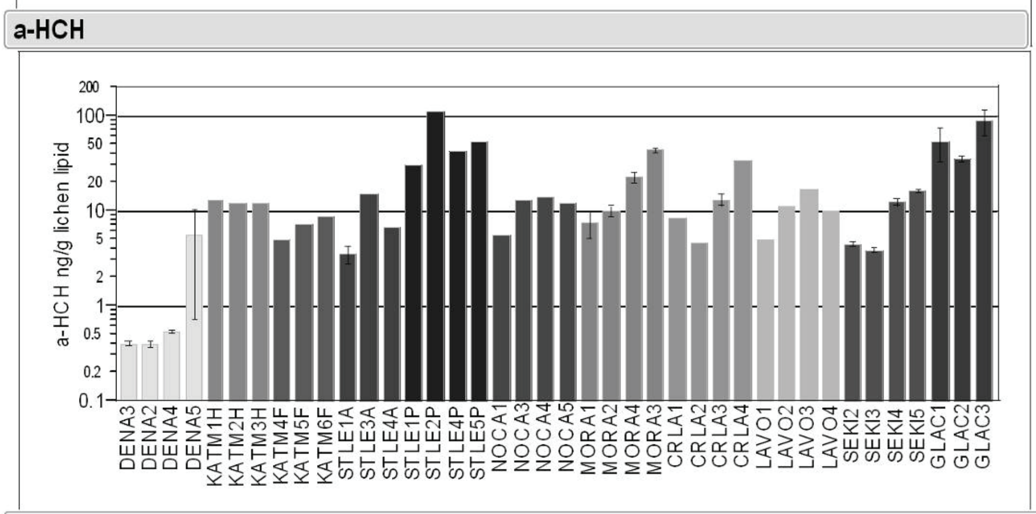
Appendix 4A.10. Relationship between Elevation and SOC Concentrations in Lichens Showing Significant Elevational Trends.

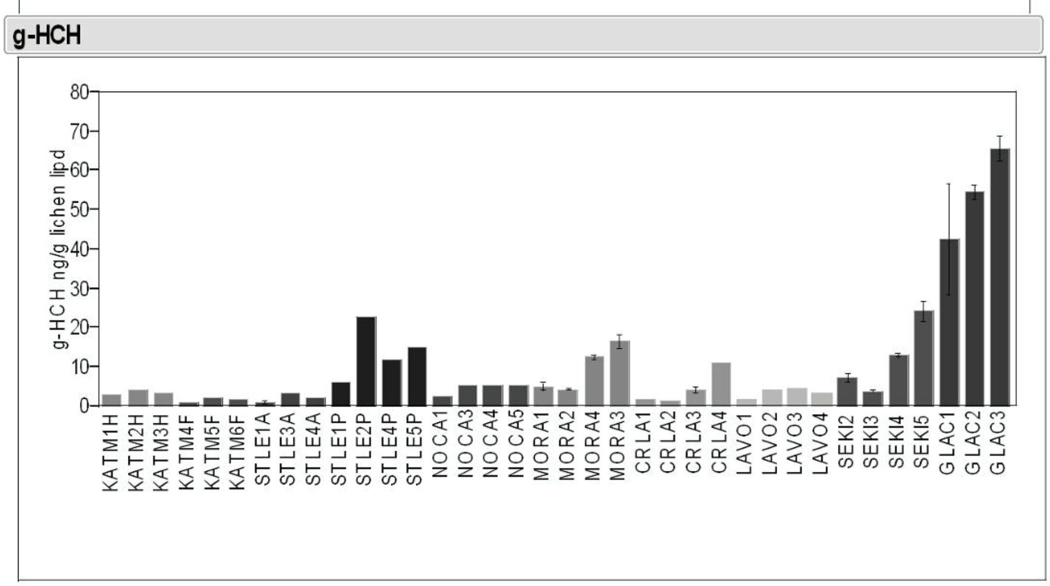
Pesticides and PCBs increase with elevation as predicted by the cold condensation hypothesis: PAHs decrease with elevation. See Chapter 3 for data selection criteria for elevational trends analyses. See Appendix 4A.11 for park name acronyms, lichen species, and evidence of significant trends. Sites within parks are listed in order of increasing elevation. Bars represent one standard error.



Appendix 4A.10. (continued).

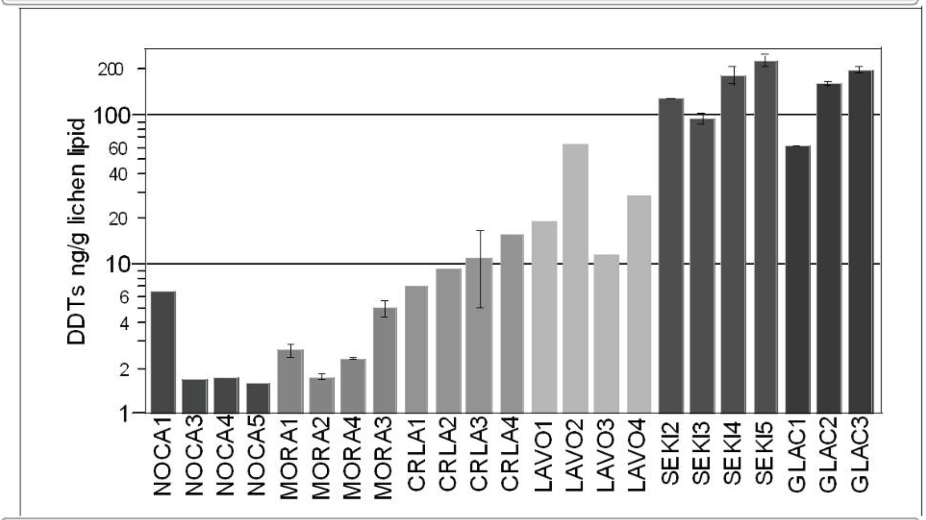




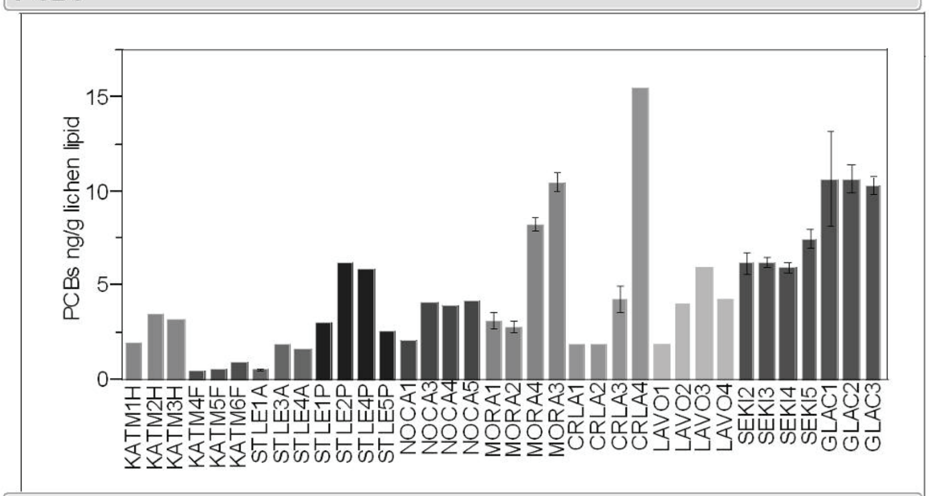


Appendix 4A.10. (continued).

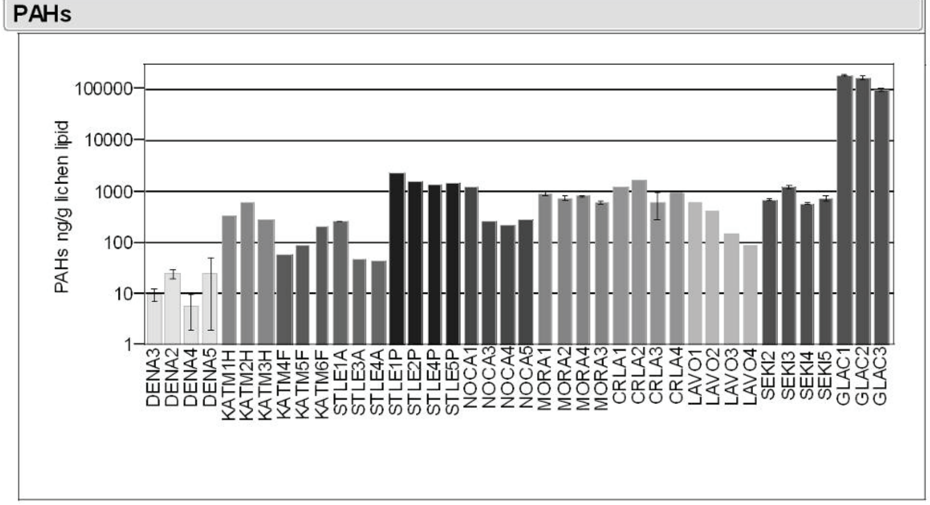
DDTs



PCBs



PAHs



Appendix 4A.11. Analysis of Elevation Trends. June 06, 2007.

Notes:

Parks and lichen species used in analyses:

BAND = Bandolier National Monument, *Usnea* (all other parks were compared to BAND)
CRLA = Crater Lake National Park, *Letharia vulpina*
GLAC = Glacier National Park, *Platismatia glauca*
KATMF = Katmai National Park, *Flavocetraria cucullata*
KATMH = Katmai National Park, *Hypogymnia physodes*
LAVO = Lassen Volcanic National Park, *Letharia vulpina*
MORA = Mt. Rainier National Park, *Alectoria sarmentosa*
NOCA = North Cascades National Park, *Alectoria sarmentosa*
SEKI = Sequoia-Kings Canyon National Park, *Letharia vulpina*
STLEA = Stikine LeConte Wilderness, *Alectoria sarmentosa* samples
STLEP = Stikine LeConte Wilderness, *Platismatia glauca*

See Methods chapter for detailed description of multiple linear regression modeling used in this analysis. Best fit models are reported here. All SOC concentrations in ng/g lipid.

Chlorpyrifos

formula = Chlorpyrifos ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.0289	2.9688	-1.0202	0.3187
ParkGLAC	0.6053	1.8372	0.3295	0.7449
ParkMORA	5.1879	1.9115	2.7140	0.0127
ParkNOCA	5.2466	2.1913	2.3943	0.0256
Elevm	0.0035	0.0013	2.7512	0.0117

Residual standard error: 2.182 on 22 degrees of freedom
Multiple R-Squared: 0.5338
F-statistic: 6.297 on 4 and 22 degrees of freedom, the p-value is 0.001554
Residuals plot range between -2 and +4. Outliers cases 3, 8, 7.

Dacthal

formula = log(Dacthal) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	1.3079	0.4548	2.8756	0.0055
ParkCRLA	0.4283	0.3229	1.3266	0.1895
ParkDENA	-2.6363	0.3684	-7.1561	0.0000
ParkGLAC	2.9540	0.3446	8.5730	0.0000
ParkKATMF	-3.0502	0.4448	-6.8582	0.0000
ParkKATMH	-1.8507	0.5066	-3.6535	0.0005
ParkLAVO	0.9066	0.3368	2.6919	0.0091
ParkMORA	0.1803	0.3457	0.5216	0.6038
ParkNOCA	-0.0177	0.4050	-0.0437	0.9653
ParkSEKI	1.6882	0.2750	6.1383	0.0000
ParkSTLEA	-2.1385	0.4717	-4.5336	0.0000
ParkSTLEP	0.5618	0.4509	1.2460	0.2174
Elevm	0.0010	0.0002	5.9044	0.0000

Residual standard error: 0.4726 on 62 degrees of freedom
Multiple R-Squared: 0.9654
F-statistic: 144.2 on 12 and 62 degrees of freedom, the p-value is 0
Residuals plot range between -1 and +1. Case 23 still very low outlier? Cases 2 and 9 outliers.

Endosulfan I

formula = log(EndosulfanI) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	1.0719	0.4124	2.5994	0.0117
ParkCRLA	0.3379	0.2927	1.1545	0.2527
ParkDENA	-2.3074	0.3340	-6.9082	0.0000
ParkGLAC	1.0709	0.3124	3.4278	0.0011
ParkKATMF	-0.8374	0.4032	-2.0767	0.0420
ParkKATMH	-0.1960	0.4593	-0.4267	0.6711
ParkLAVO	0.0536	0.3053	0.1754	0.8613
ParkMORA	0.7714	0.3134	2.4610	0.0167
ParkNOCA	0.3777	0.3672	1.0286	0.3077
ParkSEKI	1.2972	0.2494	5.2023	0.0000
ParkSTLEA	-0.7928	0.4277	-1.8538	0.0685
ParkSTLEP	0.4945	0.4088	1.2095	0.2311
Elevm	0.0009	0.0001	6.4791	0.0000

Residual standard error: 0.4285 on 62 degrees of freedom
Multiple R-Squared: 0.9454
F-statistic: 89.46 on 12 and 62 degrees of freedom, the p-value is 0
Residuals plot range between -1 and +1.5. Outliers 23 (low) and 9 and 19.

Endosulfan II

formula = log(EndosulfanII) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	0.8008	0.6029	1.3283	0.1905
ParkCRLA	0.7646	0.4062	1.8824	0.0660
ParkGLAC	2.6674	0.4423	6.0307	0.0000
ParkLAVO	0.2030	0.4230	0.4799	0.6335
ParkMORA	1.0557	0.4466	2.3641	0.0223
ParkNOCA	0.7703	0.5208	1.4790	0.1458
ParkSEKI	2.2890	0.3455	6.6257	0.0000
ParkSTLEA	-3.5596	0.6148	-5.7897	0.0000
ParkSTLEP	-1.2996	0.5856	-2.2192	0.0313
Elevm	0.0008	0.0002	3.4741	0.0011

Residual standard error: 0.5928 on 47 degrees of freedom
Multiple R-Squared: 0.9297
F-statistic: 69.02 on 9 and 47 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Case 11 very low, case 2 low, case 9 high outliers.

Endosulfan Sulfate

formula = log(Endosulfansulfate) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	2.3087	0.4924	4.6883	0.0000
ParkCRLA	0.5475	0.3496	1.5664	0.1224
ParkDENA	-3.2553	0.3988	-8.1618	0.0000
ParkGLAC	2.9316	0.3730	7.8584	0.0000
ParkKATMF	-1.6192	0.4815	-3.3626	0.0013
ParkKATMH	0.7742	0.5484	1.4117	0.1630
ParkLAVO	0.2440	0.3646	0.6693	0.5058
ParkMORA	0.7754	0.3743	2.0717	0.0425

ParkNOCA	0.4146	0.4384	0.9457	0.3480
ParkSEKI	1.3638	0.2978	4.5803	0.0000
ParkSTLEA	-1.0649	0.5107	-2.0853	0.0412

Residual standard error: 0.5116 on 62 degrees of freedom
Multiple R-Squared: 0.9541
F-statistic: 107.3 on 12 and 62 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Case 23 very low, case 2 low and 19 high outliers.

Sum Endosulfans

formula = log(SumEndosulfans) ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	2.7285	0.4776	5.7130	0.0000
ParkCRLA	0.5354	0.3390	1.5792	0.1194
ParkDENA	-3.0838	0.3868	-7.9718	0.0000
ParkGLAC	2.7030	0.3618	7.4708	0.0000
ParkKATMF	-1.5187	0.4670	-3.2520	0.0019
ParkKATMH	0.4639	0.5319	0.8721	0.3865
ParkLAVO	0.1960	0.3536	0.5541	0.5815
ParkMORA	0.8161	0.3630	2.2482	0.0281
ParkNOCA	0.4569	0.4252	1.0745	0.2867
ParkSEKI	1.5097	0.2888	5.2277	0.0000
ParkSTLEA	-1.1371	0.4953	-2.2959	0.0251
ParkSTLEP	1.7579	0.4735	3.7129	0.0004
Elevm	0.0009	0.0002	5.1807	0.0000

Residual standard error: 0.4962 on 62 degrees of freedom
Multiple R-Squared: 0.9541
F-statistic: 107.3 on 12 and 62 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Case 23 very low, 73 and 19 high outliers.

HCB

formula = sqrt(HCB) ~ Park + Elevm, data = HCB
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	0.1100	0.6700	0.1641	0.8702
ParkCRLA	1.2685	0.4715	2.6906	0.0092
ParkDENA	-0.0181	0.5564	-0.0325	0.9741
ParkGLAC	7.1881	0.5048	14.2398	0.0000
ParkKATMF	3.3725	0.6519	5.1730	0.0000
ParkKATMH	5.1370	0.7439	6.9051	0.0000
ParkLAVO	0.5347	0.4916	1.0876	0.2811
ParkMORA	1.5388	0.5070	3.0351	0.0036
ParkNOCA	1.5773	0.5935	2.6579	0.0101
ParkSEKI	0.8270	0.4015	2.0598	0.0438
ParkSTLEA	1.9689	0.6928	2.8419	0.0061
ParkSTLEP	8.2182	0.6619	12.4167	0.0000
Elevm	0.0012	0.0002	5.1381	0.0000

Residual standard error: 0.6897 on 60 degrees of freedom
Multiple R-Squared: 0.9368
F-statistic: 74.15 on 12 and 60 degrees of freedom, the p-value is 0
Residual plot range between -1 and +2. Cases 2 (low) and 9 and 18 high.

α-HCH

formula = log(aHCH) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.8944	0.5394	-1.6580	0.1024
ParkCRLA	0.7264	0.3829	1.8971	0.0625
ParkDENA	-0.6901	0.4369	-1.5795	0.1193
ParkGLAC	3.2538	0.4087	7.9623	0.0000
ParkKATMF	1.7755	0.5275	3.3660	0.0013
ParkKATMH	3.1398	0.6008	5.2263	0.0000
ParkLAVO	0.3980	0.3994	0.9965	0.3229
ParkMORA	2.2500	0.4100	5.4876	0.0000
ParkNOCA	1.9666	0.4803	4.0947	0.0001
ParkSEKI	0.0906	0.3262	0.2778	0.7821
ParkSTLEA	2.2205	0.5594	3.9691	0.0002
ParkSTLEP	4.1586	0.5348	7.7764	0.0000
Elevm	0.0013	0.0002	6.7546	0.0000

Residual standard error: 0.5605 on 62 degrees of freedom
Multiple R-Squared: 0.8793
F-statistic: 37.65 on 12 and 62 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Cases 23, 73, and 19 high.

γ-HCH

formula = sqrt(gHCH) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.0997	0.6836	-1.6087	0.1128
ParkCRLA	-0.0675	0.4853	-0.1392	0.8898
ParkDENA	0.2013	0.5537	0.3635	0.7175
ParkGLAC	6.3376	0.5179	12.2379	0.0000
ParkKATMF	1.1518	0.6684	1.7231	0.0899
ParkKATMH	2.6427	0.7613	3.4712	0.0009
ParkLAVO	-0.3969	0.5062	-0.7841	0.4360
ParkMORA	2.3683	0.5196	4.5580	0.0000
ParkNOCA	1.7265	0.6087	2.8365	0.0062
ParkSEKI	0.9654	0.4134	2.3354	0.0228
ParkSTLEA	1.9234	0.7089	2.7131	0.0086
ParkSTLEP	3.9268	0.6777	5.7945	0.0000
Elevm	0.0016	0.0002	6.4561	0.0000

Residual standard error: 0.7102 on 62 degrees of freedom
Multiple R-Squared: 0.897
F-statistic: 45.01 on 12 and 62 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Cases 23 (very low) and 19 and 73 high outliers.

trans-Chlordane

formula = transChlordane ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.3755	1.3069	-1.8176	0.0750
ParkCRLA	1.7337	0.8895	1.9490	0.0568
ParkGLAC	3.9573	0.9647	4.1020	0.0001
ParkKATMF	1.1313	1.2488	0.9060	0.3692
ParkKATMH	2.7274	1.4353	1.9003	0.0631

ParkLAVO	1.8793	0.9267	2.0280	0.0478
ParkMORA	2.0931	0.9728	2.1516	0.0362
ParkNOCA	1.3339	1.1355	1.1747	0.2456
ParkSEKI	4.8500	0.7568	6.4087	0.0000
ParkSTLEA	1.9919	1.3370	1.4898	0.1424
ParkSTLEP	2.9709	1.2744	2.3312	0.0237
Elevm	0.0018	0.0005	3.7280	0.0005

Residual standard error: 1.299 on 51 degrees of freedom
Multiple R-Squared: 0.7684
F-statistic: 15.38 on 11 and 51 degrees of freedom, the p-value is 1.306e-012
Residual plot range between -2 and +2. Cases 51 (low) and 61 and 9 high outliers.

cis-Nonachlor

formula = cisNonachlor ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.3992	0.5406	-2.5884	0.0125
ParkCRLA	0.7191	0.3679	1.9546	0.0561
ParkGLAC	1.7262	0.3990	4.3263	0.0001
ParkKATMF	0.8340	0.5165	1.6148	0.1125
ParkKATMH	1.7377	0.5936	2.9271	0.0051
ParkLAVO	0.5762	0.3833	1.5034	0.1389
ParkMORA	0.8960	0.4024	2.2268	0.0304
ParkNOCA	0.7204	0.4697	1.5339	0.1312
ParkSEKI	1.8485	0.3130	5.9055	0.0000
ParkSTLEA	1.2299	0.5530	2.2241	0.0306
ParkSTLEP	2.0254	0.5271	3.8424	0.0003
Elevm	0.0009	0.0002	4.8589	0.0000

Residual standard error: 0.5373 on 51 degrees of freedom
Multiple R-Squared: 0.7595
F-statistic: 14.64 on 11 and 51 degrees of freedom, the p-value is 3.254e-012
Residuals plot range between -1 and +1. Cases 11 (low) and 61 and 9 high outliers.

trans-Nonachlor

formula = transNonachlor ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.5202	1.3352	-1.8875	0.0648
ParkCRLA	1.8376	0.9088	2.0221	0.0484
ParkGLAC	3.7946	0.9856	3.8502	0.0003
ParkKATMF	1.3459	1.2757	1.0550	0.2964
ParkKATMH	3.3647	1.4663	2.2947	0.0259
ParkLAVO	1.7117	0.9467	1.8081	0.0765
ParkMORA	1.8813	0.9938	1.8930	0.0640
ParkNOCA	1.3925	1.1601	1.2004	0.2355
ParkSEKI	4.1004	0.7731	5.3036	0.0000
ParkSTLEA	2.2491	1.3659	1.6466	0.1058
ParkSTLEP	3.5636	1.3020	2.7371	0.0085
Elevm	0.0017	0.0005	3.5885	0.0007

Residual standard error: 1.327 on 51 degrees of freedom
Multiple R-Squared: 0.6971
F-statistic: 10.67 on 11 and 51 degrees of freedom, the p-value is 8.093e-010
Residuals plot range between -2 and +2. Cases 17, 61 and 9 high outliers.

Sum of Chlordanes

formula = sqrt(SumChlordane) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	0.1250	0.6599	0.1894	0.8505
ParkCRLA	0.8772	0.4492	1.9530	0.0563
ParkGLAC	1.5560	0.4871	3.1943	0.0024
ParkKATMF	0.1564	0.6305	0.2480	0.8051
ParkKATMH	1.5729	0.7247	2.1704	0.0347
ParkLAVO	1.1679	0.4679	2.4959	0.0158
ParkMORA	1.0416	0.4912	2.1206	0.0388
ParkNOCA	0.1812	0.5734	0.3161	0.7532
ParkSEKI	2.2368	0.3821	5.8537	0.0000
ParkSTLEA	0.3788	0.6751	0.5612	0.5771
ParkSTLEP	1.4204	0.6435	2.2074	0.0318
Elevm	0.0009	0.0002	3.9338	0.0003

Residual standard error: 0.6559 on 51 degrees of freedom

Multiple R-Squared: 0.7878

F-statistic: 17.22 on 11 and 51 degrees of freedom, the p-value is 1.558e-013

Residuals plot range between -1 and +1. Cases 61 and 9 high outliers.

Sum of DDTs

formula = log(DDTSum) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	2.0223	0.5692	3.5531	0.0010
ParkCRLA	-0.4842	0.3569	-1.3567	0.1825
ParkGLAC	2.5460	0.4011	6.3469	0.0000
ParkLAVO	0.4262	0.3707	1.1497	0.2571
ParkMORA	-1.4277	0.4077	-3.5015	0.0012
ParkNOCA	-1.5304	0.4727	-3.2379	0.0024
ParkSEKI	2.1791	0.3028	7.1970	0.0000
Elevm	0.0004	0.0002	1.7519	0.0875

Residual standard error: 0.5186 on 40 degrees of freedom

Multiple R-Squared: 0.9321

F-statistic: 78.46 on 7 and 40 degrees of freedom, the p-value is 0

Residual plot range between -1 an +1. Cases 2 (low) and 18 and 33 high outliers.

PCB 118

formula = log(PCB118) ~ Park + Elevm

Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.1580	0.6202	-1.8671	0.0694
ParkCRLA	0.3751	0.4939	0.7594	0.4522
ParkGLAC	1.2140	0.4376	2.7739	0.0085
ParkKATMH	0.6093	0.6653	0.9159	0.3654
ParkLAVO	0.3561	0.6363	0.5596	0.5789
ParkMORA	0.8471	0.4454	1.9018	0.0646
ParkNOCA	0.7244	0.5166	1.4024	0.1687
ParkSEKI	0.1868	0.3318	0.5628	0.5768
ParkSTLEA	0.1196	0.6301	0.1899	0.8504
ParkSTLEP	1.3307	0.6724	1.9790	0.0549
Elevm	0.0006	0.0002	2.5688	0.0141

Residual standard error: 0.5684 on 39 degrees of freedom
Multiple R-Squared: 0.3786
F-statistic: 2.376 on 10 and 39 degrees of freedom, the p-value is 0.02623
Residuals range between -1 and +1. Case 8 very low outlier.

PCB 153

formula = PCB153 ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.1434	0.6019	-0.2383	0.8126
ParkCRLA	0.2482	0.4096	0.6060	0.5472
ParkGLAC	1.5311	0.4443	3.4464	0.0011
ParkKATMF	-0.0854	0.5751	-0.1485	0.8825
ParkKATMH	0.7329	0.6610	1.1088	0.2727
ParkLAVO	-0.1258	0.4267	-0.2948	0.7693
ParkMORA	1.0255	0.4480	2.2891	0.0262
ParkNOCA	0.1088	0.5229	0.2081	0.8360
ParkSEKI	0.1757	0.3485	0.5040	0.6164
ParkSTLEA	0.2515	0.6157	0.4084	0.6847
ParkSTLEP	1.0623	0.5869	1.8101	0.0762
Elevm	0.0006	0.0002	2.9983	0.0042

Residual standard error: 0.5982 on 51 degrees of freedom
Multiple R-Squared: 0.5345
F-statistic: 5.324 on 11 and 51 degrees of freedom, the p-value is 0.00001521
Residual plot range between -1 and +1. Cases 11 (low) and 9 and 61 high outliers.

PCB 183

formula = PCB183 ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.0418	0.1495	-0.2798	0.7807
ParkCRLA	0.0133	0.1064	0.1247	0.9012
ParkGLAC	0.0769	0.1103	0.6974	0.4888
ParkKATMF	-0.0353	0.1427	-0.2476	0.8055
ParkKATMH	0.2192	0.1641	1.3356	0.1877
ParkLAVO	-0.0787	0.1058	-0.7441	0.4603
ParkMORA	0.1935	0.1112	1.7402	0.0880
ParkNOCA	0.0463	0.1298	0.3566	0.7229
ParkSEKI	0.1099	0.0864	1.2719	0.2093
ParkSTLEA	0.0446	0.1529	0.2918	0.7717
ParkSTLEP	0.1799	0.1457	1.2349	0.2226
Elevm	0.0002	0.0001	2.9410	0.0049

Residual standard error: 0.1483 on 50 degrees of freedom
Multiple R-Squared: 0.4552
F-statistic: 3.798 on 11 and 50 degrees of freedom, the p-value is 0.0005441
Residual plot range between -.2 and +.2. Outliers 60, 47 and 48 high.

Sum of PCBs

formula = PCBSum ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.3328	2.3896	-0.5577	0.5795
ParkCRLA	0.7753	1.6264	0.4767	0.6356
ParkGLAC	7.8398	1.7639	4.4446	0.0000

ParkKATMF	-0.4112	2.2832	-0.1801	0.8578
ParkKATMH	3.6197	2.6243	1.3793	0.1738
ParkLAVO	-1.1251	1.6943	-0.6641	0.5096
ParkMORA	4.2087	1.7787	2.3662	0.0218
ParkNOCA	1.9161	2.0762	0.9229	0.3604
ParkSEKI	1.1741	1.3837	0.8485	0.4001
ParkSTLEA	1.4407	2.4446	0.5894	0.5582
ParkSTLEP	4.1668	2.3301	1.7882	0.0797
Elevm	0.0030	0.0009	3.5145	0.0009

Residual standard error: 2.375 on 51 degrees of freedom
Multiple R-Squared: 0.6174
F-statistic: 7.481 on 11 and 51 degrees of freedom, the p-value is 1.879e-007
Residual plot range between -4 and +4. Cases 38, 9 and 10 high outliers.

FLO

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formula = log(FLO) ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	2.3852	0.6061	3.9355	0.0003
ParkCRLA	2.1241	0.5901	3.5996	0.0008
ParkDENA	-1.3529	0.5818	-2.3254	0.0248
ParkGLAC	4.8701	0.4977	9.7859	0.0000
ParkKATMF	-0.6778	0.6617	-1.0242	0.3115
ParkKATMH	0.9093	0.6266	1.4512	0.1540
ParkLAVO	1.1731	0.4635	2.5307	0.0151
ParkMORA	1.4319	0.5047	2.8370	0.0069
ParkNOCA	0.8034	0.5392	1.4899	0.1435
ParkSEKI	2.3795	0.4319	5.5098	0.0000
ParkSTLEA	-0.4440	0.6011	-0.7387	0.4641
ParkSTLEP	2.1383	0.5821	3.6736	0.0007
Elevm	-0.0007	0.0002	-4.1979	0.0001

Residual standard error: 0.4004 on 43 degrees of freedom
Multiple R-Squared: 0.9479
F-statistic: 65.24 on 12 and 43 degrees of freedom, the p-value is 0
Residual plot range between -.5 and +1. Cases 16 (low) and 18 and 33 high outliers.

PHE

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formula = log(PHE) ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	6.5184	0.3276	19.8970	0.0000
ParkDENA	-3.5566	0.3037	-11.7123	0.0000
ParkGLAC	4.6367	0.2378	19.4966	0.0000
ParkKATMF	-3.0210	0.3624	-8.3357	0.0000
ParkKATMH	-0.9352	0.3694	-2.5319	0.0146
ParkLAVO	-1.0698	0.2674	-4.0000	0.0002
ParkMORA	-0.6393	0.2347	-2.7238	0.0089
ParkNOCA	-1.2356	0.2852	-4.3325	0.0001
ParkSEKI	0.2895	0.1961	1.4764	0.1462
ParkSTLEA	-3.0623	0.3402	-9.0024	0.0000
ParkSTLEP	0.6759	0.3226	2.0951	0.0413
Elevm	-0.0006	0.0001	-4.2772	0.0001

Residual standard error: 0.3659 on 49 degrees of freedom
Multiple R-Squared: 0.9754

F-statistic: 176.4 on 11 and 49 degrees of freedom, the p-value is 0
Residual plot range between -.5 and +.5. Cases 25 and 3 low and 8 high outliers.

Retene

formula = log(Retene + 1e-006) ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	4.3334	2.9265	1.4807	0.1442
ParkCRLA	4.7735	2.0253	2.3570	0.0219
ParkDENA	-3.5747	2.5152	-1.4212	0.1607
ParkGLAC	6.8797	2.1943	3.1352	0.0027
ParkKATMF	0.9801	2.8216	0.3474	0.7296
ParkKATMH	0.1757	3.2315	0.0544	0.9568
ParkLAVO	3.9156	2.1109	1.8549	0.0688
ParkMORA	2.4660	2.1962	1.1229	0.2662
ParkNOCA	1.5408	2.5672	0.6002	0.5508
ParkSEKI	4.9443	1.7239	2.8681	0.0058
ParkSTLEA	-0.7905	3.0098	-0.2626	0.7938
ParkSTLEP	1.4773	2.8721	0.5144	0.6090
Elevm	-0.0015	0.0010	-1.4802	0.1443

Residual standard error: 2.96 on 57 degrees of freedom
Multiple R-Squared: 0.4881
F-statistic: 4.529 on 12 and 57 degrees of freedom, the p-value is 0.00004422
Residual plot better, but messy, range -5 and +5. Many very low outliers, especially low cases 4 and 14.

CHR/TRI

formula = log(CHR.TRI) ~ Park + Elevm,
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	3.7637	0.6259	6.0133	0.0000
ParkCRLA	1.3432	0.4425	3.0351	0.0035
ParkDENA	-2.7154	0.5061	-5.3647	0.0000
ParkGLAC	5.5466	0.4760	11.6536	0.0000
ParkKATMF	-1.2986	0.6107	-2.1264	0.0375
ParkKATMH	-1.7043	0.6961	-2.4483	0.0172
ParkLAVO	-0.6584	0.4616	-1.4265	0.1588
ParkMORA	0.7754	0.4748	1.6331	0.1076
ParkNOCA	0.1692	0.5560	0.3043	0.7619
ParkSEKI	0.8921	0.3769	2.3667	0.0211
ParkSTLEA	-1.6393	0.6483	-2.5289	0.0140
ParkSTLEP	-0.3516	0.6195	-0.5676	0.5724
Elevm	-0.0005	0.0002	-2.3518	0.0219

Residual standard error: 0.6476 on 61 degrees of freedom
Multiple R-Squared: 0.9271
F-statistic: 64.65 on 12 and 61 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Cases 7 (low) and 8 and 19 high outliers.

B(a)A

formula = log(BaA) ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	4.3467	0.8383	5.1850	0.0000
ParkCRLA	-0.1428	0.5875	-0.2431	0.8088
ParkDENA	-4.5253	0.6755	-6.6989	0.0000

ParkGLAC	4.7703	0.6338	7.5271	0.0000
ParkLAVO	-1.1255	0.6126	-1.8373	0.0714
ParkMORA	-1.2420	0.6331	-1.9618	0.0547
ParkNOCA	-3.2363	0.7408	-4.3688	0.0001
ParkSEKI	0.6786	0.5002	1.3565	0.1803
ParkSTLEA	-3.0583	0.8657	-3.5327	0.0008
ParkSTLEP	-2.1140	0.8268	-2.5568	0.0133
Elevm	-0.0014	0.0003	-4.6703	0.0000

Residual standard error: 0.8593 on 57 degrees of freedom
Multiple R-Squared: 0.8998
F-statistic: 51.21 on 10 and 57 degrees of freedom, the p-value is 0
Residual plot better, range between -1 and +1. Cases 57 (low) and 58 and 19 high outliers.

SUM OF PAHs

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formula = log(PAHSum) ~ Park + Elevm
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	7.0345	0.6864	10.2479	0.0000
ParkCRLA	1.5044	0.4853	3.0996	0.0029
ParkDENA	-4.1538	0.5551	-7.4830	0.0000
ParkGLAC	5.8868	0.5220	11.2776	0.0000
ParkKATMF	-1.7076	0.6697	-2.5496	0.0133
ParkKATMH	-0.8984	0.7634	-1.1768	0.2439
ParkLAVO	0.3340	0.5062	0.6597	0.5119
ParkMORA	0.5403	0.5207	1.0377	0.3035
ParkNOCA	-0.2387	0.6098	-0.3915	0.6968
ParkSEKI	1.5335	0.4134	3.7094	0.0005
ParkSTLEA	-2.0292	0.7109	-2.8542	0.0059
ParkSTLEP	0.8172	0.6794	1.2029	0.2337
Elevm	-0.0009	0.0002	-3.5744	0.0007

Residual standard error: 0.7102 on 61 degrees of freedom
Multiple R-Squared: 0.9374
F-statistic: 76.11 on 12 and 61 degrees of freedom, the p-value is 0
Residual plot range between -1 and +1. Case 19 is high outlier. Several other outliers. Cases 17 and others low.

Appendix 4A.12. Summary Statistics of Element Concentrations (ppm) in Lichen Samples from the Core WACAP Parks.

		GAAR		NOAT		DENA		OLYM		MORA	SEKI	GLAC			ROMO
		Flcu	Mari	Flcu	Mari	Flcu	Mari	Alsa	Plgl	Alsa	Levu	Alsa	Levu	Plgl	Xant
	N	3	2	2	4	6	6	6	2	6	3	3	3	3	3
Al	**Mean**	**675.5**	**90.5**	**133.0**	**48.2**	**237.9**	**47.0**	**34.0**	**422.5**	**60.3**	**283.3**	**99.7**	**383.3**	**897.6**	**3066.7**
	s.d.	131.5	5.0	1.9	13.5	29.5	9.0	8.9	116.7	16.3	55.1	12.4	79.3	184.8	957.1
	s.e.	75.9	3.5	1.3	6.7	12.0	3.7	3.6	82.5	6.6	31.8	7.2	45.8	106.7	552.6
As	**Mean**	**0.66**	**0.19**	**0.20**	**0.07**	**0.39**	**0.16**	**0.06**	**0.31**	**0.10**	**0.30**	**0.18**	**0.58**	**0.60**	
	s.d.	0.06	0.02	0.05	0.03	0.09	0.04	0.02	0.03	0.04	0.05	0.04	0.09	0.03	
	s.e.	0.03	0.01	0.04	0.01	0.04	0.02	0.01	0.02	0.02	0.03	0.02	0.05	0.02	
Ba	**Mean**	**9.49**	**3.31**	**70.00**	**41.02**	**9.59**	**3.38**	**9.94**	**56.17**	**1.66**	**5.72**	**17.49**	**11.22**	**71.38**	**31.24**
	s.d.	1.98	0.05	3.34	26.72	1.57	1.08	2.43	16.34	0.59	0.84	3.51	1.94	4.64	12.64
	s.e.	1.14	0.03	2.36	13.36	0.64	0.44	0.99	11.56	0.24	0.49	2.02	1.12	2.68	7.30
Bi	**Mean**	**0.023**	**0.023**	**0.056**	**0.026**	**0.017**	**0.013**	**0.007**	**0.028**	**0.016**	**0.017**	**0.021**	**0.051**	**0.071**	
	s.d.	0.003	0.008	0.003	0.025	0.010	0.006	0.001	0.006	0.009	0.002	0.007	0.007	0.018	
	s.e.	0.002	0.006	0.002	0.013	0.004	0.002	0.000	0.004	0.004	0.001	0.004	0.004	0.010	
Ca	**Mean**	**21956**	**18090**	**4139**	**2517**	**1341**	**1252**	**3000**	**2514**	**4234**	**1564**	**1754**	**2729**	**2913**	**17062**
	s.d.	1506	857	158	1410	42	378	1358	414	1128	235	251	737	92	4870
	s.e.	870	606	112	705	17	154	554	293	460	136	145	425	53	2812
Cd	**Mean**	**0.220**	**0.202**	**0.194**	**0.136**	**0.101**	**0.064**	**0.077**	**0.084**	**0.068**	**0.072**	**0.100**	**0.337**	**0.379**	**0.663**
	s.d.	0.050	0.003	0.021	0.053	0.027	0.013	0.034	0.036	0.020	0.006	0.012	0.077	0.043	0.137
	s.e.	0.029	0.002	0.015	0.026	0.011	0.005	0.014	0.026	0.008	0.003	0.007	0.044	0.025	0.079
Ce	**Mean**	**2.38**	**0.44**	**0.18**	**0.12**	**0.39**	**0.13**	**0.08**	**0.36**	**0.20**	**0.55**	**0.24**	**1.44**	**1.78**	
	s.d.	0.25	0.05	0.01	0.05	0.04	0.05	0.02	0.00	0.03	0.12	0.04	0.22	0.11	
	s.e.	0.15	0.03	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.07	0.02	0.13	0.06	
Co	**Mean**	**0.47**	**0.12**	**0.16**	**0.11**	**0.28**	**0.12**	**0.11**	**0.25**	**0.07**	**0.15**	**0.10**	**0.27**	**0.36**	**0.24**
	s.d.	0.08	0.02	0.01	0.03	0.06	0.02	0.06	0.08	0.03	0.03	0.00	0.03	0.03	0.00
	s.e.	0.05	0.01	0.01	0.02	0.02	0.01	0.02	0.06	0.01	0.02	0.00	0.02	0.02	0.00
Cu	**Mean**	**2.51**	**1.04**	**1.70**	**0.75**	**1.55**	**0.80**	**0.72**	**2.50**	**1.06**	**2.93**	**1.22**	**1.97**	**3.40**	**10.43**
	s.d.	0.27	0.01	0.06	0.09	0.12	0.08	0.14	0.08	0.30	0.31	0.03	0.35	0.26	4.51
	s.e.	0.15	0.01	0.04	0.05	0.05	0.03	0.06	0.06	0.12	0.18	0.01	0.20	0.15	2.60
Dy	**Mean**	**0.118**	**0.041**	**0.021**	**0.013**	**0.027**	**0.017**	**0.008**	**0.023**	**0.015**	**0.031**	**0.019**	**0.115**	**0.106**	
	s.d.	0.034	0.000	0.002	0.005	0.004	0.007	0.002	0.004	0.003	0.007	0.005	0.019	0.008	
	s.e.	0.019	0.000	0.001	0.003	0.002	0.003	0.001	0.003	0.001	0.004	0.003	0.011	0.005	
Er	**Mean**	**0.049**	**0.019**	**0.011**	**0.005**	**0.015**	**0.008**	**0.003**	**0.011**	**0.009**	**0.016**	**0.012**	**0.064**	**0.056**	
	s.d.	0.013	0.001	0.001	0.002	0.002	0.004	0.002	0.000	0.003	0.004	0.004	0.011	0.003	
	s.e.	0.008	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.001	0.002	0.002	0.006	0.002	
Eu	**Mean**	**0.045**	**0.010**	**0.005**	**0.004**	**0.009**	**0.004**	**0.002**	**0.007**	**0.004**	**0.008**	**0.005**	**0.028**	**0.029**	
	s.d.	0.007	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.004	0.002	
	s.e.	0.004	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.002	0.001	
Fe	**Mean**	**1656.7**	**245.8**	**272.0**	**98.9**	**405.4**	**101.2**	**50.7**	**525.0**	**64.7**	**363.3**	**132.3**	**562.7**	**1325.6**	**2905.8**
	s.d.	119.3	3.2	2.7	19.1	92.1	24.6	15.8	91.9	19.0	51.3	9.2	106.3	172.1	891.1
	s.e.	68.9	2.3	1.9	9.5	37.6	10.0	6.5	65.0	7.8	29.6	5.3	61.4	99.4	514.5
Ga	**Mean**	**0.211**	**0.033**	**0.054**	**0.015**	**0.080**	**0.018**	**0.014**	**0.128**	**0.022**	**0.087**	**0.043**	**0.137**	**0.370**	
	s.d.	0.032	0.002	0.002	0.003	0.012	0.004	0.003	0.028	0.007	0.013	0.001	0.024	0.057	
	s.e.	0.019	0.001	0.002	0.001	0.005	0.002	0.001	0.020	0.003	0.008	0.001	0.014	0.033	

Gd	**Mean**	**0.192**	**0.051**	**0.027**	**0.019**	**0.039**	**0.020**	**0.008**	**0.028**	**0.022**	**0.041**	**0.026**	**0.143**	**0.143**	
	s.d.	0.038	0.003	0.001	0.007	0.010	0.008	0.004	0.005	0.005	0.009	0.002	0.029	0.009	
	s.e.	0.022	0.002	0.001	0.004	0.004	0.003	0.002	0.003	0.002	0.005	0.001	0.017	0.005	
Hg	**Mean**	**0.017**	**0.023**	**0.022**	**0.026**	**0.012**	**0.021**	**0.232**	**0.268**	**0.154**	**0.301**	**0.136**	**0.388**	**0.266**	
	s.d.	0.002	0.003	0.003	0.003	0.002	0.006	0.036	0.025	0.023	0.017	0.017	0.067	0.020	
	s.e.	0.001	0.002	0.002	0.002	0.001	0.003	0.015	0.018	0.009	0.010	0.010	0.039	0.012	
Ho	**Mean**	**0.020**	**0.007**	**0.004**	**0.003**	**0.005**	**0.003**	**0.002**	**0.005**	**0.004**	**0.006**	**0.003**	**0.022**	**0.021**	
	s.d.	0.005	0.001	0.000	0.001	0.001	0.002	0.000	0.000	0.001	0.001	0.001	0.005	0.003	
	s.e.	0.003	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.001	0.003	0.002	
K	**Mean**	**1840**	**1418**	**2611**	**1476**	**2603**	**1462**	**1583**	**1494**	**1821**	**2319**	**1917**	**2246**	**2047**	**2963**
	s.d.	159	33	264	88	270	234	183	114	130	64	166	190	27	195
	s.e.	92	23	187	44	110	95	75	80	53	37	96	110	16	113
La	**Mean**	**1.133**	**0.212**	**0.084**	**0.054**	**0.182**	**0.057**	**0.036**	**0.178**	**0.089**	**0.285**	**0.113**	**0.684**	**0.864**	
	s.d.	0.139	0.013	0.000	0.022	0.024	0.022	0.009	0.000	0.014	0.053	0.016	0.113	0.070	
	s.e.	0.080	0.009	0.000	0.011	0.010	0.009	0.004	0.000	0.006	0.031	0.009	0.065	0.041	
Li	**Mean**	**0.837**	**0.096**	**0.135**	**0.022**	**0.224**	**0.038**	**0.028**	**0.204**	**0.027**	**0.238**	**0.125**	**0.311**	**0.557**	**2.067**
	s.d.	0.135	0.069	0.002	0.000	0.051	0.026	0.012	0.051	0.018	0.072	0.050	0.031	0.155	0.505
	s.e.	0.078	0.049	0.001	0.000	0.021	0.010	0.005	0.036	0.007	0.042	0.029	0.018	0.089	0.292
Lu	**Mean**	**0.007**	**0.003**	**0.001**	**0.001**	**0.002**	**0.001**	**0.000**	**0.001**	**0.001**	**0.002**	**0.001**	**0.008**	**0.007**	
	s.d.	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.001	
	s.e.	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	
Mg	**Mean**	**793.2**	**192.6**	**686.2**	**186.9**	**383.5**	**116.7**	**346.6**	**386.0**	**261.4**	**453.9**	**325.3**	**600.2**	**639.4**	**932.0**
	s.d.	10.9	7.1	21.0	27.0	57.7	25.5	42.8	29.5	16.2	33.8	9.6	51.7	37.8	171.0
	s.e.	6.3	5.0	14.8	13.5	23.6	10.4	17.5	20.9	6.6	19.5	5.6	29.8	21.8	98.7
Mn	**Mean**	**58.0**	**21.3**	**385.3**	**97.2**	**208.8**	**31.1**	**100.1**	**164.0**	**153.7**	**97.3**	**160.6**	**262.2**	**126.3**	**77.0**
	s.d.	4.2	0.2	30.9	28.9	52.8	13.7	48.0	118.2	67.9	2.4	23.7	113.4	5.1	42.2
	s.e.	2.4	0.2	21.8	14.4	21.5	5.6	19.6	83.6	27.7	1.4	13.7	65.5	2.9	24.3
Mo	**Mean**	**626.94**	**0.61**	**0.51**	**0.34**		**0.29**	**0.30**	**0.86**	**166.33**		**0.58**	**0.35**	**0.42**	**1.82**
	s.d.	58.67	0.22	.	0.08		.	0.11	.	190.53		0.39	.	.	0.31
	s.e.	33.87	0.16	.	0.06		.	0.08	.	77.78		0.28	.	.	0.18
Na	**Mean**	**1.2**	**94.3**	**718.3**	**226.6**	**144.7**	**150.3**	**137.0**	**104.6**	**0.1**	**67.2**	**137.1**	**95.5**	**105.6**	**92.1**
	s.d.	0.1	4.9	23.8	192.5	38.8	162.0	35.8	56.2	0.0	54.2	173.2	33.7	35.1	11.8
	s.e.	0.1	3.5	16.9	96.2	15.8	66.1	14.6	39.7	0.0	31.3	100.0	19.5	20.2	6.8
Nd	**Mean**	**1.274**	**0.230**	**0.107**	**0.073**	**0.197**	**0.083**	**0.042**	**0.187**	**0.323**	**0.230**	**0.125**	**0.746**	**0.873**	
	s.d.	0.229	0.029	0.001	0.027	0.015	0.033	0.013	0.004	0.262	0.047	0.024	0.124	0.060	
	s.e.	0.132	0.020	0.001	0.013	0.006	0.013	0.005	0.003	0.107	0.027	0.014	0.071	0.035	
Ni	**Mean**	**544.378**	**0.225**	**0.802**	**0.413**	**0.717**	**0.325**	**0.446**	**2.124**	**674.208**	**0.916**	**0.810**	**0.594**	**2.128**	**4.330**
	s.d.	45.214	0.033	0.300	0.063	0.198	0.228	0.114	0.810	117.317	0.229	0.393	0.102	0.077	0.410
	s.e.	26.104	0.023	0.212	0.032	0.081	0.093	0.047	0.573	47.894	0.132	0.227	0.059	0.054	0.237
P	**Mean**	**1**	**330**	**763**	**491**	**538**	**327**	**433**	**740**	**1**	**738**	**648**	**583**	**705**	**1112**
	s.d.	0	23	16	116	143	113	98	142	0	73	96	110	56	165
	s.e.	0	16	11	58	59	46	40	101	0	42	55	63	32	95
Pb	**Mean**	**0.30**	**0.86**	**0.25**	**0.42**	**0.53**	**0.48**	**1.09**	**4.22**	**0.03**	**1.39**	**0.96**	**3.90**	**6.59**	**21.16**
	s.d.	0.03	0.02	0.02	0.13	0.04	0.17	0.23	0.44	0.01	0.18	0.23	.	.	1.65
	s.e.	0.02	0.01	0.01	0.07	0.01	0.07	0.09	0.31	0.00	0.10	0.13	.	.	0.95
Pr	**Mean**	**3.924**	**0.055**	**0.024**	**0.016**	**0.049**	**0.018**	**0.010**	**0.046**	**3.623**	**0.062**	**0.030**	**0.182**	**0.223**	
	s.d.	0.325	0.004	0.001	0.006	0.006	0.007	0.002	0.000	0.875	0.015	0.005	0.029	0.016	
	s.e.	0.188	0.003	0.001	0.003	0.002	0.003	0.001	0.000	0.357	0.009	0.003	0.017	0.009	

Rb	**Mean**	**330.93**	**2.46**	**3.38**	**2.42**	**8.05**	**4.72**	**1.70**	**2.50**	**409.43**	**8.10**	**1.51**	**1.80**	**3.11**	
	s.d.	39.88	0.05	0.24	0.26	1.44	1.52	0.79	0.45	88.62	0.20	0.28	0.03	0.29	
	s.e.	23.03	0.03	0.17	0.13	0.59	0.62	0.32	0.32	36.18	0.11	0.16	0.02	0.16	
S	**Mean**	**0**	**227**	**296**	**244**	**244**	**240**	**353**	**585**	**0**	**1017**	**568**	**1073**	**985**	**1227**
	s.d.	0	47	6	29	32	60	75	83	0	64	22	107	46	154
	s.e.	0	33	4	15	13	25	31	59	0	37	13	62	27	89
Sb	**Mean**	**0.237**	**0.032**	**0.101**	**0.016**	**0.070**	**0.021**	**0.012**	**0.017**	**0.023**	**0.016**	**0.052**	**0.124**	**0.140**	
	s.d.	0.027	0.005	0.008	0.008	0.016	0.010	0.008	0.005	0.007	0.006	0.005	0.008	0.014	
	s.e.	0.016	0.004	0.006	0.004	0.007	0.004	0.003	0.003	0.003	0.004	0.003	0.005	0.008	
Sm	**Mean**	**15.941**	**0.052**	**0.023**	**0.016**	**0.040**	**0.018**	**0.010**	**0.037**	**5.753**	**0.044**	**0.025**	**0.144**	**0.165**	
	s.d.	1.211	0.010	0.007	0.005	0.002	0.007	0.004	0.002	1.728	0.009	0.002	0.023	0.005	
	s.e.	0.699	0.007	0.005	0.003	0.001	0.003	0.002	0.001	0.705	0.005	0.001	0.013	0.003	
Sr	**Mean**	**0.03**	**8.68**	**6.46**	**2.60**	**3.17**	**1.59**	**12.18**	**15.81**	**0.00**	**6.14**	**5.92**	**3.88**	**19.55**	**21.75**
	s.d.	0.00	0.77	0.06	0.85	0.23	0.22	2.53	6.73	0.00	0.92	0.96	0.58	0.08	4.11
	s.e.	0.00	0.55	0.04	0.42	0.10	0.09	1.03	4.76	0.00	0.53	0.55	0.34	0.05	2.37
Tb	**Mean**	**0.414**	**0.007**	**0.004**	**0.002**	**0.005**	**0.003**	**0.001**	**0.005**	**0.021**	**0.005**	**0.003**	**0.019**	**0.021**	
	s.d.	0.004	0.000	0.001	0.001	0.000	0.001	0.000	0.001	0.022	0.001	0.000	0.002	0.001	
	s.e.	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.001	0.000	0.001	0.001	
Th	**Mean**	**0.007**	**0.030**	**0.031**	**0.023**	**0.041**	**0.028**	**0.007**	**0.061**	**0.001**	**0.115**	**0.024**	**0.205**	**0.384**	
	s.d.	0.000	0.008	0.013	0.026	0.018	0.029	0.000	0.016	0.000	0.022	0.012	0.115	0.149	
	s.e.	0.000	0.006	0.009	0.013	0.007	0.012	0.000	0.012	0.000	0.013	0.007	0.066	0.086	
Tm	**Mean**	**0.064**	**0.003**	**0.001**	**0.001**	**0.002**	**0.001**	**0.000**	**0.002**	**0.001**	**0.002**	**0.002**	**0.009**	**0.008**	
	s.d.	0.010	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.002	0.001	
	s.e.	0.006	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	
U	**Mean**	**1.341**	**0.041**	**0.007**	**0.006**	**0.024**	**0.011**	**0.003**	**0.021**	**0.108**	**0.059**	**0.011**	**0.022**	**0.059**	
	s.d.	0.191	0.008	0.002	0.004	0.009	0.004	0.005	0.006	0.103	0.004	0.009	0.003	0.005	
	s.e.	0.110	0.006	0.002	0.002	0.004	0.002	0.002	0.004	0.042	0.002	0.005	0.002	0.003	
V	**Mean**	**0.01**	**0.34**	**0.48**	**0.12**	**0.50**	**0.14**	**0.10**	**0.97**	**0.01**	**0.50**	**0.22**	**0.89**	**1.94**	**5.30**
	s.d.	.	0.16	0.02	0.03	0.07	0.02	0.05	0.14	0.00	0.11	0.06	0.20	0.04	1.76
	s.e.	.	0.11	0.01	0.01	0.03	0.01	0.02	0.10	0.00	0.07	0.03	0.12	0.03	1.02
W	**Mean**						**0.017**		**0.016**		**0.022**	**0.018**	**0.020**	**0.026**	
	s.d.						0.006		0.005		0.004	0.004	0.002	0.009	
	s.e.						0.004		0.003		0.002	0.003	0.001	0.005	
Y	**Mean**	**0.52**	**0.23**	**0.13**	**0.09**	**0.16**	**0.09**	**0.05**	**0.12**	**0.10**	**0.16**	**0.11**	**0.65**	**0.55**	
	s.d.	0.10	0.00	0.00	0.03	0.02	0.04	0.01	0.01	0.02	0.03	0.02	0.13	0.02	
	s.e.	0.06	0.00	0.00	0.02	0.01	0.02	0.00	0.01	0.01	0.02	0.01	0.07	0.01	
Yb	**Mean**	**0.042**	**0.021**	**0.008**	**0.006**	**0.012**	**0.009**	**0.004**	**0.011**	**0.007**	**0.015**	**0.010**	**0.054**	**0.052**	
	s.d.	0.010	0.000	0.001	0.002	0.002	0.003	0.001	0.001	0.002	0.003	0.002	0.011	0.004	
	s.e.	0.005	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.002	0.001	0.006	0.002	
Zn	**Mean**	**27.4**	**20.7**	**0.5**	**25.0**	**23.3**	**13.8**	**17.3**	**23.7**	**22.7**	**27.0**	**20.0**	**38.7**	**24.9**	**54.9**
	s.d.	2.4	0.8	0.3	2.2	1.4	1.3	0.8	0.8	4.3	4.4	0.6	2.3	1.5	2.8
	s.e.	1.4	0.6	0.2	1.1	0.6	0.5	0.3	0.6	1.8	2.5	0.3	1.3	0.9	1.6
Zr	**Mean**	**0.86**	**0.28**		**0.35**	**0.30**	**0.29**	**0.30**	**0.65**	**0.35**	**0.46**	**0.26**	**0.82**	**1.77**	
	s.d.	0.06	0.06		0.25	0.06	0.20	0.16	0.42	0.09	0.21	0.03	0.24	0.34	
	s.e.	0.03	0.04		0.13	0.02	0.08	0.06	0.30	0.04	0.12	0.02	0.14	0.20	

Notes: Flcu= *Flavocetraria cucullata*, Mari = *Masonhalea richardsonii*, Alsa = *Alectoria sarmentosa*, Plgl = *Platismatia glauca*, Levu = *Letharia vulpina*, Xant = *Xanthoparmelia sp.*
s.d.= standard deviation; s.e. = mean standard error; N = number of samples. Laboratory replicates were averaged before calculating means, field replicates were treated as independent measurements.

Appendix 4A.13. Summary Statistics for Nitrogen Concentrations (ppm) in Lichens from the 20 WACAP Parks.

		Alaska							Pacific Northwest				California			N Rockies			S Rockies		
		GAAR	NOAT	DENA	KATM	WRST	GLBA	STLE	NOCA	OLYM	MORA	CRLA	LAVO	YOSE	SEKI	GLAC	GRTE	ROMO	GRSA	BAND	BIBE
Alsa	**Ave**						**3890**	**3183**	**4223**	**4094**	**5141**					**8197**					
	s.d.							640	763	505	909					451					
	s.e.							320	382	191	262					260					
	N						1	4	4	7	12					3					
Bryo	**Ave**									**7778**											
	s.d.									299											
	s.e.									172											
	N									3											
Clar	**Ave**					**5360**		**3380**													
	s.d.																				
	s.e.																				
	N					1		1													
Flcu	**Ave**	**4800**	**5318**	**4074**	**4335**	**4370**															
	s.d.	144	364	370	303	.															
	s.e.	83	258	117	175	.															
	N	3	2	10	3	1															
Hyph	**Ave**				**7347**	**7133**								**9265**		**10300**					
	s.d.				2288	1895										3162					
	s.e.				1321	1094										1826					
	N				3	3								1		3					
Levu	**Mean**											**5759**	**7508**	**10800**	**17555**	**10498**	**8768**				
	s.d.											1111	1877	580	3531	1706					
	s.e.											497	840	410	1117	853					
	N											5	5	2	10	4	-1				
Loor	**Ave**							**18860**		**22050**											
	s.d.									501											
	s.e.									289											
	N							1		3											
Mari	**Ave**	**4150**	**3618**	**3985**					**5200**	**5115**							**9883**				

	s.d.	141	536	853					559			698				
	s.e.	100	169	246					395			493				
	N	2	10	12				1	2			0				
Plgl	**Ave**				**2920**	**7860**	**5498**				**10557**					
	s.d.						793				1557					
	s.e.						397				519					
	N				1	1	2				9					
Spgl	**Ave**					**5425**										
	s.d.					403										
	s.e.					285										
	N					2										
Tham	**Ave**			**2920**												
	s.d.															
	s.e.															
	N			1												
Usne	**Ave**														**1609 3**	**1475 5**
	s.d.														735	1138
	s.e.														367	805
	N														4	2
Xant	**Ave**									**13460**			**15667**	**11120**	**1528 0**	
	s.d.												2050	4851	3748	
	s.e.												1184	3430	2650	
	N									1			3	2	2	

Notes: Alsa= *Alectoria sarmentosa*, Bryo = *Bryoria* spp., Clar = *Cladina arbuscula*, Flcu= *Flavocetraria cucullata*, Hypphy = *Hypogymnia physodes*, Levu = *Letharia vulpina*, Loor = *Lobaria oregana*, Mari = *Masonhalea richardsonii*, Plgl = *Platismatia glauca*, Spgl = Sphaerophorus *globosus*, Tham = *Thamnolia* sp., Usne = *Usnea* spp., Xant = *Xanthoparmelia* spp.; s.d.= standard deviation; s.e. = mean standard error; N = number of samples. Laboratory replicates were averaged before calculating means, field replicates were treated as independent measurements.

Appendix 4A.14. Distribution of Cadmium, Mercury, Nitrogen, Lead, and Sulfur Concentrations in Lichen Genera in National Parks and Forests of the United States, 1977-2005. Ninety percent quantiles (yellow highlight) were used as thresholds for background ranges to assess enhancement in WACAP lichen samples. Data were obtained from the NPS national database NPElement (Bennett, 2007), the NPS Arctic Parks database courtesy of P. Neitlich (all *Masonhalea* and some *Flavocetraria* data), and the USFS National Lichens and Air Quality database (US Forest Service 2007). For a list of public lands from which distributions were calculated, see Appendix 3.15.

Cd ppm

Quantiles	*Alectoria*	*Bryoria*	*Cladina*	*Flavocetraria*	*Hypogymnia*	*Letharia*	*Lobaria*	*Masonhalea*	*Platismatia*	*Sphaerophorus*	*Usnea*	*Xanthoparmelia*
100.00%	9.95	3.45	17.80	0.48	3.76	5.13	9.81	0.52	17.30	0.32	3.43	3.40
99.50%	1.07	3.35	17.80	0.48	1.55	4.06	8.75	0.52	1.65	0.32	3.43	3.40
97.50%	0.50	0.50	1.54	0.46	0.90	2.01	0.87	0.52	0.64	0.22	3.24	3.14
90.00%	**0.24**	**0.30**	**0.47**	**0.24**	**0.40**	**0.34**	**0.20**	**0.28**	**0.40**	**0.18**	**3.04**	**0.79**
75.00%	0.18	0.20	0.30	0.21	0.30	0.22	0.12	0.24	0.27	0.12	0.32	0.60
50.00%	0.12	0.15	0.15	0.14	0.22	0.16	0.10	0.17	0.19	0.12	0.18	0.50
25.00%	0.10	0.12	0.12	0.10	0.18	0.12	0.10	0.06	0.14	0.10	0.10	0.40
10.00%	0.02	0.10	0.10	0.07	0.10	0.10	0.10	0.05	0.12	0.10	0.06	0.31
2.50%	0.01	0.10	0.06	0.06	0.04	0.00	0.07	0.05	0.10	0.10	0.03	0.20
0.50%	0.00	0.01	0.06	0.06	0.00	0.00	0.01	0.05	0.00	0.08	0.01	0.10
0.00%	0.00	0.00	0.06	0.06	0.00	0.00	0.01	0.05	0.00	0.08	0.01	0.10
Mean	0.15	0.20	0.41	0.16	0.27	0.28	0.21	0.17	0.25	0.12	0.72	0.64
Std Dev	0.33	0.29	1.69	0.08	0.25	0.54	0.72	0.11	0.54	0.04	1.15	0.60
Std Err	0.01	0.02	0.16	0.01	0.01	0.02	0.05	0.02	0.02	0.00	0.08	0.05
Upper 95%	0.17	0.24	0.73	0.18	0.29	0.32	0.30	0.22	0.28	0.13	0.87	0.75
Lower 95%	0.14	0.17	0.09	0.14	0.26	0.24	0.12	0.12	0.22	0.12	0.57	0.53
N	1491	262	111	48	1079	819	251	22	1192	110	230	122

Hg ppm

Quantiles	*Alectoria*	*Bryoria*	*Cladina*	*Flavocetraria*	*Hypogymnia*	*Letharia*	*Lobaria*	*Masonhalea*	*Platismatia*	*Sphaerophorus*	*Usnea*	*Xanthoparmelia*
100.00%	0.518	0.290	0.070	0.090	0.330	7.195	0.120	0.033	0.287		0.960	0.470
99.50%	0.518	0.290	0.070	0.090	0.330	7.195	0.120	0.033	0.287		0.960	0.470
97.50%	0.518	0.290	0.070	0.090	0.330	4.675	0.120	0.033	0.287		0.810	0.470

90.00%	**0.399**	**0.208**	**0.070**	**0.048**	**0.264**	**0.717**	**0.120**	**0.032**	**0.287**		**0.630**	**0.405**
75.00%	0.270	0.170	0.063	0.033	0.200	0.418	0.105	0.026	0.287		0.403	0.285
50.00%	0.185	0.160	0.050	0.025	0.090	0.170	0.045	0.022	0.263		0.210	0.255
25.00%	0.137	0.120	0.040	0.018	0.060	0.070	0.013	0.018	0.249		0.050	0.173
10.00%	0.010	0.078	0.040	0.013	0.040	0.026	0.010	0.015	0.247		0.030	0.030
2.50%	0.010	0.060	0.040	0.010	0.030	0.010	0.010	0.014	0.247		0.020	0.030
0.50%	0.010	0.060	0.040	0.010	0.030	0.010	0.010	0.014	0.247		0.010	0.030
0.00%	0.010	0.060	0.040	0.010	0.030	0.010	0.010	0.014	0.247		0.010	0.030
Mean	0.204	0.149	0.052	0.029	0.128	0.379	0.056	0.023	0.267		0.254	0.230
Std Dev	0.118	0.050	0.012	0.017	0.086	0.964	0.045	0.005	0.019		0.237	0.121
Std Err	0.023	0.010	0.005	0.003	0.014	0.130	0.016	0.002	0.009		0.021	0.032
Upper 95%	0.250	0.170	0.064	0.034	0.156	0.640	0.094	0.026	0.290		0.296	0.300
Lower 95%	0.157	0.127	0.039	0.023	0.099	0.119	0.019	0.019	0.243		0.212	0.160
N	27	23	6	40	37	55	8	12	5		126	14

N ppm

Quantiles	*Alectoria*	*Bryoria*	*Cladina*	*Flavocetraria*	*Hypogymnia*	*Letharia*	*Lobaria*	*Masonhalea*	*Platismatia*	*Sphaerophorus*	*Usnea*	*Xanthoparmelia*
100.00%	10300	20000	5360	5630	25500	26100	27800	5430	17300	8800	16300	24400
99.50%	8371	19953	5360	5630	20214	23777	27800	5430	15200	8800	16300	24400
97.50%	7042	18300	5360	5609	15690	16220	25970	5430	12355	6974	15202	18980
90.00%	**5300**	**14700**	**5360**	**5355**	**10300**	**10940**	**24100**	**4964**	**7768**	**5027**	**13240**	**17520**
75.00%	4353	12200	5360	4943	7500	8800	22500	4200	5690	4400	10200	15500
50.00%	3600	9650	4370	4560	5800	6830	21100	3640	4500	3800	5960	13460
25.00%	3100	7095	3380	4263	4900	5430	19050	3120	3700	3225	4000	11500
10.00%	2603	5667	3380	3710	4180	4640	16660	2632	3176	2672	3418	10280
2.50%	2100	3829	3380	1244	3368	3818	14930	2440	2657	2265	2567	8592
0.50%	1500	1605	3380	1180	2112	3115	13500	2440	2000	1870	1200	0
0.00%	1400	1480	3380	1180	1700	2020	13500	2440	910	1870	1200	0
Mean	3825	9875	4370	4489	6684	7539	20756	3678	5116	3913	7308	13625
Std Dev	1182	3543	1400	820	2971	3228	2799	765	2271	1067	3817	3126

Std Err	39	226	990	112	101	122	218	129	66	93	285	242
Upper 95%	3901	10320	16949	4713	6883	7779	21187	3941	5245	4097	7869	14103
Lower 95%	3749	9430	-8209	4265	6485	7298	20326	3415	4987	3729	6747	13147
N	942	246	2	54	861	695	165	35	1195	132	180	167

Ni ppm

Quantiles	*Alectoria*	*Bryoria*	*Cladina*	*Flavocetraria*	*Hypogymnia*	*Letharia*	*Lobaria*	*Masonhalea*	*Platismatia*	*Sphaerophorus*	*Usnea*	*Xanthoparmelia*
100.00%	93.96	39.07	6.00	10.50	186.82	5153.00	19.00	5.38	94.00	48.24	15.00	549.00
99.50%	17.61	36.07	6.00	10.50	94.92	58.70	15.41	5.38	39.23	48.24	12.55	549.00
97.50%	13.42	9.91	4.00	9.00	52.85	26.70	4.00	5.38	18.61	38.60	7.00	148.00
90.00%	**9.00**	**4.00**	**3.00**	**3.37**	**19.00**	**9.20**	**2.88**	**4.06**	**8.00**	**26.40**	**5.00**	**80.45**
75.00%	5.50	2.99	1.77	1.76	10.00	5.00	2.00	3.36	6.00	20.00	2.79	48.67
50.00%	3.00	2.00	1.61	0.72	6.35	2.80	1.71	0.74	4.27	20.00	1.42	21.99
25.00%	2.00	1.68	1.00	0.64	4.57	1.80	1.00	0.45	3.08	16.80	0.90	8.29
10.00%	1.68	1.68	1.00	0.51	3.36	1.70	1.00	0.30	2.25	16.80	0.59	6.17
2.50%	1.00	1.18	0.84	0.24	1.58	1.70	0.23	0.28	1.75	11.51	0.39	5.38
0.50%	0.84	0.73	0.84	0.24	0.86	1.20	0.01	0.28	1.68	6.23	0.32	4.46
0.00%	0.61	0.68	0.84	0.24	0.42	0.80	0.00	0.28	1.68	6.23	0.31	4.46
Mean	4.34	2.88	1.65	1.52	10.60	10.59	1.85	1.77	5.45	20.27	2.12	36.65
Std Dev	4.18	3.43	0.79	1.70	15.13	170.91	1.34	1.66	6.01	5.38	1.90	54.08
Std Err	0.10	0.20	0.07	0.25	0.46	5.67	0.08	0.35	0.17	0.49	0.11	3.99
Upper 95%	4.54	3.28	1.79	2.01	11.49	21.71	2.02	2.49	5.78	21.24	2.34	44.51
Lower 95%	4.14	2.48	1.50	1.03	9.70	-0.54	1.69	1.05	5.11	19.29	1.91	28.78
N	1685	284	116	48	1102	909	255	23	1229	119	297	184

Pb ppm

Quantiles	*Alectoria*	*Bryoria*	*Cladina*	*Flavocetraria*	*Hypogymnia*	*Letharia*	*Lobaria*	*Masonhalea*	*Platismatia*	*Sphaerophorus*	*Usnea*	*Xanthoparmelia*
100.00%	93.96	39.07	6.00	10.50	186.82	5153.00	19.00	5.38	94.00	4.82	41.00	549.00
99.50%	17.62	36.07	6.00	10.50	94.92	59.10	15.41	5.38	39.58	4.82	39.69	549.00

97.50%	13.47	9.91	4.00	10.50	52.85	26.80	4.00	5.38	18.65	3.86	19.27	148.60
90.00%	**9.08**	**4.00**	**3.00**	**3.37**	**19.00**	**9.30**	**2.88**	**5.38**	**8.01**	**2.64**	**11.75**	**80.78**
75.00%	5.59	2.99	1.77	3.23	10.00	5.00	2.00	3.98	6.00	2.00	8.00	49.00
50.00%	3.00	2.00	1.61	1.05	6.35	2.80	1.71	3.36	4.24	2.00	3.73	22.00
25.00%	2.00	1.68	1.00	0.64	4.57	1.80	1.00	3.36	3.08	1.68	1.87	8.25
10.00%	1.68	1.68	1.00	0.64	3.36	1.70	1.00	3.35	2.24	1.68	0.80	6.16
2.50%	1.00	1.18	0.84	0.64	1.58	1.70	0.23	3.35	1.75	1.15	0.61	5.36
0.50%	0.91	0.73	0.84	0.64	0.86	1.20	0.01	3.35	1.68	0.62	0.44	4.46
0.00%	0.62	0.68	0.84	0.64	0.42	0.80	0.00	3.35	1.68	0.62	0.40	4.46
Mean	4.39	2.88	1.65	1.81	10.60	10.63	1.85	3.72	5.45	2.03	5.72	36.90
Std Dev	4.19	3.43	0.79	1.87	15.13	171.39	1.34	0.70	6.02	0.54	5.83	54.49
Std Err	0.10	0.20	0.07	0.31	0.46	5.70	0.08	0.23	0.17	0.05	0.36	4.05
Upper 95%	4.59	3.28	1.79	2.44	11.49	21.82	2.02	4.26	5.79	2.12	6.41	44.90
Lower 95%	4.18	2.48	1.50	1.17	9.70	-0.56	1.69	3.18	5.11	1.93	5.02	28.91
N	1663	284	116	36	1102	904	255	9	1223	119	270	181

S ppm

Quantiles	*Alectoria*	*Bryoria*	*Cladina*	*Flavocetraria*	*Hypogymnia*	*Letharia*	*Lobaria*	*Masonhalea*	*Platismatia*	*Sphaerophorus*	*Usnea*	*Xanthoparmelia*
100.00%	2430	1800		549	1970	2000	2010	525	3500	770	2800	2900
99.50%	820	1750		549	1830	1772	2010	525	1626	770	2800	2889
97.50%	673	1119		527	1532	1300	1740	525	1274	641	1948	2004
90.00%	**530**	**940**		**405**	**1100**	**901**	**1430**	**464**	**910**	**501**	**1410**	**1558**
75.00%	430	800		352	880	700	1160	339	690	460	973	1300
50.00%	350	720		310	690	600	970	255	560	410	723	1100
25.00%	290	630		251	560	520	810	216	470	340	558	950
10.00%	240	520		0	480	460	630	191	410	319	450	776
2.50%	200	330		0	380	390	495	191	360	240	380	504
0.50%	165	310		0	270	320	440	191	300	200	310	40
0.00%	140	310		0	200	87	440	191	200	200	310	0
Mean	376	732		283	748	651	1001		622	409	832	1156

Std Dev	144	193	127	271	221	295	255	91	404	366
Std Err	5	12	19	9	8	22	7	8	35	25
Upper 95%	386	756	320	767	666	1045	637	425	901	1205
Lower 95%	367	709	245	730	635	958	607	393	763	1108
N	949	262	46	832	777	179	1171	128	134	221

Notes: The 50% quantile is the median and the 100% and 0% quantiles are maximum and minimum values in the data sets. Std Dev and Std Error are the standard deviation and standard error of the mean. Upper 95% and lower 95% are the upper and lower 95% confidence intervals around the mean. N = number of measurements. Because most samples come from remote sites, field replicates were treated as independent measurements.

Appendix 4A.15. List of Public Lands in the Western United States from Which Background Distributions of Lichen Cadmium, Mercury, Nitrogen, Nickel, and Sulfur Concentrations in Table 4A.11 were calculated. N = number of measurements.

Genus	Code	National Land	N	N(Cd)	N(Hg)	N(N)	N(Ni)	N(Pb)	N(S)
Alectoria	CHU	Chugach National Forest, AK	71	69	0	0	69	69	0
	CLE	Clearwater National Forest, ID	3	1	0	2	2	2	2
	COL	Colville National Forest, WA	1	1	0	1	1	1	1
	CRLA	Crater Lake National Park, OR	3	3	3	0	3	3	0
	DES	Deschutes National Forest, OR	121	82	9	107	98	90	102
	GIP	Gifford Pinchot National Forest, WA	198	169	0	167	170	176	176
	MBS	Mt Baker-Snoqualmie National Forest, WA	8	8	0	8	8	8	8
	WIL	Willamette National Forest, OR	1	1	0	1	1	1	1
	MORA	Mount Rainier National Park, WA	209	173	0	0	0	209	0
	MTH	Mt. Hood National Forest, OR	283	242	0	239	248	256	246
	NEP	Nez Perce National Forest, ID	2	0	0	0	2	2	2
	OLYM	Olympic National Park, WA	246	142	0	0	32	246	0
	BIT	Selway-Bitterroot Wilderness, ID	1	0	0	0	0	0	1
	SIU	Siuslaw National Forest, OR	3	2	0	2	2	2	3
	TON	Tongass National Forest, AK	273	246	0	0	245	245	0
	UMP	Umpqua National Forest, OR	135	102	0	110	119	105	115
	WAW	Wallowa-Whitman National Forest, OR	12	11	0	12	11	11	10
	WEN	Wenatchee National Forest, WA	3	3	0	3	3	3	3
	WIL	Willamette National Forest, OR	276	202	0	251	234	221	248
	WIN	Winema National Forest, OR	15	12	0	8	14	13	9
Bryoria	CLE	Clearwater National Forest, ID	1	0	0	0	1	1	1
	CRLA	Crater Lake National Park, OR	3	3	3	0	3	3	0
	DES	Deschutes National Forest, OR	120	111	0	113	114	107	110
	FRE	Fremont National Forest, OR	7	6	0	5	6	6	6
	WIN	Fremont National Forest, OR	1	1	0	1	1	1	1
	GIP	Gifford Pinchot National Forest, WA	12	10	0	10	10	10	10
	GRTE	Grand Tetons National Park, WY	5	5	0	5	5	5	0

	KLA	Klamath National Forest, CA	4	4	0	0	4	4	0
	MTH	Mt. Hood National Forest, OR	7	4	0	5	4	4	6
	NEP	Nez Perce National Forest, ID	3	0	0	0	3	3	3
	OLYM	Olympic National Park, WA	5	4	0	0	4	4	0
	PAY	Payette National Forest, ID	6	0	0	0	6	6	6
	ROMO	Rocky Mountain National Park, CO	2	2	2	0	2	2	0
	SAC	Salmon-Challis National Forest, ID	7	0	0	0	7	7	7
	SJR	San Juan-Rio Grande National Forest, CO	2	0	0	0	2	2	2
	BIT	Selway-Bitterroot Wilderness, ID	1	0	0	0	1	1	1
	UMP	Umpqua National Forest, OR	15	9	0	13	12	11	14
	WAW	Wallowa-Whitman National Forest, OR	31	25	0	25	25	25	26
	WIL	Willamette National Forest, OR	26	11	0	21	15	16	25
	WIN	Winema National Forest, OR	51	49	0	43	50	48	44
	YELL	Yellowstone National Park, WY	18	18	18	0	18	18	0
Cladina	CHU	Chugach National Forest, AK	63	57	0	0	57	57	0
	DENA	Denali National Park and Preserve, AK	6	3	6	0	6	6	0
	NOAT	Noatak National Preserve, AK	2	0	0	0	2	2	0
	TON	Tongass National Forest, AK	52	48	0	0	48	48	0
	YELL	Yellowstone National Park, WY	3	3	0	0	3	3	0
Flavocetraria	NOAT	Noatak National Preserve, AK	35	34	27	33	33	33	33
	ROMO	Rocky Mountain National Park, CO	2	2	2	0	2	2	0
	SJR	San Juan-Rio Grande National Forest, CO	1	0	0	0	1	1	1
Hypogymnia	ANG	Angeles National Forest, CA	6	6	0	0	6	6	0
	CRG	Columbia River Gorge National Scenic Area, OR & WA	137	115	0	106	115	115	116
	COL	Colville National Forest, WA	3	2	0	2	2	2	3
	DES	Deschutes National Forest, OR	66	61	0	54	61	61	56
	FINL	Finley National Wildlife Refuge, OR	2	2	0	2	2	2	2
	FRE	Fremont National Forest, OR	4	4	0	4	4	4	4
	GIP	Gifford Pinchot National Forest, WA	67	59	0	60	59	59	62
	MBS	Mt Baker-Snoqualmie National Forest, WA	7	6	0	6	6	6	7

	KLGO	Klondike Gold Rush National Historical Park, AK	24	24	0	24	24	15	0
	LOL	Lolo National Forest, MT	1	1	0	1	1	1	1
	MBS	Mount Baker-Snoqualmie National Forest, WA	35	33	0	30	33	33	31
	MTH	Mt. Hood National Forest, OR	239	217	0	193	217	216	197
	OKA	Okanogan National Forest, WA	7	7	0	6	7	7	6
	OLYM	Olympic National Park, WA	66	62	0	0	62	58	0
	ORCA	Oregon Caves National Monument, OR	3	3	2	0	3	3	0
	PORE	Point Reyes National Seashore, CA	14	14	14	14	14	14	0
	REDW	Redwood National Park, CA	50	27	21	0	49	49	0
	KICA	Sequoia and Kings Canyon National Park, CA	12	0	0	0	12	12	0
	SEKI	Sequoia and Kings Canyon National Park, CA	12	12	0	0	12	12	0
	SIU	Siuslaw National Forest, OR	122	106	0	106	107	107	106
	TON	Tongass National Forest, AK	72	65	0	0	65	65	0
	UMP	Umpqua National Forest, OR	44	38	0	36	38	38	35
	WAW	Wallowa-Whitman National Forest, OR	18	17	0	16	17	17	17
	WEN	Wenatchee National Forest, WA	5	5	0	4	5	5	4
	WIL	Willamette National Forest, OR	181	163	0	158	165	165	158
	WEN	Winema National Forest, OR	3	3	0	2	3	3	2
	WIN	Winema National Forest, OR	28	27	0	26	27	27	25
Letharia	ANG	Angeles National Forest, CA	18	18	0	0	18	18	0
	BEA	Beaverhead-Deer Lodge National Forest, MT	8	1	0	2	5	7	7
	BIT	Bitterroot National Forest, ID	4	0	0	0	3	2	4
	BRT	Bridger-Teton National Forest, WY	2	0	0	0	2	2	2
	CLE	Clearwater National Forest, ID	1	0	0	0	1	0	1
	CLV	Cleveland National Forest, CA	6	6	0	0	6	6	0
	CRG	Columbia River Gorge National Scenic Area, OR & WA	20	19	0	18	19	19	18
	COL	Colville National Forest, WA	11	9	0	9	9	9	11
	CODA	Coulee Dam National Recreation Area, WA	12	9	0	10	9	9	11
	CRLA	Crater Lake National Park, OR	12	12	12	0	12	12	0
	DES	Deschutes National Forest, OR	312	257	17	263	262	260	277

	ELD	Eldorado National Forest, CA	18	18	0	0	18	18	0
	FRE	Fremont National Forest, OR	28	25	0	24	25	25	23
	WIN	Fremont National Forest, OR	2	2	0	1	2	2	1
	GIP	Gifford Pinchot National Forest, WA	2	2	0	2	2	2	2
	HEL	Helena National Forest, MT	2	1	0	1	1	1	2
	KLA	Klamath National Forest, CA	12	12	0	0	12	12	0
	KOO	Kootenai National Forest, MT	2	0	0	0	0	2	2
	LABE	Lava Beds National Monument, CA	6	6	6	0	6	6	0
	LOL	Lolo National Forest, MT	2	2	0	2	2	2	2
	MTH	Mt. Hood National Forest, OR	35	28	0	24	28	28	31
	NEP	Nez Perce National Forest, ID	5	0	0	0	5	5	5
	OKA	Okanogan National Forest, WA	8	6	0	8	6	6	6
	PAY	Payette National Forest, ID	6	0	0	0	6	6	6
	SAC	Salmon-Challis National Forest, ID	46	0	0	0	41	45	46
	SAW	Sawtooth Wilderness, ID	4	0	0	0	0	3	4
	KICA	Sequoia and Kings Canyon National Park, CA	12	0	0	0	12	12	0
	SEKI	Sequoia and Kings Canyon National Park, CA	27	27	0	0	27	27	0
	STA	Stanislaus National Forest, CA	12	12	0	0	12	12	0
	TAR	Targhee National Forest, WY	3	0	0	0	3	3	3
	UMP	Umpqua National Forest, OR	2	2	0	2	2	2	2
	WAW	Wallowa-Whitman National Forest, OR	108	94	0	92	94	94	100
	WEN	Wenatchee National Forest, WA	5	5	0	5	5	5	5
	WIL	Willamette National Forest, OR	13	10	0	11	11	11	11
	WIN	Winema National Forest, OR	236	214	0	192	217	216	188
	YELL	Yellowstone National Park, WY	15	15	14	0	15	15	0
Lobaria	BIT	Bitterroot National Forest, ID	1	0	0	0	1	0	1
	CHU	Chugach National Forest, AK	26	24	0	0	24	24	0
	CLE	Clearwater National Forest, ID	3	0	0	0	3	1	3
	CRG	Columbia River Gorge National Scenic Area, OR & WA	10	10	0	10	10	10	10
	FINL	Finley National Wildlife Refuge, OR	4	2	0	2	2	2	4

	GIP	Gifford Pinchot National Forest, WA	29	21	0	25	25	22	26
	MBS	Mt Baker-Snoqualmie National Forest, WA	1	1	0	1	1	1	1
	KOO	Kootenai National Forest, MT	1	0	0	0	0	0	1
	MTH	Mt. Hood National Forest, OR	38	31	0	35	33	31	36
	NEP	Nez Perce National Forest, ID	2	0	0	0	2	1	2
	OLYM	Olympic National Park National Park, WA	6	5	0	5	5	5	5
	REDW	Redwood National Park, CA	8	6	8	0	8	8	0
	SIU	Siuslaw National Forest, OR	17	13	0	15	15	13	16
	TON	Tongass National Forest, AK	86	83	0	0	83	83	0
	UMP	Umpqua National Forest, OR	3	3	0	3	3	3	3
	WIL	Willamette National Forest, OR	79	52	0	65	66	51	71
Masonhalea	NOAT	Noatak National Preserve, AK	9	8	0	8	9	9	8
Platismatia	CLE	Clearwater National Forest, ID	2	1	0	1	1	1	2
	CRG	Columbia River Gorge National Scenic Area, OR & WA	179	171	0	153	171	171	150
	COL	Colville National Forest, WA	5	4	0	5	4	4	4
	CODA	Coulee Dam National Recreation Area, WA	8	6	0	6	6	6	8
	DES	Deschutes National Forest, OR	30	21	0	24	23	23	27
	FINL	Finley National Wildlife Refuge, OR	3	2	0	2	2	2	2
	GIP	Gifford Pinchot National Forest, WA	221	187	0	187	192	192	190
	MBS	Gifford Pinchot National Forest, WA	19	16	0	16	16	16	17
	KLGO	Klondike Gold Rush National Historical Park, AK	13	13	0	13	13	10	0
	MBS	Mount Baker-Snoqualmie National Forest, WA	49	44	0	43	44	44	41
	MTH	Mt. Hood National Forest, OR	291	262	0	257	263	263	258
	OLYM	Olympic National Park, WA	20	13	0	0	20	20	0
	SIU	Siuslaw National Forest, OR	30	23	0	28	23	23	30
	UMP	Umpqua National Forest, OR	141	120	0	114	125	125	116
	WAW	Wallowa-Whitman National Forest, OR	47	45	0	41	45	45	43
	WEN	Wenatchee National Forest, WA	3	3	0	2	3	3	2
	WIL	Willamette National Forest, OR	304	250	0	279	270	271	269
	WIN	Winema National Forest, OR	3	2	0	3	3	3	3

Sphaerophorus	CRG	Columbia River Gorge National Scenic Area, OR & WA	3	3	0	3	3	3	3
	GIP	Gifford Pinchot National Forest, WA	31	26	0	28	28	26	25
	MTH	Mt. Hood National Forest, OR	9	6	0	8	6	6	8
	OLYM	Olympic National Park, WA	13	2	0	0	13	9	0
	SIU	Siuslaw National Forest, OR	72	53	0	63	66	54	63
	UMP	Umpqua National Forest, OR	3	3	0	3	3	3	3
	WIL	Willamette National Forest, OR	28	17	0	25	25	18	26
Usnea	BIBE	Big Bend National Park, TX	44	44	44	44	44	44	0
	CHIR	Chiricahua National Monument, AZ	7	0	0	0	7	7	7
	CLE	Clearwater National Forest, ID	1	0	0	0	1	0	1
	CRG	Columbia River Gorge National Scenic Area, OR & WA	18	17	0	15	17	17	14
	DENA	Denali National Park and Preserve, AK	1	1	1	0	1	1	0
	ELMO	El Morro National Monument, NM	5	0	0	0	5	5	5
	FINL	Finley National Wildlife Refuge, OR	1	1	0	1	1	1	1
	GIP	Gifford Pinchot National Forest, WA	5	5	0	3	5	5	3
	GILA	Gila National Forest, NM	10	0	0	0	10	9	10
	GRTE	Grand Tetons National Park, WY	6	6	0	6	6	6	0
	OLYM	Olympic National Park, WA	1	1	0	0	1	1	0
	ORCA	Oregon Caves National Monument, OR	3	3	2	0	3	3	0
	PORE	Point Reyes National Seashore, CA	38	37	37	38	37	37	0
	REDW	Redwood National Park, CA	65	46	36	0	62	62	0
	ROMO	Rocky Mountain National Park, CO	6	6	6	0	4	6	0
	SAC	Salmon-Challis National Forest, ID	3	0	0	0	3	3	3
	SJR	San Juan-Rio Grande National Forest, CO	18	0	0	0	18	17	17
	SIU	Siuslaw National Forest, OR	50	37	0	46	43	38	45
	TAR	Targhee National Forest, WY	2	0	0	0	2	2	2
	UMP	Umpqua National Forest, OR	1	1	0	1	1	0	1
	WIL	Willamette National Forest, OR	6	6	0	6	6	6	6
Xanthoparmelia	ANG	Angeles National Forest, CA	3	3	0	0	3	3	0
	BIBE	Big Bend National Park, TX	4	4	4	4	4	4	0

BRT	Bridger-Teton National Forest, WY	4	0	0	0	2	4	2
CHCU	Chaco Culture National Historical Park, NM	5	0	5	0	0	5	0
CHIR	Chiricahua National Monument, AZ	11	0	0	0	11	10	11
CLE	Clearwater National Forest, ID	1	0	0	0	1	1	1
CRG	Columbia River Gorge National Scenic Area, OR & WA	86	62	0	63	62	62	65
DES	Deschutes National Forest, OR	3	2	0	2	2	2	3
DINO	Dinosaur National Monument, CO	2	0	0	0	2	2	2
GILA	Gila National Forest, NM	7	0	0	0	7	7	7
HUT	Humboldt-Toiyabe National Forest, NV	1	0	0	0	1	1	1
MAL	Manti-La Sal National Forest, UT	2	0	0	0	2	2	2
MEB	MedicineBow National Forest, WY	3	0	0	3	0	0	3
NEP	Nez Perce National Forest, ID	27	22	0	22	22	22	22
PAY	Payette National Forest, ID	2	0	0	0	2	2	2
ROMO	Rocky Mountain National Park, CO	9	2	2	7	0	0	7
ROO	Roosevelt National Forest, CO	2	0	0	2	0	0	2
ROU	Routt National Forest, CO	25	0	0	25	0	0	25
SAC	Salmon-Challis National Forest, ID	5	0	0	0	5	5	5
SJR	San Juan-Rio Grande National Forest, CO	26	0	0	0	26	22	26
MAL	Uinta National Forest, UT	2	0	0	0	2	2	2
WAW	Wallowa-Whitman National Forest, OR	27	21	0	23	21	21	21
WAC	Wasatch-Cache National Forest, UT	1	0	0	0	1	1	1
WHR	White River National Forest, CO	8	0	0	8	0	0	8
YELL	Yellowstone National Park, WY	3	3	3	0	3	3	0

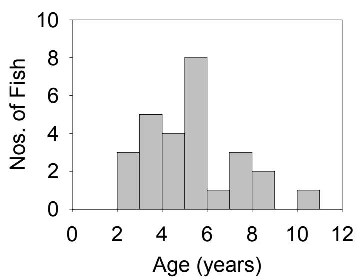
APPENDIX 5A

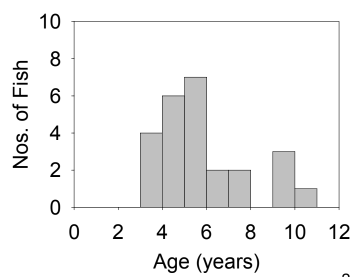
Fish Biological Data

Table 5A-1. **Fish Biological and Mercury Data from SEKI and Year Sampled.** Data are mean (min – max) except vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

SEKI	Emerald Lake	Pear Lake 2003
Species	*Salvelinus fontinalis*	*Salvelinus fontinalis*
Total Nos. of Fish	28	27
Condition Factor	0.9 (0.6 – 1.2, N = 28)	0.9 (0.7 – 1.2, N = 27)
$Sex_{(M / F)}$	6 / 4	8 / 2
$Vitellogenin_{male}$[1]	DH (none) DL (0.44 – 0.62) ND (<0.20)	DH (none) DL (0.40 – 0.76) ND (<0.20)
17ß-$estradiol_{female}$	1.04 (<0.25 – 2.67, N = 4)	2.31 (1.94 – 2.68, N = 2)
17ß-$estradiol_{male}$	<0.25[2] (N = 6)	0.21[2] (<0.25 – 0.50, N = 8)
$11kT_{male}$	2.14 (0.79 – 4.08, N = 6)	2.64 (<0.63 – 8.11, N = 8)
$Testosterone_{female}$	1.06 (0.38 – 1.73, N = 4)	1.55 (1.31 – 1.78, N = 2)
$Testosterone_{male}$	0.80 (0.40 – 1.45)	1.78 (0.46 – 4.66, N = 8)
Kidney MAs	18.98 (10.59 – 35.48, N = 10)	11.27 (4.05 – 19.31, N = 10)
Liver MAs	0.26 (0.04 – 1.25, N = 10)	0.15 (0.00 – 0.88, N = 10)
Spleen MAs	7.24 (1.86 – 16.05, N = 10)	7.82 (0.35 – 21.14, N = 10)
Histopathology[3] Numbers in ( ) are affected fish out of 15	Kidney: cI(2), iN(1) fF(1), Gr(1), CaD(2) Liver: none Spleen: CaD(1) Gonad: Spn(1), CaD(1) Gill: none	Kidney: CaD(1), cI(1) Liver: fL(1), pC(2) Spleen: Spn(2), Gr(1), CaD(1), mgC(1) Gonad: none Gill: none
$Hg_{total\ whole\text{-}body}$	99.52 (52.03 – 151.67, N = 10)	114.26 (40.56 – 212.99, N = 10)
Age[1]	5 (2 – 10, N = 27)	5 (3 – 10, N = 25)

Age Frequency Histograms[1]



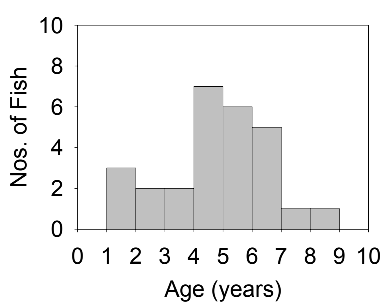


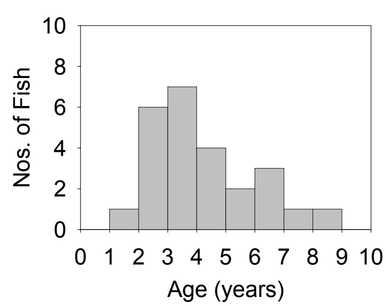
[1]Data are from all fish regardless if analyzed for SOC, SOC & Biology (Biol), or trace elements (Elem). [2]Data are from fish for which there are corresponding SOC and Hg data (N = 10). [3]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [4]>50% non-detects. [5]cI = chronic inflammation, iN = interstitial nephritis, fF= focus of fibroplasia, Gr = granulomas, CaD = calcium deposit(s), fL = foci of lymphocytes, pC = perivascular cuffing, Spn = embedded spine characteristic of setae from Lepidopteran larvae & associated fibroplasia, mgC = multi-nucleated giant cell.

Table 5A-2. Fish Biological and Mercury Data for ROMO and Year Sampled. Data are mean (min – max) except vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

ROMO	**Mills Lake**	**Lone Pine Lake 2003**
Species	*Oncorhynchus mykiss* *Oncorhynchus clarki*	*Salvelinus fontinalis*
Total Nos. of Fish	28	25
Condition Factor	1.2 (0.7 – 1.5, N = 28)	1.0 (0.6 – 1.1, N = 25)
Sex$_{(M / F)}$	4 / 6	6 / 4
Vitellogenin$_{male}$[1]	DH (11.89 – 25.85, N = 2) DL (0.40 – 0.58, N = 2) ND (none)	DH (1.17 – 2.72, N = 2) DL (0.29 – 0.49, N = 4) ND (none)
17ß-estradiol $_{female}$	1.78 (<0.25 – 2.86, N = 6)	18.90 (4.69 – 26.11, N = 4)
17ß-estradiol$_{male}$	0.26 (<0.25 – 0.36, N = 4)	0.27 (<0.25 – 0.57, N = 6)
11kT$_{male}$	2.85 (0.62 – 4.60, N = 4)	11.58 (<0.25 – 32.28, N = 6
Testosterone$_{female}$	3.88 (<0.25 – 9.52, N = 6)	15.89 (12.10 – 20.03, N = 4)
Testosterone$_{male}$	3.61 (<0.25 – 7.22, N = 4)	5.57 (<0.25 – 16.18, N = 6)
Kidney MAs	7.34 (0.40 – 22.44, N = 10)	8.93 (0.83 – 20.12, N = 10)
Liver MAs	0.28 (0.00 – 1.35, N = 10)	0.02 (0.00 – 0.10, N = 10)
Spleen MAs	0.58 (0.05 – 3.82, N = 10)	3.55 (0.03 – 7.78, N = 10)
Histopathology[2] Numbers in ( ) are affected fish out of 15	Kidney: ciN(1) Liver: cdI(1), bDH(1), fI(1) Spleen: none Gonad: none Gill: none	Kidney: none Liver: none Spleen: none Gonad: IS(1) Gill: mfH(1)
Hg$_{total\ whole\text{-}body}$	55.65 (24.40 – 85.77, N = 10)	75.94 (35.58 – 137.14, N = 10)
Age	4 (1 – 8, N = 27)	4 (1 – 8, N = 25)

Age Frequency Histograms



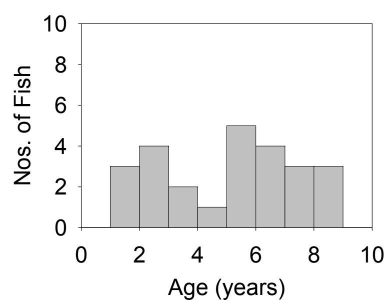


[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]ciN = chronic interstitial nephritis, cdI = chronic, diffuse inflammation, bDH = bile duct hyperplasia, fI = focal inflammation, IS = intersex male, mfH = mild focal hyperplasia.

Table 5A-3. Fish Biological and Mercury Data for OLYM and Year Sampled. Data are mean (min – max) except Vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

OLYM	**PJ Lake**	**2003**
Species	*Salvelinus fontinalis*	
Total Nos. of Fish	29	
Condition Factor	1.0 (0.9 – 1.2, N = 29)	
$Sex_{(M / F)}$	4 / 6	
$Vitellogenin_{male}$[1]	DH (none) DL (0.44, N = 1) ND (<0.20, N = 3)	
$17ß\text{-}estradiol_{female}$	3.50 (1.54 – 5.44, N = 6)	
$17ß\text{-}estradiol_{male}$	0.19[2] (<0.25 – 0.38, N = 4)	
$11kT_{male}$	1.74 (1.41 – 2.00, N = 4)	
$Testosterone_{female}$	1.49 (0.73 – 3.40, N = 6)	
$Testosterone_{male}$	1.36 (1.05 – 1.49, N = 4)	
Kidney MAs	10.32 (1.07 – 19.58, N = 10)	
Liver MAs	0.07 (0.00 – 0.24, N = 10)	
Spleen MAs	2.40 (0.05 – 7.39, N = 10)	
Histopathology Out of 15 fish	Kidney: none Liver: none Spleen: none Gonad: none Gill: none	
$Hg_{total\ whole\text{-}body}$	102.37 (52.29 – 202.29, N = 10)	
Age	5 (1 – 8, N = 25)	

Age Frequency Histogram

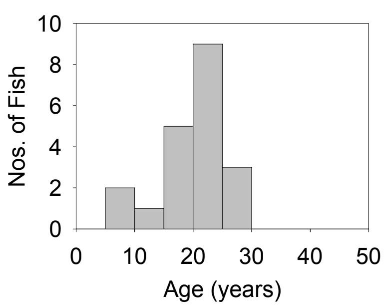


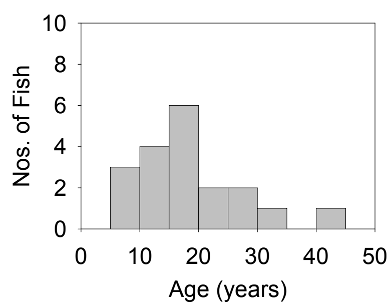
[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]>50% non-detects.

Table 5A-4. Fish Biological and Mercury Data from the NOAT/GAAR and Year Sampled. Data are mean (min – max, N) except Vitellogenin (min – max, N). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

	GAAR, Matcharak Lake	**NOAT, Burial Lake 2004**
Species	*Salvelinus namaycush*	*Salvelinus namaycush*
Total Nos. of Fish	20	20
Condition Factor	1.0 (0.7 – 1.4, N = 20)	1.0 (0.7 – 1.2, N = 20)
$\text{Sex}_{(M / F)}$	5 / 5	5 / 5
$\text{Vitellogenin}_{male}$[1]	DH (none) DL (0.47 – 0.81, N = 2) ND (<0.20, N = 3)	DH (none) DL (0.25 – 0.34, N = 2) ND (<0.20, N = 3)
$\text{17ß-estradiol}_{female}$	4.38 (<0.25 – 14.36, N = 5)	3.27 (0.26 – 8.87, N = 5)
$\text{17ß-estradiol}_{male}$	0.16[2] (<0.25 – 0.27, N = 5)	0.17[2] (<0.25 – 0.31, N = 5)
11kT_{male}	4.39 (1.07 – 10.14, N = 5)	3.29 (< 0.63 – 13.16, N = 5)
$\text{Testosterone}_{female}$	11.28 (<0.25 – 29.63, N = 5)	15.40 (<0.25 – 39.73, N = 5)
$\text{Testosterone}_{male}$	7.88 (<0.25 – 21.56 , N = 5)	4.59[2] (<0.25 – 22.18, N = 5)
Kidney MAs	5.97 (1.69 – 11.21, N = 10)	6.43 (0.57 – 14.65, N = 10)
Liver MAs	0.05 (0.00 – 0.18, N = 10)	0.18 (0.00 – 1.54, N = 10)
Spleen MAs	1.82 (0.04 – 5.49, N = 10)	0.39 (0.00 – 1.28, N = 10))
Histopathology[3] Numbers in ( ) are affected fish out of 15	Kidney: none Liver: WGr(3), Gr(3), Li(1), nNW(4) Spleen: none Gonad: tMA(1) Gill: mifH(1), eH(1), mCp(1), tpL(1), cpL(1), HtL(1) Gut: WGr(1), nNW(1)	Kidney: FcD(2), F(2), W(1) Liver: LI(1), dcLI(1), mLI(1), miLI(1), fL(1) Spleen: none Gonad: none Gill: rC(1), HMW(1)
$\text{Hg}_{total\ whole\text{-}body}$	129.71 (31.59 – 204.50, N = 10)	217.54 (68.27 – 411.01, N = 10)
Age	19.5 (7 – 29, N = 20)	17.9 (5 – 41, N = 19)

Age Frequency Histograms



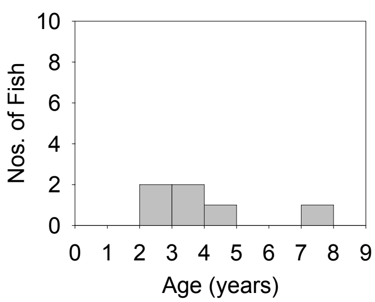


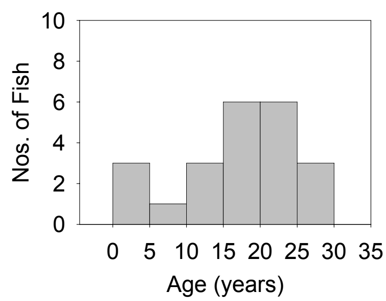
[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]>50% non-detects. [3]WGr = worms in granulomas, Gr = granulomas, LI = lymphocyte infiltration, nNW = numerous Nematodes or worms, tMA = testis with MA pigments, mifH = mild focal hyperplasia, eH = epithelial hyperplasia, HMW = Monogene worm with hyperplasia, mCp = mucus cell proliferation, tpL = thickened cartilage element of primary lamellae, cpL = cortical proliferation of primary lamellae, HtL = hyperplasia on tips of lamellae, FcD = flukes in collecting duct, F = flukes, W = worms, dcLI = diffuse chronic lymphocyte infiltration, mLI = moderate lymphocyte infiltration, miLI = mild lymphocyte infiltration, fL = foci of lymphocytes, rC = rare ciliates no pathology.

Table 5A-5. Fish Biological and Mercury Data for DENA and Year Sampled. Data are mean (min – max) except vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

DENA	**McLeod Lake**	**Wonder Lake 2004-05**
Species	*Lota lota* *Prosopium cylindraceum*	*Salvelinus namaycush*
Total Nos. of Fish	6	24
Condition Factor[1]	0.7 (0.5 – 0.8, N = 6)	1.1 (0.8 – 1.4, N = 24)
$Sex_{(M / F)}$	1 / 0	6 / 4
$Vitellogenin_{male}$[1]	NA[2]	DH (none) DL (0.56 – 0.66, N = 2) ND (<0.20, N = 4)
17ß-estradiol $_{female}$	NA	4.49 (0.30 – 9.84, N = 4)
17ß-$estradiol_{male}$	0.52 (N = 1)	0.17[3] (<0.25 – 0.26, N= 6)
$11kT_{male}$	0.70 (N = 1)	12.13 (4.14 – 18.22, N = 6)
$Testosterone_{female}$	NA	23.95 (0.29 – 63.11, N = 4)
$Testosterone_{male}$	<0.25 (N = 1)	10.22 (4.06 – 17.23, N = 6)
Kidney MAs	NA	10.34 (4.84 – 18.67, N = 10)
Liver MAs	NA	0.24 (0.00 – 0.55, N = 10)
Spleen MAs	NA	7.27 (2.54 – 13.29, N = 10)
Histopathology[4] Numbers in ( ) are affected fish out of 15 Gonad: none	Kidney: none Liver: none Spleen: none Gonad: oMA(2) Gill: none	Kidney:WU(1) Liver: none Spleen: none Gill: eM(1)
$Hg_{total\ whole\text{-}body}$	58.34 (26.64 – 75.73, N = 4)	112.59 (87.61 – 140.30, N = 10)
Age	4 (2 – 7, N = 6)	17 (2 – 29, N = 24)

Age Frequency Histograms



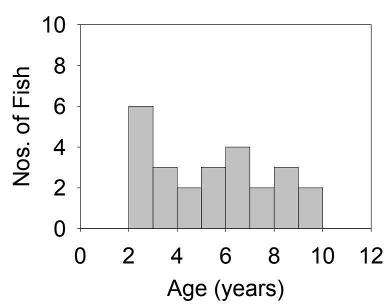


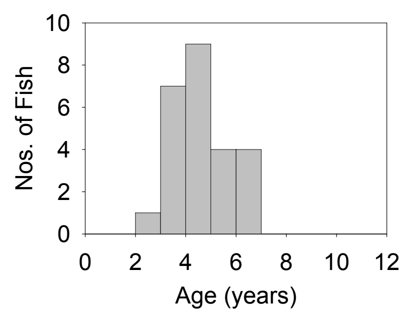
[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]NA = not available. [3]>50% non-detects. [4]WU = worms in ureters, oMA = ovary with MA pigments, eM = encysted metacercariae.

Table 5A-6. Fish Biological and Mercury Data for MORA and Year Sampled. Data are mean (min – max) except Vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

MORA	**Lake LP19**	**Golden Lake 2005**
Species	*Salvelinus fontinalis*	*Salvelinus fontinalis*
Total Nos. of Fish	25	25
Condition Factor	1 (0.7 – 1.2, N = 25)	1.0 (0.8 – 1.2, N = 25)
$Sex_{(M / F)}$	5 / 5	7 / 3
$Vitellogenin_{male}$[1]	DH (none) DL (none) ND (<0.20, N = 5)	DH (6.92, N = 1) DL (none) ND (<0.20, N = 6)
$17ß\text{-}estradiol_{female}$	7.95 (<0.25 – 19.29, N = 5)	9.89 (7.35 – 11.35, N = 3)
$17ß\text{-}estradiol_{male}$	0.24 (<0.25 – 0.28, N = 5)	0.21[2] (<0.25 – 0.53, N =7)
$11kT_{male}$	5.06 (2.13 – 7.94, N = 5)	6.74 (4.87 – 8.71, N =7)
$Testosterone_{female}$	3.94 (2.66 – 6.54, N = 5)	3.70 (3.04 – 4.07, N = 3)
$Testosterone_{male}$	3.41 (2.06 – 6.00, N = 5)	5.05 (2.50 – 6.31, N =7)
Kidney MAs	13.98 (1.11 – 31.22, N = 10)	15.73 (3.24 – 25.46, N = 10)
Liver MAs	0.24 (0.00 – 2.17, N = 10)	0.05 (0.00 – 0.13, N = 10)
Spleen MAs	4.79 (0.07 – 14.47, N = 10)	1.63 (0.08 – 3.36, N = 10)
Histopathology[3] Numbers in ( ) are affected fish out 15	Kidney: none Liver: BKDGr(1), mGr(1) Spleen: none Gonad: none Gill: none	Kidney: none Liver: bDH(1) Spleen: none Gonad: none Gill: none
$Hg_{total\ whole\text{-}body}$	145.68 (56.63 – 267.50, N = 15)	80.60 (54.75 – 102.02, N = 15)
Age	5 (2 – 9, N = 25)	4 (2 – 6, N = 25)

Age Frequency Histograms



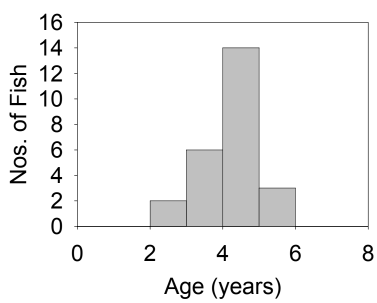


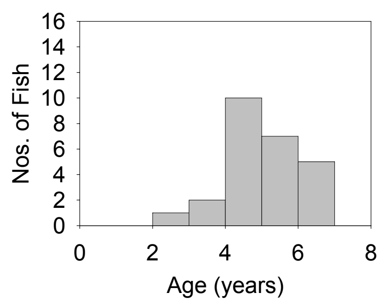
[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]>50% non-detects. [3]BKDGr = bacterial kidney disease like granuloma, mGr = multiple granulomas, bDH = bile duct hyperplasia (suspected).

Table 5A-7. Fish Biological and Mercury Data for GLAC and Year Sampled. Data are mean (min – max) except Vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

GLAC	**Oldman Lake**	**Snyder Lake 2005**
Species	*Oncorhynchus clarki bouvieri*	*Oncorhynchus clarki lewisi*
Total Nos. of Fish	25	25
Condition Factor	1.1 (0.6 – 1.3, N = 25)	0.9 (0.7 – 1.1, N = 25)
Sex$_{(M / F)}$	6 / 4	5 / 5
Vitellogenin$_{male}$[1]	DH (4.40, N =1) DL (none) ND (<0.20, N = 5)	DH (5.58, N = 1) DL (0.75, N = 1) ND (<0.20, N = 3)
17ß-estradiol$_{female}$	13.70 (11.08 – 20.46, N = 4)	2.32 (<0.25 – 5.73, N = 5)
17ß-estradiol$_{male}$	0.59 (0.50 – 0.76, N = 6)	0.30 (<0.25 – 0.49, N = 5)
11kT$_{male}$	13.20 (8.92 – 18.67, N = 6)	7.32 (1.31 – 13.57, N = 5)
Testosterone$_{female}$	14.32 (9.97 – 17.80, N = 4)	2.41 (1.18 – 4.54, N = 5)
Testosterone$_{male}$	14.68 (7.25 – 22.90, N = 6)	6.62 (1.24 – 11.72, N = 5)
Kidney MAs	2.14 (0.32 – 4.11, N = 10)	10.70 (2.93 – 25.66, N = 10)
Liver MAs	0.00 (N = 10)	0.10 (0.00 – 0.52, N = 10)
Spleen MAs	0.18 (0.01 – 0.53, N = 10)	1.15 (0.23 – 4.52, N = 10)
Histopathology[2] Numbers in ( ) are affected fish out of 15	Kidney: none Liver: pC(1), fLi(1) Spleen: none Gonad: IS(1) Gill: none	Kidney: none Liver: none Spleen: none Gonad: none Gill: none
Hg$_{total\ whole\text{-}body}$	37.06 (24.33 – 45.62, N = 10)	36.74 (16.90 – 59.60, N = 15)
Age	4 (2 – 5, N = 25)	5 (2 – 6, N = 25)

Age Frequency Histograms



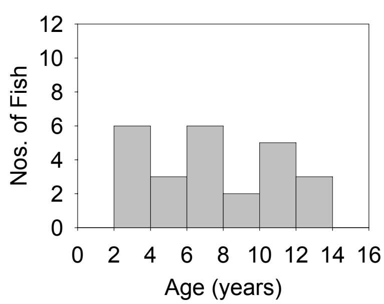


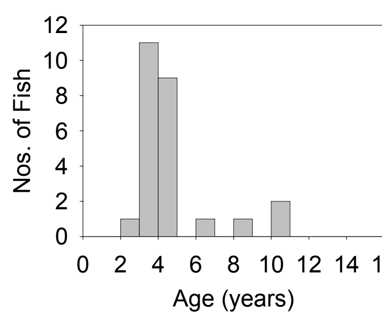
[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]pC = perivascular cuffing, fLi = fatty liver, IS = intersex male.

Table 5A-8. Fish Biological and Mercury data for OLYM and Year Sampled. Data are mean (min – max) except Vitellogenin (min – max). Sex (listed only for fish with accompanying gonad samples), Vitellogenin (µg/ml), 17ß-estradiol (ng/ml), 11keto-testosterone (11kT ng/ml), Testosterone (ng/ml), MAs (average % area), Hg (ng/g ww), Age (years).

OLYM	**Hoh Lake**	**PJ Lake**	**2005**
Species	*Salvelinus fontinalis*	*Salvelinus fontinalis*	
Total Nos. of Fish	25	25	
Condition Factor	1.0 (0.7 – 1.4, N = 25)	1.0 (0.7 – 1.1, N = 25)	
Sex$_{(M / F)}$	5 / 5	5 / 5	
Vitellogenin$_{male}$[1]	DH (none)	DH (none)	
	DL (none)	DL (0.43, N = 1)	
	ND (<0.20, N = 5)	ND (<0.20, N = 4)	
17ß-estradiol $_{female}$	8.07 (<0.25 – 14.56, N = 5)	8.01 (0.49 – 15.43)	
17ß-estradiol$_{male}$	0.30 (<0.25 – 0.49, N = 5)	0.19[2] (<0.25 – 0.42)	
11kT$_{male}$	5.56 (2.83 – 8.66, N = 5)	5.48 (1.06 – 11.66)	
Testosterone$_{female}$	4.88 (0.68 – 8.26, N = 5)	6.52 (0.84 – 17.39)	
Testosterone$_{male}$	5.20 (3.49 – 7.77, N = 5)	4.38 (1.14 – 11.91)	
Kidney MAs	21.24 (3.45 – 34.91, N= 10)	12.66 (3.72 – 35.76, N = 10)	
Liver MAs	0.29 (0.00 – 0.94, N = 10)	0.29 (0.00 – 1.64, N = 10)	
Spleen MAs	9.07 (0.11 – 25.83, N = 10)	3.98 (0.00 – 12.76, N = 10)	
Histopathology	Kidney: none	Kidney: none	
Out of 15 fish	Liver: none	Liver: none	
	Spleen: none	Spleen: none	
	Gonad: none	Gonad: none	
	Gill: none	Gill: none	
Hg$_{total\ whole\text{-}body}$	141.67 (78.44 – 284.02, N = 15)	102.36 (30.16 – 227.35, N = 15)	
Age	7 (3 – 13, N = 25)	4 (2 – 10, N = 25)	

Age Frequency Histograms





[1]DH = detectable high (>1µg/ml), DL = detectable low, ND = non-detectable. [2]>50% non-detects.

APPENDIX 5B

Correlations between Hg and Age

Data are first analyzed using all fish, then analyzed by species, then park, and then lake. Data are provided for the model that had the strongest statistical significance. The categories in bold are significant at P < 0.05.

Analysis	F	d.f.	$R^{squared}$	P	Best Fit Model
All fish	**58.10**	**2, 162**	**0.42**	**<0.0001**	**2^{nd} order polynomial (parabolic)**
Brook trout	**129.38**	**1, 98**	**0.57**	**<0.0001**	**Linear**
Lake trout	0.39	1, 28	-0.01	0.54	Linear
Cutthroat trout	**7.84**	**1, 23**	**0.25**	**0.01**	**Double reciprocal**
Rainbow trout	**114.89**	**1, 8**	**0.93**	**<0.0001**	**Double reciprocal**
Sequoia	**38.31**	**1, 18**	**0.68**	**<0.0001**	**Double reciprocal**
Pear	**42.95**	**1, 8**	**0.84**	**0.0002**	**S-curve**
Emerald	**9.11**	**1, 8**	**0.63**	**0.02**	**Double reciprocal**
Rocky Mountain	**82.08**	**1, 18**	**0.82**	**<0.0001**	**Double reciprocal**
Mills	**114.89**	**1, 8**	**0.93**	**<0.0001**	**Double reciprocal**
Lone Pine	**31.14**	**1, 8**	**0.80**	**0.0005**	**Squared X**
Gates of the Arctic					
Matcharak	1.44	1, 8	0.15	0.26	Reciprocal Y; Squared X
Noatak					
Burial	**5.55**	**1, 8**	**-0.41**	**0.05**	**Reciprocal Y; Squared X**
Denali					
Wonder	0.98	1, 8	0.11	0.35	Double squared
Mount Rainier	**37.33**	**1, 28**	**0.57**	**<0.0001**	**Square root Y; Squared X**
LP19	**38.18**	**1, 13**	**0.75**	**<0.0001**	**Log Y; Square-root X**
Golden	2.68	1, 13	0.17	0.12	Double reciprocal
Glacier	**7.84**	**1, 23**	**0.25**	**0.01**	**Double reciprocal**
Oldman	4.04	1, 8	0.33	0.08	Double squared
Snyder	**11.07**	**1, 13**	**0.46**	**0.005**	**Double reciprocal**
Olympic	**106.82**	**1, 38**	**0.74**	**<0.0001**	**Double squared**
PJ2003	**5.37**	**1, 8**	**0.40**	**0.05**	**Double reciprocal**
PJ2005	**44.74**	**1, 13**	**0.77**	**<0.0001**	**Double squared**
Hoh	**44.96**	**1, 13**	**0.78**	**<0.0001**	**Squared X**

APPENDIX 5C

Correlations between Macrophage Aggregates and Hg

Data analyzed using all fish and then separated into species age classes when possible. Data are provided for the model that had the strongest statistical significance. The categories in bold are significant at $P < 0.05$.

Analysis	F	d.f.	$R^{squared}$	P	Best Fit Model
All Fish					
Spleen MAs	**52.25**	**1, 163**	**0.24**	**<0.0001**	**Log_{10}(X)**
Kidney MAs	**35.89**	**1, 163**	**0.18**	**<0.0001**	**Log_{10}(X)**
Sum of MAs	**48.69**	**1, 163**	**0.23**	**<0.0001**	**Log_{10}(X)**
Brook trout					
Spleen MAs	**82.82**	**1, 98**	**0.45**	**<0.0001**	**Log_{10}(X)**
1-3 y	**6.03**	**1, 28**	**0.18**	**0.02**	**Double Squared**
4-6 y	**26.27**	**1, 46**	**0.36**	**<0.0001**	**Log_{10}(X)**
7-13 y	2.59	1,20	0.11	0.12	Squared Y; Reciprocal X
Kidney MAs			**42.64**	**1, 98**	**0.30 <0.0001**
Log_{10}(X)					
1-3 y	2.51	1, 28	0.08	0.12	Double Squared
4-6 y	**6.65**	**1, 46**	**0.13**	**0.01**	**Double Reciprocal**
7-13 y	1.8	1, 20	0.08	0.19	Double Squared
Sum of MAs	**66.92**	**1, 98**	**0.41**	**<0.0001**	**Log_{10}(X)**
1-3 y	3.16	1, 28	0.10	0.09	Double Squared
4-6 y	**13.06**	**1, 46**	**0.22**	**0.0007**	**Double Reciprocal**
7-13 y	3.21	1, 20	0.14	0.09	Double Squared
Lake trout					
Spleen MAs	**6.99**	**1, 28**	**-0.2**	**0.01**	**Linear**
< 20 y	**4.77**	**1, 15**	**-0.24**	**0.04**	**Squared Y**
> 20 y	**22.64**	**1, 11**	**-0.67**	**0.0006**	**Reciprocal Y; Squared X**
Kidney MAs	0.32	1, 28	-0.01	0.57	Squared Y; Log X
< 20 y	0.00	1, 15	0.0001	0.97	Linear
> 20 y	0.00	1, 11	0.0002	0.96	Linear
Sum of MAs	1.62	1, 28	-0.05	0.21	Squared Y; Square root X
< 20 y	1.48	1, 15	-0.09	0.24	Double squared
> 20 y	0.67	1, 11	-0.06	0.43	Reciprocal Y; Square root X
Cutthroat trout					
Spleen MAs	**15.46**	**1, 23**	**0.40**	**0.0007**	**Double squared**
Kidney MAs	**16.10**	**1, 23**	**0.41**	**0.0005**	**Double squared**
Sum of MAs	**17.15**	**1, 23**	**0.43**	**0.0004**	**Double squared**
Rainbow trout					
Spleen MAs	4.13	1, 8	0.34	0.08	Linear
Kidney MAs	**28.83**	**1, 8**	**0.79**	**0.0007**	**Double reciprocal**
Sum of MAs	**33.83**	**1, 8**	**0.81**	**0.0004**	**Double reciprocal**
SEKI – Brook Trout					
Spleen MAs	**35.65**	**1, 18**	**0.66**	**<0.0001**	**Square-root Y; Log X**
Kidney MAs	**6.12**	**1, 18**	**0.25**	**0.02**	**Multiplicative**
Sum of MAs	**15.05**	**1, 18**	**0.45**	**0.001**	**Square-root Y; Log X**
Pear					
Spleen MAs	**31.24**	**1, 8**	**0.80**	**0.0005**	**Linear**
Kidney MAs	**9.85**	**1, 8**	**0.55**	**0.01**	**Linear**
Sum of MAs	**19.18**	**1, 8**	**0.71**	**0.002**	**Linear**

Analysis	**F**	**d.f.**	**$R^{squared}$**	**P**	**Best Fit Model**
Emerald					
Spleen MAs	4.46	1, 8	0.36	0.07	Reciprocal Y; Log X
Kidney MAs	**8.35**	**1, 8**	**0.51**	**0.02**	**Double reciprocal**
Sum of MAs	**7.98**	**1, 8**	**0.50**	**0.02**	**Double reciprocal**
ROMO					
Spleen MAs	**37.35**	**1, 18**	**0.67**	**<0.0001**	**Double squared**
Kidney MAs	**16.73**	**1, 18**	**0.48**	**0.0007**	**Double squared**
Sum of MAs	**35.87**	**1, 18**	**0.67**	**<0.0001**	**Squared Y**
Mills – rainbow trout					
Spleen MAs	4.13	1, 8	0.34	0.08	Linear
Kidney MAs	**28.83**	**1, 8**	**0.79**	**0.0007**	**Double reciprocal**
Sum of MAs	**33.83**	**1, 8**	**0.81**	**0.0004**	**Double reciprocal**
Lone Pine – brook trout					
Spleen MAs	**21.21**	**1, 8**	**0.73**	**0.002**	**Squared Y; Square-root X**
Kidney MAs	**16.38**	**1, 8**	**0.67**	**0.004**	**Double squared**
Sum of MAs	**34.55**	**1, 8**	**0.81**	**0.0004**	**Double squared**
GAAR					
Matcharak – lake trout					
Spleen MAs	4.75	1, 8	-0.37	0.06	Squared Y; Reciprocal X
≤ 20 y	4.53	1, 3	0.60	0.12	Linear
> 20 y	5.35	1, 3	-0.64	0.10	Squared Y; Reciprocal X
Kidney MAs	0.26	1, 8	0.03	0.63	Reciprocal Y; Squared X
≤ 20 y	6.35	1, 3	0.68	0.09	Linear
> 20 y	0.18	1, 3	-0.06	0.70	Double reciprocal
Sum of MAs	1.17	1, 8	-0.13	0.31	Squared Y; Reciprocal X
≤ 20 y	7.12	1, 3	0.70	0.08	Linear
> 20 y	0.88	1, 3	-.23	0.42	Squared Y; Reciprocal X
NOAT					
Burial – lake trout					
Spleen MAs	**12.56**	**1, 8**	**-0.64**	**0.009**	**Squared Y; Reciprocal X**
< 15 y	**67.70**	**1, 2**	**0.97**	**0.01**	**Linear**
> 15 y	1.11	1,4	-0.21	0.35	Linear
Kidney MAs	1.47	1, 8	-0.15	0.26	Squared Y; Reciprocal X
< 15 y	8.07	1, 2	0.80	0.10	Linear
> 15 y	0.01	1, 4	0.21	0.93	Linear
Sum of MAs	2.42	1, 8	-0.23	0.16	Squared Y; Reciprocal X
< 15 y	9.56	1, 2	0.83	0.09	Linear
> 15 y	0.01	1, 4	0.13	0.94	Linear
DENA – Lake Trout					
Wonder					
Spleen MAs	4.21	1, 8	0.34	0.07	Reciprocal Y; Squared X
Kidney MAs	**5.49**	**1, 8**	**0.41**	**0.05**	**Reciprocal Y**
Sum of MAs	7.61	1, 8	0.49	0.03	Double squared
MORA – Brook Trout					
Spleen MAs	**46.03**	**1, 28**	**0.62**	**<0.0001**	**$Log_{10}(X)$**
Kidney MAs	**7.26**	**1, 28**	**0.21**	**0.01**	**Double reciprocal**
Sum of MAs	**11.20**	**1, 28**	**0.29**	**0.002**	**Square root Y; Reciprocal X**

Analysis	F	d.f.	$R^{squared}$	P	Best Fit Model
LP19					
Spleen MAs	**89.51**	**1, 13**	**0.87**	**<0.0001**	**S-curve**
Kidney MAs	**37.27**	**1, 13**	**0.74**	**<0.0001**	**Double reciprocal**
Sum of MAs	**48.48**	**1, 13**	**0.79**	**<0.0001**	**S-curve**
Golden					
Spleen MAs	1.87	1, 13	0.13	0.19	S-curve
Kidney MAs	**4.46**	**1, 13**	**0.26**	**0.05**	**Double reciprocal**
Sum of MAs	4.25	1, 13	0.25	0.06	Double reciprocal
GLAC – West Slope Cutthroat					
Spleen MAs	**15.46**	**1, 23**	**0.40**	**0.0007**	**Double squared**
Kidney MAs	**16.10**	**1, 23**	**0.41**	**0.0005**	**Double squared**
Sum of MAs	**17.15**	**1, 23**	**0.43**	**0.0004**	**Double squared**
Oldman					
Spleen MAs	**25.26**	**1, 8**	**0.76**	**0.001**	**Double reciprocal**
Kidney MAs	2.71	1, 8	0.25	0.14	Squared Y; reciprocal X
Sum of MAs	3.23	1, 8	0.29	0.11	Squared Y; reciprocal X
Snyder					
Spleen MAs	**16.53**	**1, 13**	**0.56**	**0.001**	**Squared X**
Kidney MAs	**21.21**	**1, 13**	**0.62**	**0.0005**	**Double squared**
Sum of MAs	**23.22**	**1, 13**	**0.64**	**0.0003**	**Double squared**
OLYM – Brook Trout					
Spleen MAs	**43.10**	**1, 38**	**0.53**	**<0.0001**	**Linear**
Kidney MAs	**30.29**	**1, 38**	**0.44**	**<0.0001**	**Linear**
Sum of MAs	**40.29**	**1, 38**	**0.52**	**<0.0001**	**Linear**
PJ2003					
Spleen MAs	**14.45**	**1, 8**	**0.64**	**0.005**	**Squared Y**
Kidney MAs	3.87	1, 8	0.33	0.08	Double reciprocal
Sum of MAs	5.00	1, 8	0.38	0.06	Double reciprocal
PJ2005					
Spleen MAs	**4.98**	**1, 13**	**0.28**	**0.04**	**Square-root X**
Kidney MAs	**16.92**	**1, 13**	**0.56**	**0.001**	**Reciprocal Y; Square-root X**
Sum of MAs	**13.30**	**1, 13**	**0.51**	**0.003**	**Reciprocal Y; Square-root X**
Hoh					
Spleen MAs	**30.86**	**1, 13**	**0.70**	**0.0001**	**Reciprocal X**
Kidney MAs	**29.95**	**1, 13**	**0.70**	**0.0001**	**Squared Y; Log X**
Sum of MAs	**34.54**	**1, 13**	**0.73**	**0.0001**	**Squared Y; Log X**
All Fish					
Spleen MAs		Failed lack of fit test			
Kidney MAs		Failed lack of fit test			
Sum of MAs	**51.46**	**1, 163**	**0.24**	**<0.0001**	**S-curve**
Brook trout					
Spleen MAs	**91.11**	**1, 98**	**0.48**	**<0.0001**	**Reciprocal X**
Kidney MAs	**75.84**	**1, 98**	**0.46**	**<0.0001**	**Reciprocal X**
Sum of MAs	**104.67**	**1, 98**	**0.52**	**<0.0001**	**Reciprocal X**
Lake trout					
Spleen MAs	**35.25**	**1, 28**	**0.57**	**<0.0001**	**Double reciprocal**
Kidney MAs	**61.07**	**1, 28**	**0.68**	**<0.0001**	**Double reciprocal**
Sum of MAs	**70.02**	**1, 28**	**0.71**	**<0.0001**	**Double reciprocal**

Analysis	F	d.f.	$R^{squared}$	P	Best Fit Model
Cutthroat trout					
Spleen MAs	18.47	1, 23	0.44	0.0003	Square-root Y; Squared X
Kidney MAs	11.44	1, 23	0.33	0.003	Squared X
Sum of MAs	12.88	1, 23	0.36	0.002	Square-root Y; Squared X
Rainbow trout					
Spleen MAs	19.91	1, 8	0.71	0.002	Squared X
Kidney MAs	52.16	1, 8	0.87	0.0001	Exponential
Sum of MAs	61.84	1, 8	0.88	<0.0001	Exponential
SEKI					
Spleen MAs	26.39	1, 18	0.59	0.0001	S-curve
Kidney MAs	8.7	1, 18	0.33	0.009	Double reciprocal
Sum of MAs	16.23	1, 18	0.47	0.0008	S-curve
Pear					
Spleen MAs	28.74	1, 8	0.78	0.0007	S-curve
Kidney MAs	7.5	1, 8	0.48	0.03	Double reciprocal
Sum of MAs	13.83	1, 8	0.63	0.006	Double reciprocal
Emerald					
Spleen MAs	6.11	1, 8	0.43	0.04	Double reciprocal
Kidney MAs	7.20	1, 8	0.47	0.03	Double reciprocal
Sum of MAs	8.49	1, 8	0.51	0.02	Double reciprocal
ROMO					
Spleen MAs	20.57	1, 18	0.53	0.0003	Double squared
Kidney MAs	23.69	1, 18	0.57	0.0001	Double reciprocal
Sum of MAs	38.64	1, 18	0.68	<0.0001	Double squared
Mills					
Spleen MAs	19.91	1, 8	0.71	0.002	Squared X
Kidney MAs	52.16	1, 8	0.87	0.0001	Exponential
Sum of MAs		61.84	1, 8	0.88	<0.0001
Exponential					
Lone Pine					
Spleen MAs	11.53	1, 8	0.59	0.009	Double squared
Kidney MAs	6.62	1, 8	0.45	0.03	Double squared
Sum of MAs	11.67	1, 8	0.59	0.009	Double squared
GAAR					
Matcharak					
Spleen MAs	28.45	1, 8	0.78	0.0007	Square-root Y
Kidney MAs	19.86	1, 8	0.71	0.002	Reciprocal Y; Log X
Sum of MAs	38.39	1, 8	0.83	0.0003	Reciprocal Y; Log X
NOAT					
Burial					
Spleen MAs	86.15	1, 8	0.93	<0.0001	Double reciprocal
Kidney MAs	30.16	1, 8	0.79	0.0006	Double reciprocal
Sum of MAs	34.27	1, 8	0.81	0.0004	Double reciprocal
DENA					
Wonder					
Spleen MAs	1.83	1, 8	0.19	0.21	Double squared
Kidney MAs	0.41	1, 8	0.05	0.54	Reciprocal Y; Squared
Sum of MAs	1.4	1, 8	0.15	0.27	Double squared

Analysis	F	d.f.	$R^{squared}$	P	Best Fit Model
MORA					
Spleen MAs	**55.96**	**1, 28**	**0.67**	**<0.0001**	**S-curve**
Kidney MAs	**61.38**	**1, 28**	**0.69**	**<0.0001**	**Double reciprocal**
Sum of MAs	**69.46**	**1, 28**	**0.71**	**<0.0001**	**Double reciprocal**
LP19					
Spleen MAs	**44.00**	**1, 13**	**0.77**	**<0.0001**	**S-curve**
Kidney MAs	**61.30**	**1, 13**	**0.82**	**<0.0001**	**Double reciprocal**
Sum of MAs	**72.66**	**1, 13**	**0.84**	**<0.0001**	**S-curve**
Golden					
Spleen MAs	**6.64**	**1, 13**	**0.34**	**0.02**	**Double squared**
Kidney MAs	**5.93**	**1, 13**	**0.31**	**0.03**	**Double reciprocal**
Sum of MAs	**6.17**	**1, 13**	**0.32**	**0.03**	**Double reciprocal**
GLAC					
Spleen MAs	**18.47**	**1, 23**	**0.44**	**0.0003**	**Square-root Y; Squared X**
Kidney MAs	**11.44**	**1, 23**	**0.33**	**0.003**	**Squared X**
Sum of MAs	**12.88**	**1, 23**	**0.36**	**0.002**	**Square-root Y; Squared X**
Oldman					
Spleen MAs	**5.20**	**1, 8**	**0.39**	**0.05**	**Double squared**
Kidney MAs	2.47	1, 8	0.24	0.15	Squared Y; Square-root X
Sum of MAs	2.92	1, 8	0.27	0.13	Squared Y
Snyder					
Spleen MAs	**6.01**	**1, 13**	**0.32**	**0.03**	**Double reciprocal**
Kidney MAs	2.43	1, 13	0.16	0.14	Log Y; Squared X
Sum of MAs	2.81	1, 13	0.18	0.11	Log Y; Squared X
OLYM					
Spleen MAs	**41.97**	**1, 38**	**0.52**	**<0.0001**	**Linear**
Kidney MAs	**49.92**	**1, 38**	**0.57**	**<0.0001**	**Linear**
Sum of MAs	**58.09**	**1, 38**	**0.60**	**<0.0001**	**Linear**
PJ2003					
Spleen MAs	**48.23**	**1, 8**	**0.86**	**0.0001**	**Double reciprocal**
Kidney MAs	**34.67**	**1, 8**	**0.81**	**0.0004**	**Double reciprocal**
Sum of MAs	**37.32**	**1, 8**	**0.82**	**0.0003**	**Double reciprocal**
PJ2005					
Spleen MAs	3.2	1, 13	0.20	0.10	Reciprocal X
Kidney MAs	**9.27**	**1, 13**	**0.42**	**0.009**	**Log Y; Squared X**
Sum of MAs	**7.04**	**1, 13**	**0.35**	**0.02**	**Exponential**
Hoh					
Spleen MAs	**250.45**	**1, 13**	**0.95**	**<0.0001**	**S-curve**
Kidney MAs	**113.38**	**1, 13**	**0.90**	**<0.0001**	**Squared Y; Log X**
Sum of MAs	104.83	1, 13	0.89	<0.0001	$Log_{10}(X)$

Western Airborne Contaminants Assessment Project

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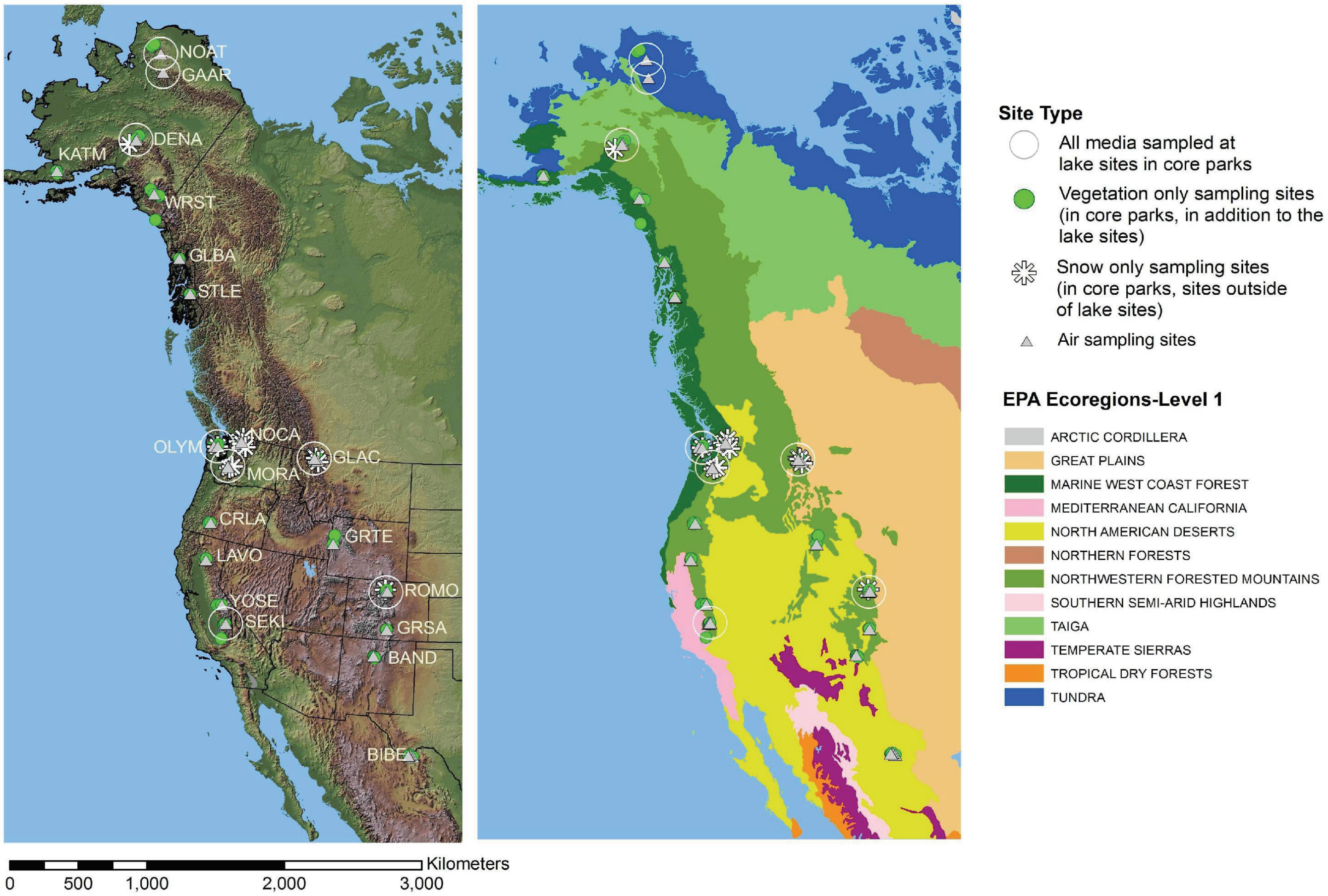

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