Airborne Contaminants

SOUTHEAST ALASKA NETWORK – PROTOCOL DEVELOPMENT SUMMARY

PARKS WHERE PROTOCOL WILL BE IMPLEMENTED: GLBA, KLGO, SITK

Justification/Issues Being Addressed

The low population densities, lack of large-scale industrial development, proximity to Pacific Ocean, and vast stretches of wild-lands lead many people believe the air quality of Southeast Alaska is among the most pristine in the world. However, a lichen-based air quality study completed in 1999 demonstrated that sulfur, nitrogen, and heavy metal concentrations in the KLGO-Skagway area exceeded nutrient enhancement and heavy metal concentration thresholds established by the USDA for the adjacent Tongass National Forest (Geiser et al. 1994, Furbish et al. 2000, Dillman pers. com.). All SEAN parks may be impacted by near-field mobile sources including cruise ships and other marine traffic, near-field point source such as diesel fired generators, and far-field industrial sources in Eurasia (figure 1).

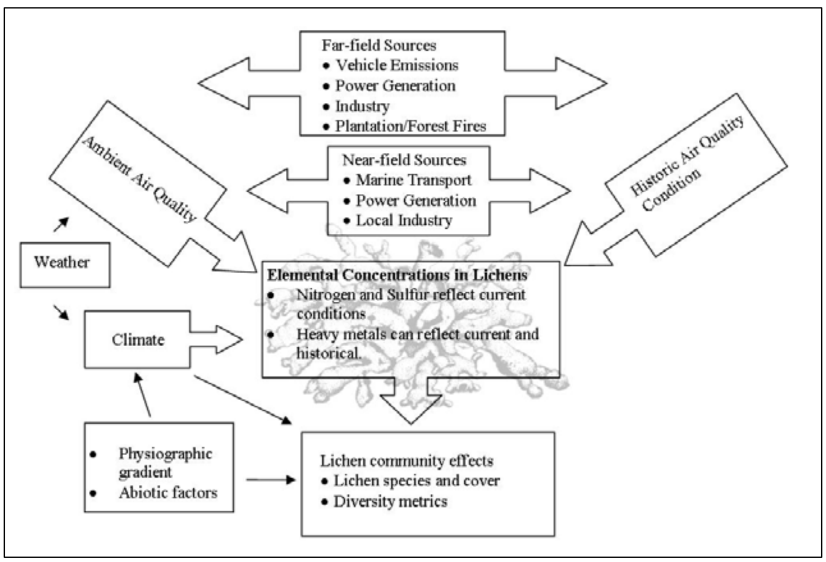

Figure 1. Lichen – air quality effects conceptual model

In addition to air contamination degrading visibility and impacting the parks' scenic beauty, deposition of air contaminants in sensitive park ecosystems has the potential to contribute to foliar damage (Fenn 2006), terrestrial and marine community compositions shifts (Geiser 1994, Fenn 2006) and bioaccumulation of contaminants in marine and terrestrial organisms (Goodyear and McNeil 1998, Pedersen and Lierhagen 2006). While all parks are required to preserve the scenery unimpaired (NPS 1916), Glacier Bay has the additional requirement of maintaining a Class 1 airshed, which requires the highest level of protection under the federal Clean Air Act passed in 1963 (PL 91-604) as amended in 1977 (PL 95-9) and reaffirmed in 1990 amendments. Thus, measurable air quality parameters are of high value to natural area managers.

Lichens are ideal long-term integrators of atmospheric deposition due to their longevity and lack of inter seasonal morphological variation. Lichens lack roots, get their mineral nutrients from the air, and their tissue structure traps airborne particulates and soluble metal ions.

Because most sources of airborne pollution in the region are currently unregulated mobile sources (marine traffic) or are transported from far-field sources, and funding is limited, this protocol focuses on easily obtainable measures of air quality and ecological effects rather than the much more costly air quality parameters that are currently used in the regulatory arena. However, elemental concentrations in lichens and their ecological effect on lichen communities may enter the regulatory arena in the near future in determining critical loads (Porter et al. 2004, Leith et al. 2006). A long-term, 10 year revisit cycle is warranted due to slowly increasing levels of tourism, low levels of industrial development and slow population grown in the region. One data point per decade will provide managers and researchers with a broad picture of trends in air quality and how park conditions compare to other sites conducting comparable monitoring across the region (Tongass National Forest) and in the Pacific Northwest.

Mercury (Hg) may be an important contaminant in Southeast Alaska due to its proximity to Eurasian sources and the prevailing weather patterns (figure 2). Once Hg becomes bioavailability in an organic form, methyl mercury (MeHg) it is 100 time more toxic and can bioaccumulate in a variety of taxa and reaching concentrations one-million times greater than environmental concentrations (Wolfe et al. 1998). Because the use of lichen to monitor Hg deposition is not fully developed, and a well established network of wet-deposition Hg monitoring stations already exists across the country, we intend to join the national Mercury Deposition Network (MDN) for an initial period of 3-years.

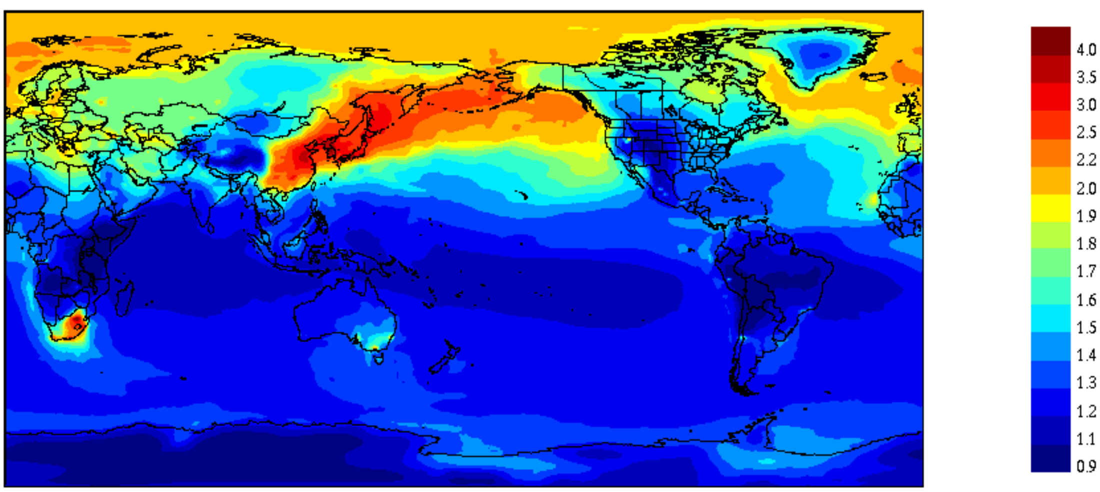

Figure 2: Model of global transport of atmospheric mercury, showing Alaska at the receiving end of coal burning emissions from China. Values are average elemental mercury surface concentrations for July 2001 (ng/m3). GRAHM (Global/Regional Atmospheric Heavy Metals Model) simulation—Ashu Dastoor, Meteorological Service of Canada, Environment Canada.

Specific Monitoring Questions and Objectives Addressed by the Protocol

1. Determine concentrations and decadal trends of airborne contaminants as manifested in concentrations in lichen tissue, and determine how contaminant concentrations in lichen tissue relate to ambient air concentrations and rates of deposition.
2. Determine whether lichen communities are changing over time in response to changes in air quality.
3. Determine Hg wet deposition amounts and temporal patterns and compare these rates with other sites in Alaska to assess temporal and spatial variation in Hg deposition rates across Alaska sites.
4. Develop a protocol (following Oakley et al 2003) for long-term monitoring of air quality trends with lichens as 1) air quality sensors for elemental analysis in conjunction with passive chemical sensors and deposition samplers and 2) bioindicators as expressed through community monitoring plots for the SEAN I&M program.

Basic Approach

Objective 1. Determine concentrations and decadal trends of airborne contaminants as manifested in concentrations in lichen tissue, and determine how contaminant concentrations in lichen tissue relate to ambient air concentrations and rates of deposition.

A) Determine the concentrations of selected chemical elements in tissue of three lichen species (*Hypogymnia heteromorphy, H. inactive, Platismatia glauca*) from 5 sites / collection plots across the network (two that were previously used in KLGO (Furbish 2000), two in GLBA and one in SITK). These data will be the site specific reference conditions against which future samples will be compared.

   Sample size & frequency: Each lichen collection macro-plot consists of a relative homogenous land-cover patch of about 2 hectares. During years when sampling occurs, 30 10-20 gram samples (dry weight) of each of the three elemental analysis lichen species are collected at the end of the summer season. Sample collection occurs once per year for two consecutive years, followed by a nine year break for a decadal sampling regime.

   Area of inference: These lichen collection plots will be part of a region wide monitoring program run by the USDA Forest Service. By leveraging the 73 plot already in place on Forest Service Land, course spatial resolution inferences can be made throughout Southeast Alaska. Fine-scale, park-wide inferences would require additional intra-park sample sites.

   Metrics include elemental concentration values in µg/g for a suite of elements including P, K, Ca, Mg, Na, Al, Fe, Mn, Cu, B, Pb, Ni, Cr, Cd, Co, Mo, Si, Ti, Be, Sr, Rb, Li, V, Ba, total nitrogen and total sulfur expressed as a percent, and nitrate expressed in ppm.

B) Spatial differences: Test for significant differences (H_o = no difference exists) in elemental concentrations between sites across the network.

C) Compare elemental concentration results with reference data from the greater Southeast Alaska area and the Pacific Northwest.

D) As part of protocol development measure actual concentration (ppm or ppb) of SO_2, NHO_3, NH_3, NO_2 and NO_x in ambient air with Ogawa passive air samplers. Because some potential sites in GLBA may not be accessible on a weekly or biweekly basis, only throughfall samplers (see below) will be deployed at these sites if selected. The results from the Ogawa samplers yield data for ambient air concentrations for selected compounds measured in ppm or ppb. Nitrogen monoxide (NO) is calculated by subtracting NO_2 from NO_x. Weekly monitoring will commence on April 15th (3 weeks prior to the beginning of the tourist season) and terminate on Oct 15th (3 weeks after the end of the tourist season). For the Dewey Lake site, between June and August, during the second week of each month we will shift to a daily sampling frequency. This information will be used to examine the relationship between daily and weekly variation in air chemistry, together with weather conditions and number of and types of cruise ships in port. Overall, results from the passive samplers will be used to develop models **(**e.g. Fenn et al. 2003**)** linking elemental concentrations in lichen tissue with concentrations detected in ambient air during the study. Dr. Andrjez Bytnerowicz is the project collaborator for the passive air samplers.

E) Also as part of protocol development measure deposition (total wet and dry in kg/ha/yr) by deploying passive through-fall samplers. Passive throughfall samplers following the methods of Fenn and Poth (2004) will be deployed at each lichen plot. These devices will be left in place from mid-April through mid-October. Throughfall samplers yield data on atmospheric wet and dry deposition of target compounds including sulfates, nitrates, ammonium and hydrogen ions calculated in kg/ha for the sampling period. Ten throughfall sampling tubes will be deployed in forested portions of each 4-5 acre lichen collection plot along with an addition 5 sampling tubes in canopy gaps. For nonforested plots in upper GLBA only 5 throughfall sampling tubes are required (M. Fenn pers. comm. 2007). Results from the passive throughfall samplers will be used to develop models (e.g. Fenn et al. 2003) linking elemental concentrations in lichen tissue and lichen community data with deposition rates detected during the study. Tying deposition rates of key anthropogenic components of air, with measurable effects on lichen community structure and diversity can be used to determine critical loads for specific pollutants. In some parts of the country and in Europe critical loads have been used to set limits on industrial emissions (Porter et al. 2005). Dr. Mark Fenn is the project's collaborator for throughfall sampling.

F) Passive air chemistry and throughfall measurement data will be used to create model(s) tying pollutant concentrations in ambient air with elemental concentration in lichens. This will expand on active work in this area (Blum and Tjutjunnik 1992, Geiser pers. com.). Note: Most of this component is already funded by WASO-AQD at KLGO for FY08-09.

G) Lichen air quality sites conducted in KLGO in 1998-9 will be revisited during the development and testing phase of this protocol. Test for significant changes (H_o = no difference exists) in elemental concentrations between the 1998/99 and the 2008/9 sampling period at each KLGO site.

Objective 2. Determine whether lichen communities are changing over time in response to changes in air quality.

A) Establish lichen community plots following methods used in the Tongass National Forest and Forests in the Pacific Northwest (Geiser et al 1994, Geiser 2004) as reference data for inter site comparisons and future intra site trend analysis and comparisons. These sites will adjacent to the lichen collection areas in objective A-1.

Sample size & frequency: Two lichen community plots per collection macro-plot are read once per decadal sampling cycle.

Metrics: Standard site information (percent cover of dominant species by strata, abiotic data, etc.), abundance categories per lichen species, species richness and other diversity metrics for lichens, compositional gradient score. A voucher of each species is collected at each plot (Geiser 2004).

Area of inference: These lichen plots will be part of a region wide monitoring program run by the USDA Forest Service. By leveraging the 73 plot already in place on Forest Service Land, course spatial resolution inferences can be made throughout Southeast Alaska. Fine-scale, park-wide inferences would require additional intra-park sample sites.

B) Re-read lichen community plots at next sampling cycle in approximately 10 years.

C) Develop models of the relationship between lichen community plot data and metrics (e.g., diversity indices) and elemental concentrations in lichen tissue using inter site comparisons metrics. Expand on models drafted by Geiser and Neitlich (2006).

Note: In addition to air quality, climate change may affect the lichen community parameters being investigated. This will be controlled for by the existence of several plots sites within the SEAN and the Tongass National Forest. The assumption being that climate effects may manifest at broader scales than near-field pollution effects. Methods to tease apart climate and pollution effects are presented in Geiser and Neitlich 2006.

Objective 3. Determine Hg wet deposition amounts and temporal patterns and compare these rates with other sites in Alaska to assess temporal and spatial variation in Hg deposition rates across Alaska sites.

A) Re-establish the wet-deposition monitoring station in GLBA and run it continuously for at least 3 years following MDN protocols (http://nadp.sws.uiuc.edu/mdn/).

Sample size & frequency: Precipitation samples are collected weekly, year-round.

Metrics: Hg concentration in ng/l

Area of inference: This Hg monitoring site will be part of a region wide monitoring network run by the NADP MDN program and funded by the NPS and the State of Alaska Department of Environmental Quality. The NPS will have a site in Gates of the Arctic National Park and the State has sites on Kodiak Island and Dutch Harbor. Spatial inference may be possible at the State wide level depending on the intra-site variation and correlation in Hg concentrations. These data will be analyzed after 3 years specifically to look at Alaska wide spatial and temporal patterns in Hg wet deposition. Fine-scale, parkwide inferences are not an expect outcome.

Objective 4. Develop a protocol (following Oakley et al 2003) for long-term monitoring of air quality trends with lichens as 1) air quality sensors for elemental analysis in conjunction with passive chemical sensors and deposition samplers and 2) bioindicators as expressed through community monitoring plots for the SEAN I&M program.

Use results from Objectives 1-3 to critically evaluate the most efficient and balanced sampling design for long-term monitoring of air contaminants within the SEAN.

Principal Investigators and NPS Lead

NPS: Dave Schirokauer, Klondike Gold Rush National Historical Park, Brendan Moynahan, SEAN

Other Agency: US Forest Service Dr. Linda Geiser, National Deposition Monitoring Network (Mercury)

Development Schedule, Budget, and Expected Interim Products

Schedule and Budget:

	FY08		FY09		FY10	FY18	FY19
Item	Protocol dev pilot sampling SEAN	Protocol dev WASO-AQD & KLGO	Protocol dev & pilot sampling SEAN	Protocol dev WASO AQD & KLGO	Protocol writing SEAN & KLGO	Future Sample year 1	Future Sample year 2
GS-7 Bio Tech 4.5pp @ $1,625 pp		$7,312		$7,500		10,000	10,000
USFS Linda Geiser Travel 7 day		$1,000		$3,000		0	0
USFS L. Geiser Salary (0.5 pp)	1,600	$4,500	1,600	$2,700	$4,500	0	0
UFSU Lichenologist Karen Dillman: Set up and read 4 lichen community bio-monitoring plots	$3,200	$2,200	0	0	0	6,000	0
Lichen elemental analysis for 5 sites (45 samples @ $150) setup	$6,750	$6,750	$6,750	$6,750	0	$14,100	$14,100
Ogawa sampler analysis for **5 sites** - SO_2, NO_2, NO_X, HNO_3, NH_3 26 weeks @ 10 samples per week for 6 sites (1300) and an additional 20 samples for 18 days from two sites (360). USFS cost of $7 per sample.	$11,620	$11,620	$12,620	$12,620	0	0	0
Throughfall sampling resins filters and analysis for 5 sites (15 collectors per site)	$4,500	$4,500	$5,250	$1,000	$1,500	0	0
MDN Station	$13,000		$13,000		$13,000	$13,000	$13,000
MDN Equipment	$ 6,000		0		0	0	0
Supplies: Sample bags, shipping	$ 2,500	$1,500	$ 1,500	$500	0	$500	$500
Total	$49,170	$39,382	$40,720	$34,070	$19,000	$43,600	$37,600

Interim products include annual reports and field and lab data. Data on weekly ambient concentrations of nitrogen and sulfur oxides, seasonal deposition rates, annual elemental concentration data from lichen tissue and decadal data lichen community composition – plot data.