Airborne Contaminants Monitoring Protocol Development

Southeast Alaska Inventory & Monitoring Program

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Kayaker and cruise ship in Tracy Arm Wilderness USFS Photo

Haze from Eurasian fires and pollution over Glacier Bay National Park & Preserve

Introduction

The low population densities, lack of large-scale industrial development, proximity to Pacific Ocean, and vast stretches of wild-lands lead many people to believe the environmental quality of Southeast Alaska is among the most pristine in the world. However, the lichen-based air quality study completed in 1999 demonstrated that sulfur, nitrogen, and heavy metal concentrations in the Skagway area exceeded thresholds established by the US Forest Service for the area.

Southeast Alaskan National Parks are exposed to a number of local and regional air pollution sources. Ferries, barges and small boats operate year-round. Air traffic consists of small planes and helicopters. Emissions in the region increase dramatically during the summer season when cruise ships ply the waters of Southeast Alaska. Up to two large cruise ships visit Glacier Bay each day and Skagway becomes the 16th busiest cruise ship port in the world. Diesel powered tourist trains also operate several times a day. Regional sources of air pollution include sooty fine particulates, nitrogen oxides, and other pollutants associated with forest fires and wind-blown dust and industrial emissions transported from Eurasia. Local and regional air pollutants are a concern because of the potential adverse effects to human health and to air pollution sensitive components of national park ecosystems from the air pollutants themselves and because of the impacts they have on visibility, an important air quality related value. Visible haze from stack emissions is common in Southeast Alaskan National Parks.

With this study we will be initiating a long-term air quality monitoring program by collecting the second temporal reference point for bio-monitoring program at Klondike Gold Rush NHP and initiating monitoring at Glacier Bay National Park & Preserve, and Sitka National Historical Site, along with creating monitoring protocols.

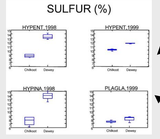
Monitoring Objectives

- ♦ Determine concentrations and decadal trends of airborne contaminants as manifested in lichen tissue, and passive sensors;
- ♦ Determine how contaminant concentrations in lichen tissue relate to ambient air concentrations and rates of deposition;
- ♦ Determine whether lichen communities are changing in response to changes in airborne contaminants;

Linking Results for Model Development

Models linking lichen elemental concentration data to passive sensor data

USFS Photo



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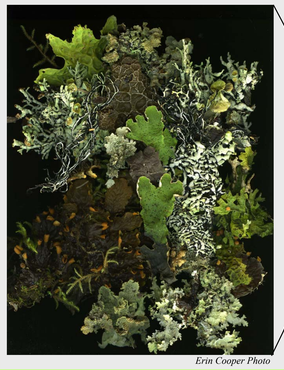
Models linking lichen community data with to passive sensor and elemental concentration data



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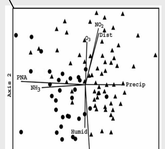

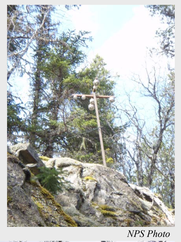

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Methods - Lichen Community Plots

Assessment of lichens as long-term bio-indicators as with community monitoring plots.

Erasmus Darwin (Charles Darwin's grandfather) documented that lichens failed to grow near Copper Smelters at Parys Mountain in Wales over 200 years ago. Sulfur and nitrogen air pollutants stress particular lichen species while enhancing or fertilizing others species altering community composition, even when effects on higher plants are difficult to detect. Lichen communities may be used to indicate air quality and point to potential impacts on other ecosystem components. Hundreds of papers worldwide have documented the relationship between lichen communities and airborne contaminants, especially SO_2, NO_2, and acidifying or fertilizing nitrogen and sulfur-based pollutants.

An example of lichen community data (Motiejūnaitė 2006)

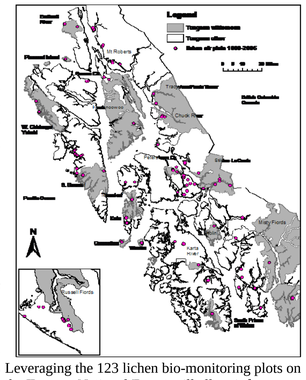
Epiphytes	I plot				II plot				III plot				IV plot				V plot				VI plot			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	2	3	4	
Acrocordia gemmata																+	+							
Arthothelium ruanum														+								+		
Bacidia rubella																						+		
Bacidia subincompta																	+				+	+		
Bacidina sp.			+	+					+	+	+									+	+			
Biatora sp.	+								+		+	+	+	+			+				+			
Buellia griseovirens													+	+	+		+			+				+
Candelariella xanthostigma				+																	+			
Dimerella pineti														+										
Graphis scripta																						+		+
Lecanora argentata																						+		
L. chlarotera	+												+	+			+							+
L. expallens										+		+					+	+	+	+				
Lecidella elaeochroma	+	+	+	+					+	+		+	+	+			+				+	+	+	
Lepraria lobificans																	+		+	+				
Lepraria sp.															+	+			+	+		+		
Melanelia fuliginosa	+	+		+							+		+	+	+	+		+						
Opegrapha rufescens	+																					+	+	

- ♦ Install permanent lichen community monitoring plots in proximity to other airborne contaminant monitoring stations and lichen elemental analysis plots;
- ♦ Monitor plots once per decade, assess if lichen diversity and species composition is changing over time;
- ♦ Establish models linking lichen community data with ambient concentrations and deposition of airborne contaminants;

Methods - Elemental Analysis of Lichen Tissue

Measure the concentrations of nitrogen, sulfur, and heavy metals contained in lichen tissue.

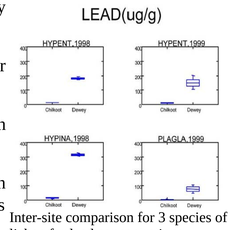
Lichens are long-term integrators of atmospheric deposition due to their longevity and lack of inter-seasonal morphological variation. Lichens lack roots, get their mineral nutrients directly from the air, and their tissue structure traps airborne particulates and soluble metal ions. Lichens that grow on trees get their nutrients primarily from atmospheric sources; (precipitation, dry deposition of fine particulates, direct absorption of gases, and from leachates in canopy throughfall). As a result, many chemical elements in air and water are absorbed and accumulated by lichens. Mobile elements like nitrogen, sulfur, and potassium are easily absorbed and also easily leached, maintaining a dynamic equilibrium with seasonal changes in the availability of these nutrients. Chemical properties of other elements, (lead and cadmium), cause them to bond more strongly to lichen tissue and may take years to decrease in concentration after the source has been removed. Examining the concentrations of chemicals in lichen tissue may reveal signs of air pollution before more overt signs, such as lichen death or changes in the species composition of lichens in an area, become apparent. Lichen tissue analysis is an indirect method for gathering information about air pollutants in lieu of placing sensors in the field.



Leveraging the 123 lichen bio-monitoring plots on the Tongass National Forest will allow inference across the region.

Lichen elemental analysis will be conducted for two consecutive years per decade. The Tongass National Forest has been conducting lichen-based bio-monitoring of air quality in Southeast Alaska since the late 1980's and a rich reference dataset exists for dry weight element concentrations of select arboreal lichens. We will use these reference data, as well as the standards and thresholds set by the Forest Service for the nitrogen, sulfur, and heavy metals concentrations in lichen tissues as air quality indicators. Passive sensors will be used to tie ambient concentrations and deposition of contaminants to ecological effects on lichen communities. During the protocol development stage of this Vital Sign, the data from lichen thalli elemental analysis will allow:

- ♦ Quantification of inter-decadal variation in elemental concentrations of key pollutants in 3 species of lichen;
- ♦ Comparison of elemental concentrations data from 1999 and 2009 for four sites in Klondike Gold Rush NHP;
- ♦ Comparison of elemental concentrations of key pollutants in lichen thalli with thresholds developed for the Tongass National Forest;
- ♦ Assessment of the inter-site variation in concentrations of key pollutants in lichen thalli for 9 sites within Southeast Alaskan National Parks and 123 sites in the surrounding Tongass National Forest.
- ♦ Metrics include elemental concentration for P, K, Ca, Mg, Na, Al, Fe, Mn, Hg, Cu, B, Pb, Ni, Cr, Cd, Co, Mo, Si, Ti, Be, Sr, Rb, Li, V, Ba, total nitrogen and total sulfur.



Inter-site comparison for 3 species of lichen for lead concentrations Klondike Gold Rush NHP

Methods - Deposition of NO_3, SO_4, NH_4 & PO_4 (kg/ha)

Passively measure the accumulated deposition of key ecosystem altering contaminants during the summer.

Passive Deposition samplers employ small PVC tubes filled with Amberlite™ IRN 150 Mixed Bed ion exchange resin beads. The resin is a mixture of strong base anion and strong acid cation exchange polymers that captures ions of nitrogen and sulfur. Arrays of passive deposition samplers deployed in forested sites measure 'throughfall' or the deposition not absorbed by the forest canopy. When possible, these samplers are also deployed in adjacent open sites to capture all the deposition. Deposition samplers are deployed continuously for 25 weeks (May-October) for two consecutive years out of every decade. During the protocol development stage of this Vital Sign, the data from passive deposition samplers will allow:

- ♦ Assessment of the sensitivity of deposition samplers to detect low levels of nitrogen and sulfur deposition expected in Southeast Alaskan parks;
- ♦ Quantification of inter-decadal variation for key pollutants;
- ♦ Quantification of the total exposure a site has to key pollutants;
- ♦ Assessment of the inter-site variation in the deposited quantities of these contaminants

NPS Photo

Methods -Ambient Concentrations of NO_2, NO_x, SO_4, NH_3 & HNO_3

Passively measure weekly average concentrations of key ecosystem altering contaminants.

The remote nature of Southeast Alaskan parks requires a passive approach to directly monitor the concentrations of the various oxides of nitrogen and sulfur that are produced by burning fossil fuels. Ogawa™ samplers employ small coated filter pads that accumulate these pollutants over the course an exposure period, are unobtrusive, silent, and easily deployed in remote locations. These samplers will be deployed for 25 weeks (May-October) for two consecutive years out of every decade. During the protocol development stage of this Vital Sign, the data from Ogawa samplers will allow:

- ♦ Assessment of the sensitivity of Ogawa samplers to detect low levels of contaminants expected in Southeast Alaskan parks;
- ♦ Quantification of intra-seasonal variation for key pollutants;
- ♦ Quantification of inter-decadal variation for key pollutants;
- ♦ Quantification of the total exposure a site has to key pollutants;
- ♦ Description of any weather conditions and local sources (cruise ships, busses, etc) linked to high levels of these pollutants;
- ♦ Assessment of the inter-site variation in the concentrations of these key contaminants

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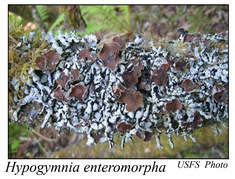
Visible cruse ship emissions near Klondike Gold Rush National Historical Park

ADEC Photo

Platismatia glauca *USFS Photo*



Hypogymnia enteromorpha *USFS Photo*

Lichens used for elemental analysis

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Visit the Southeast Alaska Inventory and Monitoring Program at: http://science.nature.nps.gov/im/units/sean/

Visit the NPS Air Resource Division at: http://www.nature.nps.gov/air/

Visit the US Forest Service Lichen Bio-monitoring Program at: http://gis.nacse.org/lichenair/

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