Monitoring air quality in the Southeast Alaska Network:
Linking ambient and depositional pollutants with ecological effects

Assessment of conditions, trends, and refinement of passive sampling and lichen bio-monitoring protocols

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Passive deposition and Ogawa ambient air concentration samplers in Dyea, Klondike Gold Rush NHP

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Appendix A – 2008 Budget Table…….. Separate attachment

Abstract

Airborne contaminant monitoring was initiated in Southeast Alaska network parks during the 2008 field season and continued during the 2009 season. This project will result in the development of vital sign monitoring protocols for airborne contaminants for the Southeast Alaska Network (SEAN). This study follows-up on a pilot study conducted in Klondike Gold Rush NHP in 1999, refines the original methodology, expanded the study area to include all NPS areas in Southeast Alaska, and partnered with the Tongass National Forest (TNF) in order to initiate decadal monitoring of airborne contaminants at Klondike Gold Rush NHP (KLGO), Glacier Bay National Park (GLBA), and Sitka National Historical Park (SITK). This effort is funded by several sources (Appendix A) including the NPS Air Resource Division, The SEAN Inventory and Monitoring Program, The NPS NRPP-Small Parks program, and the Municipality of Skagway. The study design called for two consecutive summer seasons (mid-April through early October) of fieldwork and included:

1) Deployment of Ogawa passive atmospheric concentration sensors for HNO_3, NO_2, NO_x, NH_3, $S0_2$ at five sites in KLGO, one site in GLBA and one site in SITK;
2) Deployment of passive deposition samplers for nitrogen and sulfur ions at eight sites in KLGO, three sites in GLBA, and two sites in SITK;
3) Collection of lichen tissue for elemental analysis at six sites in KLGO, two sites in GLBA and one site in SITK;
4) Lichen community plots (data and voucher specimen collections) at eight sites in KLGO, three sites in GLBA, and one site in SITK;
5) Collection of lichen tissue for elemental analysis at eight sites in KLGO, three sites in GLBA and one site in SITK and
6) Compilation of emissions inventory for Skagway for application to an airshed model.

Results from the 2008 season for the Ogawa samplers demonstrated elevated levels of all analytes at sites around Skagway and an unexplained spike in ammonia concentrations at SITK. Results from the deposition samplers were not yet available at the time of this report. Lichen tissue data from the 2008 season is available but has not yet been analyzed. Draft Standard Operating Procedure (SOPs) following NPS standards were also developed for all field components of the project.

Collecting lichen tissue for elemental analysis near Skagway

Specific Monitoring Questions, Objectives

The objects below were originally presented in the projects implementation plan and are provided below for reference

A) How are concentrations of contaminants in the air changing on a decadal cycle as manifested in concentrations in lichen tissue?

1) Determine the concentrations of selected chemical elements in tissue of three lichen species (*Hypogymnia heteromorphy, H. inactive, Platismatia glauca*) from collection plots across the network (four that were previously used in KLGO (Furbish et al. 2000) plus two additional sites in KLGO, two sites in GLBA and one in SITK). These data will be the site specific reference conditions against which future samples will be compared.
2) Spatial differences: Test for significant differences (H_o = no difference exists) in elemental concentrations between sites across the network.
3) Compare elemental concentration results with reference data from the greater Southeast Alaska area and the Pacific Northwest.
4) **As part of protocol development** measure actual concentration ($\mu g\ m^{-3}$) of SO_2, HNO_2, NH_4, NO_2, NO_x in ambient air with Ogawa passive air samplers. Also, measure deposition (total wet and dry in kg/ha) by deploying passive through-fall samplers. Then use these data to create model(s) tying pollutant concentrations in ambient air with elemental concentration in lichens and lichen community effects. This will expand on active work in this area (Blum and Tjutjunnik 1992, L. Geiser pers. com.).
5) Lichen air quality sites conducted in KLGO in 1998-99 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 2008/09 sampling period at each KLGO site.

B) How are lichen communities changing over time in response to changes in air quality?

1) Establish lichen community plots following methods used in the Tongass National Forest and National Forests in the Pacific Northwest (Geiser et al 1994, Geiser 2004). Use data from these studies as reference data for inter site comparisons and future intra-site trend analysis and comparisons. These sites will be immediately adjacent to the lichen collection areas in objective A-1.
2) Re-read lichen community plots at next sampling cycle in 5 to 10 years.
3) Develop models of the relationship between lichen community plot data and metrics (diversity indices), and elemental concentrations in lichen thalli using inter site comparisons metrics. Expand on and test the modeling methods described in Geiser and Neitlich (2007).

C) Develop a protocol (Oakley et al. 2003) for long-term monitoring of air quality in Southeast Alaska parks.

Approaches and Methods

In order to repeat the previous KLGO study and compare results, the general methods regarding collecting and analyzing lichen followed Geiser et al. (1994), and Furbish (2000) and collection sites will follow Furbish et al. (2000). However, we will be collecting additional air chemistry data by deploying passive air and through-fall samplers, which were not part of the 1998-99 study in KLGO. This study will also be enhanced by the addition of lichen community composition plots at each site following the methods used by the US Forest Service (Geiser et al. 1994 and Geiser 2004). An additional two sites in the KLGO– Skagway area and two or three sites in GLBA and one additional site in SITK will be added.

Study Sites

The four sites investigated during the 1998-99 study (Dewey, Chilkoot, Sturgill's and Dyea) were revisited during this study. The descriptions of the previously visited sites are taken from Furbish et al. (2000). The Dewey and Chilkoot sites were selected to encompass the range of exposures to local sources of air pollution. The results (Furbish et al. 2000) revealed that the greatest exposure was near the town of Skagway and the harbor, and the least exposure was near the beginning of the Chilkoot Trail. The two sites are positioned to be similar in terrain, vegetative cover, slope, aspect and elevation. But they are not identical; the Chilkoot site is farther from marine waters than the Dewey site. All the sites are briefly described below.

Dewey (most exposed) - This site is about 4.4 hectares (10.9 acres) in size. It is situated on a low bench along the lower edge of the 1500 meter high ridge that is the east wall of the Skagway River valley, overlooking the Skagway small boat harbor. The plot elevation ranges from about 50 to 175 meters. The plot slope ranges from about 10 to 45 degrees, facing west-northwest (295 degrees). Vegetative cover is a western hemlock - lodgepole pine - Sitka spruce - paper birch woodland in mid-seral stage. Burn scars remain from a fire 55+ years ago. Understory is sparse, composed of rusty menziesie, feather and other mosses, and foliose and fruticose lichens. This site is located on land owned by the Municipality of Skagway.

Chilkoot (least exposed) – This site is about 4.9 hectares (12.1 acres) in size. It sits on a small hill known locally as "Saintly Hill" which is a low section of the AB Mountain ridge that forms the east wall of the Taiya River valley. The plot elevation ranges from 85 to 110 meters. The plot slopes to the west-northwest (280 degrees) at 20 to 40 degrees. Vegetative cover is a western hemlock - lodgepole pine - Sitka spruce - paper birch woodland in mid-seral stage. Burn scars remain from a fire 15+ years ago. Understory is sparse, composed of rusty menziesii, shag, feather and other mosses, and foliose and fruticose lichens.

Sturgill's This site is about 4.0 hectares (8.6 acres) in size. It sits on a 150 meter high bench at the base of a 1500 meter ridge that is the east wall of the Skagway River valley, approximately 1 kilometer south of the Dewey site. The Sturgill site is on the southeast side of a low ridge, and on the south side of the depression that forms Dewey Lake. Elevation is 150 to 175 meters, with a gentle slope (4-15 degrees) facing south-southeast (140 degrees). Vegetative cover is a western hemlock - lodgepole pine - Sitka spruce - paper birch woodland in mid-seral stage. Understory is sparse, composed of rusty menziesie, feather and other mosses, and foliose and fruticose lichens. This site is also located on land owned by the Municipality of Skagway**.**

Dyea This site was about 4.2 hectares (10.3 acres) in size. It is located on the terminal delta of the Taiya River floodplain. Elevation is 3-18 meters, with near level slope. The site is located on a low bench above tidal grass/sedge meadows. Site of the historic 1989 gold rush town of Dyea, the area

was cleared for agriculture during the decades after the gold rush. Soils are very sandy and well drained. Vegetative cover is coastal Sitka spruce - black cottonwood - western hemlock in mid-seral stage. Trees are 20-30 meters tall. Cottonwood and Sitka spruce dominate, with some paper birch, lodgepole pine, Scoulers willow and unusually large Sitka willows. Many of the dead, lower limbs of trees are covered with lush foliose lichens, such as *Hypogymnia inactiva*. Undisturbed ground is covered with a deep bed of mosses and, in season, mushrooms.

Dewey 1700 – This new site near Skagway on Municipal land and was added and expanded the scope of the study. It is in a mountain hemlock and Sitka spruce forest at 1700' above Skagway. This site is estimated to be just below the elevation of an inversion cap that commonly occurs during summer morning in the Skagway valley. The Skagway Borough funded most of the work this site in 2008 and 2009.

Icy Junction–This new site near Skagway in a lodgepole pine forest was only used temporarily while Dewey 1700 was inaccessible due to snow and ice conditions. It is intended as a replicate of the similar elevation site at Lower Dewey lake, not a substitution for Dewey 1700.

Upper Dewey– This alpine tundra site at Upper Dewey lake sits at 3,200'and is just below the terminus of an alpine glacier. It was only used to site a bulk deposition sampler. It is intended to capture regional / global background levels of bulk deposition rather than detect local effects.

Bartlett Cove- This site is adjacent to the only development in GLBA and is the only site where regular weekly access for filter changes is possible. This site is at sea level in the upper portion of Glacier Bay is also the only place in a dense hemlock – Sitka spruce forested area where a clearing exists to deploy the Ogawa samplers.

Blue Mouse Cove- This densely forested site at sea level is in the middle portion of Glacier Bay and is only accessible by boat. Lichen community data and throughfall deposition samplers were deployed at this site.

Tarr Inlet- This recently de-glaciated site in upper Glacier Bay has no forest canopy and no lichens suitable for elemental analysis were present. Bulk deposition samplers were deployed here. This is an area where cruise ships and tour vessels linger to observe wildlife and calving glaciers.

Indian River-This was the only site away from centers of visitor activity available in SITK. This site is a mixed forest of Sitka spruce and red alder with an understory of salmonberry. All components of the project occurred at this site.

Progress:

Lichen Species and Collections

The three species used by Furbish et al. (2000) and currently used as biomonitors in the region are *Hypogymnia enteromorpha, Hypogymnia inactiva* and *Platismatia glauca*. These locally abundant species were selected from a list of species that are used for biomonitoring of air quality in Southeast Alaska. At each site, three 7-20 gram samples of each species were collected at the end of each summer season. Collections occurred during the late summer near the end of the tourist season because bioaccumulation of contaminant is likely to be highest at this time. No lichens were collected for elemental analysis at the non-forested plots in upper GLBA because suitable lichen species were not abundant. A list of samples is provided in Appendix B.

Training in lichen identification was accomplished by using vouchers in KLGO's herbarium and instruction from an accomplished lichenologist, Toby Spribille, working in the park on the concurrent lichen inventory. Lichens were collected from tree trunks and branches and sealed in airtight, metalized polyester samples bags. Samples were cleaned and air-dried in a secured room. Elemental analysis of the lichen tissue was conducted at the University of Minnesota, Soil Science Department Research Analytical Lab. Analysis determined the dry concentrations of aluminum, boron, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, nitrogen, phosphorus, potassium, sodium, sulfur, and zinc. This lab was used during the previous study and has more than 20 years experience in analyzing lichens. Lab methodology is available at http://ral.coafes.umn.edu/plant.htm. Results from the 2008 samples were returned to the NPS in June of 2009 and have not been analyzed, 2009 results are not expected until May of 2010.

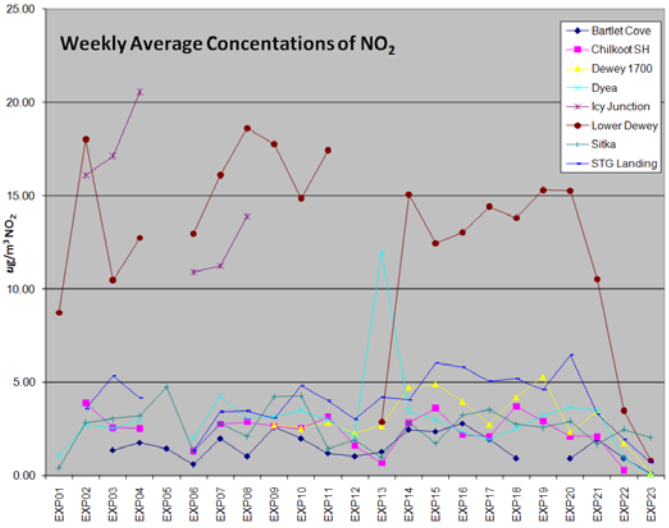
Lichen Community Plots

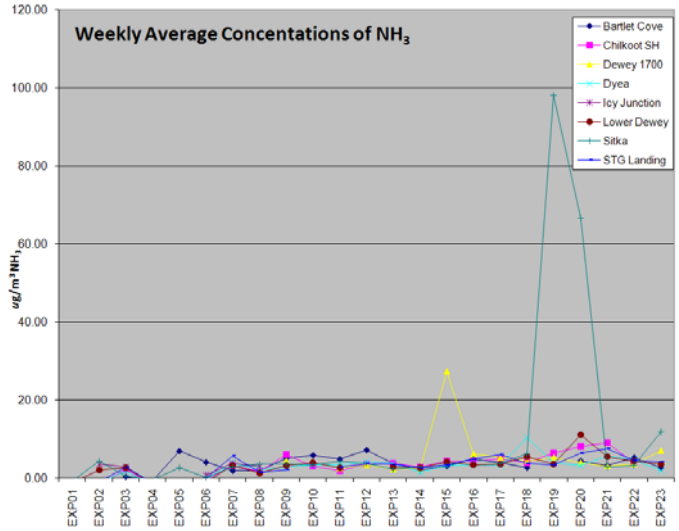
Lichen community composition plots provide quantitative information on the macro lichen species composition and relative abundance within fixed area permanent plots. Because some lichen species are more sensitive to changes in air chemistry than others (Farmer et al. 1992, Johnson 1979, Holopainen, T. and L. Kärenlampi 1985, and several others), these permanent plots will provide reference data for future change detection analysis in lichen communities. Lichen community plots have been installed throughout Southeast Alaska (Dillman 2007); therefore, future assessments could include not only temporal intra-site changes in lichen communities, but also spatial comparisons across reference sites throughout southeast Alaska.

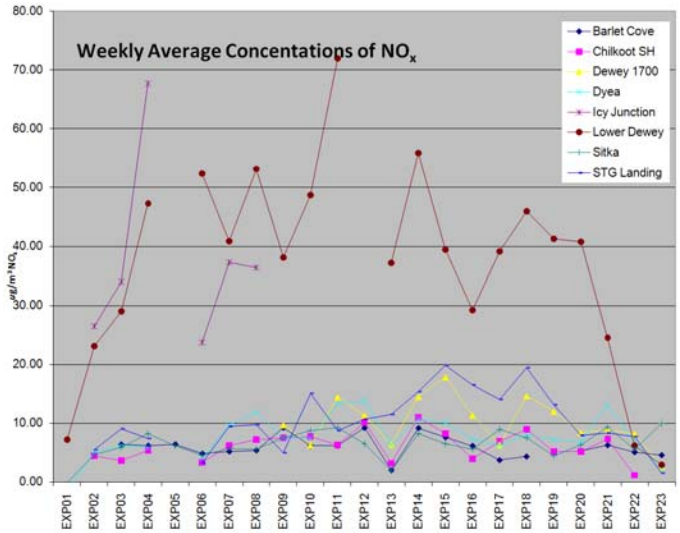
Two lichen community plots were installed at each assessment site, including the non-forested sites in upper GLBA, following methods established on the TNF (Geiser at al. 1994 and US Forest Service 2004). Karen Dillman, the lichenologist for the TNF, is the collaborator for this portion of the project and established all the plots for this project during the 2008 season. Several additional plots following slightly different methods (FIA) were established by Heather Root in the Skagway area as part of a Forest Service effort to establish a pollution gradient model for lichen communities in SE Alaska.

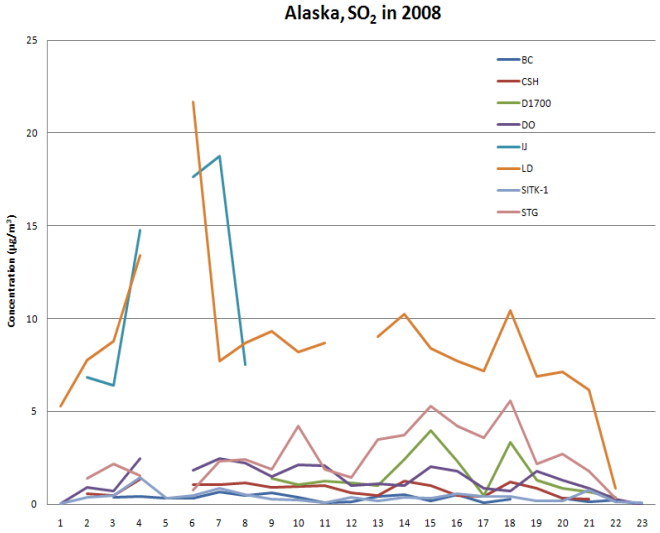
Passive Ambient Air Samplers

Ogawa passive air samplers with collection pads for SO_2, HNO_3, NH_3, NO_2 and NO_x were deployed at a subset of the lichen collection sites during the summer seasons in 2008 and 2009. Due to limited access and the requirement for weekly filter swaps, only one site in GLBA (Bartlett Cove) had an Ogawa sampler. SITK had one Ogawa due to the parks small size and high visitation rates; only one area out of public view was available. The results from the Ogawa samplers yield data for ambient air concentrations for the selected compounds measured in ppm or ppb. Weekly monitoring commenced on April 15th (3 weeks prior to the beginning of the tourist season) and terminated on Oct 15th (3 weeks after the end of the tourist season). Sub-weekly sampling was not attempted at any of the site at the recommendation of Dr. Bytnerowicz, the atmospheric chemist collaborating on this component of the project. Overall, results from the passive samplers will be used to develop models **(**e.g., Fenn et al. 2007**)** linking elemental concentrations in lichen tissue with concentrations detected in ambient air during the study. Preliminary results from 2008 show elevated levels of pollutants at the site near Skagway and an unexplained ammonia spike at the Sitka site. Results for HNO_3 for 2008 along with data from 2009 sampling will be available by March of 2010.









Passive Throughfall and Bulk Samplers

Passive throughfall samplers following the methods of Fenn and Poth (2004) were be deployed at each lichen plot including the Tarr Inlet site in upper GLBA. These devices were left in place from mid-April through mid-October during 2008 and 2009. 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 were deployed in forested portions of each 4-5 acre lichen collection plot along with an additional five sampling tubes in canopy gaps. Canopy gap site were not available for all of the sites. For the non-forested plot at Tarr Inlet in upper GLBA, only five throughfall sampling tubes were required. Resin tubes from 2008 and 2009 sampling are still awaiting lab analysis. Results from the passive throughfall samplers will be used to develop models (e.g. Fenn et al. 2007) 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 United States and 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.

Passive air sampler filters and the throughfall samplers were provided and will be analyzed by the USDA Forest Service Lab in Riverside, California (methodology available from the US Forest Service, Dr. Andrzej Bytnerowicz and Dr. Mark Fenn). http://www.ogawausa.com/about.html.

Air Dispersion Model

An airshed model conducted with AERMOD (EPA 2008) will be used to assist with quantification of the concentration and depositional impact of nitrogen and sulfur from cruise ships, ferries, busses, the railroad, and the municipal incinerator near KLGO. The modeling will complement the larger ecological indicator study by (1) demonstrating areas of maximum impact from these sources, (2) quantifying the attribution to the total depositional impacts, and (3) potentially be used to simulate the difference in impacts from emission reduction strategies.

The model requirements for digital locations of emission sources, terrain, and meteorology were provided to Rick Graw of the PNW Research Station in Portland OR. Local meteorological data was enhanced by deploying a series of temperature monitors (OnSet Pendants) across an elevation gradient near Skagway that was used to quantify the duration and elevation of inversion layers common during the morning hours in Skagway. The model also requires detailed data on the location and chemistry of emission sources. Ideally, in creating an accurate emission inventory, one would need to quantify the number and type of marine vessels docked in port each hour of each day throughout the year. However, certain assumptions can be made which will simplify this task while maintaining meaningful representation for modeling purposes. These assumptions are as follows:

- Emissions only occur during the cruise ship operating season (May 1 – September 30).
- Emission generating activities are the same each week during this period.
- The diurnal variation of emissions will be developed based upon local observations.

Mr. Albert Faure of the Alaska Department of Environmental Conservation (AK DEC) developed the following list of information required to quantify emissions from marine vessels. A datasheet designed to capture the information below was developed:

- Vessel Name
- Cruise Line Name
- Technical Hull particulars: Length; Beam; Height, and height from water line top exhaust (stack); stack pattern (fore / aft) (determination stack location, etc.)
- Stack type (e.g., round oval diameters) capped, bend, and estimated exhaust gas temperature
- Fuel type combusted while in port: 1) distillate (diesel) (MDO), 2) Residual fuel (IFO HFO). Fuel type and Sulfur content based on percent of fuel weight
- Operation mode while docked (e.g., engine / turbine selection auxiliary / boilers, incinerators, etc.)
- Description of the combustion source, RPM, Rating in relation to the generator output (kWe), engine cylinder displacement. Note that for diesel electric power generation the engine RPM is constant (frequency)
- Arrival time (time that dock operations mode starts)

- Departure time (time start up / commence maneuvering)

The cruise ship lines visiting Skagway were queried for data on ship operations while docked in Skagway; most complied and provided adequate information. Emission inventories were developed for these sources for the 2008 tourist season in Skagway which begins May 1st and ends September 30th. Emissions from marine vessels were quantified while docked in port only. Similarly, emissions from busses and locomotives were calculated for the period and location when they are stationary.

The model has been set-up and run for an initial trial. However, the meteorology data from the temp monitors is still being evaluated for inclusion. Output products will include deposition isopleths of seasonal N and S deposition (kg/ha/season). Additionally, source contribution to the model-predicted deposition rates will also be provided. What-if scenarios may then be evaluated to determine the effects of potential changes. A final report will be delivered documenting the methodology and results during the winter of 2010.

Data Management and Database Development

Data management will follow the general protocols prescribed by the NPS I&M program. The large bulk of data being generated for this project will come from the lichen elemental analysis and the passive air samplers' analyses. During the winter of 2009-10, the SEAN I&M data manager will develop a database following I&M program standards that will hold collections site characteristics, lichen plot community data, as well as the tissue analysis and passive sampler lab results. This work will be conducted in consolation with the USDA Forest Service collaborators.

Data Analyses

Data analysis will commence some during the winter of 2009-10. Several statistical tests will be conducted to look for difference in elemental concentrations between sites within parks, between parks, and with US Forest Service reference data sets from the Tongass (and possibly the Chugach) National Forests in southeastern Alaska, and from national forests in western Oregon and Washington. For normally distributed elemental concentrations data, paired *t*-tests will be conducted to test for significant differences between sites within the park. Additional ANOVA tests will be conducted to test for significant differences between the park data set and US Forest Service reference data sets. For non-normally distributed elemental concentration data, a Mann-Whitney U test will be employed to test for differences in elemental concentrations between collection sites in the park, and between park sites and reference datasets that are available for the Tongass National Forest.

Models relating elemental concentration in lichen tissue with data from the passive air samplers will be developed using methods described in Fenn et al. (2007) and Glavich & Geiser (2008). The SEAN I&M Coordinator and Data Manager will provide statistical assistance during the analysis phase of the project.

Principle Project Managers

Dave Schirokauer, Biologist and Natural Resource Program Manager, Klondike Gold Rush National Historical Park, Skagway, AK.

Dr. Linda H. Geiser, Ecologist and Air Quality Specialist, US Forest Service Pacific Northwest Region Air Program, Corvallis, OR.

Project Co investigators

Dr. Mark Fenn, Plant Pathologist, US Forest Service Pacific Southwest Research Station, Riverside, CA.

Dr. Andrzej Bytnerowicz, Atmospheric Chemist, US Forest Service Pacific Southwest Research Station, Riverside, CA.

Dr. Rick Graw, Air Resource Management Specialist, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Karen Dillman, Ecologist, Tongass National Forest, Petersburg, AK.

Dr. Sarah Jovan, Forest Ecologist, National Coordinator Forest Health Monitoring Program, US Forest Service Region 10, Portland, OR.

Tasks, Organization, and Schedule

The schedule below was submitted as part to the projects implementation plan. Field work was completed in schedule; however, lab work at the UMN Research Analytical Lab and the USDA Forest Service Pacific Southwest Research Station Riverside Science Lab is taking significantly longer than anticipated. It is likely that analysis of lab data and final protocol development will not be complete until sometime in FY11.

Completion Date	FY 2008								FY 2009								FY 2010			
Task	11/9	3/14	4/11	4/21	6/27	7/15	9/1	9/29	10/9	2/10	3/14	4/11	4/21	6/27	9/1	9/29	2/1	3/1	4/1	5/1
Compliance project entry into PEPC and get signature on CE	■																			
Hire seasonal bio-techs		■																		
Complete set-up / conduct training in operating Ogawa and throughfall passive samplers			■									■								
Initiate **weekly** (Monday) change cycle for passive air samplers				■									■							
Compile emissions inventory for the KLGO area for (AERMOD)				■	■	■	■	■												
Run AERMOD for KLGO – Skagway area										■	■	■								
Read lichen community plots						■														
Complete training lichen ID and collection methods					■									■						
Initiate lichens collecting							■								■					
Clean and dry lichens							■	■							■					
Terminate passive air and throughfall sampling									■							■				
Ship lichen samples to lab								■								■				
I&M draft protocol submitted																			■	

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Appendix A- Plot Locations and Descriptions

Appendix B- 1989-1990 Elemental Analysis Data

Appendix C- 1991-1992 Sulfur and nitrogen data for *Alectoria sarmentosa* from shorepine muskeg plots.

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Swapping Ogawa ambient air concentration samplers on near the Chilkoot Trail , Klondike Gold Rush NHP

Monitoring air quality in the Southeast Alaska Network	FY 2009 BUDGET					V. 11-2-09	
Funding Source	**TOTAL**	AQD Eco Effects	SEAN I&M	NPS Coastal Cluster	KLGO NRPP Small Parks	Municipality of Skagway	USFS FY08 Carry-over
Project Oversight fieldwork and misc supplies							
GS-7 Bio Tech 6.8 pp @ $1,787 pp	$6,600				$6,600		
USFS Linda Geiser Salary	$6,500		$4,500		$2,000		
Winter Intern 2009-10 SCA	$8,600		$2,000			$6,600	
Supplies: Sample bags, misc shipping	$1,328		$564		$764		
Lichen community bio-monitoring							
Karen Dillman USFS PI: Travel costs to set up & read plots and collect							
Karen Dillman Salary for plots and collections (1.5 pp)	$3,400		$3,400				
Karen Dillman Travel KLGO lichen community plots & collections							
Karen Dillman Travel GLBA lichen community plots & collections	$900		$900				
Karen Dillman Travel SITK lichen community plots & collections	$500		$500				
Lichen elemental analysis: 3 samples for 3 species per site - $1,350 per							
Dr Linda Geiser and Karen Dillman USFS PIs							
KLGO Lichen elemental analysis - 5 sites (45 samples)	$2,700		$2,700				
GLBA Lichen elemental analysis - 3 sites (27 Samples)	$1,620		$1,620				
SITK Lichen elemental analysis - 1 sites (9 Samples)	$540		$540				
KLGO Lichen Hg analysis - 5 sites (22 samples)	$880		$880				
GLBA Lichen Hg analysis - 3 sites (13 Samples)	$520		$520				
SITK Lichen Hg analysis - 1 sites (5 Samples)	$200		$200				
Air Concentration Analysis - Dr Andrzej Bytnerowicz							
KLGO Skagway - Ogawa & HNO_3 pads & analysis 5 sites	$27,176	$27,120	$56				
GLBA - Ogawa & HNO_3 pads & analysis 1 site	$5,435		$5,435				
SITK - Ogawa & HNO_3 pads & analysis 1 site	$5,435		$5,435				
October 08 Analysis	$2,000						$2,000
Deposition Analysis - Dr Mark Fenn							
KLGO Skagway - 5 forested sites (60 collectors), 2 Open (12)	$1,850		$1,850				
GLBA - 2 forested (22 collectors), 1 open (6 collectors)	$750		$750				
SITK - 1 forested (12 collectors), 1 open site (6 collectors)	$525		$525				
Atmospheric Model of Skagway Airshed– Dr. Rick Graw USFS PI							
USFS Rick Graw Salary	$5,000			$5,000			
USFS Overhead 3%	$1,664		$1,664				
Totals	**$82,459**	**$27,120**	**$34,039**	**$5,000**	**$9,364**	**$6,600**	**$2,000**
Totals to transfer to USFS	$57,135	$27,120	$25,015	$5,000			
Total Available	$84,160	$27,120	$34,040	$5,000	$9,400	$6,600	$2,000

Funds to be transferred to the US Forest Service – Cooperative Agreement between NPS ARD and Linda Geiser USFS Pacific Northwest Research Station

Appendix B: Lichen collections for elemental analysis

Site	Species	Year	Samples	Lab Results
Glacier Bay National Park				
Bartlett Cove	*Hypogymnia enteromorpha*	2008	3	Available
Bartlett Cove	*Platismatia glauca*	2008	2	Available
Bartlett Cove	*Platismatia glauca*	2009	2	NA
Bartlett Cove	*Alectoria sarmentosa*	2009	2	NA
Blue Mouse	*Hypogymnia enteromorpha*	2008	4	Available
Blue Mouse	*Hypogymnia enteromorpha*	2009	2	NA
Blue Mouse	*Platismatia glauca*	2008	2	Available
Blue Mouse	*Platismatia glauca*	2009	2	NA
Klondike Gold Rush NHP				
Chilkoot Trail	*Hypogymnia inactiva*	1998	5	Available
Chilkoot Trail	*Hypogymnia inactiva*	2008	3	Available
Chilkoot Trail	*Hypogymnia inactiva*	2009	3	NA
Chilkoot Trail	*Platismatia glauca*	1999	3	Available
Chilkoot Trail	*Platismatia glauca*	2008	3	Available
Chilkoot Trail	*Platismatia glauca*	2009	3	NA
Chilkoot Trail	*Hypogymnia enteromorpha*	1998	2	Available
Chilkoot Trail	*Hypogymnia enteromorpha*	1999	2	Available
Chilkoot Trail	*Hypogymnia enteromorpha*	2008	3	Available
Chilkoot Trail	*Hypogymnia enteromorpha*	2009	3	NA
Lower Dewey	*Hypogymnia enteromorpha*	1998	4	Available
Lower Dewey	*Hypogymnia enteromorpha*	1998	3	Available
Lower Dewey	*Hypogymnia enteromorpha*	2008	3	Available
Lower Dewey	*Hypogymnia enteromorpha*	2009	3	Available
Lower Dewey	*Hypogymnia inactiva*	1998	3	Available
Lower Dewey	*Hypogymnia inactiva*	2008	4	Available
Lower Dewey	*Hypogymnia inactiva*	2009	3	NA
Lower Dewey	*Platismatia glauca*	1998	1	Available
Lower Dewey	*Platismatia glauca*	1999	3	Available
Lower Dewey	*Platismatia glauca*	2008	3	Available
Lower Dewey	*Platismatia glauca*	2009	3	NA
Dyea	*Hypogymnia inactiva*	1998	2	Available
Dyea	*Hypogymnia inactiva*	2008	3	Available
Dyea	*Hypogymnia inactiva*	2009	3	Available
Dyea	*Hypogymnia enteromorpha*	2008	3	Available
Dyea	*Hypogymnia enteromorpha*	2009	3	NA
Dyea	*Platismatia glauca*	1998	3	Available
Dyea	*Platismatia glauca*	2008	3	Available
Dyea	*Platismatia glauca*	2009	3	Available
Icy Junction	*Hypogymnia inactiva*	2008	3	Available
Icy Junction	*Hypogymnia inactiva*	2009	3	Available
Icy Junction	*Hypogymnia enteromorpha*	2008	3	Available
Icy Junction	*Hypogymnia enteromorpha*	2009	3	NA
Icy Junction	*Platismatia glauca*	2008	3	Available
Icy Junction	*Platismatia glauca*	2009	3	Available
Sturgills	*Hypogymnia inactiva*	1998	3	Available
Sturgills	*Hypogymnia inactiva*	2008	5	Available
Sturgills	*Hypogymnia inactiva*	2009	3	NA
Sturgills	*Hypogymnia enteromorpha*	1998	2	Available
Sturgills	*Hypogymnia enteromorpha*	2008	3	Available
Sturgills	*Hypogymnia enteromorpha*	2009	3	NA
Sturgills	*Platismatia glauca*	1998	2	Available
Sturgills	*Platismatia glauca*	2008	6	Available
Sturgills	*Platismatia glauca*	2009	3	NA
Upper Dewey	*Hypogymnia enteromorpha*	2008	4	Available
Upper Dewey	*Hypogymnia enteromorpha*	2009	3	NA
Upper Dewey	*Platismatia glauca*	2008	4	Available
Upper Dewey	*Platismatia glauca*	2009	3	NA
Sitka NHP				
Indian River	*Platismatia glauca*	2008	3	Available