Alaska Park Science

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Monitoring the "Vital Signs" of Healthy Park Ecosystems

Volume 9, Issue 1

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Cover photo: Tyler Lewis (CAKN seasonal employee) samples for aquatic insects in Amy Creek, Wrangell-St. Elias National Park and Preserve as part of the stream monitoring program.

NPS photograph by Trey Simmons

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Shallow Lakes

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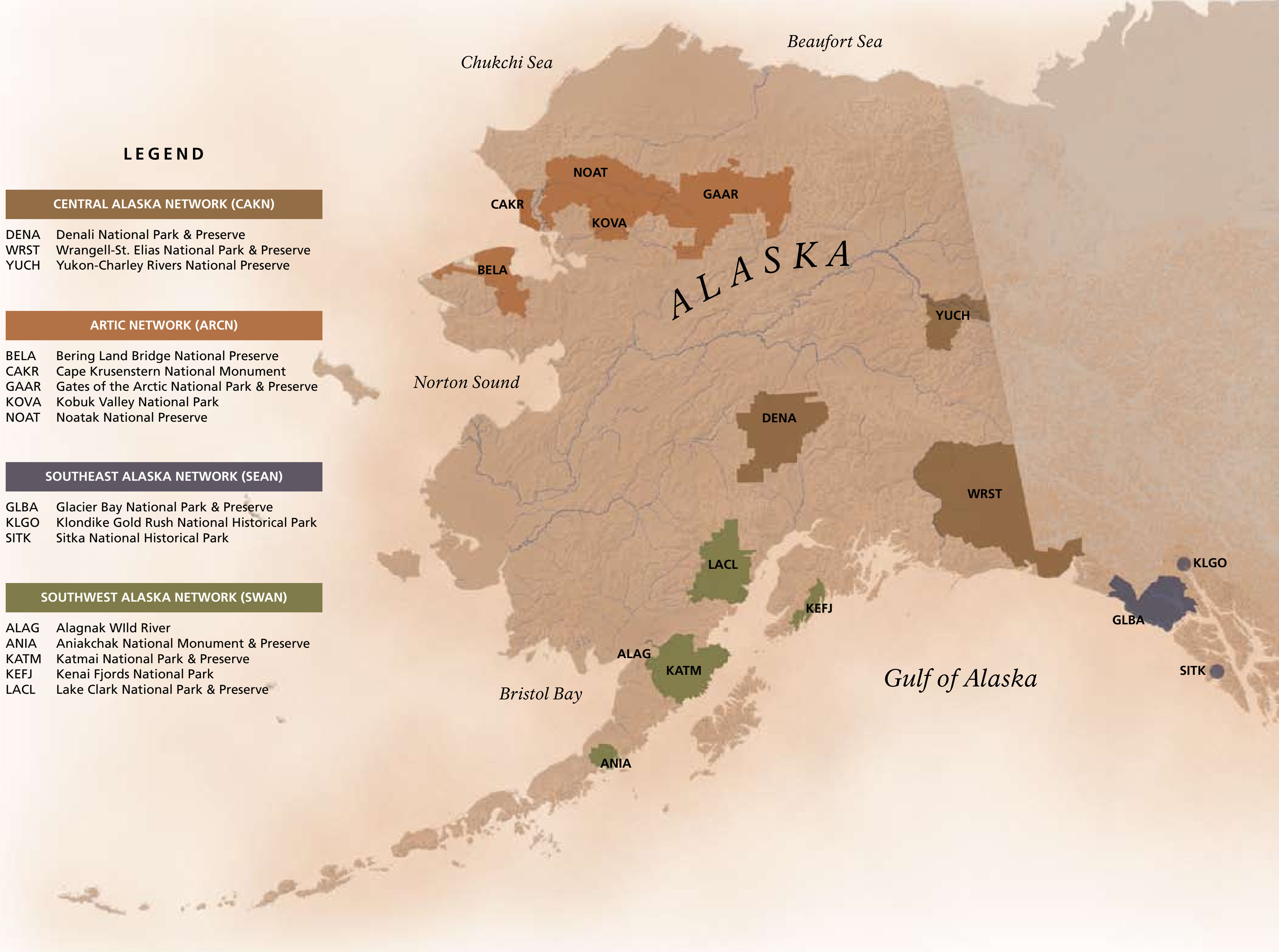
Photograph courtesy of Amy Larsen



LEGEND

CENTRAL ALASKA NETWORK (CAKN)

DENA	Denali National Park & Preserve
WRST	Wrangell-St. Elias National Park & Preserve
YUCH	Yukon-Charley Rivers National Preserve

ARTIC NETWORK (ARCN)

BELA	Bering Land Bridge National Preserve
CAKR	Cape Krusenstern National Monument
GAAR	Gates of the Arctic National Park & Preserve
KOVA	Kobuk Valley National Park
NOAT	Noatak National Preserve

SOUTHEAST ALASKA NETWORK (SEAN)

GLBA	Glacier Bay National Park & Preserve
KLGO	Klondike Gold Rush National Historical Park
SITK	Sitka National Historical Park

SOUTHWEST ALASKA NETWORK (SWAN)

ALAG	Alagnak WIld River
ANIA	Aniakchak National Monument & Preserve
KATM	Katmai National Park & Preserve
KEFJ	Kenai Fjords National Park
LACL	Lake Clark National Park & Preserve

Introduction

By Sara Wesser, Regional Inventory and Monitoring Coordinator

As we close the first decade of the Natural Resource Challenge, a major National Park Service (NPS) initiative for sound science in park management, we take pride in the significant advances we have made toward that goal. We dedicate this issue of Alaska Park Science to highlighting the Inventory and Monitoring Program, a key part of the Natural Resource Challenge. The Inventory and Monitoring Program (I&M), which began in the early 1990s, is the result of many years of effort to build recognition that understanding the condition of natural resources is vital to accomplishing the NPS mission of protecting park resources unimpaired for future generations. The goals of the I&M program are to develop scientifically sound information on the current conditions and long-term trends in park ecosystems and to determine how well current management practices are sustaining those ecosystems. These goals remain relevant today, particularly in the little studied, remote areas that comprise Alaska parks. During the 1990s, we began basic inventories which included maps of vegetation (landcover), soils, and geology, databases documenting the vertebrate species and vascular plants that occur in parks, as well as information on air quality, climate, and aquatic resources. These inventories, referred to collectively as the Baseline Inventories, will ultimately be completed for all national park units in the state, providing a rich set of reference material on current conditions for park managers, scientists, and the public.

Figure 1. (Left) The national park units in Alaska, grouped into four Inventory and Monitoring Networks.

With the advent of the Natural Resource Challenge in 2000, the 16 Alaska park units were organized into four networks of parks related by ecology and geography (see map on inside cover) in order to efficiently share resources and enhance collaboration with others. These networks, under the oversight of park managers, set the conceptual foundation of the vital signs monitoring program. NPS uses the term “vital signs”, borrowing from the medical professions, to mean a small set of information-rich attributes that are used to track the overall condition or health of park ecosystems. All networks followed the same process, which emphasized sustainability and relevance of the monitoring — synthesizing existing information, developing objectives and ecological models portraying current understanding, identifying potential indicators and selecting the small subset that the network would monitor over time. Upon completion of a vital signs monitoring plan for each network, staff turned to the challenging work of designing statistically valid and logistically feasible monitoring protocols for each vital sign.

Now, ten years after establishment of the Natural Resource Challenge, we have moved out of design and into full implementation. This issue presents a sampling of the many vital signs now being monitored. Over time, the information derived from the natural resource monitoring will enhance the National Park Service’s understanding of how management decisions and other factors affect resources in the parks, will improve planners’ understanding of the resources under NPS stewardship, and increase understanding among park interpreters and the public of the condition of the nation’s heritage, now and in the future.

For more information, see http://science.nature.nps.gov/im/units/akro/

NPS photograph

Figure 2. A field researcher collects vegetation data for use in land cover mapping in Kenai Fjords National Park.

Alaska Region

Natural Resources Conservation Service photograph

Inventorying Soils in Alaska National Parks

By Parker Martyn

Introduction

Soil inventories in Alaska national parks provide valuable information about the influences soil has on landscapes and ecosystems. On various scales, soil influences ecological processes that modify and drive vegetation patterns, regional hydrology, nutrient dynamics, habitat development, and landscape evolution. Through its structure, texture, and permeability, soil influences vegetation and succession processes and provides a way for nutrients to be recycled and used again. Soil also modifies the atmosphere by emitting and absorbing gases such as carbon dioxide, methane, and water vapor. In Alaska, and in permafrost-affected soils in particular, soil can be a long-term reservoir of organic carbon sequestered from the atmosphere. Such processes create complex and diverse landscapes that challenge soil scientists and park stewards as they search to understand the ecological status and trends of national parks in Alaska.

National Park Service (NPS) Alaska Region Inventory and Monitoring Program (I&M) staff are working with soils experts and ecologists to conduct soils inventories for all 16 NPS units in the state. This effort is sponsored and managed by the I&M Inventory Program based in Anchorage, and includes assistance from soil scientists and ecologists from the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) in Alaska, and ecologists from ABR-Environmental Research and Services, Inc. (ABR) in Fairbanks.

What is a Soil Inventory?

A soil inventory is a snapshot in time of the condition and status of soil resources in a particular park. The primary objective with each inventory is to increase our understanding of national parks by describing and mapping the locations of soils. Climate, topographic relief, biological activity, time, and parent material, all influence and form soil (*Jenny 1941*). Soil scientists study these five factors to identify and classify soils. When mapping soils, they look for areas with similar soil-forming factors, collect information by digging 1-2 m deep soil pits, and describe what they find (*Figure 2*). Using samples taken from soil pits (*Figure 3*), scientists describe physical and chemical properties of soil horizons, such as soil color, texture, structure, and soil pH. Although the main focus is on soils, data is collected on vegetation, landforms, and surface hydrology, because soil inventories are also comprehensive ecological studies. Soils that are susceptible to erosion or other disturbances are identified. The affects wildfire has on the soil temperature, moisture, and vegetation succession are observed and recorded. Variations in the depth to permafrost are measured, and the geographic extents of these frozen soils are mapped. Observations of vegetation community type and species percent cover are also recorded.

Soil inventories are time and labor intensive. During the course of a soil inventory, scientists can dig hundreds of soil pits on transects that cross the map in the survey area. Because field seasons are short in Alaska, averaging about 100 days, it can take several years to describe the different soil types and ecological sites in the project area. Once field work is complete, scientists generate reports from their data that describe the physical and chemical properties of the soils. They also produce maps that illustrate where and how soil types and ecological sites are spatially distributed. Employing their electronic databases, soil scientists also generate interpretations for potential uses and management issues of soils, or ecological sites that exist in a given survey area. When soil inventories are finished, these reports, maps, and associated databases are published and made available to park staff and the public.

Figure 1. A scenic view of the Yukon Flats Lowlands along the Yukon River in Yukon-Charley Rivers National Park and Preserve.

Figure 2. (Inset) An inventory technician describes a soil pit in Aniakchak National Monument and Preserve.

NPS photograph

Figure 3. Soils vary widely across the landscape, seen here are a rocky well-developed soil from an alpine site, a well-drained sandy soil from an inactive vegetated dune, a poorly developed soil with interbedded organic and silt layers from infrequent flooding, and a thick peaty soil from a bog showing the upward transition from sedge peat to a sphagnum peat.

Photo courtesy of ABR-Environmental Research and Services, Inc.

Soil Inventory Methods

In Alaska, many challenges exist when matching the size and scale of parks with the level of detail needed for each inventory. With a cumulative acreage of approximately 54 million acres, or roughly 65% of all parklands in the NPS system, most Alaska national parks are large. In fact, nine of the ten largest parks in the NPS system are located in Alaska, all ranging in size from 2.5-13 million acres. Most parks are very remote and lack developed infrastructures, which necessitates the use of small boats, fixed-wing airplanes, helicopters, and in general increases the amount of logistical support needed to conduct field work. These and other related challenges influence the level of detail, the amount of data that can be collected, and the time it takes to conduct soil inventories.

To address such challenges, our soil inventory efforts take advantage of two methodologies. One utilizes expertise from the NRCS located in Alaska, and leverages the well established and nationally standardized soil survey methodology that other non-Alaskan I&M soils inventories also use. The second method, which is particularly well suited for the large expanses of parklands in Alaska, is produced by an organization that specializes in Alaska ecosystem mapping, ABR. This method merges satellite image processing techniques and statistical analysis with field data to build ecological models through which soils information (soil landscapes) can be extracted. Both methods use extensive field observations and soil sampling, and both provide ecological descriptions and use similar NRCS soil taxonomy classifications. This combination of expertise allows us to rapidly complete soil inventories, and at the same time provide reliable and consistent scientific information for subsequent soil monitoring activities, park management, and protection.

Soil/Ecological Site

Three soil mapping products, or orders of mapping, are used by NRCS to map parks in Alaska. Mapping orders provide varying levels of detail. Each order varies in intensity and has associated with it an amount of field collection effort and level of product usefulness. Soil orders can be combined with one another, which provides the flexibility to use higher levels of detail where needed, and more generalized soils information for less accessible areas, or areas with non-vegetated terrain, rock, or ice that support little or no vegetation. The three levels of mapping orders (2, 3 / 4, and 5) have standardized data collection and analysis procedures, and each adheres to the published standards and procedures of the National Cooperative Soil Survey (*NRCS 2009*). Once inventories are complete, soil survey manuscripts, ecological site reports, and interpretations for potential soil management practices are made available on the NRCS Web Soil Survey website (http://websoilsurvey.nrcs.usda.gov).

To date, one park unit in Alaska, Denali National Park and Preserve (approximately 6 million acres) has a completed NRCS soil survey. One other soil survey in Yukon-Charley Rivers National Preserve is underway and on target for completion by the end of 2012. Future NRCS soil surveys are being planned for the Southeast Alaska I&M Network (SEAN) park units (Glacier Bay National Park & Preserve, Klondike Gold Rush National Historical Park, and Sitka Historical Park).

Soil Landscapes

To expedite the soil inventory process in Alaska, a "Soil Landscapes" product has recently been developed by ABR for the Arctic I&M Network (ARCN) parks (Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Gates of the Arctic National Park and Preserve, Kobuk Valley National Park, and Noatak National Preserve), an area of approximately 20 million acres, and Wrangell-St. Elias National Park and Preserve in the Central Alaska I&M Network (CAKN), an area of about 13 million acres. The soil landscape product provides classifications for soils derived from an ecological land survey (ELS), which is developed using a combined set of ecological state factor relationships (e.g., vegetation, hydrology, geomorphology, topography, climate, time, and disturbance), field plot data analysis, and the use of satellite image processing techniques (*Jorgenson 2009*). Using

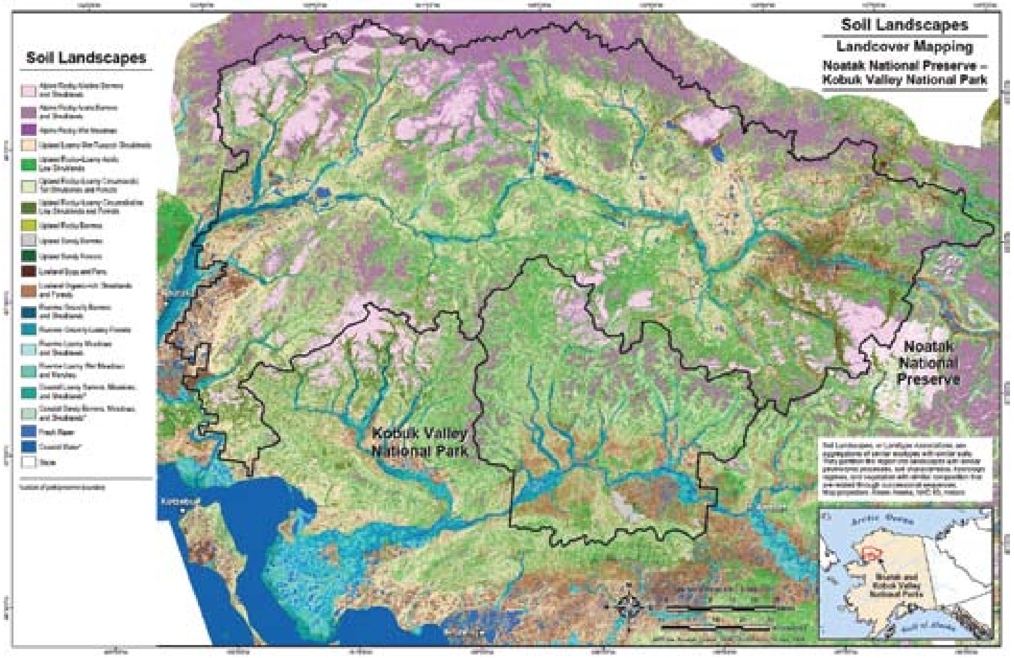


Figure 4. An example of a raster-based GIS map of soils landscape classifications for the Noatak National Preserve and Kobuk Valley National Park, both in the Arctic Network.

specialized automation routines, this method is well suited for mapping large areas of parklands. Products include reports that describe soils and ecological associations, which are published as part of the NPS Natural Resource Technical Report series, a raster-based GIS dataset, and an electronic database of the ELS from which the soil landscapes are derived. These products are made available on-line through the NPS DataStore (http://science.nature.nps.gov/nrdata/index.cfm). Figure 4 illustrates a map of soil landscape classifications that have been derived from an ELS.

In addition to the ARCN and CAKN completed efforts, this Soil Landscapes approach is currently being implemented and is in progress for the five parks that make up the Southwest Alaska I&M Network (Alagnak Wild River, Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Kenai Fjords National Park, and Lake Clark National Park and Preserve).

Conclusion

Using expertise from Alaska-based ecologists and soil scientists, the Alaska I&M Program is conducting soil inventories for all 16 national parks in the state. To date, approximately 50% of the 54 million acres of national parklands in Alaska have a completed Soil Landscape inventory. By the end of 2012, with the completion of the Yukon-Charley Rivers soil survey, about 16% of NPS lands in Alaska will have a National Cooperative Soil Survey completed by NRCS. Both soil inventory methods include field data collection, ecological process analysis, and soil classifications. NRCS soil surveys provide comprehensive soils taxonomy and ecological site descriptions for polygon-delineated soil map units that are based on national soil mapping standards. Spatial and tabular data are delivered through the Internet-based Web Soil Survey according to National Cooperative Soil Survey standards. Soil Landscape products, from ABR, combine extensive ecological land survey data, satellite image processing techniques, and statistical modeling to provide a multifaceted ecological association dataset from which soil landscapes and other ecological related maps may be derived. The reports, raster datasets, and associated databases are made available on-line through the NPS DataStore. Using both of these methods, we are able to provide reliable and consistent scientific soil inventories for use in monitoring activities, park management, and protection. In more general terms, soil inventories in Alaska national parks increase our understanding of soil ecosystem processes in parks, on a regional level, and on a global scale.

Acknowledgements

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http://www.ak.nrcs.usda.gov/soils/index.html

ABR
http://www.abrinc.com

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Recording the Trend: The Role of the Climate Monitoring Vital Sign in Understanding Park Ecosystems

By Pam Sousanes

Climate, by definition, is the long-term statistical expression of short-term weather. Climate will change in different ways, over different time scales and at different geographical scales. In the past few decades, climate change has been affecting the northern latitudes, including Alaska, more than any place on earth (*ACIA 2004*). Changes that have already taken place are evident in the decrease in extent and thickness of Arctic sea ice, permafrost thawing, coastal erosion, shrinking glaciers, and altered distribution of species (*IPCC 2007*).

Climate has been identified as one of the most important vital signs to monitor for the four National Park Service (NPS) Inventory and Monitoring (I&M) networks in Alaska. The climate varies tremendously as you travel from the maritime parks along the Gulf of Alaska, to the continental interior parks, to the Arctic parks along the Chukchi Sea. Models show that annual precipitation in the higher elevations along the southern coast can exceed 295 inches (7500 mm), while typical low elevation Interior Alaska sites record annual totals between 12-15 inches (300-400 mm) (*Figure 2*). Temperatures along the coast are moderated by warmer sea surface temperatures, while interior locations experience wide temperature fluctuations between seasons, with warm summers and cold winters. Multiple mountain ranges, local topographic features, and proximity to the ocean are all factors that influence the local temperature and precipitation patterns, which in turn drive the assemblage of flora and fauna found in the Alaska parks.

NPS photograph by Pam Sousanes

Figure 1. The 4,060 foot elevation climate station at Gates Glacier in Wrangell-St Elias National Park and Preserve is the highest station operating in the Wrangell Mountains, one of 25 deployed by the NPS from 2004-2009.

Climate patterns are key to understanding ecosystem processes, yet the available analyses, trends, and models for Alaska are based on relatively few observations. One of the fundamental ways the Alaska I&M program is helping to assess climate change is by deploying climate stations that record temperature, precipitation, wind speed and direction, soil temperature, relative humidity, snow depth, and solar radiation (*Figure 1*). These new climate stations are providing critical quantitative data for current and future research and management decisions.

Shifting baselines

An analysis of existing long-term climate data in central Alaska linked annual, and especially winter, air temperatures to atmospheric and oceanic circulations of the North Pacific Ocean (*Keen 2008*). One index that is particularly relevant to climatic trends in Alaska is the Pacific Decadal Oscillation (PDO), an index of sea surface temperatures. Typical winter sea surface temperatures during the warm phase of the PDO are warmer off of the Gulf Coast of Alaska moderating air temperatures over Alaska. Figure 3 illustrates that temperature trends that have shown climatic warming tend to be strongly biased by a sudden shift in 1976 from the cooler regime to a warmer regime (*Hartmann and Wendler 2005, Keen 2008, Wendler and Shulski 2009*). The PDO seems to cycle through a warm and cool phase every 20 -30 years.

While the north Pacific seems to explain some of the temperature trends in the region, the Arctic Ocean, and in particular the extent of sea ice plays a crucial role in the Arctic climate. Reduction of ice extent leads to warming due to increased absorption of solar radiation at the surface (*IPCC 2007*). Figure 4 shows the continued and significant reduction in the extent of the summer sea ice cover and the decrease in the amount of relatively older, thicker ice in recent years (*Richter-Menge and Overland 2009*). These are complex processes that have confounding effects; sometimes the expected does not happen, even if models predict a certain outcome, which is why weather observations in the parks are so important.

More stations, more data, better science

The available long-term climate records from the state are almost exclusively from low elevations, in populated areas near the coast, and along rivers. The NPS lands in Alaska encompass most of the mountainous areas of the

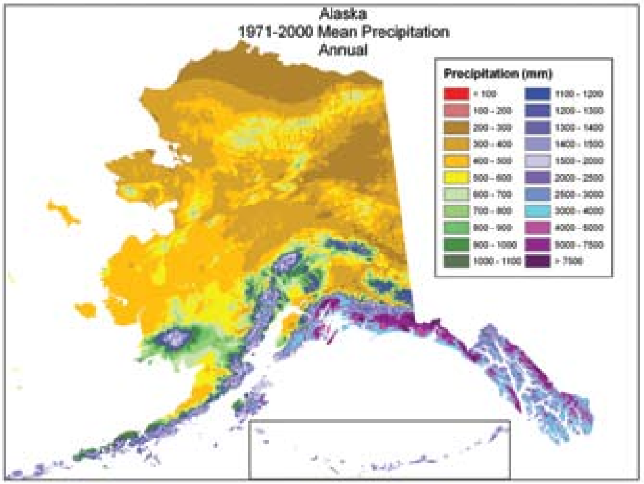

Figure 2. PRISM climate models combine observed climate measurements, landscape characteristics, and atmospheric circulation to create regional climate maps – such as this map showing mean annual precipitation for Alaska.

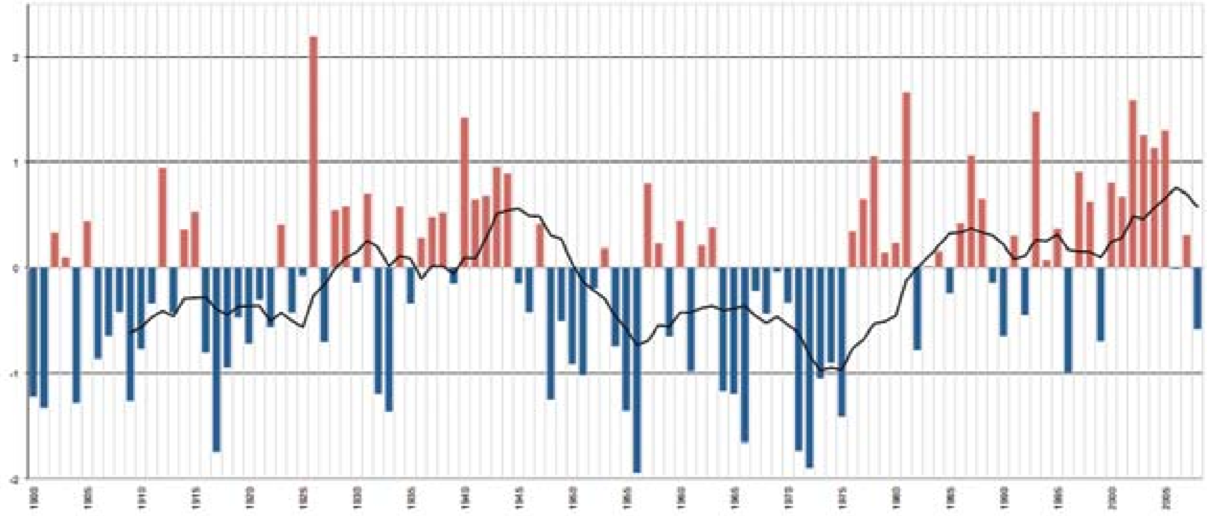

Figure 3. Mean annual temperature departure for Central Alaska; blue bars are negative and red bars are positive departures. The phase shift in the PDO is apparent as it shifts from a cool to warm phase in 1976.

state, and provide a great opportunity to fill in data gaps in the climate record. The Central Alaska Network (CAKN) and the Southwest Alaska Network (SWAN) were the first I&M networks in Alaska to implement monitoring programs; they partnered with the Western Regional Climate Center (WRCC), the National Weather Service, and others to develop robust, realistic methods for monitoring climate in remote and environmentally challenging areas.

The I&M networks share common goals and objectives to meet this challenge: to identify long and short term trends by monitoring and recording weather conditions at representative locations in the parks, a commitment to making these data available to everyone, and utilizing these data for larger-scale climate monitoring and modeling efforts. The CAKN and SWAN currently have 25 stations actively recording climate trends across 31.1 million acres of Alaska park lands (*Figure 5*). The Arctic and Southeast Alaska Networks, comprising another 22.6 million acres, are currently developing a detailed climate monitoring plan using the foundation established by CAKN and SWAN. This will result in installations of new stations in areas where data is critical, including the vast upland areas of the Arctic parks and the coastal areas in Southeast Alaska.

The climate monitoring program now has products available for use in understanding climate and ecosystem change, such as publicly accessible data and data analysis tools, climate summary maps, and reports summarizing annual climate factors and long-term trends (*Davey et al. 2006, Keen 2008*). The WRCC has been instrumental in disseminating and archiving the network climate data; these data flow systems are well established and secure, and dissemination is wide.

Into the Future

The focus for CAKN and SWAN over the next few years is to maintain the integrity of the new stations, promote the use of data for ecological and climatic analysis, improve data query tools, and integrate the NPS climate products with other climate change research and monitoring efforts. The NPS recently partnered with the PRISM (Parameter-elevation Regressions on Independent Slopes Model) Climate Group at Oregon State University to update the gridded monthly and annual precipitation and temperature data sets for Alaska for the 1971 - 2000 climate period. These maps help estimate variations in temperature and precipitation around existing climate stations and will be used to update the projected climate change scenarios for the national park units in the state. The current projections were modeled using older datasets. With the availability of new temperature and precipitation datasets, these models can be improved and refined.

The NPS has invested substantial time and effort to develop an effective and robust climate monitoring program that will answer critical questions about how the trends in temperature and precipitation are changing in Alaska national parks. These data will make a critical difference in our understanding of climate trends in Alaska over the next 50 years.

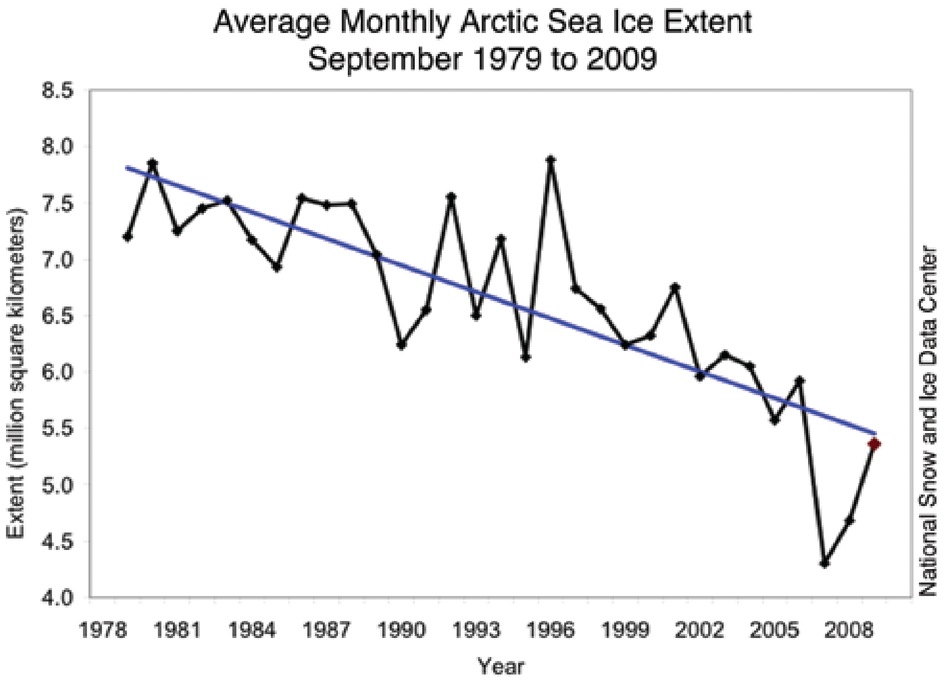

Figure 4. Average monthly sea ice extent has decreased steadily over the past 30 years, one of many contributors to rising terrestrial temperatures (Figure from the National Snow and Ice Data Center Sea Ice Index. Retrieved on November 1, 2009 from http:// nsidc.org/data/ seaice_index).

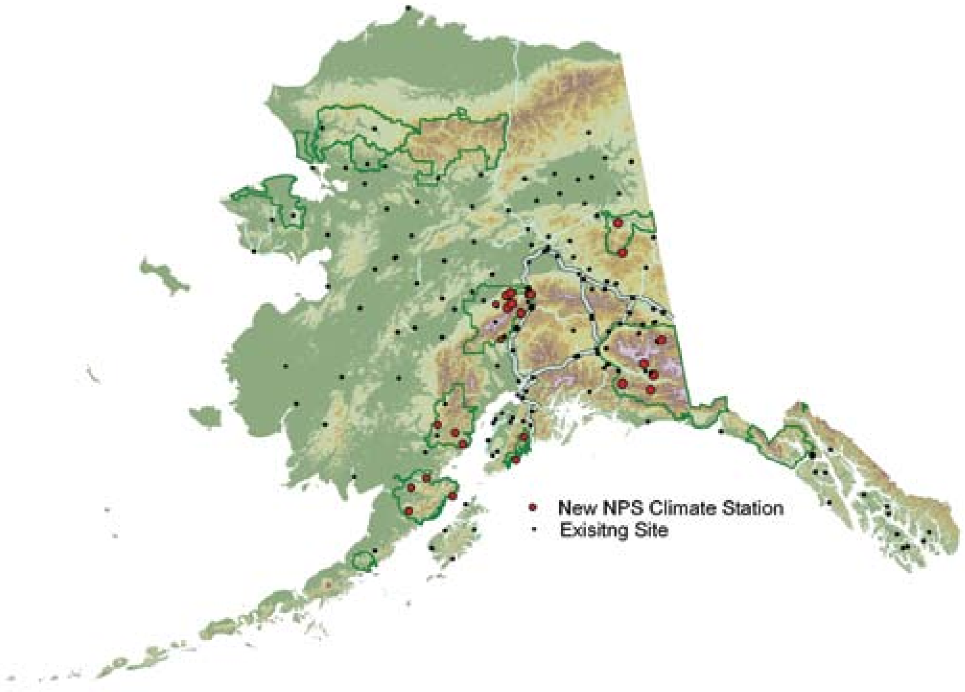

Figure 5. NPS lands in Alaska including terrain features and the location of the 25 new climate stations in the CAKN and SWAN networks.

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Monitoring Local and Global Contaminants in Alaska Parks

By Dave Schirokauer and Brendan Moynahan

Vast stretches of tundra, extensive forests and ranges of glacier-clad peaks evoke visions of wildlands untouched by the effects of major industrial development. Unsurprisingly, people assume that industrial contaminant levels in Alaska parks are among the lowest in the world. However, a recently completed assessment revealed that Alaska parks are not immune from the effects of global industrialization (*Landers et al. 2008*). Several "Persistent Organic Pollutants" (POPs) such as pesticides, flame retardants, and mercury, have been detected in biota, air, and waterways thousands of miles from use or emission sources.

Many persistent contaminants arrive in remote Alaska parks through atmospheric transport, oceanographic processes, and by way of fish and wildlife. Contaminants can become concentrated at northern latitudes due to patterns of atmospheric circulation and global distillation – phenomena by which POPs and mercury deposited at warmer, lower latitudes revolatize and travel in the atmosphere towards cooler, higher latitudes. A recent study (*Sunderland et al. 2009*) demonstrated that elemental mercury deposited in ocean waters near industrial areas was transformed into the more toxic methylmercury and transported on prevailing currents to distant coastal areas. Coastal Alaska is identified as a receptor of mercury and POPs delivered both by ocean currents and atmospheric processes. Many of these compounds are fat soluble and accumulate in fish and wildlife. The longer-lived and higher on the food chain an organism is, the higher the potential contaminant concentrations. Local, regional, and global air pollutants are a concern because of the potential adverse effects on human health and sensitive components of national park ecosystems.


NPS photograph

Figure 1. Mussel bed (*Mytilus trossulus*) in Glacier Bay National Park and Preserve.

Some pollutants – such as sooty fine particles and nitrogen oxides from transportation sources – exhibit dramatic local increases during the summer tourist season. Glacier Bay NPP (GLBA) permitted 225 visits from large cruise ships in 2009, and Skagway, the home of Klondike Gold Rush NHP (KLGO), is now the 16th busiest cruise ship port in the world. In 2009, up to five large cruise ships docked in Skagway daily from May to September. Diesel-powered tourist trains depart Skagway for White Pass and beyond, traversing KLGO and the Tongass National Forest several times daily.

In response to these issues and concerns, the Inventory and Monitoring Networks (I&M) in the region are developing a multi-pronged approach to monitor trends in environmental contaminants. Highlights include the new National Atmospheric Deposition Monitoring (NADP) site in Katmai NPP, and several vital signs focused on monitoring contaminant levels in biota including non-anadromous lake fish, moss, lichens, and marine mussels.

Mussels as marine sentinels

Oceans receive pollutants both through direct discharge (including vessel discharges, exhaust, and spills) and through deposition from airborne and terrestrial sources. Bay mussels (*Mytilus trossulus*) and blue mussels (*Mytilus edulis*) are common, long-lived (20 years), immobile organisms that accumulate contaminants. Both species are the subject of the longest running contaminant monitoring program in the country, the two decade-long Mussel Watch program (*Kimbrough et al. 2008*).

Marine contaminants in bay mussels were selected as a monitoring vital sign in Southeast Alaska Network (SEAN) and Southwest Alaska national parks. Sixty-three mussel monitoring sites have been assessed, and a small subset of these sites were selected for long-term monitoring. These sites will allow NPS biologists to detect local pollution sources, track impacts of catastrophic unintended releases (such as oil spills), and track changes in global background levels of contaminants.

Currently POPs, hydrocarbon and mercury levels in the Alaska park samples are among the lowest in the country (*Tallmon 2009*); however, DDT, chlordane, and PCBs (compounds that have not been used in the U.S. for decades) have been detected in some samples. Sites associated with heavy human activity have higher levels of some contaminants relative to most sampling sites. At all sites, mussel and sediment samples have levels of contamination that are almost uniformly well below values considered human health threats. The recent mussel sampling serves as a reference for detecting changes; some sites will be re-sampled on a rotating basis.

Mercury and POPs in freshwater systems

In 2006 and 2007, SEAN cooperators at the University of Alaska Southeast sampled juvenile coho salmon (*Oncorhynchus kisutch*), sediments, water, and macro-invertebrates in several rivers throughout the SEAN parks (*Nagorski et al. 2009*). Mercury and several POPs were detected in all of the sampled watersheds.

Elemental mercury is not generally accumulated and biomagnified by fish until it is converted by microbial activity into methylmercury. Although numerous dynamics control methylation rates, one factor is the extent of peat-rich wetlands in a watershed. When GLBA watersheds were assessed based on the time since glaciation, methylmercury levels in stream water particles, macro invertebrates, and juvenile fish were correlated with stream system age and wetland extent. The older the watershed, the more wetlands there are, and thus the higher the methylmercury concentration. This spatial pattern was not evident for the POPs (*Nagorski et al. 2009*). Juvenile coho salmon have not yet departed from their natal streams, so any tissue contaminants would be from local sources. Fish less than one-year old generally had relatively low concentrations of mercury; however, in some older watersheds, juvenile coho salmon greater than one-year old had mercury levels of 80 ng/g, which approaches or exceeds the threshold for the protection of some species of fish-eating wildlife (*Lazorchak et al. 2003*).

Several Alaska parks are monitoring mercury. GLBA and Gates of the Arctic NPP collected wet mercury deposition data weekly. Total (wet and dry) deposition is being assessed in lichen tissue at Southeast Alaska parks and in moss tissue at Cape Krusenstern National Monument. Lake sediments, which provide a historical record of deposition, are being analyzed for mercury and other persistent contaminants in parks throughout the region. Resident lake fish, known to bioaccumulate methylmercury, are being assessed at Noatak National Preserve and Katmai, Lake Clark, and Gates of the Arctic National Parks and Preserves.

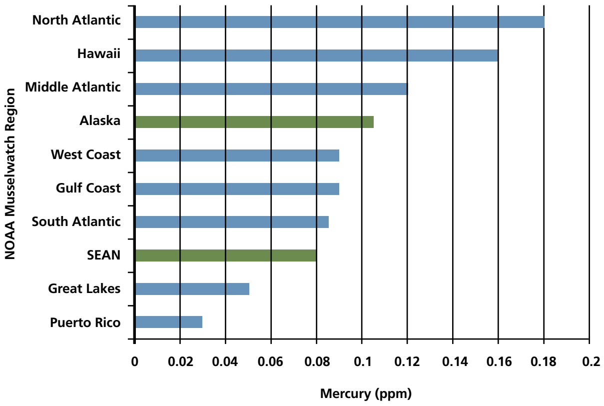

Figure 2. Mercury in mussels within SEAN parks is lower than most regions in the US, according to the NOAA Mussel Watch program data set.

Atmospheric chemistry and lichens

To complement assessment and monitoring of marine and freshwater contaminants, deposition of airborne contaminants on terrestrial habitats is also monitored by Alaska I&M programs. SEAN is assessing several ways of monitoring atmospheric chemistry, including: elemental analysis of lichen tissues, passive sensors that measure weekly average ambient concentrations of various oxides of nitrogen and sulfur, passive sensors that measure terrestrial deposition of nitrogen and sulfur on a seasonal basis, and arboreal lichen community composition. Passive chemical sensors and lichens are being used simultaneously to create models that relate signals in lichen community change and elemental concentration in tissue samples with known, quantifiable atmospheric conditions.

Lichens are useful as both short-term bio-samplers for some contaminants that are seasonally associated with human activity and for other more persistent contaminants. Lichens are long-term integrators of atmospheric deposition due to their longevity and lack of inter-seasonal morphological variation, but lichens do not retain all contaminants in the same way or over the same time frame. Mobile elements like nitrogen, sulfur, and potassium are both easily absorbed and leached, maintaining a dynamic equilibrium with seasonal changes in the availability of these nutrients. Chemical properties of other elements (e.g., lead and cadmium) may cause them to bond to lichen surfaces and may take years to decrease in concentration after the source has been removed.

SEAN is repeating a lichen-based, airborne contaminants study completed in 1999 at KLGO and assessing trends in key pollutants as part of the development and testing of monitoring methodologies. That study demonstrated that sulfur, nitrogen, and heavy metal concentrations in the KLGO and Skagway area exceeded thresholds established by the USDA Forest Service for southeastern Alaska (*Furbish et al. 2000*).

Some lichen species are more susceptible to the effects of nitrogen (fertilization), sulfur (acidification), and some metal-containing air pollutants compared to vascular plants. Some lichens decline in abundance or vanish from a plant community when exposed to low levels of oxides of nitrogen and sulfur, while other lichen species thrive in fertilized or acidified condition. To examine how species-specific responses to contaminants may be reflected on the landscape, SEAN is participating in lichen community studies that examine the composition of lichens in areas exposed to different levels of air pollution.

Conclusion

Global human population is expected to reach 9 billion in the next 40 years. Although most of this growth and the associated industrial development will occur at temperate and tropical latitudes, global deposition patterns and bioaccumulation processes spread the effects worldwide. The Alaska I&M networks are establishing monitoring programs with dual objectives of trend detection of chronic contamination in marine, freshwater, and terrestrial systems, as well as providing reference data that will be invaluable in the event of an acute contamination event, such as a spill. These data will allow scientists to better understand how contaminants travel great distances, enter local ecosystems, and move up local food chains and will help managers and policy makers as they meet local, regional, national, and international obligations to protect ecosystem and human health.

NPS photograph by Brendan Moynahan

Figure 3. Bay mussels (Mytilus trossulus) and barnacles (*Balanus spp.*) at the Glacier Bay Field Station in Juneau.

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The Twelve Baseline Inventories – the Alaskan Story

By Sara Wesser

Stewardship of national park lands requires knowledge and understanding about the condition of the natural resources set aside by the American public for preservation. Having this information readily available is ever more important as we face the growing impacts of climate change, population trends, and economic pressures. The Inventory and Monitoring Program is developing a consistent set of information on the NPS natural resources for use by managers, scientists, planners, and the public. These inventories are collectively known as the Baseline Natural Resource Inventories and cover a range of features including the presence and distribution of plants, animals, and nonliving resources such as water, landforms, and climate. An important part of the program is producing information that managers need to ensure the future health of the parks in a form that can be easily accessed and understood. Each inventory follows consistent protocols and quality assurance standards, and delivers information through easily understood and accessible means. A unique Alaska solution is necessitated by the remoteness, the short growing seasons, and inclement weather that occur in these far northern parks. In addition, due to the vast extent of the NPS lands in Alaska, the inventories would need to be accomplished at a much lower cost per acre than in the rest of the country. For example, the approach to vegetation (landcover) and soils inventories is built on a foundation of remote sensing, which provides for interpolation of costly and limited field data across much broader landscapes than would otherwise be possible. Furthermore, the data collection and analysis methods integrate ecological information to maximize the information content of the digital maps and reports that are produced with each inventory.

These baseline inventories provide a snapshot in time of the condition of a park's natural resources. Combined with information from other park programs and research efforts, park managers will have access to a library of information that informs decisions, enhances planning, and enriches the public awareness of the natural world around them. Along with repeat inventories in the future, and the status and trend information derived from the Vital Signs Monitoring Program, parks will have a rich library to draw upon to preserve and protect resources for future generations.

The 12 baseline natural resource inventories:

- Automated Bibliographies
- Base Cartography Data
- Species Occurrence Inventory
- Species Distribution Inventory
- Vegetation (Landcover) Maps
- Soils Maps
- Geologic Maps
- Water Resource Inventory
- Water Chemistry Inventory
- Air Quality Inventory
- Air Quality-Related Values Assessment
- Climate Inventory

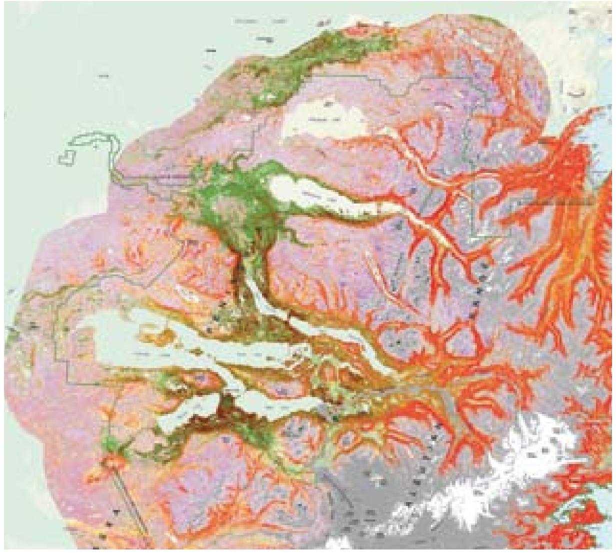

Figure 1. Portion of the Katmai National Park and Preserve landcover map.

NPS photograph

Figure 2. Visual interpretation of color infrared aerial photography provides additional information to field crews collecting data in Katmai National Park and Preserve.

Data Management in the I&M Program

By William Johnson, Scott Miller, Joshua Schmidt , and Cuyler Smith

Emerging technologies, increasing Internet speeds and ever-expanding computing power enhance scientists' ability to collect, analyze, and share data. Concurrently, natural resource managers have growing needs and expectations regarding the timeliness, accuracy, and accessibility of scientific research. Internet technologies are increasingly critical tools for the NPS Inventory and Monitoring Program (I&M) to use for documenting, publishing, and delivering information to both researchers and decision makers.

One example of how I&M's approach overcomes modern data management challenges and meets users' needs and expectations is illustrated by the Southeast Alaska Network's oceanography vital sign. Sixteen years of physical observations, about 250,000 records, have been collected in Glacier Bay. While these data are a valuable resource for decision making by park management and have potential for use by other researchers, they remained formally undocumented and unpublished as late as 2007. Non-NPS researchers interested in the ocean's response to global warming in Alaska, as an example, would have had to work very hard to learn such data existed. Once discovered, more work would be needed to obtain the data, learn its structure and collection methodology, evaluate its quality, and determine if it could be adapted to fit the researchers' objectives. Today, however, someone searching the terms "SEAN Oceanography" will locate the authoritative dataset, query the data through a browser, and download it to his/her desktop in minutes – including metadata and associated reports.

In addition to websites, NPS employs web services to deliver data from remote servers to desktop applications in real-time. For example, the Arctic Network (ARCN) uses web mapping services to distribute large-scale imagery that previously had to be physically mailed to clients. Bill Manley, of the University of Colorado's Institute of Arctic and Alpine Research, has compiled a dataset of high resolution imagery for monitoring coastlines in Bering Land Bridge National Preserve and Cape Krusenstern National Monument. The imagery consists of orthorectified digital photography, at 1 meter or better resolution, over three timeslices ranging from 1950 to 2003. Recognizing the high potential for secondary use of the dataset, ARCN teamed with the Geographic Information Network of Alaska (GINA) of the University of Alaska Fairbanks to publish the dataset as a web map service (WMS). The imagery can now be loaded seamlessly into any WMS-capable Geographic Information System or viewed through a variety of online mapping applications such as AlaskaMapped, Swath Viewer, Yahoo! Maps and Google Earth.

By focusing on innovative use of information technology and internet-based distribution, the I&M Program is successfully delivering data and decision support tools like never before. These approaches successfully support research and management, and also allow NPS professionals to more quickly and effectively accomplish our mission.

Figure 1. The Alaska Region of the NPS public web site at http://science.nature.nps.gov/im/units/AKRO/ is a convenient place to find links to the four I&M networks in the state.

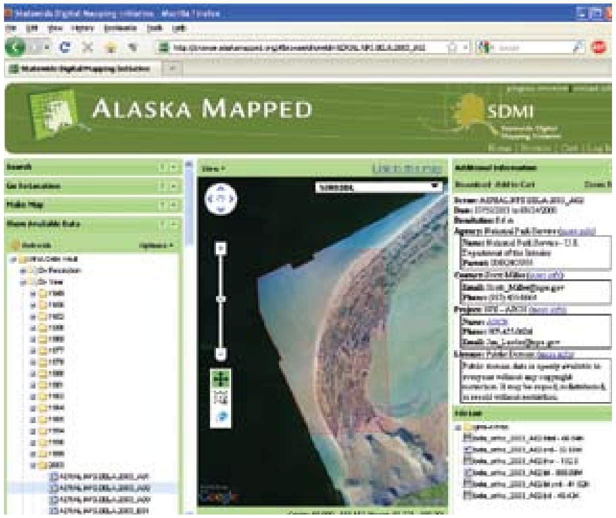

Figure 2. Imagery from the Arctic Network Coastal Erosion Monitoring program as seen through the Alaska Mapped website. The imagery is available through the internet as a web mapping service provided by the Geographic Information Network of Alaska.

The Arctic Network

Vital Signs of the Arctic

Monitoring Framework	Vital Sign	Parks Where Monitored				
		BELA	CAKR	GAAR	KOVA	NOAT
Air and Climate	Airborne Contaminants			●		
	Climate	●	●	●	●	●
	Snowpack	●	●	●	●	●
Geology and Soils	Coastal Erosion	●	●			
	Sea Ice	○	○			
	Permafrost	●	●	●	●	●
Water	Lake Communities and Ecosystems	●	●	●	●	●
	Lagoon Communities and Ecosystems		●			
	Stream Communities and Ecosystems	●	●	●	●	●
	Surface Water Dynamics	+	+	+	+	+
Biological Integrity	Land Birds	●	●	●	●	●
	Yellow-billed Loons	●	●			
	Brown Bears	●	●	●		●
	Dall's Sheep			●	●	●
	Muskox	●	●			
	Caribou	○	○	○	○	○
	Moose	○	○	○	○	○
	Fish Assemblages	+	+	+	+	+
	Small Mammal Assemblages	+	+	+	+	+
	Terrestrial Vegetation and Soils	●	●	●	●	●
	Invasive/Exotic Species	+	+	+	+	+
Human Use	Subsistence/Harvest	○	○	○	○	○
	Point Source Human Effects		+	+		+
Landscapes	Fire Extent and Severity	○	○	○	○	○
	Landscape Patterns and Dynamics	●	●	●	●	●

● Vital signs for which the network will develop protocols and implement monitoring with funding from the vital signs or water quality monitoring program.

○ Vital signs that are currently being monitored long-term by a network park, another NPS program, or by another federal or state agency. The network will collaborate with these other monitoring efforts where appropriate but will not use vital signs or water quality monitoring program funds.

+ Vital signs for which monitoring will likely be done in the future but which cannot currently be implemented due to limited staff and funding.

NPS photograph

Figure 1. Monitoring in the Arctic Network include many uniquely arctic organisms such as these muskoxen in Bering Land Bridge National Preserve.

By Jim Lawler

The Arctic Network (ARCN) is composed of Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Gates of the Arctic National Park and Preserve, Kobuk Valley National Park, and Noatak National Preserve. Park units in the network contain approximately 19.3 million acres, or a little less then 25% of the land area of National Park Service (NPS)-managed units in the United States. The ARCN parks contain a broad array of the ecosystems typical of the subarctic (boreal forest) and arctic (tundra) biomes of northwestern North America. The boundary, or ecotone, between these two biomes is represented in many different phases. In addition, these parks encompass large areas of mountainous terrain, including a major portion of the Brooks Range.

Perhaps nothing defines ARCN as much as climate. The climate of the ARCN parks varies from the extreme continentality of interior Alaska to the maritime coastal areas. However, this maritime climate is somewhat modified by the presence of pack ice, which minimizes the moderating effect of the sea during the six to nine months it is present. Winters, even in coastal areas, are intensely cold. In the tapestry of this landscape, ARCN boasts unusual geomorphic features such as permafrost, hot springs, recent volcanic flows and extensive sand dunes. The 230 miles of coastline, punctuated by coastal lagoons, serves as important habitat for fish and birds. Freshwater resources include deep lakes, shallow permafrost related ponds and free flowing rivers including seven designated wild and scenic rivers. Plant communities, ranging from spruce forests to coastal sedge meadows support diverse population of wildlife. Birds, such as the northern wheatear, travel from as far away as northern Africa to breed in ARCN parks. Intact mammalian predator-prey relationships, such as those involving wolverines and Dall's sheep, are free to unfold here. Yet people are not foreign to this landscape as local area residents continue to practice their subsistence traditions here.

With the help of NPS staff and experts from a broad array of specialties, ARCN has identified 19 elements and processes of park ecosystems for which we will begin monitoring in the next three years. These elements and processes are termed vital signs. Vital signs that we will be tracking include four related to air and climate (wetand dry contaminant deposition, air contaminants, climate and snowpack), two related to geology and soil (coastal erosion and permafrost), three related to water (lagoon communities and ecosystems, lake communities and ecosystems, and stream communities and ecosystems), one related to human use (subsistence/harvest), two related to ecosystem patterns and processes (fire extent and severity, and terrestrial landscape patterns and dynamics), and seven related to biological integrity (landbirds, yellow-billed loons, brown bears, caribou, Dall's sheep, muskox, and terrestrial vegetation and soils). This broad based, scientifically sound information obtained through monitoring will have multiple applications for management decision-making, education and promoting public understanding of park resources.

Monitoring Dall's sheep in Alaska's Arctic Parklands

By K. Rattenbury, J. Schmidt and L. Phillips

A Super Cub airplane ventures into the Brooks Range, its crew searches carefully for one of Alaska's hardiest inhabitants. The vast, wild character of these Arctic parklands impresses the pilot and observer as they scan the rugged landscape. Flying along a mountain contour, they spot a group of white dots high on a rocky slope, and, moving closer, are able to identify and count a band of Dall's sheep.

Dall's sheep are one of 28 vital signs monitored by the Arctic Network Inventory and Monitoring Program (ARCN I&M) because of their importance to the public and in assessing the overall health of the regional ecosystem. Dall's sheep are a valued subsistence species for local residents, and sport hunting is permitted in the preserves. They live at the northern limit of their range in these arctic mountains and may serve as a sensitive indicator of environmental change. As a relatively sedentary, alpine species, Dall's sheep are one of the most visible large mammals for wildlife viewing.

Dall's sheep habitat in the central and western Brooks Range encompasses about 15,800 square miles (41,000 km^2), an area roughly twice the size of New Jersey. Most of this is within Gates of the Arctic National Park and Preserve (Gates of the Arctic), Noatak National Preserve (Noatak) and Kobuk Valley National Park (Kobuk Valley) (*Figure 1*). Monitoring the abundance and distribution of Dall's sheep in these parklands is a priority for the Arctic Network, but the immense size and remote nature of this region presents a daunting challenge for designing a statistically valid sampling strategy. Practical considerations, such as accessibility and cost, limit design alternatives that can realistically be implemented.

The central and western Brooks Range likely contained 13-15% of the world's population of Dall's sheep in the early 1980s (*Valdez and Krausman 1999*). An aerial census conducted from 1982 to 1984 estimated a minimum of 10,939 Dall's sheep in Gates of the Arctic (*Singer 1984*) and 1,687 sheep in Noatak (*Singer et al. 1983*). A substantial decline was observed in the late 1980s and early 1990s concurrent with several years of severe winter weather (*Shults 2004, Whitten 1997*). Although more recent studies indicate a slight recovery and stabilization in some areas (*e.g., Shults 2004, Lawler 2004*), these numbers remain lower than were observed in the early 1980s. Most of the region has been infrequently or incompletely surveyed since 1984, and previous surveys vary in methodology and success. These inconsistencies prevent park managers from detecting trends in Dall's sheep abundance in parks, much less on a regional scale.

In 2005 and 2006, the Arctic Network attempted to systematically re-census the central and western Brooks Range by fixed-wing aircraft. Far less area was surveyed than planned, and, in 2007, the survey methods were modified for stratified random sampling. Survey subunits were stratified by sheep density based on the most recent data, and randomly selected for survey order. Data for all three years were analyzed using methods described by Gasaway et al. (*1986*). Regional abundance estimates (± 95% confidence interval; unadjusted for sightability) were 10,611 +/- 2,533 sheep in 2005-2006 and 7,258 +/-2,710 sheep in 2007 (*Rattenbury and Lawler, in prep.*). The large variances, lack of current region-wide density data, movement of sheep between subunits, and long ferry times for aircraft make stratified random sampling difficult in this large and remote region. Surveys of large units that require multiple survey days, as were done in 2005 and 2006, are problematic because weather, funding and other logistical constraints may prevent complete coverage. A new strategy was needed to improve the precision of the estimate and to decrease cost and simplify sampling logistics.

2009 Survey

In 2009, the Arctic Network collaborated with staff from the Central Alaska Network and Denali National Park and Preserve to test distance sampling methods in Gates of the Arctic. With this technique, observers search for sheep while traveling along a designated series of lines. Abundance estimates are based on the distance of animal sightings from the survey line and the assumption that detection is 100% for animals located on the line and diminishes with increasing distance from the line. In mountainous terrain, the transect lines follow elevation contours. Contour transects have been used successfully to estimate bear abundance in southwestern Alaska (*Quang and Becker 1999*), and these methods are expected to improve estimates of abundance and density of Dall's sheep without an increase in survey cost or time.

A custom ArcGIS 9.2 (ESRI, Redlands, California) application (NPS Animal Transect Tool, GeoNorth, LLC, Anchorage, Alaska) was used to generate 316, 12.4 mi (20 km) long transects on a 6.2-mi (10-km) grid across Gates of the Arctic (*Figure 2*). The transects were surveyed June 23-30 by four pilot-observer teams based in Anaktuvuk Pass, Bettles, Coldfoot and Dahl Creek. Follow-up surveys to finish 28 transects that had >30% snow cover in June were conducted July 22-25 by one team. The pilots followed the contour transects at approximately 300 ft (92 m) above ground level, and the pilot and observer worked together to search uphill from the line. When sheep were detected, the observer recorded the GPS location and group size on a laptop computer running an ArcPad (ESRI, Redlands, California) application that automatically recorded the flight path.

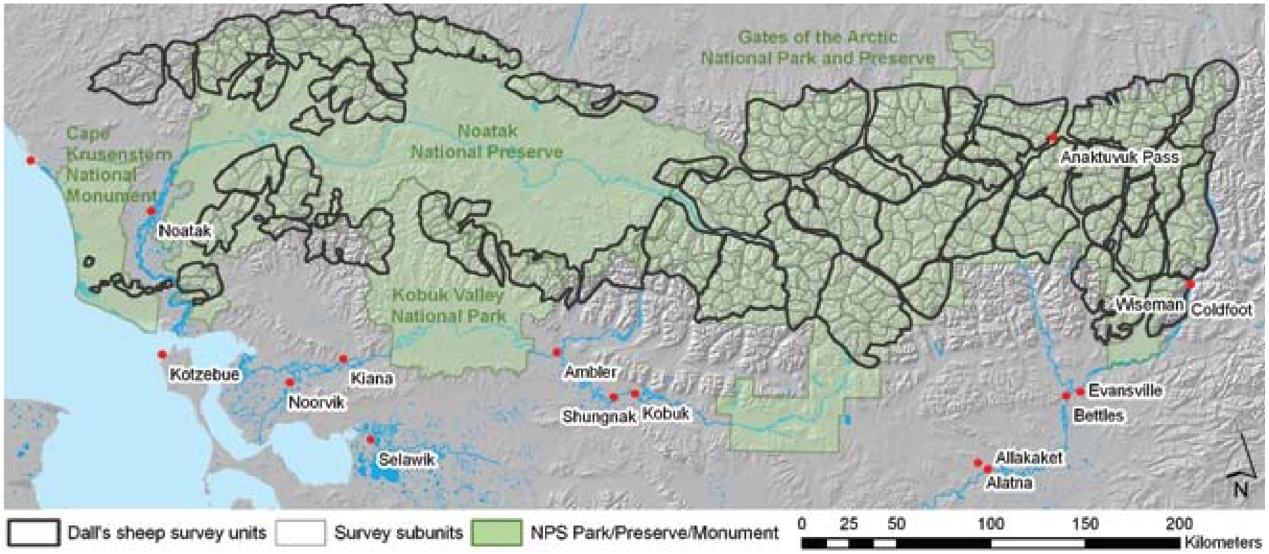

Figure 1. Over 15,800 mi^2 (41,000 km^2) of sheep habitat have been delineated in the central and western Brooks Range of Alaska. Historically, sheep surveys were conducted using survey unit boundaries designated by Singer (*1984*) and Singer et al. (*1983*).

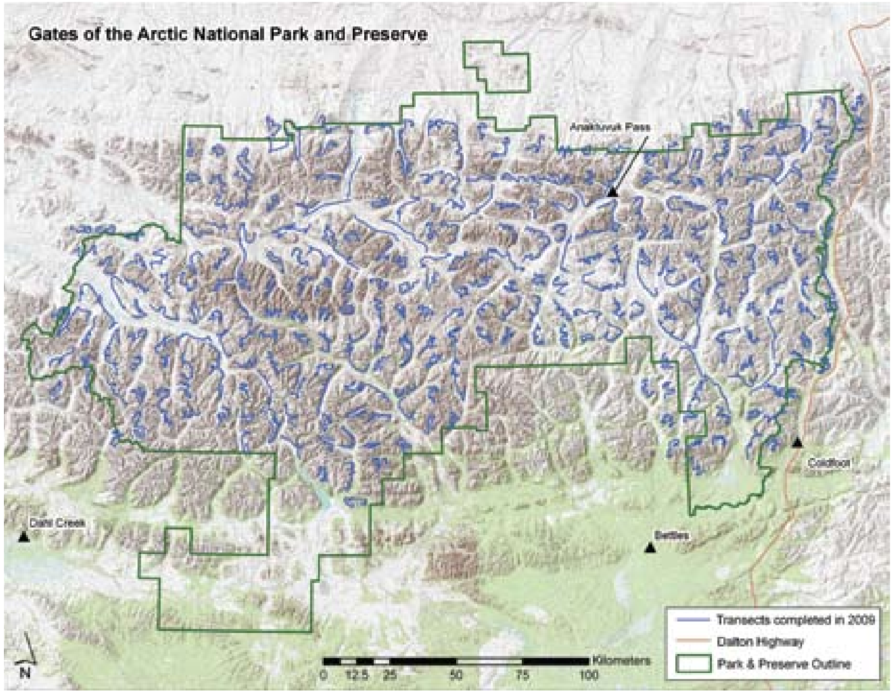

Figure 2. In 2009, the Arctic Network surveyed Dall's sheep using a new technique that required observers to search for animals along contour transect lines. Teams flew 308 randomly placed transects and recorded the locations of sheep groups using a laptop computer.

Between the June and July surveys, 308 of the 316 transects were flown. Pilot-observer teams recorded 166 groups, totaling 727 individual Dall's sheep on 73 transects. The majority of the observed sheep were in northeastern and southwestern Gates of the Arctic. Program Distance 5.0 (*Thomas et al. 2006*) will be used to calculate an abundance estimate for Gates of the Arctic.

Several transects fell below tree-line or were not in sheep habitat. Contour transects must be randomly generated in all possible Dall's sheep habitat, but this area was overestimated for the 2009 survey. Efforts in 2010 will involve spatial modeling of vegetation cover, topography, and elevation to eliminate forested areas coupled with an investigation of terrain complexity to avoid missing features such as low elevation river bluffs where Dall's sheep may be found. Additionally, future surveys will involve transects at different elevations on the same mountain to maximize coverage of potential habitat.

Implications for Future Monitoring

The Arctic Network will continue to work with the Central Alaska Network and park biologists to test distance sampling for estimating Dall's sheep abundance. Surveys with revised methods for generating contour transects are planned for 2010 in Gates of the Arctic, Wrangell-St. Elias, and Lake Clark National Parks and Preserves. If these surveys produce satisfactory results, the methods will be applied in Noatak, Kobuk Valley, and Denali National Park and Preserve. One of the main advantages of distance sampling is the ability to generate abundance estimates for entire park units including estimates of precision and accuracy for less cost than a census. Distance sampling also addresses the issue that an unknown proportion of sheep are not seen during aerial surveys by estimating the number of sheep not detected. Moreover, data from multiple survey years can be used to produce density distribution maps. A goal of the Arctic and Central Alaska Network collaboration is to provide survey protocols that can detect park-wide changes in Dall's sheep abundance and distribution.

Acknowledgements

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NPS photograph by Christy Splechter

NPS photograph by Tara Whitesell

Figure 3 and Figure 4. Observers photographed groups of Dall's sheep to aid in count and classification of large groups and 'cryptic' sheep.

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Aerial Yellow-billed Loon Surveys in Cape Krusenstern National Monument and Bering Land Bridge National Preserve, Alaska

By Melanie J. Flamme

In 2009, the Arctic Network of the NPS Inventory and Monitoring Program implemented a pilot study to test methods for aerial surveys of yellow-billed loons (*Gavia adamsii*) in Bering Land Bridge National Preserve and Cape Krusenstern National Monument. The breeding range of yellow-billed loons is restricted to large lakes (>7 hectares) (*North and Ryan 1989*) in the Arctic coastal plain of Alaska and in western Alaska on the Seward Peninsula. Population estimates for the loons in Bering Land Bridge and Cape Krusenstern represent about 20% of the U.S. population (*Schmutz 2008*).

We flew an occupancy survey in June to count adults and nests, and a productivity survey in late August to count members of family groups. Each survey covered the same 24 plots distributed among the two park units. Staff from NPS conducted the surveys in accordance with training and protocols designed specifically for these loons by U.S. Fish and Wildlife Service (*Mallek et al. 2005, Bollinger et al. 2007*). A total of 186 adults and 14 nests were counted on the plots in 2009.

The yellow-billed loon was selected by the Arctic Network as a "vital sign" for long-term monitoring. These loons return to the same breeding sites each year, making them ideal for monitoring long-term population trends. As top predators in lake ecosystems, they may be indicators of water quality and provide insight into the movement of marine-derived nutrients and shifts in riparian or coastal communities. In addition, as long-lived piscivores (fish-eaters) yellow-billed loons can bio-accumulate contaminant loads (i.e. mercury, PCPs) (*Schmutz 2008*) and may serve as contaminant indicators. Contaminants are of particular concern because both the loons and their eggs may be harvested for human subsistence.


NPS photograph by Melanie Flamme

Figure 1. Pilot Eric Sieh flies the edge of a lake in Bering Land Bridge while looking for yellow-billed loons and their nests.

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Long-term Monitoring of 1977 Tundra Fires in the Northwest Alaska Parks

By Charles Racine, Jennifer Barnes, Randi Jandt, and John Dennis

The frequency and size of lightning-caused tundra fires could increase with climate warming and may result in major ecosystem changes in vegetation, soils, and wildlife habitat over large areas of the arctic. Two of the longest monitored sites (28-32 years) in Arctic Alaska for vegetation change and post-fire tundra succession are located in Bering Land Bridge (BELA) and Noatak (NOAT) National Preserves in northwestern Alaska. These permanent vegetation plots were established following widespread tundra and forest fires in 1977, when one million acres burned during an extremely dry year in northwestern Alaska (*Racine et al. 1987, 2004*). Recently the NPS Arctic Network Inventory and Monitoring Program has supported re-measurements of these sites.

The BELA site on the Seward Peninsula is located where a large 1977 tundra fire burned a west facing slope along Imuruk Lake (Nimrod Hill). Pre-fire vegetation and soils along this slope ranged from moist tussock-shrub tundra on the lower slopes to dwarf shrub tundra on the steeper upper-slope (12%) and wet sedge meadow on the ridge top. We sampled vegetation before the fire in 1973 and at eight sites following the fire at irregular time intervals from one year to 32 years. Over the monitoring period we have seen dramatic changes in vegetation on Nimrod Hill (*Figure 1*), particularly on the severely burned upper-slope. Immediately after the fire, the upper-slope sites were dominated by pioneering mosses and liverworts (*Figure 2*), followed by sedges and grasses within a decade (*Figure 3*). Twenty to 30 years after the fire, both deciduous and evergreen shrubs expanded dramatically at all sites on the hill; particularly on the upper slope where fast growing willows (*Salix pulchra*) now up to 5 ft (1.5 m) tall, currently cover 30-40% of the slope (*Figure 4*). The thaw depths and active layer thickness have recovered to pre-fire levels at the lower-slope tussock tundra sites; however, there is evidence for major permafrost thawing and surface subsidence on the well-drained slope in the area colonized by willows. We have seen slow recovery of Sphagnum moss and lichens 32 years after fire. The loss of Sphagnum moss could change the hydrologic and water retention capacity of tussock tundra and the loss of lichens could reduce winter forage for caribou and reindeer. This long-term record of change provides valuable documentation of fire effects on vegetation, permafrost, and wildlife habitat during an era of rapid climate warming in the Alaska Arctic.

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Photograph courtesy of Charles Racine

Photograph courtesy of Charles Racine

Photograph courtesy of Charles Racine

NPS photograph by Jennifer Barnes

Figure 1. 1973 pre-fire view downslope to Imuruk Lake from the upper face of Nimrod Hill dominated by dry dwarf shrub tundra mat.

Figure 2. 1978 one year post-fire on the severely burned upper slope. Cover was dominated by early successional mosses and liverworts with bare frost boils and exposed rock.

Figure 3. 1983 six years post-fire, this site was dominated by sedges (*Carex*) and grasses (*Calamagrostis*) that overgrew the mosses and liverworts. Gary Ahlstand, former AKRO NPS Research Ecologist, shown in photo.

Figure 4. 2009 thirty-two years post fire, what once was dwarf shrub tundra at this site is now tall willow. Randi Jandt, BLM Fire Ecologist, shown in photo.

The Central Alaska Network

Vital Signs of the Central Alaska Network

Monitoring Framework	Vital Sign	Parks Where Monitored		
		DENA	WRST	YUCH
Air and Climate	Air quality	○		
	Climate	●	●	●
	Snow pack	●	●	●
Geology and Soils	Glaciers	●	●	
	Permafrost	●	●	●
	Disturbance - volcanoes and tectonics	+	+	+
Water	Disturbance - Stream flooding	●	●	●
	River/stream flow	●	●	●
	Water Quality	●	●	●
Biological Integrity	Freshwater fish	●	●	●
	Passerines	●	●	●
	Bald Eagle		●	
	Golden Eagles	●		
	Peregrine Falcon			●
	Ptarmigan	+	+	+
	Moose	●	●	●
	Sheep	○	●	○
	Small mammals	●	+	+
	Caribou	●	●	○
	Snowshoe hare	●	●	●
	Arctic ground squirrel	+	+	+
	Wolves	●	+	●
	Brown Bear	+	+	+
	Vegetation structure and composition	●	●	●
	Disturbance - Exotic species	+	+	+
	Insect Damage	+	+	+
	Subarctic steppe			+
Human Use	Consumptive use	○	○	○
	Human populations	+	+	+
	Human presence/use	+	+	+
	Trails	+	+	+
Landscapes	Disturbance - Fire occurrence and extent	○	○	○
	Land Cover	●	●	●
	Soundscape	○	+	+
	Plant phenology	○	○	○

● Vital signs for which the network will develop protocols and implement monitoring with funding from the vital signs or water quality monitoring program.

○ Vital signs that are currently being monitored long-term by a network park, another NPS program, or by another federal or state agency. The network will collaborate with these other monitoring efforts where appropriate but will not use vital signs or water quality monitoring program funds.

+ Vital signs for which monitoring will likely be done in the future but which cannot currently be implemented due to limited staff and funding.

NPS photograph

By Maggie MacCluskie

The Central Alaska Network (CAKN) includes three national parks that encompass 21.7 million acres of land. Parks included in the network are: Denali National Park and Preserve (DENA), Wrangell-St. Elias National Park and Preserve (WRST) and Yukon-Charley Rivers National Preserve (YUCH). To put the area encompassed by the network into perspective, the network acreage is larger than the entire state of Maine. The parks in the network span an ecological gradient that ranges from 125 miles (200 km) of coastline in WRST and continues north through the Alaska and Wrangell mountain ranges, which are dotted with numerous glaciers. The northern border of the network ends in YUCH where the preserve is characterized by classic fire-driven boreal forest that flanks the Yukon River for 125 mi (200 km).

From the coastline of WRST to the northern border of YUCH is about 800 miles, and it is this expanse which characterizes the network. For example the average annual precipitation on the coast of WRST is 144 inches (366 cm), while at the northern end of the network only 12 inches (30 cm) of precipitation fall during the year. Though the landscape of the network parks changes drastically from south to north, the animal and plant species present in each are very similar. All three parks have intact populations of large carnivores like bears and wolves and have the prey species to sustain them (caribou, moose, sheep). Likewise, each park is home to a diversity of bird species including breeding populations of eagles and falcons. The existence of these groups of animals is indicative of the most notable and overriding feature of the network, which is the integrity of the ecosystems the boundaries encompass. The designation of both DENA and WRST as biosphere reserves serves to underscore this fact.

Figure 1. A tranquil view of Ptarmigan Lake, Wrangell-St. Elias National Park and Preserve.

Developing a monitoring program for such a diverse area is a tremendous opportunity and a tremendous challenge. The network spent four years developing the program with biologists and ecologists in each of the parks, along with external advisors.

The result is a program that is closely tied to the natural resource work conducted in each park. During 2009, the fourth year of program implementation, the network monitored air quality, climate, snow pack, water quality in the form of shallow lakes and streams, vegetation, small mammals, song birds, eagles (golden and bald), peregrine falcons, caribou, moose, and wolves. The results of this work are given back to the parks in the form of databases, reports, presentations and handouts. Ultimately, the goal of all this work is to allow parks to incorporate the information in their planning and management of park resources.

NPS photograph

Figure 2. A magnificent view of Mt. St. Elias from Icy Bay, Wrangell-St. Elias National Park and Preserve.

The American Peregrine Falcons of Yukon-Charley Rivers National Preserve, Alaska

By Maggie MacCluskie, Skip Ambrose, Chris Florian, and Melanie Flamme

American peregrine falcons (*Falco peregrinus anatum*) are iconic birds of prey capable of flight speeds up to 200 mph (320 km/hr). Their breeding range extends from Mexico north to the tree-line in Canada and Alaska. In Alaska, they occur in the forested interior, nesting primarily on cliffs along the major rivers. In the northern parts of its range, the American peregrine falcon is highly migratory, wintering as far south as Brazil and Argentina. The upper Yukon River, from the Alaska-Yukon Territory border to Circle, Alaska, provides excellent cliff-nesting habitat for the falcons as well as an abundant variety of prey species. The majority of this habitat lies within Yukon-Charley Rivers National Preserve (YUCH), which was one of the primary reasons for the preserve's establishment in 1980 (U.S. Congress).

Beginning in the late 1940s, the use of persistent organochlorine pesticides greatly affected American peregrine falcons in North America. These pesticides affected mortality and behavior, and caused birds to lay thin-shelled eggs that often failed to hatch and consequently lowered productivity. American peregrine falcons were classified as endangered in 1973 under the Endangered Species Act. In interior Alaska, American peregrine falcons declined to approximately 20 percent of historical levels by the mid-1970s. In 1972, the U.S. restricted the use of persistent organochlorine pesticides, and since 1978, American peregrine falcons in interior Alaska have been increasing.

Though population numbers have increased, recent evidence suggests that American peregrine falcons are still threatened by environmental contaminants. Analyses of American peregrine falcon eggs from the upper Yukon River suggest that mercury, a persistent compound which bioaccumulates at high trophic levels causing toxic effects (similar to DDT), is currently at levels that may affect reproduction, and trends suggest that mercury levels may be increasing (*Ambrose et al. 2000*). High levels of mercury are biologically available through industrial processes, such as mining and waste incineration, and will likely increase with global industrialization. Additionally, DDT and other pesticides are still being used on wintering grounds, which may cause continued risk to the population.

American peregrine falcons in the upper Yukon River corridor, within and adjacent to Yukon-Charley Rivers National Preserve, have been identified by the NPS as an important vital sign in the Central Alaska Network vital signs monitoring program (CAKN). In fact, a raptor species is being monitored in each network park because they are a top trophic-level predator and changes in their status could be indicative of ecosystem changes. Because we can access some eyrie sites for peregrines, we can also monitor the presence of persistent bioaccumulative contaminants in feathers and eggshells (*MacCluskie et al. 2005*). The fact that the upper Yukon River study area was identified as one of two index areas for Alaska in the national Monitoring Plan for the American Peregrine Falcon (*USFWS 2003*) is an additional benefit in that the data are relevant not only to the park, but also to a sister agency.

The objectives for the CAKN American peregrine falcon monitoring program in the upper Yukon River study area are to: 1) Determine annual levels and variation over the previous decade of nesting territory occupancy, nesting success, and overall population productivity; 2) Describe historic levels of environmental contaminants and eggshell thickness; 3) Determine levels of organochlorine pesticides, mercury and eggshell thickness every five years; and 4) Measure changes in habitat on the breeding range.

We accomplish these objectives by conducting two surveys along the Yukon River each year. The first survey is conducted in late May/early June and determines which territories are occupied. The second survey in late June/early July provides data on success of eyries and, if

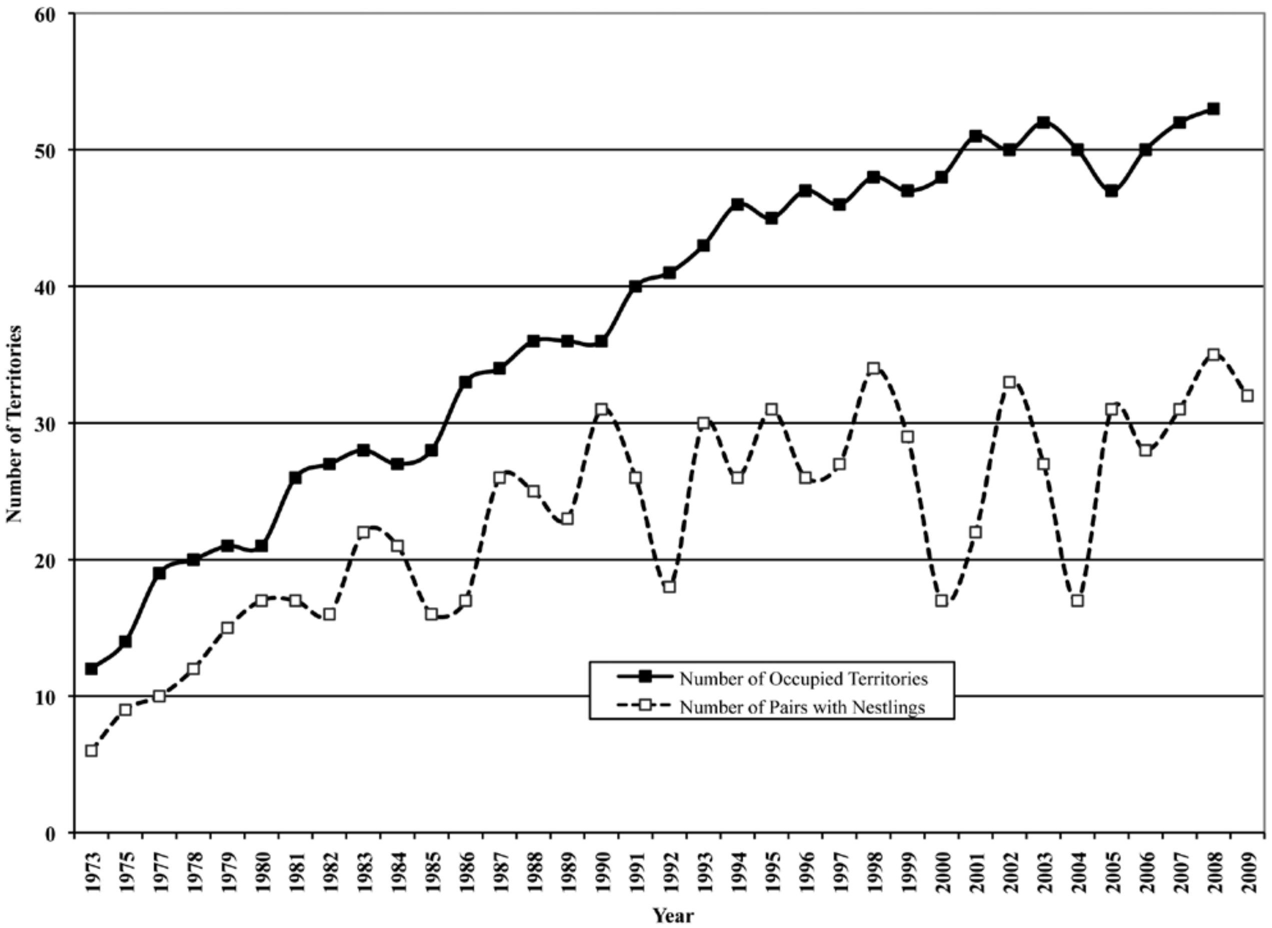

Figure 1. The number of occupied and successful (≥ 1 nestling) territories of American peregrine falcons along the upper Yukon River in Yukon-Charley Rivers National Preserve has steadily increased from 1973-2009. In 2004, only 39 of the 52 pairs were checked for breeding success and productivity due to smoke from large forest fires.

applicable, how many chicks are produced. Additionally, we collect samples from unhatched eggs and shed adult and nestling feathers for contaminants analyses during the second survey. We work cooperatively with the U.S. Fish and Wildlife Service (FWS) to have these samples analyzed for contaminants. Samples from nestling feathers indicate contaminants exposure on the breeding grounds while samples from adult feathers and unhatched eggs indicate contaminants exposure on the wintering grounds and/or migration routes.

The American peregrine falcon population breeding in the upper Yukon River valley is believed to be one of the best studied populations in North America. Over 36 years of data have documented the population's recovery from 11 pairs in 1973 (*Ritchie 1976*) to a record high 53 pairs in 2009 (*Ambrose et al. in prep*). The number of total pairs nesting along the up-

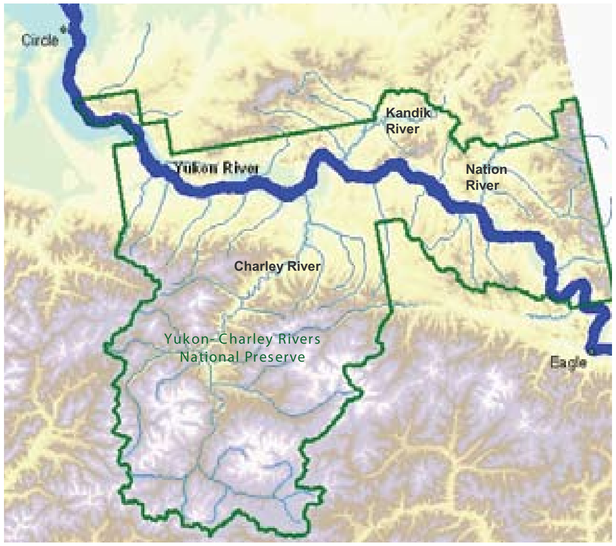

Figure 2. The Upper Yukon River American peregrine falcon study area includes all available habitat within 0.6 miles (1.0 km) of the section of the Yukon River between the Alaska - Yukon Territory border and Circle, Alaska. Yukon-Charley Rivers National Preserve is outlined in green.

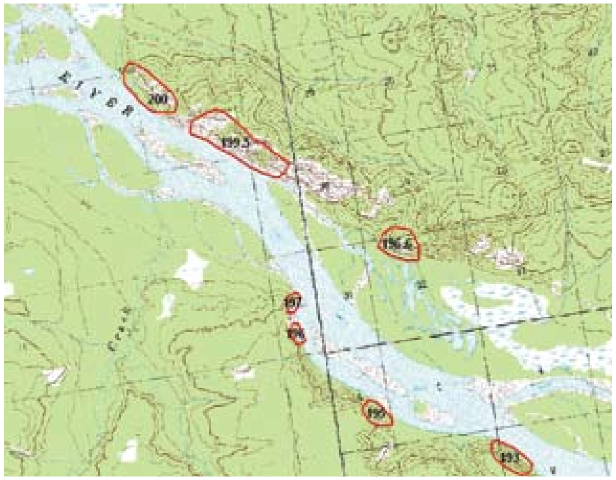

Figure 3. The locations of some of the American peregrine falcon territories along the upper Yukon River study area in Yukon-Charley Rivers National Preserve are shown here outlined in red. The photograph of territory numbers YUKO 195.5, YUKO 196.0, YUKO 197.0 and YUKO 199.5 show what the bluffs look like from the Yukon River.


NPS photograph by Skip Ambrose

Figure 4. Three American peregrine falcon nestlings huddle together as they wait for their parents to return to the eyrie with food. This eyrie is located in Yukon-Charley Rivers National Preserve.


NPS photograph by Skip Ambrose

Figure 5. Biologists Chris Florian (right) and Melanie Flamme watch for American peregrine falcon nestlings in an eyrie along the upper Yukon River in July of 2009.


NPS photograph by Skip Ambrose

Figure 6. A female American peregrine falcon keeps a close eye on biologists visiting her nestlings to collect contaminants and genetics samples; July of 2009 along the upper Yukon River.

per Yukon River has been steadily increasing, although the percentage of total pairs nesting successfully has been declining (*Figure 1*). This may be attributable to increased competition for resources due to increased density and birds moving into sub-optimal territories (i.e. territories with insufficient resources and cover from predators). Further monitoring is necessary to understand the natural variation of a "healthy" American peregrine falcon population, which will allow us to later detect population change that is beyond normal limits of variation.

One important aspect of the American peregrine falcon population in Yukon-Charley Rivers National Preserve is that nest manipulations, captive breeding programs, releases and take for harvest have never occurred. In all other populations in the Lower 48 states, there have been influences by these manipulations and captive-breed releases. Hence, the upper Yukon River population is unique as one where the recovery has been completely natural and well studied.

Surveys for American peregrine falcons along the upper Yukon River (between Circle, Alaska, and the Alaska-Yukon Territory border) have been conducted annually since 1973 by now retired FWS biologist Skip Ambrose (*Payer 2001*). He collected most of the data (over 95%) in the current data set and has expertise and intimate knowledge of the study area and the raptors. The CAKN has been working with Mr. Ambrose to train NPS biologists in the survey methodology and to compile all the historical data into a database that includes photographs of eyrie sites, notes, territories and production data. Additionally, annual reports on the status of the population are produced and are available to the public on the CAKN website (http://science.nature.nps.gov/im/units/cakn/reportpubs.cfm).

Due to their near extinction and subsequent recovery following the DDT ban throughout their breeding range, peregrine falcons have become a public symbol for conservation, and specifically for Yukon-Charley Rivers National Preserve. Nesting peregrine falcons are one of the top visitor attractions in the preserve, and there is strong public support for their protection and the monitoring program. Through the love of and interest in peregrine falcons, program staff gain support to protect the entire system of which falcons are a part. It is important that we continue to work for this support by providing species information throughout the preserves, as well as educational programs to support their conservation.

NPS photograph by Chris Florian

Figure 7. A photograph of a bluff demonstrating an American peregrine falcon territory in Yukon-Charley Rivers National Preserve. The map shows the relative location of this territory to others along the upper Yukon River (outlined in red).

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Shallow Lakes – Microcosms of Change

By Amy Larsen

When people think of Alaska parks they rarely think of the large flat expanses of land that predominate in much of the state. Wetlands occupy almost half of Alaska, including much of the state's public lands. These large expanses of wetlands provide habitat for moose to feed on new willow growth, for birds to nest and for beaver and muskrat to build lodges. Yet, it is in these largely pristine systems where scientists are seeing the first signs of climate change. These changes appear to be related to global warming, and scientists predict that these systems will show some of the greatest impacts of climate change. In the Central Alaska Network (CAKN), over 25,000 shallow lakes and ponds (lakes <16ft/5m deep) are distributed across the landscape, so these systems are an ideal context to monitor environmental change.

Because the wetlands in CAKN are relatively free of direct human modification like human sewage or industrial effluent, we have designed a unique monitoring program that has four basic elements: 1) traditional measures of the physical and chemical properties of water, 2) water quantity, 3) physical structure of shallow lakes, and 4) internal biological assessments including vegetation and macroinvertebrates.

Data from our monitoring in Denali National Park and Preserve (DENA) has already yielded interesting results. Water level in lakes in DENA declined 6 inches (16 cm) on average between 2006 and 2007, however some lakes dropped as much as 42 inches (107 cm). When we compared aerial photographs taken in 1980 with satellite images from 2007, we detected large differences large differences in lake surface area. In the first area (Minchumina basin), lakes did not change from 1980 to 2007. However in the other area (Eolian lowlands) a dramatic 26% of the lakes had shrunk in 27 years. Another 19% had dried from lakes to become wet meadows. We believe the explanation for this is the soil surrounding the lakes. In the Minchumina basin, lakes are enveloped by frozen ground that stops water from draining out of the lake, and the ground is insulated by a thick organic layer that protects the permafrost from melting. Lakes in the Eolian lowlands are surrounded by sandy soils that water percolates through. If a warming climate causes frozen soils to melt, we expect to see lake level changes in the Minchumina basin in the future.

One of the next steps we are undertaking is to take sediment cores from lakes to see how lake levels have fluctuated over the past 8,000 years. At present it is not known if lakes have dried and recovered in shorter time periods (e.g. 50 years). When we compared aerial photographs taken in 1980 with satellite images from 2007, we detected large differences in lake surface area. This, in turn, will help park managers determine what management actions are most appropriate for parks.

NPS photograph by Heidi Kristenson

Figure 1. Vegetation transects along a lake shoreline in Wrangell-St. Elias National Park and Preserve. CAKN staff monitor changes in lake level, vegetation and macroinvertebrates along these transects.

Timing is Everything – Monitoring Plant Phenology in the Central Alaska Network

By Carl Roland

The timing of biological events in the far north are often strictly controlled by physical factors associated with climate because of extreme temperature changes during the year. This means that our changing climate will have far-reaching and profound effects on species living in the north. The timing of recurring biological events, or phenology, affects how well plants and animals reproduce. It is also a measure scientists can use to track climate change and its effects. As a result, we have incorporated measures of plant phenology as an important component of our long term vegetation monitoring program.

The growing season is relatively short in central Alaska. It begins when the sun rises high enough in the sky to warm the air sufficiently to melt the snowpack, which allows soils to thaw so that plants can take up water and nutrients. Alpine areas often melt later, delaying spring onset. The growing season ends when day-length and temperature dwindles in the fall and freezing temperatures become a daily occurrence. However, wetland sites may experience plant growth later in the year because wet soils store heat and there is a reduced influence of late summer drought.

We began monitoring yearly phenology of aspen (*Populus tremuloides*) in Denali National Park and Preserve in 2005. In 2008 we included sites at Eagle on the Yukon River and at Copper Center in southcentral Alaska (*Figure 1*). Our methodology uses park staff to collect the data, and sampling plots are located close to visitor centers at each park so visitors can assist with data collection. Our goal is to detect changes in the timing of key events in the life cycle of aspen in relation to climate. We chose aspen because it is widely distributed and monitored in other national and international phenology networks. This means our results may be examined in regional, continental and global contexts. Because it is likely that the phenology of aspen is similar to many others, this data will provide insight on an important ecosystem attribute applicable to many species. Over time, these data will allow us, for example, to compare broad trends in "average" phenology like the date at which 100% of the trees at Denali Park, Eagle and Copper Center have experienced bud burst (*Figure 2*).

At present we have five years of data from Denali and two years from Eagle and Copper Center. We are already learning that phenology of aspen trees is different among the three sampling sites, and this reflects the different climate the trees experience (*Figure 2*). We are excited by these results because they confirm our initial assessment that aspen was an appropriate species to use for tracking the response of plants to climate change. We invite interested people from across Alaska to take part in this program by setting up an aspen phenology plot in your community. To do so, please contact Carl Roland carl_roland@nps.gov for more details.

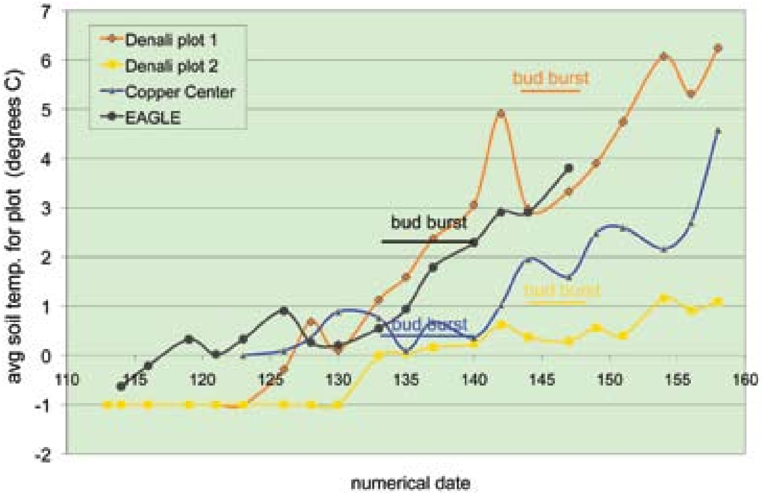


Figure 1. Map of southcentral and eastern interior Alaska showing the locations where aspen phenology observations are recorded for the Central Alaska Network program. Phenology monitoring stations are shown in blue.

Figure 2. Graph showing the mean soil temperatures recorded at four aspen phenology monitoring plots during the early season of 2008 (including the period April 22 through May 31). The horizontal lines show the approximate period for bud burst of aspen trees in these plots, spanning the date of first bud bust until leaves are unfurled in 100% of trees in plot.

The Southeast Alaska Network

Vital signs of the Southeast Alaska Network

Monitoring Framework	Vital Sign	Parks Where Monitored		
		GLBA	KLGO	SITK
Air and Climate	Airborne Contaminants	●	●	●
	Visibility and Particulate Matter	+	+	+
	Weather and Climate	●	●	+
Geology and Soils (Geomorphology and Hydrology)	Glacier Dynamics	●	●	
	Streamflow	●	●	●
	Oceanography	●		
Water	Freshwater Benthic Macroinvertebrates and Algae	+	+	○
	Freshwater Water Quality	●	●	●
	Freshwater Contaminants	●	●	●
	Marine Contaminants	●	○	●
Biological Integrity	Invasive/Exotic Animals	+	+	+
	Invasive/Exotic Plants	○	○	○
	Pests and Diseases	+	+	+
	Bald Eagles	+	+	+
	Bears	+	+	+
	Biodiversity of Select Groups	+	+	+
	Breeding Land Birds Assemblages	+	+	+
	Forage Fishes	+	+	
	Harbor Seals	+		
	Intertidal Communities	+	+	●
	Killer Whales	+		
	Marine Predators	●		
	Kittlitz's Murrelets	●		
	Salmonids	+	+	+
	Ungulates	+		
	Western Toads	+	○	
	Wetland Communities	+	+	+
	Humpback Whales	○		
	Steller Sea Lions	+		
Human Use	Consumptive Uses	+	+	+
	Human Uses and Modes of Access	○	○	○
	Airborne Sounds	+	+	+
	Underwater Sound	○		
Landscape	Landform and Landcover	●	●	●
	Phenology	+	+	+
	Plant Communities	+	+	+

● Vital signs for which the network will develop protocols and implement monitoring with funding from the vital signs or water quality monitoring program.

○ Vital signs that are currently being monitored long-term by a network park, another NPS program, or by another federal or state agency. The network will collaborate with these other monitoring efforts where appropriate but will not use vital signs or water quality monitoring program funds.

+ Vital signs for which monitoring will likely be done in the future but which cannot currently be implemented due to limited staff and funding.

NPS photograph by Brendan Moynahan

By Brendan Moynahan

The Southeast Alaska Network (SEAN) comprises Glacier Bay National Park and Preserve (GLBA), Klondike Gold Rush National Historical Park (KLGO), and Sitka National Historical Park (SITK). These units collectively encompass 3.3 million acres of diverse resources including tidewater glaciers, temperate coastal rainforest, recently deglaciated transitional landscapes, nearshore and offshore marine habitat, intertidal zones, continental subalpine and alpine zones, and a variety of freshwater resources, including streams, lakes, and ponds. GLBA includes over 2.6 million acres of marine and terrestrial wilderness, the largest marine area managed by the NPS, and close to one-quarter of all NPS coastline – nearly 1,200 miles (1,930 km). KLGO and SITK protect important cultural landscapes that overlay significant ecological resources, which themselves maintain communities' sense of history and place, to the point that cultural and natural properties are indistinguishable.

Close to the Gulf of Alaska and embedded in the maritime passages of the Alexander Archipelago, SEAN parks are profoundly influenced by two key element features: water and dynamism. SITK receives an average of nearly 100 inches (254 cm) of precipitation each year and protects the mouth of the Indian River, an important salmon stream. Coastal and ocean processes in GLBA drive tremendously productive marine systems and deliver over 30 feet (9 m) – yes, feet – of precipitation to the higher elevations of the Fairweather Range. KLGO is considerably drier (about 25 inches/64 cm annually) and contains unique, rich linkages between maritime and interior ecosystems; it is continually shaped and reshaped by the Taiya and Skagway rivers. Water – as humidity, mist, rain, snow, glaciers, icefields, icebergs, rivers, estuaries, bays, and the open ocean – drive both dramatic and subtle patterns and processes in plants, wildlife, climate, and landform. And at all scales, SEAN's dynamic ecosystems both exhibit and respond to the effects of ecological transition. The interplay between disturbance and response are spectacularly showcased along the length of Glacier Bay proper. KLGO protects human and natural histories that teach us about both sensitivity and resilience. The Indian River in SITK teaches us about connections between terrestrial, estuarine, intertidal, and submerged ecosystems, and the cultural richness woven within them.

In meeting the challenge of working effectively across these transitions and scales, SEAN staff has chosen to focus primarily on monitoring a few critical species and community level subjects (we refer to them as "response" vital signs), and a somewhat broader set of key ecological processes or drivers (i.e., "covariate" vital signs). Response vital signs include Kittlitz's murrelets, marine predators, western toads, and intertidal communities. Weather and climate, oceanography, freshwater water quality, and several contaminants projects are examples of covariate vital signs. By taking this approach, we ensure that the network will provide resource stewards with information on key resources, communities, and park features, while also providing internal and external managers and investigators with high-quality, longterm data and reports on the most fundamental ecological processes that drive park resources.

Figure 1. Stellar sea lions in Glacier Bay.

Driving the Marine Ecosystem: Oceanography as a Key Long-term Monitoring Vital Sign at Glacier Bay National Park and Preserve

By Lewis Sharman

Glacier Bay National Park and Preserve is one of the most fundamentally "marine" parks in the national park system. It is certainly one of the largest, with 1,200 miles (1,930 km) of coastline encompassing nearly 600,000 acres of federally protected marine waters, including submerged lands. Virtually everything about the park, even those terrestrial and freshwater ecosystem components centered well inland, has some critical connection to the sea (*Figure 1*). For example, almost every species of bird and mammal in the park – even alpine birds and mountain goats – has been observed foraging in the marine intertidal zone. Similarly, marine materials and energy are well known contributors to terrestrial freshwater and adjacent riparian ecosystems (*Gende et al. 2002*).

Why Oceanography?

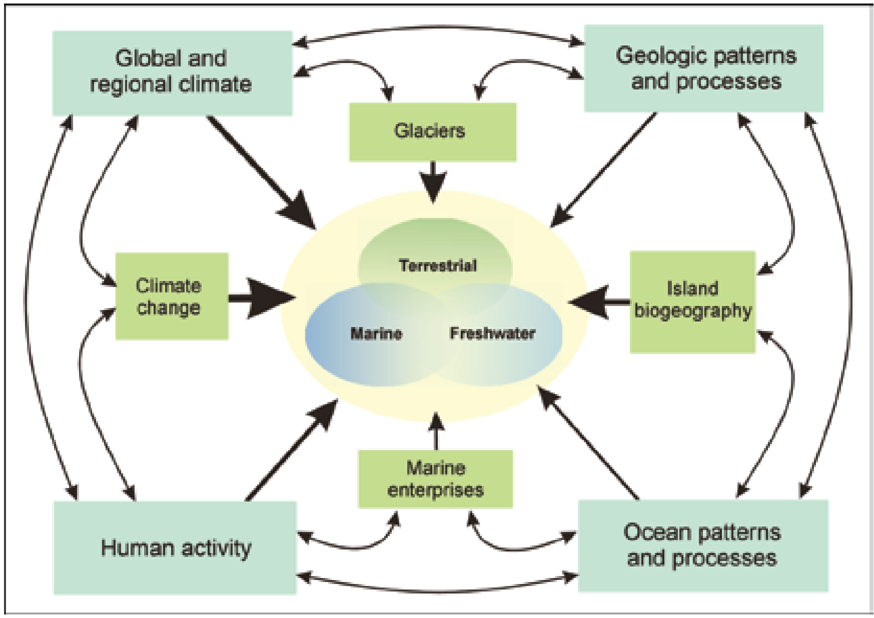
In order to fully appreciate how park ecosystems work, and thereby how to protect them, one must understand Glacier Bay itself. A dynamic glacial fjord of considerable physical and biological complexity, the bay is highly productive. This productivity is manifest in the high abundance and diversity of animals and plants throughout the park's marine waters (*Figure 3*). The biota includes all trophic levels, from microscopic phytoplankton primary producers, to apex predators such as killer whales. Members of the marine fauna range from resident sessile invertebrates (e.g., barnacles, sea anemones, sponges) to seasonally migratory vertebrates, many of them large and highly charismatic Glacier Bay "signature species" (e.g., harbor seals, puffins, humpback whales).

Glacier Bay owes its high biological diversity and abundance to the marine production cycle, a phenomenon that is reasonably well understood for glacial fjords (*Syvitski et al. 1987*). The generalized model describes a seasonal pattern of vertically well-mixed waters in winter with high nutrients but low light available for photosynthesis. As air temperature and daylength increase in the spring, freshwater runoff from land to sea increases, enhancing surface stratification and providing light levels sufficient to initiate a "bloom" of phytoplankton. Intermediate levels of vertical mixing by Glacier Bay's large tides continually re-inject nutrients into the sunlit surface waters, perpetuating bloom conditions throughout the summer and into the fall, even as threshold levels of surface water column stability are maintained (*Etherington et al. 2007*). Finally, the system reverts to the winter condition, and biological production diminishes as light levels decline and winds break down vertical stratification as colder temperatures decrease freshwater input from the land.

The fundamental key to creating and maintaining bloom conditions is bringing (and keeping) nutrients and light together. The importance of this very basic ecosystem process cannot be overemphasized, because it powers biological productivity that translates into everything from sea lions to spruce forests. Indeed, it can be argued that the annual sustained spring/summer phytoplankton bloom is the single most significant biological event in the park. At its core, this process is largely mediated by water column dynamics – how water (and the materials, energy, and information contained within it) moves. This is described by oceanography. Consequently, understanding the oceanographic factors (e.g., water temperature, salinity, availability of light for photosynthesis) that ultimately control marine productivity, and thereby influence the entire park, is critical to wise stewardship.

It is not enough simply to describe oceanographic conditions as snapshots in time, because Glacier Bay's picture is continually changing. Not only does the bay experience the substantial seasonal variations described above, it is still responding to a catastrophic retreat of its tidewater glaciers that began some 250 years ago. These changes are reflected in strong gradients in virtually all oceanographic parameters as they vary in proximity to tidewater glacier faces, the heads of turbid outwash fjords, sources of freshwater input, etc., all of which are still changing. Managers today must place these dynamics in the larger context of regional and global climate change, which raises important concerns

Figure 1. Oblique three-dimensional LandSat image of Glacier Bay.



Courtesy of Moynahan and Johnson 2008

Figure 2. Ocean patterns and processes strongly influence terrestrial and freshwater, as well as marine, ecosystems in Glacier Bay.

such as ocean acidification and sea level rise. It is imperative to monitor the long-term trends in oceanographic parameters, thus the decision by the Southeast Alaska Network (SEAN) to identify Glacier Bay oceanography as a key vital sign. This program is providing an informational context for managers to interpret and respond to long-term changes that are currently and will continue to affect Glacier Bay National Park and Preserve – how we understand it, adapt to it, and protect it.

The Long-term Monitoring Protocol

The objectives of the SEAN oceanographic monitoring program are to document interannual and seasonal variation in physical oceanographic conditions in Glacier Bay. These observations provide a baseline dataset that can be used by researchers to understand spatial and temporal variation in biological productivity, thereby contributing to informed park management.

We collect very accurate and precise measurements of water temperature, conductivity (salinity), light, turbidity, dissolved oxygen, and fluorescence (an index of chlorophyll-a concentration and thus phytoplankton abundance/primary production). These measurements are captured by an array of sensors mounted together in an instrument cluster (*Figure 4*) called a CTD (for Conductivity/Temperature/Depth). A pressure sensor keeps track of depth as the CTD is lowered through the entire water column at a rate on 1 m/second from the surface to just above the bottom. Parameters are measured twice per second, and the data from each "cast" is stored in the CTD and downloaded later. Together these measurements yield a vertical profile of important water column characteristics.

There are 22 standard oceanographic "stations" located mid-channel throughout Glacier Bay (*Figure 5*) where sampling is conducted on a regular schedule. Seven of the stations are sampled monthly, from March through October, to describe seasonal variation during times of the strongest physical structure and highest productivity and dynamism. Twice a year, in July and December/January, we sample all 22 stations to detect annual or longer signals. This design achieves a balance between intensive temporal sampling to resolve seasonal signals, and intensive spatial sampling to resolve annual signals and reveal long-term trends.

Raw data for all parameters are processed and verified following each sampling trip. Data from the previous year are summarized and plotted in an annual winter report that focuses on seasonal patterns. Five-year reports carefully analyze data for annual and longer patterns and trends.

Making the Data Available

The program places a high priority on providing information access. SEAN actively disseminates oceanographic data products, along with the comprehensive detailed protocol, via the SEAN (http://science.nature.nps.gov/im/

NPS photograph

Figure 3. Highly productive kelp forests provide shelter for a wide variety of species within Glacier Bay and adjacent marine waters.

NPS photograph

Figure 4. The CTD ready to be deployed at an oceanographic station.

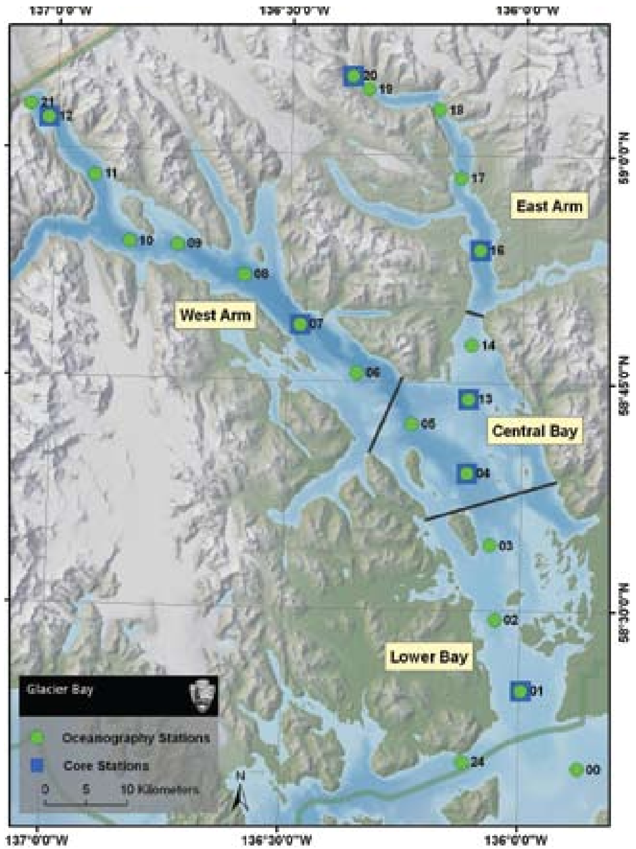


Figure 5. Current oceanographic sampling stations in Glacier Bay. Shaded bathymetry indicates relative water depth (darker means deeper). Station depth ranges from 174 ft (53 m) at Station 00 to 1,427 ft (435 m) at Station 07.

units/sean/OC_Main.aspx) and partner web sites. Subordinate linked pages provide access to formal metadata, references to relevant published and gray literature, etc. Interested parties can also search "Southeast Alaska Network" and access the information via the oceanography page.

Findings So Far

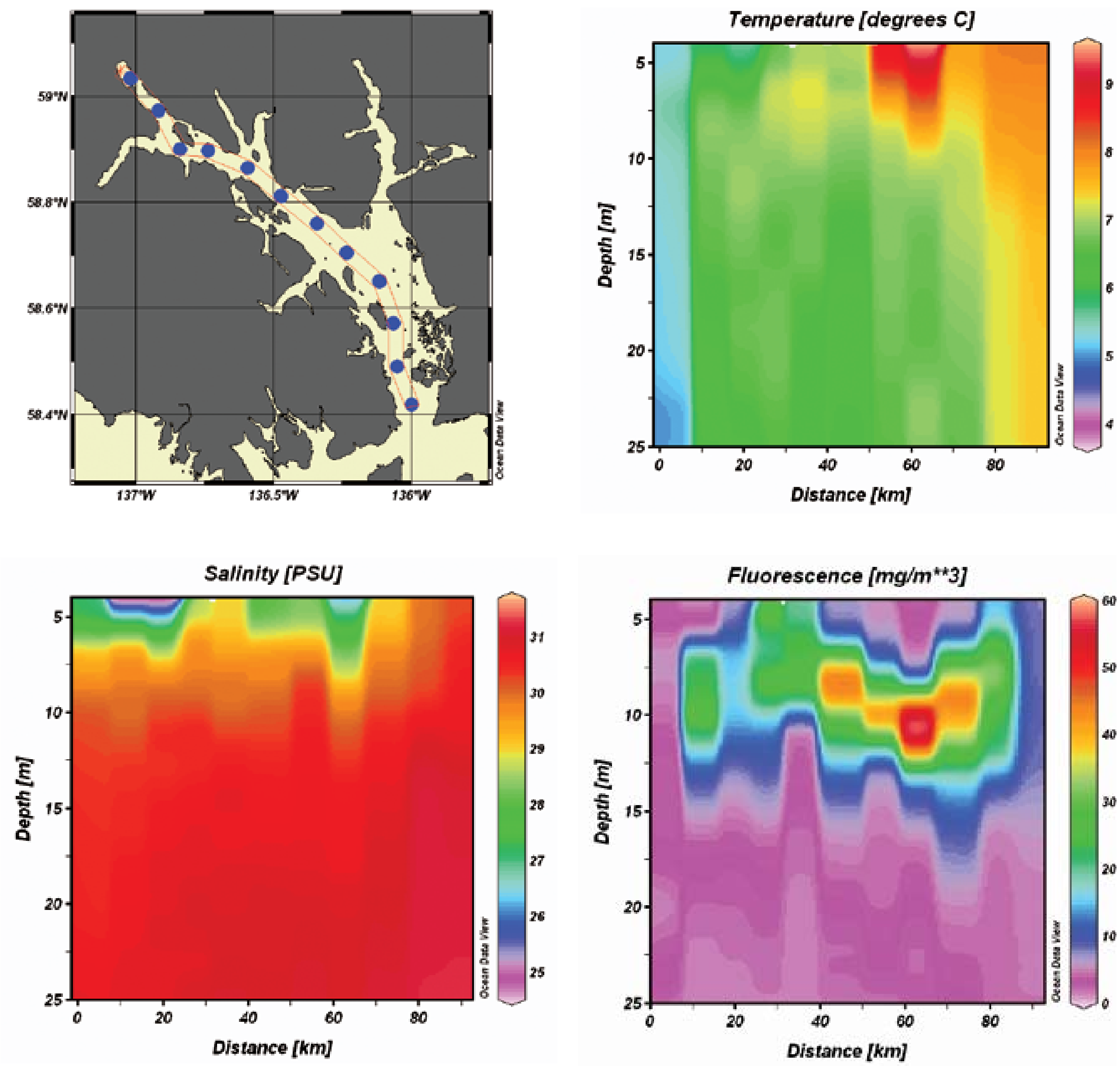
The SEAN is fortunate to be able to sustain a robust oceanographic dataset that was initiated in 1993. Etherington et al. (*2007*) summarized observations from the first ten years (1993-2002). The most interesting results highlighted not only the importance of water column stability to productivity, but that stability is influenced by strong competing forces in Glacier Bay. While high-energy tidal currents at the main entrance enhance vertical mixing in the lower bay, the upper arms are characterized by strong water column stratification that is maintained through much of the year, likely due to high freshwater input. In the central region of the bay where these two processes meet, observed high and sustained chlorophyll-a levels may be due to optimal surface conditions of intermediate stratification, potential nutrient renewal from depth, and decreased suspended sediment levels and thus more light available for photosynthesis (*Figure 6*).

To date we cannot confidently conclude that significant annual changes have occurred since monitoring began. However, we are hopeful that the upcoming summary report (expected in 2010) covering the years 2003 to the present (and adding the previous ten years of data) will be able to determine whether the current comprehensive 16-year dataset is sufficient to detect any long-term temporal changes or trends in measured oceanographic parameters.

The Future

The Glacier Bay long-term oceanographic monitoring program aims to provide data that will inform process studies. For example, important outstanding questions include the source of nutrients to power intense bloom events in the extreme upper arms of fjords. Similarly, accumulating oceanographic data should help managers understand and perhaps even predict patterns of distribution and abundance of forage fishes and the marine vertebrate predators that subsist on them. In direct response to emerging concerns related to climate change, the SEAN is currently collaborating with partners on a proposal to add ocean acidification measures to the existing long-term monitoring protocol. In addition, we hope to geographically expand the program beyond Glacier Bay proper to waters of the park's exposed outer coast.

As described above, ocean dynamics are key to the health of populations and communities across park ecosystems. The SEAN will integrate oceanographic data with those generated from other ongoing vital signs monitoring (e.g., weather/climate, marine contaminants) to improve our understanding of the spatial and temporal dynamics of additional target vital signs (Kittlitz's murrelets, marine predators). In a rapidly changing world, the ultimate goal



Visualizations produced using Ocean Data View software

Figure 6 (a-d). Length-of-Bay transect through the West Arm (a), showing spring/summer patterns of water temperature (b) and salinity (c) with depth in the upper 82 ft (25 m). How rapidly these two parameters change with depth correlates positively with degree of water column stratification. Fluorescence (d) is a proxy for phytoplankton abundance and thus amount of primary productivity. Note that an intermediate level of stratification in the central portion of the transect sustains the highest overall level of fluorescence. Data are from monthly surveys March-August 2009.

of the oceanographic monitoring program is to enhance the ability of managers to preserve Glacier Bay's remarkable and increasingly precious resources.

Acknowledgements

The long-term dataset underpinning Glacier Bay's oceanographic monitoring program owes its beginnings and maintenance to the vision of Philip Hooge, Lisa Etherington, and a host of USGS and NPS staff at the park. Thanks also to Brendan Moynahan, Bill Johnson, and Seth Danielson for driving development of the program's current protocol. This article benefitted from the thoughtful comments of Brendan Moynahan and Robert Winfree.

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Indian River Stream Gauge Monitoring

By Geoffrey Smith

Flowing through Sitka National Historical Park (SITK), the Indian River is an important natural resource for the park and for the local community. The river is a biologically rich environment that supports a variety of aquatic resources, including three species of Pacific salmon. The upper Indian River basin is protected in the Tongass National Forest, but intensive suburban development has occurred between the forest and the park. In addition, two diversion structures extract water from the river. A local college maintains the largest diversion, which can take up to 30 cubic feet per second (cfs), to operate a fish hatchery. There is concern that water extraction of this magnitude may harm components of the Indian River aquatic ecosystem.

The NPS responsibility is stated in the park General Management Plan: to "insure that ecological processes and conditions associated with the Indian River…are protected" and "maintain water quality and minimum streamflows needed to sustain the dependent biota of the Indian River, particularly native fish populations" (http://www.nps.gov/sitk/parkmgmt/planning.htm). It follows that the primary objective for monitoring Indian River stream flow is to quantify instream flow in the Indian River and to make the data available to those charged with maintaining streamflows and protecting anadromous fish spawning, incubation, and rearing.

Historically, the U.S. Geological Survey (USGS) maintained two Indian River stream gauges. The upper gauge was in the forest above all diversion structures. The second gauge was located just outside the park boundary and below all suburban development and diversion structures. When the USGS discontinued operation of these gauges in 2007, the park entered into a partnership with the City and Borough of Sitka (CBS) and Alaska Department of Fish and Game (ADF&G) to replace both gauges to meet our monitoring objective. ADF&G reestablished streamflow gauge devices near the original sites during the spring of 2007. SEAN, CSB, and ADF&G contributed funds to hire a contractor to process gauge data and to maintain gauge quality control. Data from the gauges has been revealing; in August 2007, as salmon were entering the river to spawn, water diversions between the upper and lower gauges took 50% of the river's volume 26% of the time. That month, zero days reached ADF&G's recommended instream flow for spawning salmon in the Indian River. Diversions dropped the river volume below the ADF&G recommendation (61 cfs) 65% of the time in the first 23 days of August 2008. With the gauges in place, park managers now have solid information to share with stakeholders and to ultimately identify a stronger strategy to protect the Indian River ecosystem.


NPS photograph by Geoffrey Smith

Figure 1. Pink salmon running in the Indian River in the park.


NPS photograph by Geoffrey Smith

Figure 2. The water diversion system in the Indian River, upstream from the park.


NPS photograph by Geoffrey Smith

Figure 3. Low water and dead salmon in Sitka National Historical Park's Indian River.

A Hotspot of Lichen Diversity - Klondike Gold Rush National Historical Park

By Toby Spribille and David Schirokauer

Throughout the world, biological inventories occasionally reveal areas where undescribed species come to light, sometimes several at a time. These hotspots of biodiversity, often discovered in dense, remote, tropical rain forests, are hailed as landmark discoveries. But we seldom think of such undiscovered treasures as occurring in the temperate and boreal environments of North America. The 2007-2008 lichen inventory at Klondike Gold Rush National Historical Park deals not with a 'lost forest' but with a well traversed area made famous during the Klondike Gold Rush of 1898-1899. In the park's first intensive lichen inventory, at least 766 taxa of lichenized and lichenicolous fungi were detected. In an area of only 13,000 acres, this represents one of the largest numbers of lichens per unit area ever reported and the largest number of lichen species reported from any national park.

Klondike Gold Rush NHP is unique among small protected areas in that it harbours a strong and diverse climatic and geographic gradient due to its position on the edge of the North American mainland. The mountain passes provide a strong ecotonal gradient between a maritime and a dry, continental interior ecoregion. Habitats in the park extend from relatively warm intertidal and low elevation mesic coastal forests dominated by Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*), through mid-elevation forests that add mountain hemlock (*Tsuga mertensiana*) to the mix, up to high elevation forests dominated by subalpine fir (*Abies lasiocarpa*). The mountain passes and adjacent peaks contain pockets of alpine tundra surrounded by lichen-dominated talus slopes and bedrock.

At least four lichen species will be described as new to science and further laboratory analysis of specimens is likely to yield additional new finds. One of the most remarkable finds was a new genus and species, which will be called *Steineropsis alaskana*. The new genus bears similarity to the genus *Steinera* found in New Zealand and represents one of the most significant new finds in western North America macrolichens in many years. Another new macrolichen will be described in the genus *Stereocaulon* and named after the National Park, as *Sterocaulon klondikense*. Two crustose lichen species, in the genera *Coccotrema* and *Pertusaria*, are new species growing on conifer trunks and twigs. One of them, *Coccotrema hahriae*, is being named for the park's former Natural Resource Manager Meg Hahr, who recently passed away, while the other, *Pertusaria mccroryae*, is named after a prominent, recently deceased Canadian conservationist. Both species appear to have strong affinities for old forest stands, and in the park, are found on gnarled trees over rocky, shallow soils. These new species descriptions, along with a checklist, will appear in an upcoming issue of *The Bryologist* and in a check-list of Alaska lichens to be published in collaboration with other lichenologists from the region in late 2010/2011.

NPS photograph

NPS photograph by Dave Schirokauer

Figure 1. (Top) Toby Spribille searches for rare lichens on a rock outcrop near the Chilkoot Trail, Klondike Gold Rush NHP.

Figure 2. (Left) *Coccotrema hahriae* is a new species of epiphytic lichen described from Klondike Gold Rush. It is named after a former Natural Resource Program Manager, Meg Hahr, who passed away unexpectedly in 2009.

The Southwest Alaska Network

Vital signs of the Southwest Alaska Network

Monitoring Framework	Vital Sign	Parks Where Monitored				
		ALAG	ANIA	KATM	KEFJ	LACL
Air and Climate	Visibility and Particulate Matter		○	●		○
	Weather and Climate			●	●	●
Geology and Soils	Glacier Extent			●	●	●
	Geomorphic Coastal Change		+	+	●	●
	Volcanic and Earthquake Activity	○	○	○	○	○
Water	Freshwater Chemistry	●	●	●	●	●
	Surface Water Hydrology	●	●	●	●	●
	Marine Water Chemistry			●	●	●
Biological Integrity	Invasive/Exotic Species	○	○	○	○	○
	Insect Outbreaks	○		○	○	○
	Kelp and Seagrasses			●	●	●
	Marine Intertidal Invertebrates			●	●	●
	Resident Lake Fish			●		●
	Salmon	○		○		○
	Black Oystercatcher			●	●	
	Marine Birds			●	●	●
	Bald Eagle	+	+	+	●	○
	Brown Bear	+	+	●		●
	Wolf	+		+		+
	Moose			●		●
	Sea Otter			●	●	
	Caribou			○		○
	Harbor Seal			○	○	○
	Vegetation Composition and Structure	●	●	●	●	●
	Sensitive Vegetation Communities			●	●	●
Human Use	Consumptive use	○	○	○		○
	Visitor Use	○	○	○	○	○
Landscapes	Land Cover	●	●	●	●	●
	Landscape Processes	●	●	●	●	●

● Vital signs for which the network will develop protocols and implement monitoring with funding from the vital signs or water quality monitoring program.

○ Vital signs that are currently being monitored long-term by a network park, another NPS program, or by another federal or state agency. The network will collaborate with these other monitoring efforts where appropriate but will not use vital signs or water quality monitoring program funds.

+ Vital signs for which monitoring will likely be done in the future but which cannot currently be implemented due to limited staff and funding.

NPS photograph

Figure 1. Erik Beever (USGS) sampling the soft sediment intertidal for bivalves in Katmai National Park and Preserve in July 2009.

By Michael Shephard

The Southwest Alaska Network (SWAN) consists of five park units: Alagnak Wild River, Aniakchak National Monument and Preserve, Lake Clark National Park and Preserve, Katmai National Park and Preserve, and Kenai Fjords National Park. These units comprise 9.4 million acres or 11.6% of the total land area managed by the National Park Service. SWAN is approximately the size of Maryland and Delaware combined.

SWAN parks occur in one of the more geologically active regions in the world. During the great Alaska earthquake of 1964, lands in Kenai Fjords dropped 3 to 6 feet (1-2 m), whereas coastal lands of Lake Clark and Katmai rose by an equivalent amount. Volcanoes (17 active in SWAN units) steam or explode on a decadal scale, dispersing ash and generating mud flows in river valleys. Both Aniakchak and Katmai became park units due to their spectacular volcanic landscapes.

SWAN parks are aligned along the northern Gulf of Alaska, where the climate is dominated by maritime influences. Steep mountains and volcanoes create areas of high precipitation on the windward side of the mountains and rain shadows on the leeward side. These mountains are some of the snowiest places on the planet (3-15 ft/1-4.5 m of annual precipitation) resulting in approximately one-fifth of the landmass of this network being covered in ice or permanent snowfields.

Almost one-quarter of the marine coastline of the NPS (1,200 miles/1,930 km) occurs in this network. The coast ranges from the rocky, convoluted shoreline of Kenai Fjords to the more broad intertidal flats of Lake Clark. The salt marshes, rocky headlands, and intertidal areas provide key food resources to brown and black bears, bald eagles, shorebirds, and marine mammals.

Two of the three largest lakes in the NPS system occur within this network, Naknek Lake and Lake Clark, as well as many other multi-lake systems and thousands of miles of rivers and streams that are integral to nationally and internationally significant salmon runs. The salmon-based ecosystems are a flagship resource of the network.

SWAN has spent four years developing a monitoring program with biologists from each of the park units and other collaborators. The resulting monitoring objectives complement the natural resource work now being conducted in the parks. The network is currently focusing on 21 separate vital signs. Another seven vital signs are being monitored by other agencies. Annual reports, databases, resource briefs, and other summary materials are available on the internet to park staff and others interested in long-term monitoring efforts in the network. SWAN is collaborating with researchers at U.S. Geological Survey and the University of Georgia to use a structured decision making approach for linking monitoring data to management decisions, with sea otters being used as a test case.

Water, Water Everywhere: Large Lake Monitoring in Southwest Alaska National Parks

By Jeff Shearer

> *"These pristine 'great lakes of Alaska' are fountains of pure water and nurseries of the Bristol Bay salmon. They are of incalculable worth to our nation and humanity going forward into an era of global climate change in a more crowded and polluted world. If there ever was a truly strategic commodity in the world, it is pure water, which Bristol Bay has a great abundance."*
> - John Branson, Lake Clark National Park and Preserve historian, in *The Canneries, Cabins and Caches of Bristol Bay, Alaska*

Connections to the Land

Extending out from the western end of the Alaska Range onto the Alaska Peninsula spans a series of massive waterbodies that dominate the landscape. With names like Iliamna, Clark, Kukaklek, Nonvianuk, Naknek, Brooks, Becharof, and Ugashik, these lakes and their connecting rivers generate a network of freshwater that has bound cultures and ecosystems for generations (*Figure 1*).

Bristol Bay salmon, especially sockeye salmon (*Oncorhynchus nerka*), are the life blood flowing through this freshwater network. The role salmon play in transporting critical marine-derived nutrients to freshwater and terrestrial systems across all trophic levels from plants to bears has been well documented (*e.g. Gende et al. 2002, Naiman et al. 2002*). Lakes are an integral part of the pathway for those marine-derived nutrients to spread throughout the landscape.

The connections between salmon and the landscape serve as an important reminder that lakes are not microcosms whose influences stop at the shoreline as early limnologists once thought. Instead, lakes are better described as flow systems comprised of inflowing tributaries, outlets, and interconnected basins functioning as one contiguous system. As such, these systems are integrators of water, energy, nutrients, solutes, and pollutants from the landscape and atmosphere, and thus are ideal indicators of environmental change, especially climate change (*Adrian et al. 2009*).

Sentinels of Change

The physical and chemical composition of lakes are a direct reflection of the surrounding geology and climate. For example, many lakes in Lake Clark National Park and Preserve (LACL) have distinct "U-shaped" valleys reflecting their glacially-carved origins. The Iliuk Arm of Naknek Lake in Katmai National Park and Preserve (KATM) is gray in color due to ash runoff from the nearby Valley of Ten Thousands Smokes. Important processes and phenological events within a lake, such as duration of ice cover, thermal stratification, and water level fluctuations, are all dictated to some extent by the geologic and climatic setting of that lake. These processes, in turn, largely influence the biological productivity of lakes and associated wildlife species (e.g. salmon).

The goal of SWAN's lake monitoring program is to evaluate the long-term trends in water quality and surface hydrology in the large lake systems of KATM and LACL. We are monitoring the chemical and physical parameters of water that ultimately dictate the biological productivity of large lake systems and tracking how those parameters are affected by natural and anthropogenic influences. In an effort to maintain a holistic approach to monitoring these freshwater systems, we will integrate freshwater monitoring data with trends observed in other I&M programs, such as landscape processes (e.g. ice cover), glacial extent, and climate monitoring, to provide a more complete synopsis of changes throughout the watershed and potential implications of those changes on lake system dynamics.

Monitoring Approach

The volume of freshwater in southwestern Alaska parks is extraordinary, covering 12% of KATM's surface area alone. In order to monitor such a vast expanse of water, lakes were prioritized based on accessibility, management priority, and spatial representativeness (e.g. glacial vs. non-glacial waters, anadromous vs. non-anadromous). The majority of SWAN's efforts focus on the Lake Clark/Kontrashibuna and the Naknek/Brooks Lake systems. Naknek Lake and Lake Clark represent the largest and third largest lakes, respectively, in terms of surface area in the national park system.

In these lake systems, we collect a series of standardized measurements of water temperature, pH, dissolved oxygen, specific conductivity, turbidity and hydrology (lake level and lake discharge). We use a variety of instruments to collect these data, such as multiparameter water quality meters, automated data loggers, and temperature thermistors. Conditions in lakes vary in both space and time. We account for spatial variability by collecting data at randomly selected, spatially balanced sites throughout the lake basin (synoptic sites) where measurements are recorded at the water surface and

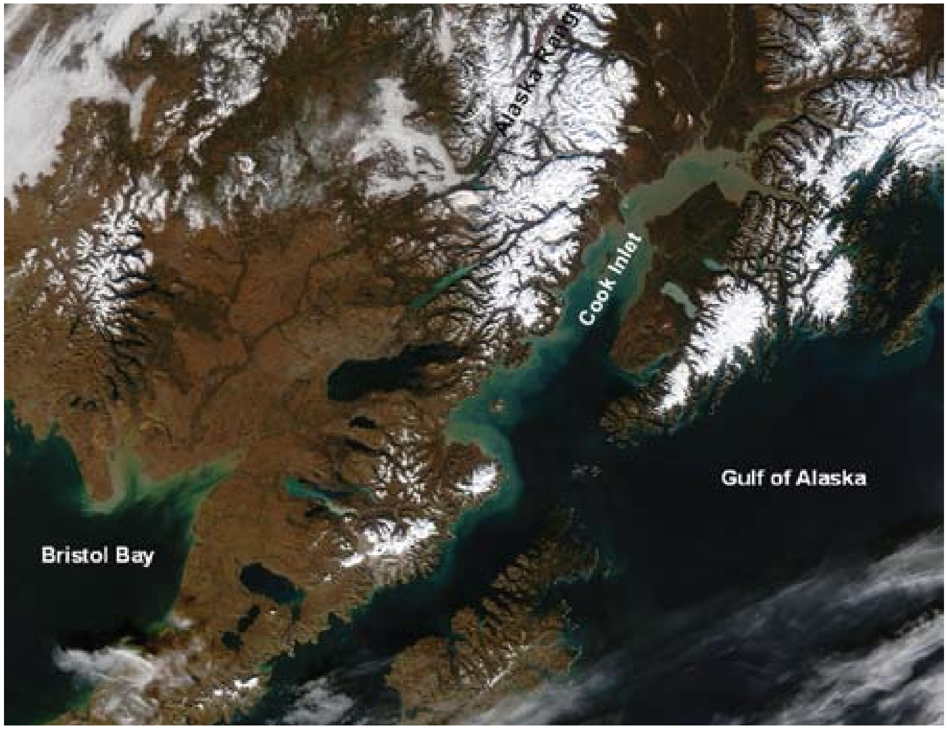

Figure 1. Oblique LandSat image of southwestern Alaska depicting the convergence of marine, mountain, and freshwater systems.

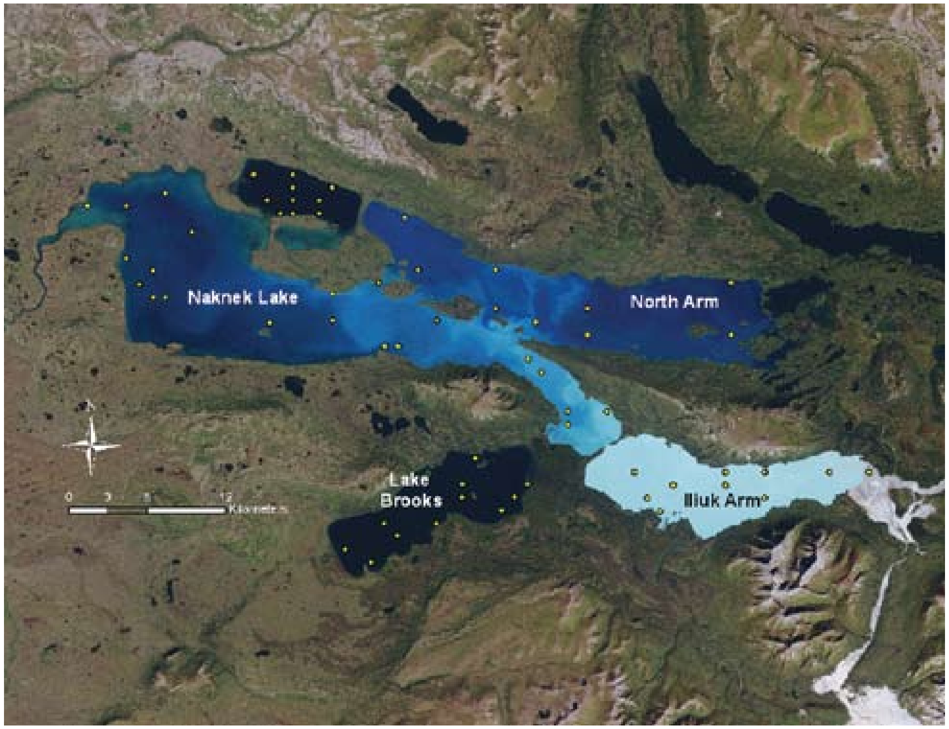

Figure 2. Synoptic sampling sites (yellow dots) for the Naknek/Brooks Lake system. Note the contrast between turbid waters of the Iliuk Arm versus clear waters of the North Arm. Within lake variability illustrates the importance of proper spatial sampling coverage.

at fixed intervals to a depth of 160 feet (50 m) (*Figure 2*).

Temporal variability is assessed by collecting hourly observations at a handful of predetermined sites (continuous deployment sites). Synoptic sites are sampled once per year during the mid-summer index period, whereas continuous deployment sites are monitored year round (within the lakes) or during the open water period (at outlets and inflowing tributaries).

Making Sense of the Data

Monitoring water quality and hydrology, especially through the use of automated data loggers, generates a tremendous volume of data. Appropriate data management procedures are critical to ensure proper archiving, processing, and synthesizing of the information collected. Additionally, SWAN has placed emphasis on making data available to park managers and the public through a variety of avenues, such as summary reports, resource briefs, and the network's website http://science.nature.nps.gov/im/units/swan/

Most freshwater monitoring activities have just started and trend analysis is not yet possible. However, several observations from Lake Clark have revealed the large degree to which these lakes systems are influenced by geologic and weather-related events. Typically, Lake Clark exhibits a turbidity gradient ranging from turbid glacial water in the upper lake to clear water in the lower lake. However, the 2009 eruptions of Mt. Redoubt changed the turbidity gradient. These eruptions blanketed much of the Lake Clark watershed with a layer of volcanic ash (*Figure 3A*). As the snow melted and washed into Lake Clark, the input of volcanic ash "homogenized" water clarity, creating turbid conditions lake-wide for much of the summer of 2009 (*Figure 3B*). Previous research on Lake Clark has suggested that sockeye salmon fry and least cisco (*Coregonus sardinella*), the two primary pelagic forage fish within the lake, partition themselves along a turbidity gradient. Least cisco tend to inhabit the more turbid upper lake while sockeye salmon fry tend to inhabit the lower lake. Future research will examine the biological ramifications of altering lake turbidity, whether resulting from natural or anthropogenic causes, on sockeye salmon fry growth and survival.

We are also continuously monitoring water temperature at these lakes through a series of permanent temperature arrays. The Lake Clark temperature array was established in September 2006 and measures water temperature in Lake Clark from near the surface to 330 ft (100 m) depth at 33-ft (10-m) intervals every hour year round (*Figure 4*).

In Lake Clark and other southwestern Alaska lakes, strong wind events vertically mix the water column, limiting stratification and disrupting thermocline formation. A thermocline is a layer of water with a steep temperature gradient that can strongly influence primary productivity and fish distribution within lakes. An example of these strong wind events occurred on July 21, 2009. Weather stations in LACL and KATM recorded wind gusts in excess of 80 mph (128 kph). The resulting wind-generated waves and subsequent water column mixing on Lake Clark and Naknek Lake caused surface water temperatures to drop 14.4°F (8° C) in less than a day (*see Figure 4*). Such an abrupt change is more common in shallow ponds and wetlands, but is relatively rare in large, deep lakes that typically moderate temperature changes on the surrounding landscape. We will continue to analyze the data to determine possible implications for drastic weather-induced condition changes on biological productivity.

Our 2009 field observations on Lake Clark remind us that the large lake systems of southwestern Alaska parks are driven by extremes. While researchers often report the average or "mean" of their collective observations, it is the variability and extremes that dictate the limits of these lake systems and how they function in their environment. Understanding how those extremes influence critical park resources, such as sockeye salmon, often leave park managers with more questions than answers. Add in the uncertainty surrounding climate change and the problem is only exacerbated. Through a simple, yet effective, long-term monitoring program, SWAN aims to provide answers for those 'great lakes of Alaska' and the NPS staff who oversee their preservation.

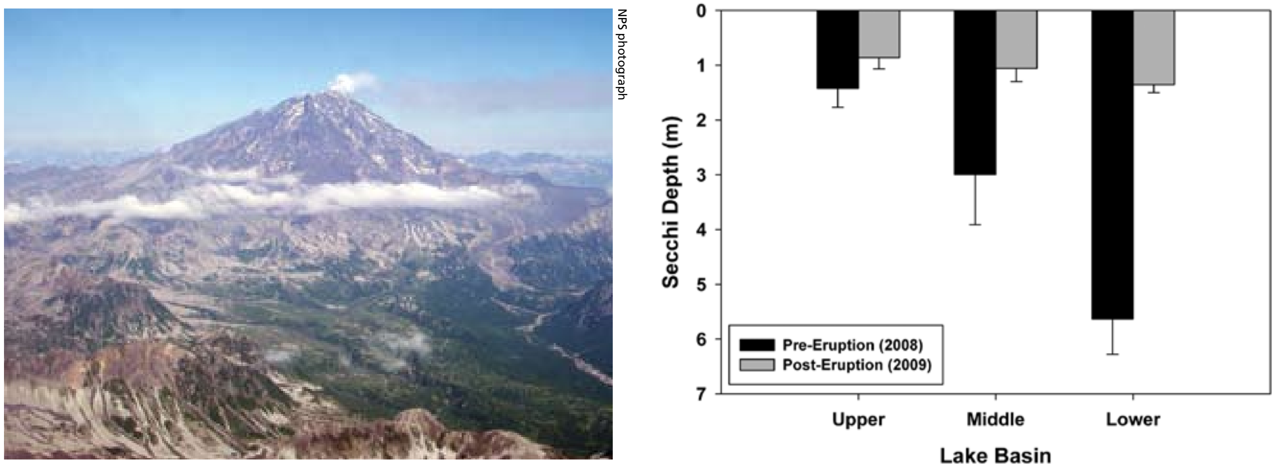
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Figure 3. (A) (Left) Steam rises from Mt. Redoubt as volcanic ash blankets the landscape; (B) (Right) Secchi depth, a measure of water clarity (mean +/- 1 SD), of Lake Clark before and after the eruption of Mt. Redoubt.

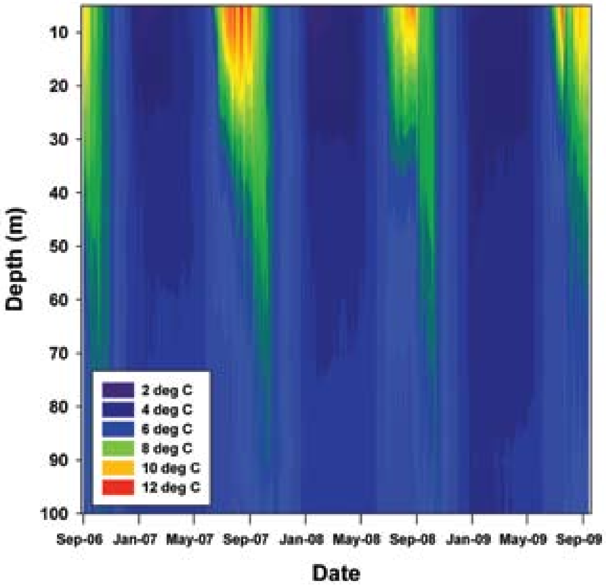

Figure 4. Isotherm of mean daily water temperature for Lake Clark showing patterns of summer stratification, inverse stratification in winter months (colder water near surface), and spring and fall isothermy (uniform temperature throughout water column).

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Salt Marsh Monitoring in Lake Clark and Katmai National Parks and Preserves

By Torre Jorgenson, Gerald Frost, and Amy Miller

The coastal ecosystems of Lake Clark (LACL) and Katmai (KATM) National Parks and Preserves are among the most rare in the world owing to a combination of rapid tectonic uplift, high input of glacial sediments, frequent disturbance by volcanic eruptions, abundant spawning grounds for wild salmon, and a dense population of brown bears. Accordingly, salt marshes have been identified by the Southwest Alaska Network (SWAN) as a vital sign for assessing ecosystem health in the parks.

Salt marsh monitoring in SWAN focuses on major habitat characteristics and drivers of change that affect nearshore and terrestrial food webs and associated indicators (e.g., brown bears, seabirds, intertidal marine invertebrates, and algae). Drivers of change include geomorphic processes, changing topography and surface hydrology, tidal fluctuations and storm surges, sedimentation and erosion, salinity, and physical disturbance.

A sampling approach that incorporates intensive and extensive ground measurements and remote sensing techniques is being used for monitoring. Monitoring sites at Silver Salmon Creek and Chinitna Bay (LACL), and Hallo Bay (KATM) (*Figure 1*) consist of four transects perpendicular to the coastal gradient, with 4 x 10 m monitoring plots located at least every 330 ft (100 m) along the transects (*Figure 2*). Species cover, sediment accumulation, soil pH, and salinity are measured at each plot. Topographic surveys are completed across each transect, and one submersible pressure transducer (water level) and two soil temperature loggers are installed at each site. The monitoring effort requires a team of six people to sample three sites over a three-week period. Vegetation and soil sampling, and topographic surveys, will be repeated every ten years.

Sampling conducted in 2007-2008 provided baseline data on site conditions. Surface elevations vary less than 1.6 ft (0.5 m) across the inactive tidal flats, excluding the tidal channels, and 10-13 ft (3-4 m) across the barrier dunes. Large differences in mean water depths and soil salinity are evident among plant communities along the topographic gradient. High water levels typically reach ~8.2 ft (~2.5 m) above mean sea level, and no major storms have been recorded during the ice-free season.

A total of 127 taxa and 19 plant communities (*Figures 3-4*) were recorded in vegetation plots. A number of species provide forage for brown bears, including lupine (*Lupinus nootkatensis*), seaside arrowgrass (*Triglochin maritima*), goose tongue (*Plantago maritima*), Lygbye's sedge (*Carex lyngbyei*), and Ramensk's sedge (*Carex ramenskii*).

Landscape change was analyzed using a time-series of IKONOS satellite images (2005) and historical airphotos (1950s, 1980s) georectified to a common base (*Figure 5*).

Waterbody mapping showed sediment deposition along the shoreline and migration of the shoreline seaward, with tidal guts decreasing 0.9% and tidal rivers increasing 0.6% in area. Shoreline accretion rates were similar at Hallo Bay (7.5 ft/2.3 m per year) and Silver Salmon Creek (5.2 ft/1.6 m per year) over the roughly 50-year interval, but lower at Chinitna Bay (1.6 ft/0.5 m per year). Increases in Sitka-Lutz spruce (2.0 ± 1.6%) and decreases in wet saline meadows dominated by *Carex ramenskii* (-1.2 ± 1.0%) were among the other changes recorded through photo interpretation.

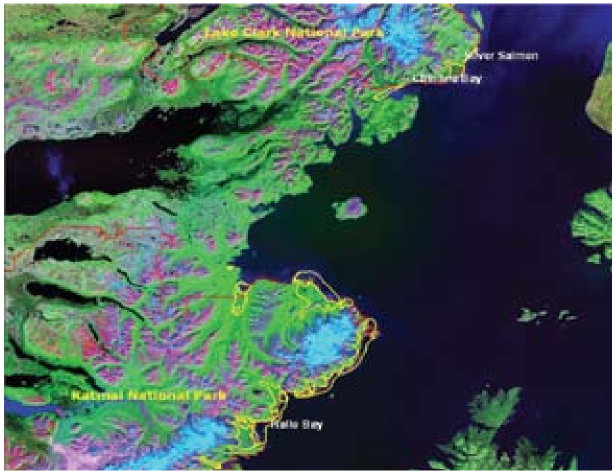

Figure 1. Locations of salt marsh study sites at Silver Salmon, Chinitna Bay, and Hallo Bay.

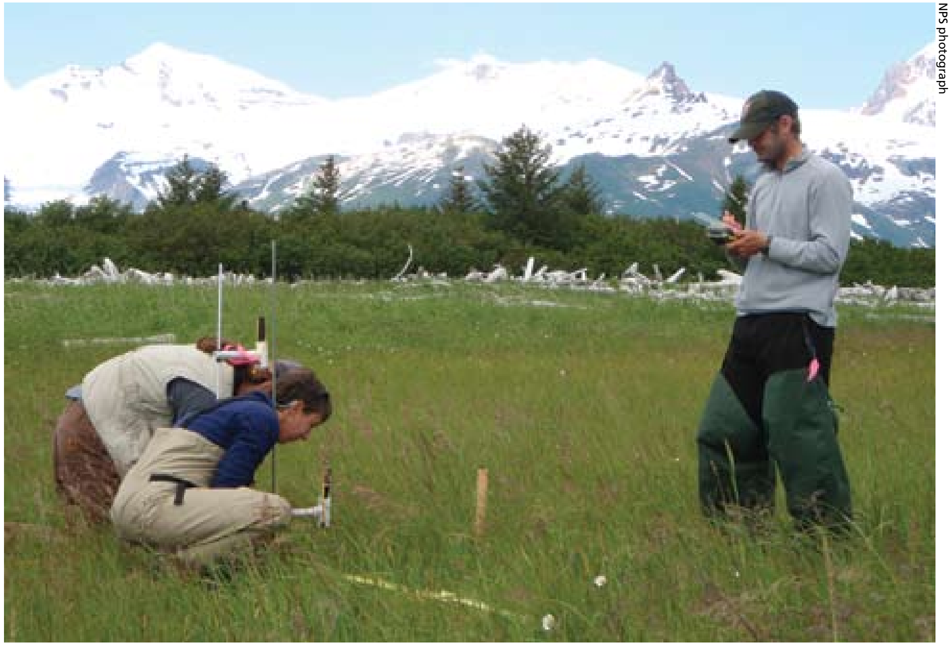

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Figure 2. Measurement of species cover in a *Carex ramenskii* meadow using point-intercept methods.

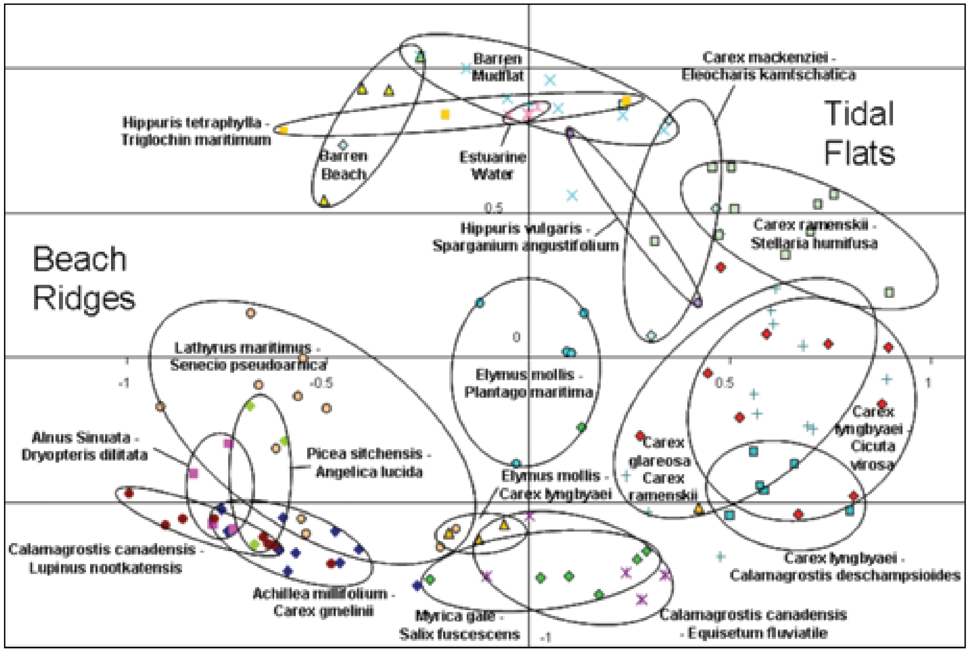

Figure 3. Floristic analysis of the vegetation data revealed 19 plant communities that inhabit the range of environmental conditions associated with varying soil texture, salinity, and water level. The communities are named by their dominant species and an indicator species that differentiates them from similar communities.

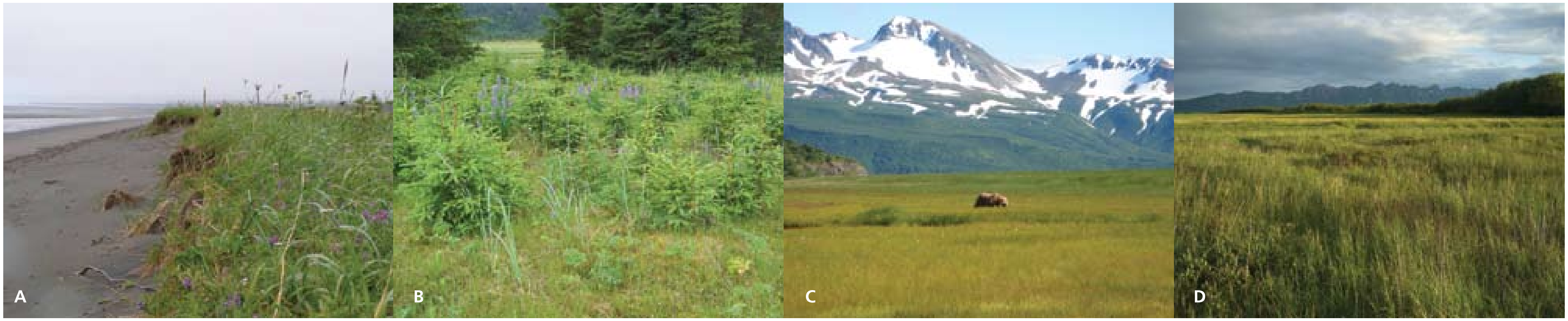

Figure 4. Example of common plant communities associated with salt marshes, including dunegrass-beach pea meadow (A); Sitka-Lutz spruce encroachment into a dunegrass-umbel meadow (B); *Carex ramenskii* meadow, a source of high quality forage for bears (C); and sweetgale shrubland at the upper, inland margins of inactive tidal flats (D).

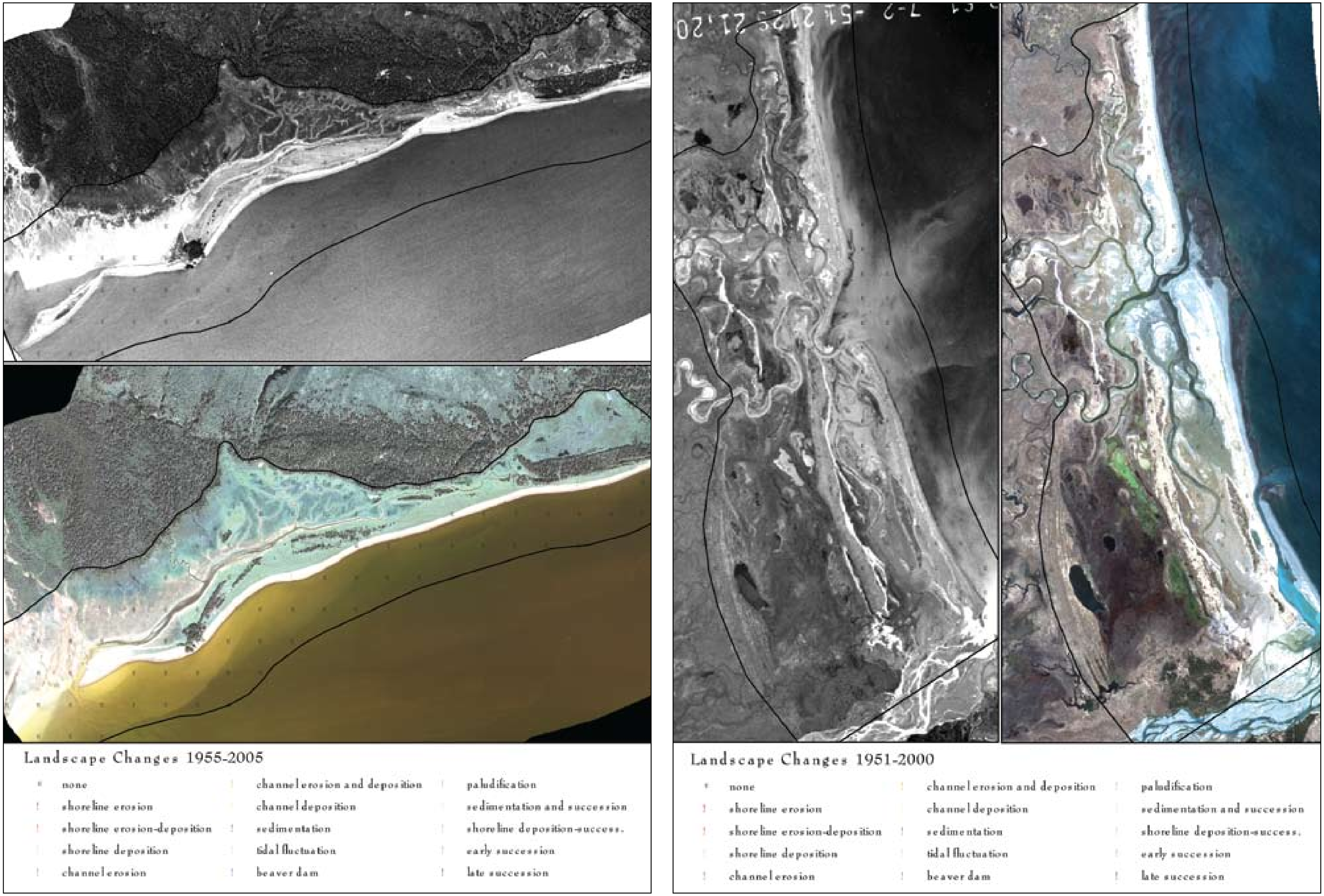

Figure 5. Examples of shoreline change that have occurred over the last 50 years (1951-2005) in salt marshes of the SWAN. Changes were photo-interpreted at 650 ft (200 m) spacing denoted by the small cross-hairs; points where change was evident are color coded. Most of the change is associated with shoreline erosion and deposition (left), tidal channel migration, and plant succession on beach ridges, including spruce establishment (right).

Long-term Monitoring of the Marine Nearshore in the Southwest Alaska Network

By Heather A. Coletti, James L. Bodkin, Thomas A. Dean, and Kimberly A. Kloecker

Approximately 1,200 miles (1,930 km) of marine coastline, one-fourth of the marine coastline of the entire national park system, lies within the Southwest Network. The marine nearshore component of this coastline, which is bounded by the 65-130 feet (20-40 m) depth contour offshore (light penetration limit) and the high tide line inshore, is an important link between the terrestrial and oceanic ecosystems. The marine nearshore provides critical habitat for a variety of species including invertebrates, fishes and several marine mammal and bird species that define a unique marine food web where kelps provide much of the primary production. The nearshore also supports important human activities such as commercial fishing, subsistence and recreation.

Several resources that are of conservation concern to the NPS reside in or utilize the marine nearshore. Six of these resources have been identified by the SWAN I&M program as vital signs for monitoring the overall status of the marine nearshore environment. These include: kelp and seagrass, marine intertidal invertebrates, marine birds, black oystercatcher (*Haematopus bachmani*), sea otter (*Enhydra lutris*), and marine water chemistry. For each biological vital sign, metrics that encompass measurements of abundance, distribution, density, size, productivity or diet are collected. The marine water chemistry vital sign monitors salinity, temperature and levels of various contaminants in the marine nearshore system.

The nearshore monitoring program is designed to provide information regarding levels of natural variation in the system, detect changes and track trends at a variety of temporal (hourly to multi-annual) and spatial (2.7 ft^2/0.25 m^2 quadrat to network-wide) scales. Simultaneously, the design incorporates well known ecological processes and trophic interactions at spatially balanced, randomly selected sites in the nearshore, from primary production to primary consumers to apex predators. The physical measurements may help inform causes of change that occur in the nearshore food web.

For example, we may detect a decreasing trend in the size distribution and density of intertidal invertebrates at some spatial scale in the network. Hypotheses regarding the causes of the decline would be formulated based on available data currently being collected through the SWAN nearshore monitoring program. Examples of alternative hypotheses include: 1) increasing contaminant levels on a local or region-wide scale, 2) changing predator density and distribution on a local or regional scale, and 3) changing marine water temperature or salinity. The variety of temporal and spatial scales as well as the processes and species interactions inherent in the nearshore monitoring design will help to evaluate causes of change that are detected. This information will aid resource managers in the determination of appropriate actions, if possible, and to alleviate human effects on the resource of concern.

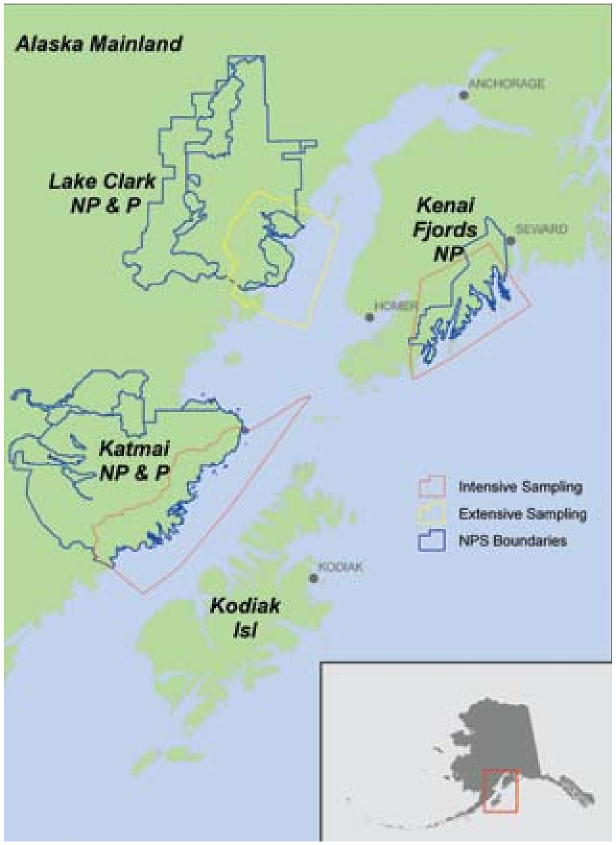

Figure 1. Sampling locations for the SWAN nearshore vital signs monitoring program. Intensive sampling blocks (indicated in red) are locations for monitoring all vital signs. Less frequent monitoring of a limited number of vital signs is to be conducted in the extensive block at Lake Clark National Park and Preserve (indicated in yellow). Park boundaries are indicated in blue.

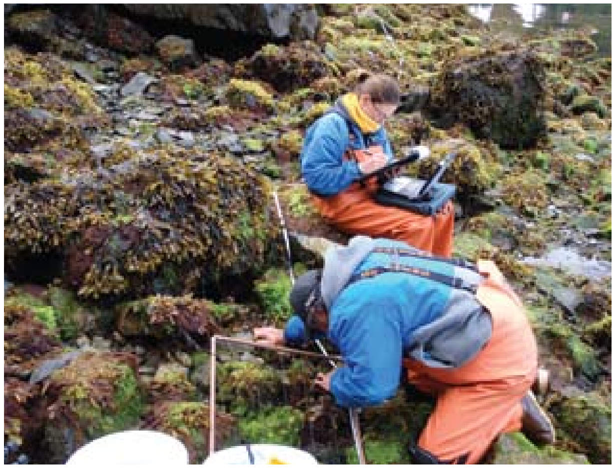
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Figure 2. Dr. Allan Fukuyama and Heather Coletti sample the rocky intertidal.


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Figure 3. Two adult black oystercatchers with two chicks in Katmai National Park and Preserve.


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Figure 4. Limpets grazing on intertidal algae in Lake Clark National Park and Preserve.


NPS photograph

Figure 5. Kimberly Kloecker sampling a mussel bed in Kenai Fjords National Park.


NPS photograph

Figure 6. NPS biologists sampling the soft sediment intertidal for bivalves in Lake Clark National Park and Preserve.


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Figure 7. NPS and USGS biologists conducting marine birds surveys in March 2008 along the Kenai Fjords National Park coast.

Alaska Park Science

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