Southwest Alaska Network
Inventory & Monitoring Program

National Park Service
U.S. Department of the Interior

Vital Signs Monitoring Resource Briefs

Alagnak **Aniakchak** **Katmai** **Kenai Fjords** **Lake Clark**

April 2014
http://science.nature.nps.gov/im/

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Vital Sign Resource Briefs

Vital Signs Inventory and Monitoring

Weather and Climate

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Alagnak *Aniakchak* *Katmai* *Kenai Fjords* *Lake Clark*

April 2014

Climate

Climate monitoring efforts supplement knowledge of patterns in remote areas

Four years of weather observations (2008-2012) support the following general observations. Weather stations across the SWAN region capture synoptic-scale weather events, but the magnitude of these events (temperature swings, precipitation intensity, and wind speed) are typically greater at more remote, higher-elevation SWAN stations. Average temperatures are typically below freezing November to April. Winter temperatures are more variable than summer temperatures, with long cold-snaps that are punctuated by several (2-5/yr) warm air advection events with above-freezing temperatures, strong wind, and rain. Most precipitation occurs in the fall, and the winter snowpack develops through discrete events. Winds are persistent with several (5-30/yr) events (typically in winter) exceeding 100 km/hr.

Importance

Climate is considered the most important broad-scale factor influencing ecosystems. Because global climate models indicate that climate change and variability will be greatest at high latitudes, climate monitoring is critical to understanding the changing conditions of park ecosystems. Potential effects in SWAN park units include a reduced snowpack, earlier lake ice break-up, warmer winters, and wetter summers. These changes may affect the distribution, abundance, growth, and productivity of plants and animals.

Biological science technician Bob Peterson sets up a remote automated weather station at Three Forks, near the Valley of 10,000 Smokes in Katmai.

SWAN Climate Overview

The weather and climatic conditions of the SWAN region are largely influenced by the region's high latitude, proximity to oceans, complex topography, and the interaction of these features with global atmospheric circulation. Much of the seasonal variation in the timing of maximum precipitation is explained by the location and intensity of the Aleutian Low. Annual to decadal climate variability is primarily influenced by large-scale changes in atmospheric and oceanic circulation (ENSO, PDO). Temperature data from long-term stations show a significant increase in both mean winter temperatures (Homer +5.4 F or +3.0 C, King Salmon +8.0 F or +4.4 C) and mean annual temperatures (Homer +3.4 F or +1.9 C, King Salmon+ 3.4F or +1.9 C) for 1949-2011. Climate projections based on an intermediate climate change scenario suggest that mean annual temperatures for SWAN parks will increase by 0.9-1.1 F or 0.5-0.6 C per decade. Precipitation is also generally projected to increase with 11-26% more snowfall in winter and 10-12% more rain in summer. It appears that the most severe environmental stresses in Alaska at present are climate related. Accurate, long-term climate data sets are fundamental to understanding the effects.

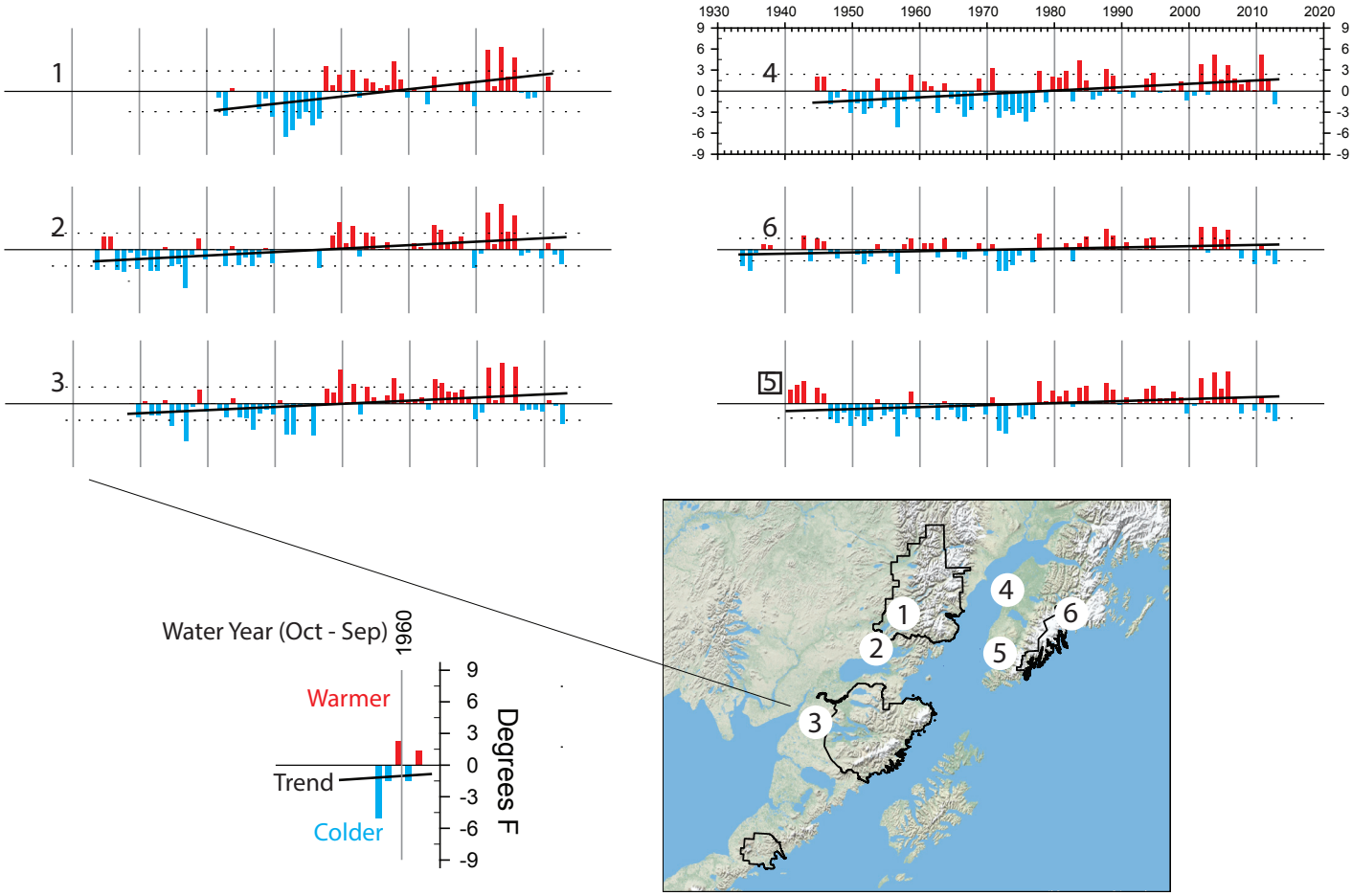
Monitoring Approach

In order to address the scarcity of climate information from national parks in southwestern Alaska, SWAN operates 10 remote automated weather stations in three network parks. The objective is to record and archive weather observations in locations that are characteristic of the diverse landscape and topography within these parks. This effort will support real-time needs, identify natural variability in weather patterns and long-term climate trends, provide reliable climate data to researchers, and help interpret ecosystem changes.

New Developments in Monitoring Efforts

A new weather station was installed on the west side of Cook Inlet near Silver Salmon Lakes in Lake Clark, and another weather station in Katmai was moved from Contact Creek to the Three Forks cabin near the Valley of Ten Thousand Smokes. Both weather stations are fully automated and powered by solar panels and large capacity deep-cycle batteries. Weather observations are transmitted every hour to a weather satellite and are publicly available on the internet at http://mesowest.utah.edu/cgi-bin/droman/mesomap.cgi?state=AFC&rawsflag=290. Weather observations include: temperature, relative humidity, wind speed and direction, precipitation, snow depth, and solar radiation. A time lapse camera is also present at Silver Salmon Lakes, taking daily photographs that document vegetation and snow pack conditions.

The Silver Salmon Lakes weather station will eventually replace a weather station that was installed in 2008 at Hickerson Lake (located nearby at a higher elevation). This weather station has proven difficult to access and will be removed in 2014 after both stations have operated for one year. The Three Forks weather station was moved from a location at Contact Creek (located in southwestern Katmai) where a weather station was installed in 2008. This original weather station was replaced with a Climate Reference Network (CRN) Station that was installed by the National Oceanic and Atmospheric Administration (NOAA) in September 2012.



In addition to operating and maintaining 10 remote weather stations in network parks, SWAN also obtains climate data from long-term weather stations throughout the region. Temperature anomalies (annual departures from long-term average) are shown for: 1) Port Alsworth, 2) Iliamna, 3) King Salmon, 4) Kenai, 5) Homer, and 6) Seward. Long-term warming is evident; however, it is clear that this trend is non-linear. The step-wise shift in the late 1970s corresponds with a shift in the Pacific Decadal Oscillation.

Recent Reports

Lindsay, C. 2013. Climate monitoring in the Southwest Alaska Network: Annual report for the 2012 hydrologic year. Natural Resource Technical Report NPS/SWAN/NRTR-2013/716. National Park Service, Fort Collins, Colorado.

Lindsay, C. 2011. Climate monitoring in the Southwest Alaska Network: Annual report for the 2011 hydrologic year. Natural Resource Technical Report NPS/SWAN/NRTR-2011/517. National Park Service, Fort Collins, Colorado.

Lindsay, C. 2011. Climate monitoring in the Southwest Alaska Network: Annual report for the 2010 hydrologic year. Natural Resource Technical Report NPS/SWAN/NRTR-2011/463. National Park Service, Fort Collins, Colorado.

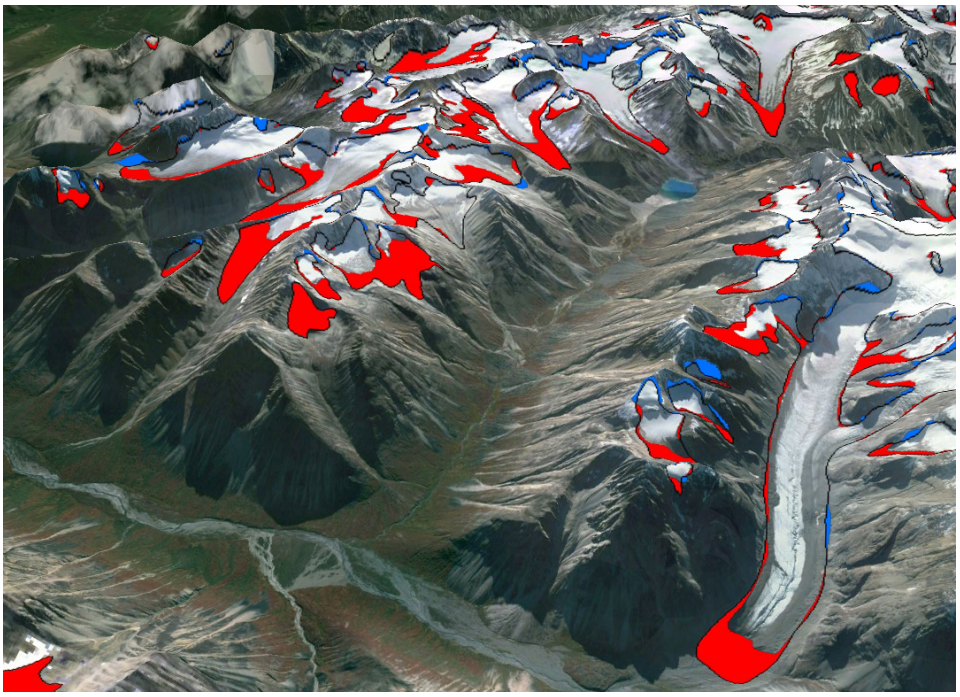
Contact: Chuck Lindsay, NPS-SWAN, chuck_lindsay@nps.gov

Weather data are available from the SWAN website at: http://science.nature.nps.gov/im/units/swan/monitor/weather.cfm

Glacier Extent

Glacier changes since 1950s documented for Katmai, Kenai Fjords, and Lake Clark

A new inventory of glaciers in national parks in Alaska by collaborators at the University of Alaska Fairbanks and Alaska Pacific University is almost finished. The inventory for Katmai, Kenai Fjords, and Lake Clark is complete and is based on glacier outlines delineated for two time intervals, the 1950s 'baseline extent' and late 2000s 'modern extent'. Results document park-wide changes in glacier cover and the following changes are summarized for glaciers located within the administrative boundaries of SWAN parks. During the time frames examined, glacier extent in Katmai was reduced by 147.4 km^2 or 14.0%, glacier extent in Kenai Fjords was reduced by 149.7 km^2 or 10.2%, and glacier extent in Lake Clark was reduced by 328.4 km^2 or 12.3%. Notable glacier changes include significant ice loss at low elevations in Katmai, particularly near the coast; minor glacier advance of some ash-covered—and therefore insulated—glaciers near the Valley of Ten Thousand Smokes; the conspicuous retreat of most large glaciers in Kenai Fjords; and the significant retreat and sometimes complete disappearance of small, but numerous higher elevation cirque glaciers in Lake Clark.



Left: Change in glacier extent near the headwaters of the Chilligan River in Lake Clark (view is to the south). Modern (2009) glacier outlines are shown in black, red indicates glacier ice that has been lost since the 1950s, and blue indicates minor ice gain or glacier ice that was not recognized in the 1950s. The late 20th and early 21st century has witnessed the significant retreat and sometimes complete disappearance of small, but numerous higher elevation cirque glaciers in Lake Clark.

Importance

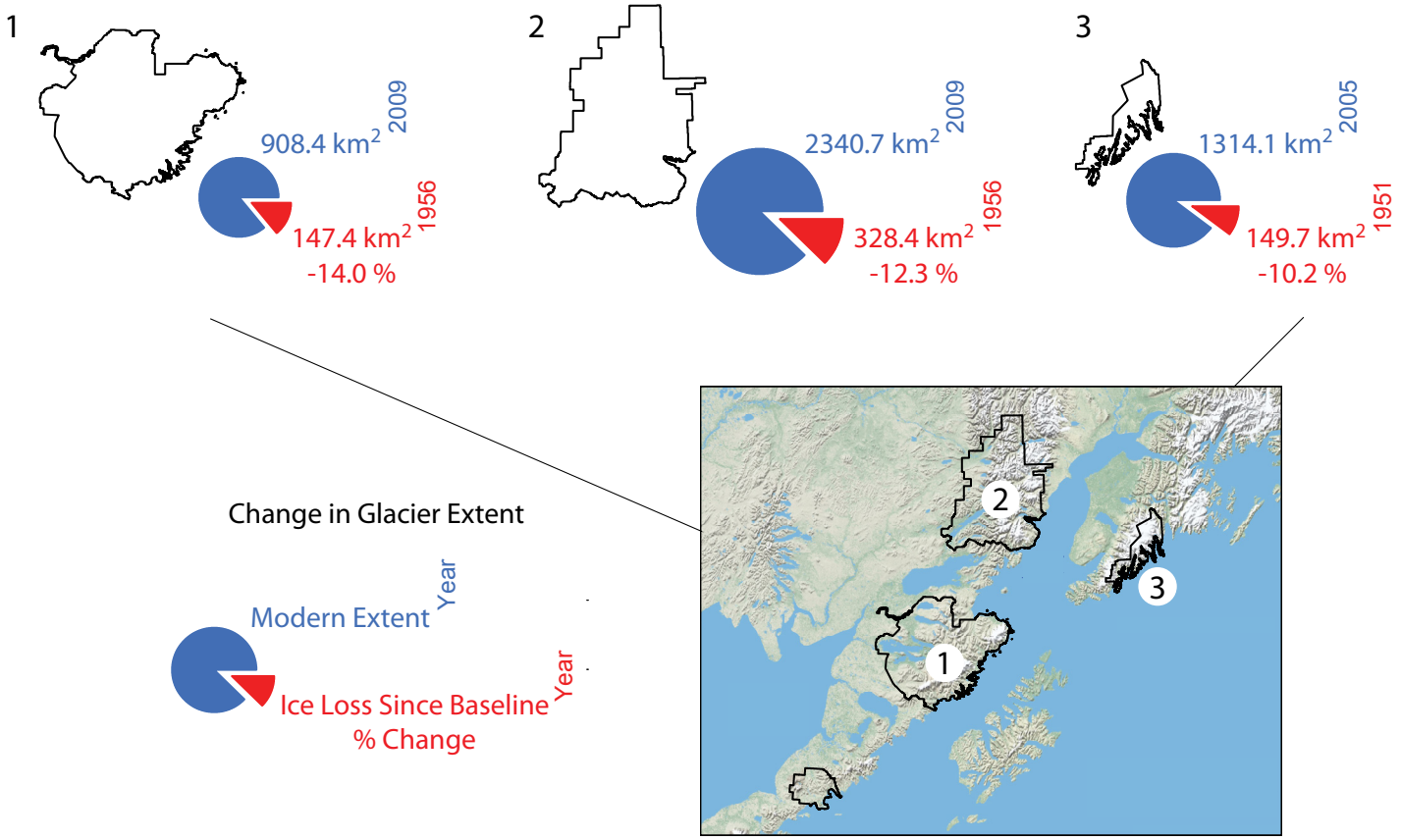
Glaciers are sensitive to temperature change over a range of timescales, so they are natural integrators of climate variability and provide some of the most visible evidence of climate change. Glaciers currently cover approximately one-eighth of the combined area of Katmai, Kenai Fjords, and Lake Clark National Parks in southwest Alaska. Although glacier response varies by location and elevation, glaciers in SWAN parks have, for the most part, experienced widespread thinning and retreat since the end of the Little Ice Age (about 1900 A.D.). Changes to these glaciers have both global and local consequences with impacts ranging from their contribution to global sea level rise to the transformation of scenic and recreational values for park visitors.

Natural Resource Specialist Deb Kurtz acquires a precise GPS location at a glacier mass balance monitoring stake on the Harding Icefield in Kenai Fjords. This information is used to determine glacier rate of flow and measure changes in surface elevation.

Monitoring Approach

To date, the SWAN monitoring approach has focused on refining methods for mapping glacier extent from late-season (i.e. September) Landsat satellite imagery and mapping glacier extent using a GIS on approximately decadal time series. These methods have included manual (heads-up) digitizing, supervised classification, and band-ratio techniques. We have learned that different mapping methodologies, cloud-cover, debris-covered ice, shadows, and variations in the amount of persistent snowpack and/or fresh snow are problematic and affect the accuracy of detected change. We also have learned that some amount of manual editing of glacier margins is always required.

The results of the new inventory of glaciers in national parks in Alaska by collaborators at the University of Alaska Fairbanks and Alaska Pacific University (highlighted above) involved delineating glacier outlines for two time intervals, the 1950s and late 2000s. 'Baseline' 1950s outlines were derived from USGS topographic maps that were generated from aerial photographs acquired 1949 to 1957. 'Modern' glacier outlines were derived from late-summer Landsat and Ikonos satellite imagery acquired 2004 to 2010. Digitizing was done at a scale appropriate to the base imagery (Landsat 1:10,000 to 1:20,000; Ikonos 1:1,500 to 1:5,000). A basin delineation algorithm was used to isolate specific glacier basins. Geostatistics (ID No., geographic name, date of imagery used, centroid latitude and longitude, glacier area, and area-weighted minimum, maximum, mean, median glacier elevations) and hypsometry (frequency distribution of elevations using 50m bins) were determined for each basin.



Change in glacier extent between the 1950s and late 2000s in Katmai (1), Lake Clark (2), and Kenai Fjords (3). Pie charts show the modern extent of ice within each park (in blue) and the extent of ice that has been lost since the 1950s baseline (in red).

Recent Reports

Arendt, A., C. Larsen, M. Loso, N. Murphy, and J. Rich. 2012. Alaskan National Park glaciers: Status and trends – second progress report. Natural Resource Data Series NPS/AKR/NRDS-2012/404. National Park Service, Fort Collins, Colorado.

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LeBris, R., F. Paul, H. Frey, and T. Bolch. 2011. A new satellite-derived glacier inventory for western Alaska. Annals of Glaciology 52(59):135-143.

Contacts: Chuck Lindsay, NPS-SWAN, chuck_lindsay@nps.gov;
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More information on glacier monitoring in SWAN available at: http://science.nature.nps.gov/im/units/swan/monitor/landscape.cfm?tab=1

Forest Insects and Disease

Recent spruce beetle outbreaks impact large areas of south central Alaska

Over the last two decades, roughly 1.5 million hectares of forest in south central Alaska has been killed by the spruce beetle (*Dendroctonus rufipennis*). Since 2008, there has been an increase in spruce beetle activity in Lake Clark NPP (LACL), primarily around Lake Clark, Kontrashibuna, and Upper Tazimina. Beetle activity in Katmai NPP (KATM) has also increased, mainly around Lake Brooks. In addition, spruce needle rust (*Chrysomyxa ledicola*) outbreaks in 2008, 2011, and 2012 have temporarily affected broad swaths of remaining live spruce (U.S. Forest Service 2013). Native defoliators (e.g., geometrid moths, noctuid moths) have affected alder, willow, and dwarf birch in shrublands as far west as Dillingham.

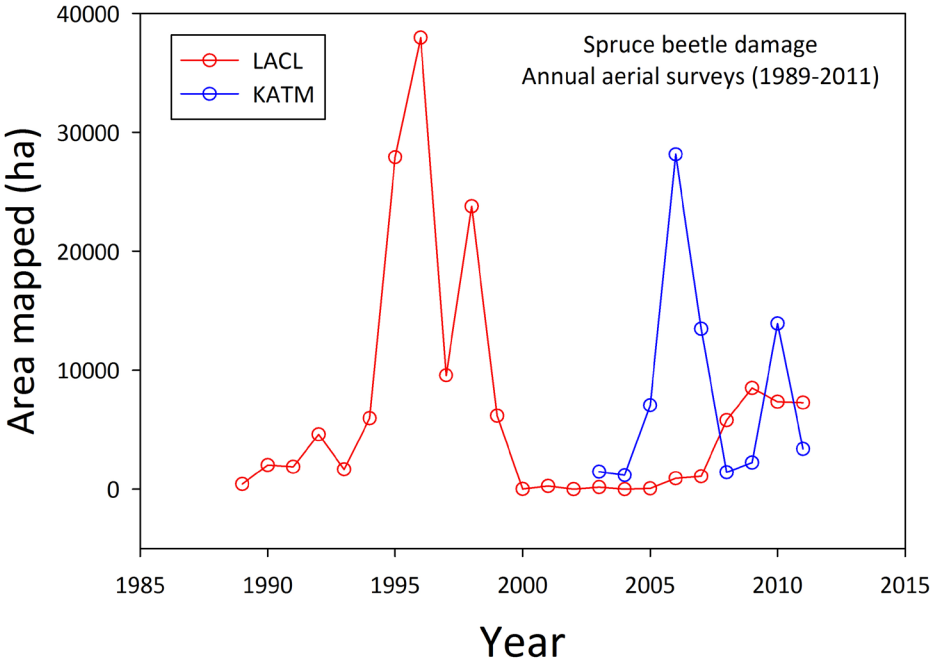


Figure 1. Mapped area (hectares) affected by spruce beetle annually in Lake Clark (LACL) and Katmai (KATM). Data are from U.S. Forest Service aerial surveys (1989-2011; http://agdc.usgs.gov/data/projects/fhm/#L) and reflect the areas where surveys were flown rather than total land area affected.

Left: SWAN biotech Evan Heck takes measurements in a vegetation plot. These plots are being used to track vegetation responses in the areas hardest hit by spruce beetle outbreaks.

SWAN cooperator, Dr. Rosemary Sheriff, collects a tree core to analyze for periods of growth and stress.

Monitoring Approach

To better understand long-term forest disturbance dynamics, SWAN is using tree-ring data to examine the frequency of spruce beetle outbreaks in LACL and KATM as well as the relationship between climate and beetle outbreaks regionally. Annual aerial surveys conducted by the U.S. Forest Service and state Department of Natural Resources are being used to track general trends in beetle activity (U.S. Forest Service 2013; Fig. 1), and plot measurements are being used to monitor vegetation response at the hardest-hit sites.

Importance

Insect outbreaks have led to widespread mortality in the forests of south central and southwest Alaska. These dieback events, in turn, may result in broad-scale changes in forest structure and composition, including changes in understory species composition.

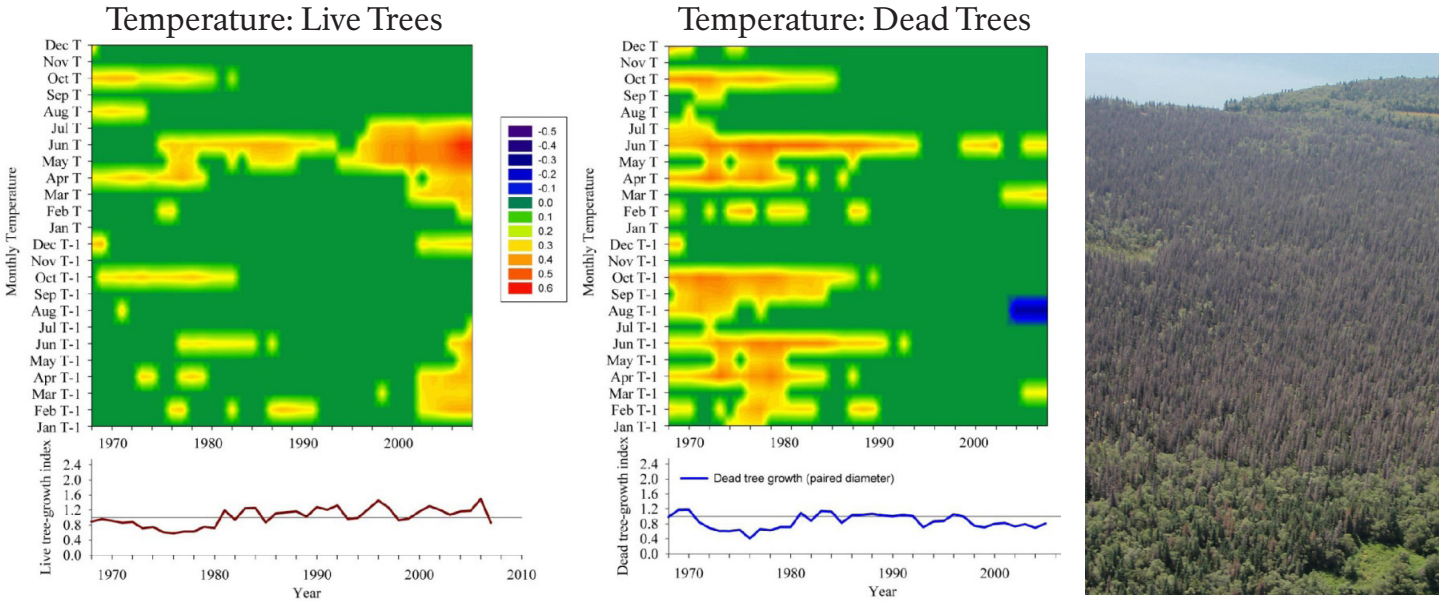
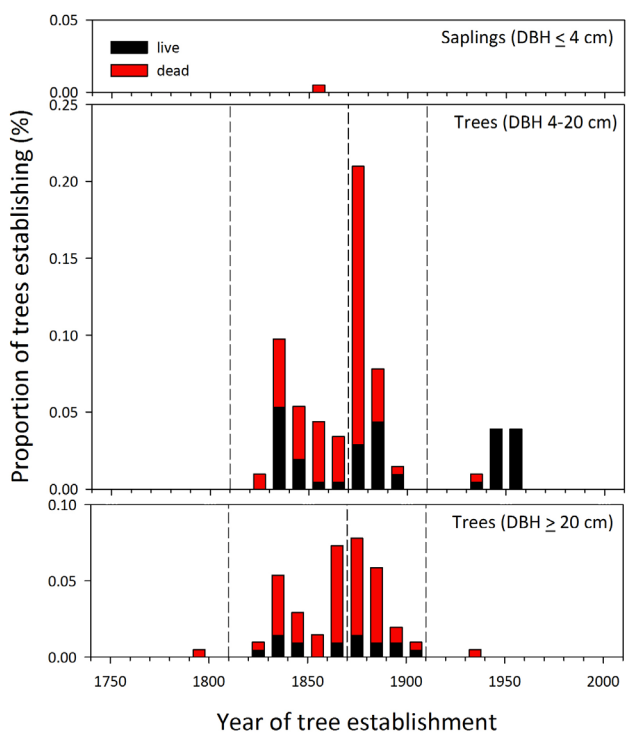


Figure 2. A moving correlation between temperature and growth for a site in KATM shows that the first trees to be killed by the spruce beetle were those that had been most sensitive to warming in the 1970s and 1980s (R. Sherriff, unpublished data). The X-axis shows years from 1968-2006, and the Y-axis shows the correlation between temperature and growth for months one year prior to (T-1) and in the year of (T) growth. Warm colors indicate a positive correlation between temperature and growth, cool colors a negative correlation, and green no correlation. In trees that survived the spruce beetle outbreak (left), tree growth was relatively insensitive to temperature up until the mid-1990s. In contrast, trees that were killed by the spruce beetle in the mid-2000s (right) showed a strong positive response to temperature in both the year prior to and the year of growth. After the mid-1990s, tree growth became decoupled from temperature in the trees that died (right), whereas growth was enhanced by warming in the trees that survived (left). The aerial photograph (right of Fig. 2) taken while flying over Katmai National Park and Preserve shows a large area of beetle-defoliated trees.

Tracking historical patterns of growth and stress in response to warming



Tree-ring data from the Alaska and Kenai Peninsulas show that widespread forest thinning has occurred at roughly 50 year intervals over the last 250 years (Sherriff et al. 2011; Fig. 3). Major growth releases associated with beetle outbreaks appear in the tree-ring record in the 1810s, 1870s, 1910s, and 1970s-1980s, often following a series of warmer and drier than average years (Sherriff et al. 2011). Trees killed by the spruce beetle often show greater sensitivity to temperature in the decades before beetle attack than trees that initially survived (Sherriff et al., unpublished data; Fig. 2). This finding is supported by a collaborative study with the University of Alaska and Humboldt State University, which is using stable isotopes of carbon and oxygen in tree rings to look for evidence for drought stress prior to tree death. As trees become stressed, their stomata close to reduce evaporative water loss and as a result restrict the movement of CO_2 into the leaf. The 'signature' of that restricted movement is observed in the carbon and oxygen isotope values, both of which increase with water stress. Forest monitoring plots are being used to track changes in stand structure and composition associated with the recent beetle-kill.

Figure 3. Composite age structure for forest sites in LACL and KATM (n=10). On average, 75% of trees sampled at these sites were already dead (shown in red) in 2009-2010, and a few sites showed nearly 100% mortality. Roughly one-third of trees sampled were old, large-diameter trees, and most of these had been killed by the spruce beetle. However, we also found many older trees, both live and dead, in the smaller size classes (<20 cm). Outbreak periods in the 1810s, 1870s, and 1910s are shown by vertical dashed lines; a major establishment event occurred in the 1880s, following the 1870s outbreak.

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Seasonal Processes

Local and remote imagery tell story of growing season length linked to temperature, precipitation

Snow season and growing season length are strongly controlled by temperature and precipitation. Spatial variation in snow and growing season length is driven in large part by elevation, latitude, and proximity to the coast (Figs. 1-2). Year-to-year variation is influenced by climate; e.g., cool spring temperatures and late-melting snowpack in 2008 resulted in a later start to the growing season in many areas of southwest Alaska. Warmer than average temperatures during strong El Niño years (e.g., 2002-2003) have been shown to influence lake ice (Reed et al. 2009) and are also expected to influence snow season length. A comparison of start of season (SOS) dates estimated from MODIS satellite data and Phenocam time-lapse photos shows reasonably close correspondence between the two data sources. Although our sample size is small, 75% of the Phenocam SOS dates are within 2 days of the MODIS-derived dates.

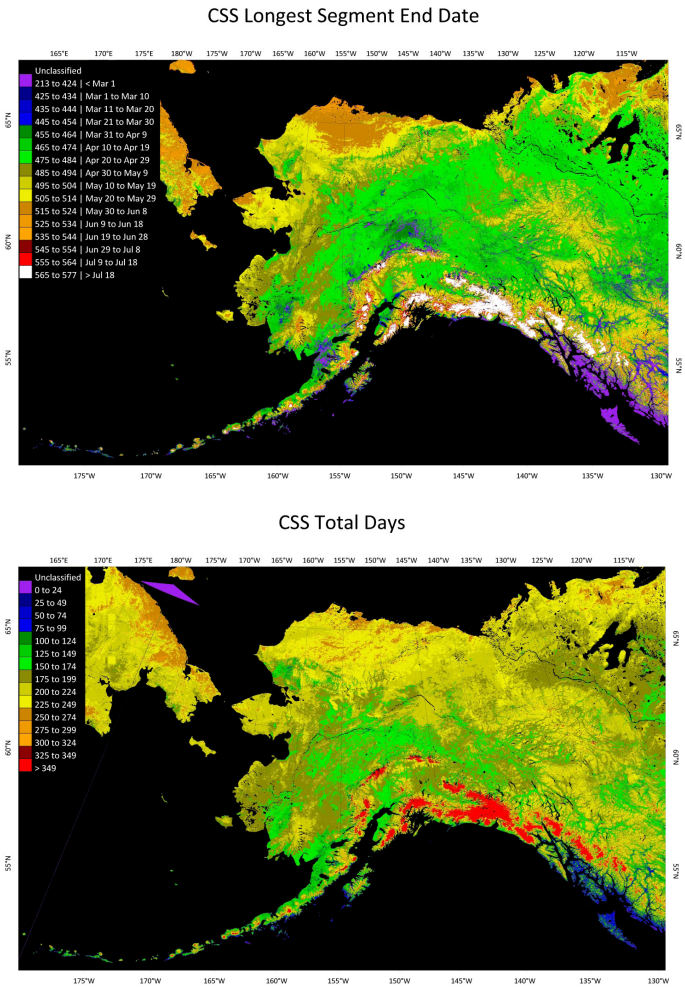

Fig. 1. Continuous snow season (CSS) metrics for the 2009-2010 snow year. Snow season length (top) and snowmelt date (bottom) are modeled from the MODIS snow product developed by the National Snow and Ice Data Center. The areas with the earliest snowmelt dates and shortest length of snow season are shown by cool colors (purple, blue, green). Areas with perennial or late-lying snow are shown in red.

Importance

This vital sign focuses on the seasonality of lake ice, snowpack, and vegetation growth. Climate variability affects the timing of these events, which in turn affect ecosystem processes. For example, the length of the snow season and the area covered by snow control the timing and volume of stream discharge. Snowmelt dates influence the timing of leaf-out, and both snowpack and forage availability affect wildlife movement.

The seasonal composite photo shows images taken by the the KEFJ Phenocam located near Exit Glaicer at the SNOTEL site. Photos left to right were taken on May 14, June 2, July 17, and September 30, 2013. The camera takes a photo every hour between 7 am and 7 pm.

Monitoring Approach

Since 2005, SWAN has collaborated with the USGS-Earth Resources Observation Systems (EROS) Data Center and the University of Alaska Fairbanks-Geographic Information Network of Alaska (GINA) to use Moderate Resolution Imaging Spectroradiometer (MODIS) data to monitor changes in seasonality. Currently, GINA serves MODIS and Advanced Very High Resolution Radiometer (AVHRR) data through web coverage (WCS) and mapping services (WMS). Growing season and snow season metrics (2001-2012) derived from eMODIS are available on GINA's website: http://www.gina.alaska.edu/projects. We are now working with GINA to develop comparable metrics for AVHRR data, which span a much longer period (1978-2012). Lake ice has been manually interpreted for 17 lakes (2001-2010) and uploaded into a SWAN database. Time-lapse cameras installed at three remote weather stations in SWAN have been used to capture data on the timing of snowfall, green-up, and senescence (2010-present). The photos have been processed to generate curves showing changes in "greenness" (an index of the spectral quality of foliage) through the growing season. We are using these data to explore methods for identifying start and end of season dates and for manually interpreting growing season and snow on/snow off dates that can be used to validate the MODIS-derived metrics.

The images from these stations are archived with the PhenoCam Network at Harvard Forest.

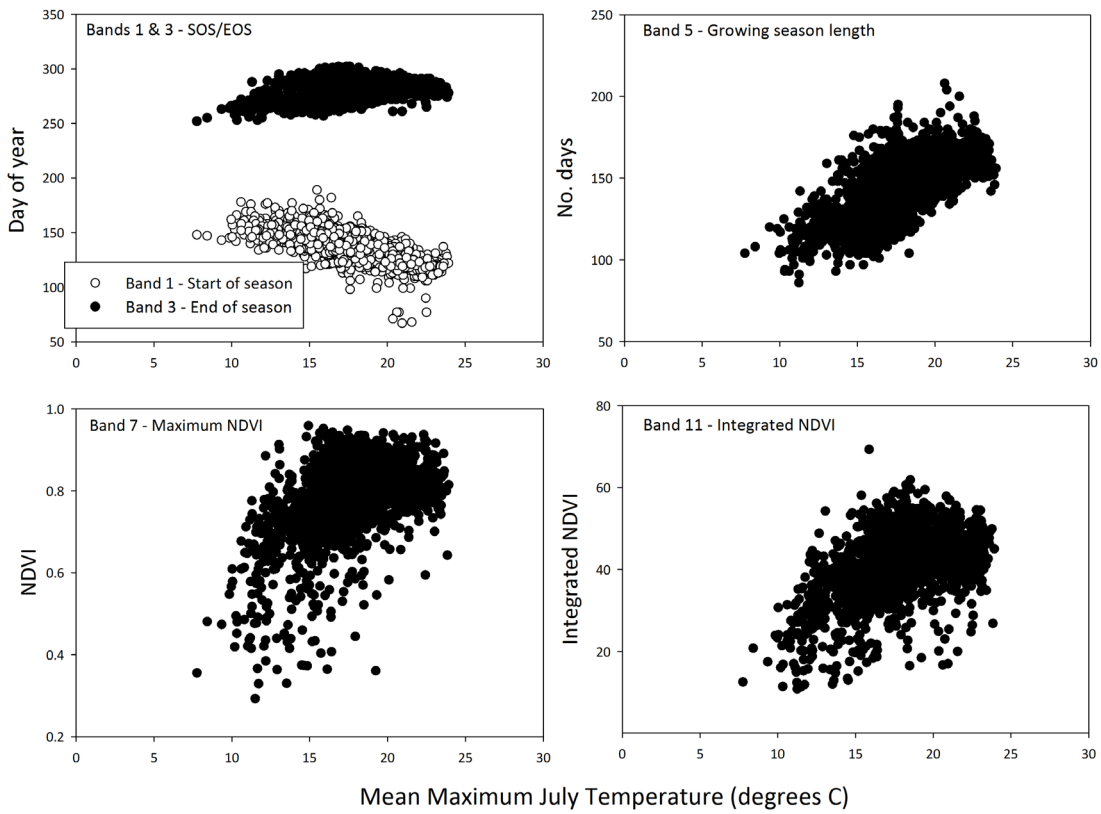

Fig.ure 2. Growing season length is strongly controlled by temperature. Panels above show the relationship between July maximum temperature and growing season metrics measured across Alaska. The MODIS metrics represent an average of 12 years of data (2000-2011) for 2500 random points assigned statewide. Temperature data are derived from the PRISM data set (1971-2000). Areas of the state that have the warmest summer temperatures (e.g., Interior AK) also had the longest growing season, mainly due to earlier start of season dates. Temperature did not affect peak biomass, estimated by maximum NDVI (Normalized Difference Vegetation Index; a graphical indicator used to analyze remote sensing measurements to assess the presence of live green vegetation).

Contacts: Amy Miller, NPS-SWAN, amy_e_miller@nps.gov;
Chuck Lindsay, NPS-SWAN, chuck_lindsay@nps.gov

References

Reed B, Budde M, Spencer P, Miller A. 2009. Integration of MODIS-derived metrics to assess interannual variability in snowpack, lake ice and NDVI in southwest Alaska. Remote Sensing of Environment 113:1443-1452.

Vegetation Composition & Structure

Responses to disturbance, species diversity documented by monitoring efforts

To date, work on the vegetation composition and structure in SWAN parks has focused on describing spatial patterns in vegetation across latitudinal and elevation gradients (e.g., Fig. 1; Carlson et al. 2013), refining sampling methods, and estimating sampling error. Repeated sampling has provided estimates of interannual variability in species cover but has also indicated short-term responses of vegetation to disturbance (Fig. 2). In forest stands affected by the spruce beetle, increases in snag densities and coarse woody debris have been observed since 2009. Most sites support high densities of saplings, but a few show higher densities of larger, older trees, suggesting a limit to recruitment. Data from forest monitoring plots in Kenai Fjords (KEFJ) supplement existing U.S. Forest Service Forest Inventory and Analysis (FIA) plots and will be used to monitor tree establishment and death, as well as changes in forest structure.

Importance

Vegetation is integral to ecosystem function, energy transfer, and element cycling. It drives ecosystem productivity in the SWAN, provides habitat and forage for wildlife, and food and materials for subsistence. Lastly, it is sensitive to environmental change.

Left: SWAN and KEFJ staff get acrobatic in KEFJ to measure the diameter at breast height (DBH) of a Sitka spruce. The coast of Kenai Fjords has some of the largest trees in the Network.

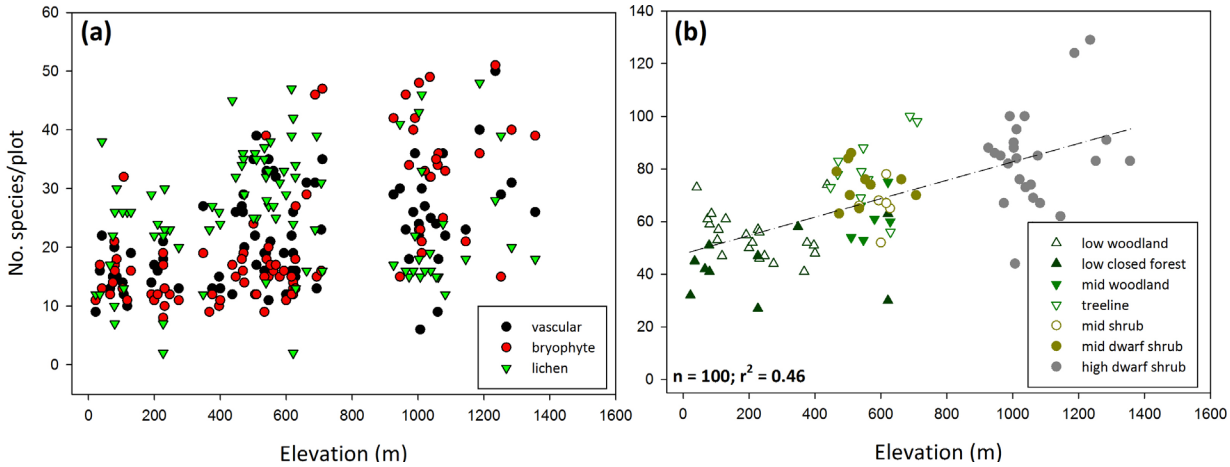

Figure 1. Species richness as a function of elevation and vegetation type in LACL and KATM. Vegetation classes that occur between 700-900 m are a current data gap. (a) Number of species per functional group (vascular, bryophyte, lichen) per plot as estimated from nested frequency plots sampled in 2009-2011. (b) Total number of species (vascular + nonvascular) per plot, grouped by vegetation type. Low woodland and closed forest were sampled at elevations between 0-450 m. Treeline spruce, shrub, and dwarf shrub tundra were sampled between 450-900 m. High elevation dwarf shrub plots were sampled >900 m.

Monitoring Approach

Vegetation composition and structure are being monitored at multiple temporal and spatial scales using a variety of sampling approaches. At the landscape scale, remotely-sensed data are being used to detect broad-scale changes in vegetation and landscape features. Image time series (e.g., historic air photos; IKONOS) developed by cooperators at St. Mary's University of Minnesota are being used to identify changes in major vegetation types associated with disturbance and succession.

At the community scale, plot measurements are being used to characterize stand structure, species composition, and selected environmental variables (e.g., soil temperature). Epiphytic lichens have been sampled at a subset of forested sites using FIA protocols. Epiphytic lichen inventories of the KEFJ plots yielded a number of common forest species (e.g., *Alectoria sarmentosa*, *Cetraria chlorophylla*, *Lobaria oregana*), as well as several atmospherically-sensitive indicators. FIA lichen inventories in Lake Clark (LACL) and Katmai (KATM) have likewise yielded over 400 collections that will be used to qualitatively assess air quality in the parks.

Tree cores collected at approximately one-third of sites are being used to describe forest age structure. Stem disks from dwarf birch collected at a lesser number of sites are being used to estimate shrub age and dates of shrub expansion. These various data sets will be used to develop an integrated analysis of change on the landscape. For example, loss of tundra habitat and/or lichen cover due to shrub encroachment may be documented through a combination of plot measurements, shrub age data, and field and aerial photos. To date, approximately 125 monitoring plots have been established across LACL, KATM, and KEFJ.

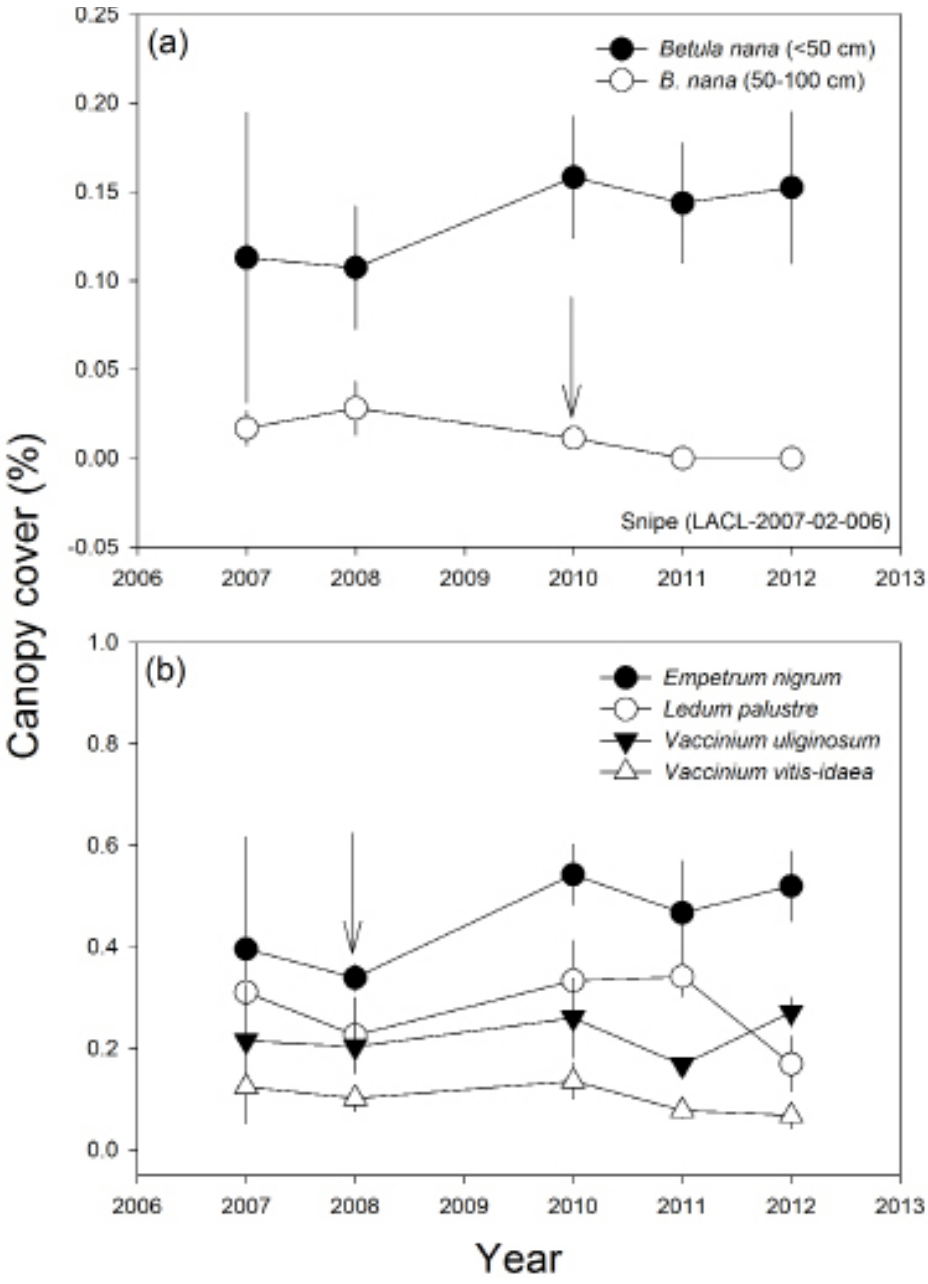

Figure 2 (Left). Inter-annual variation in species cover at a treeline site in LACL. (a) Reduction in dwarf birch *(Betula nana)* **cover in the 50-100 cm height class due to caterpillar defoliation. Arrow indicates the first year of a multi-year autumnal moth outbreak. Sprouting above the root crown has maintained cover in the <50 cm height class. (b) Recovery of crowberry** *(Empetrum nigrum)* **following frost damage in the winter of 2007-2008. Arrow indicates the year in which widespread dieback occurred in crowberry, Labrador tea** *(Ledum palustre)* **and lowbush cranberry** *(Vaccinium vitis-idaea)***.**

A KEFJ biologist measures the diameter of a Sitka spruce in order to estimate standing biomass.

Lichen Inventory

A lichen inventory, initiated in KATM in 2013 with cooperators from Oregon State University, will deliver a set of lichen collections and updated species lists for two parks in the Network. Field work in LACL is scheduled for 2014 with a final report and annotates lists due in 2016.

References

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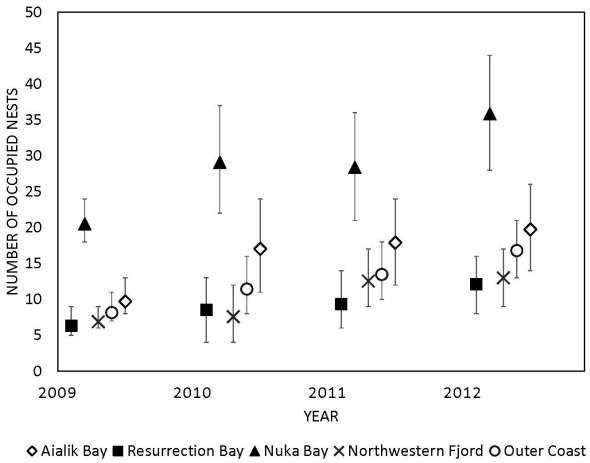
Bald Eagles

Pilot phase of monitoring complete, evaluation of methods shows areas for improvement

Nest occupancy levels were lower than usual in Katmai (KATM) and Kenai Fjords (KEFJ) in 2013 (Table 1). While these data may represent a reduction in nest occupancy, other potential reasons for the below-normal results include variation in timing of eagle arrival at nests in relation to our single-pass survey. Lake Clark (LACL) observed near-normal occupancy rates, and this rate was based on two occupancy surveys conducted in May. This result illustrates how difficult it is to infer meaning about annual occupancy based on a single snapshot survey.

Recent work by NPS staff to evaluate the survey methodology used to determine bald eagle nest occupancy in SWAN parks has led to improvements in the accuracy with which we report information about local populations of bald eagles (Wilson et al. 2013). From 2009 to 2012 two-observer aerial surveys were flown over much of the Kenai Fjords coastline to determine nest occupancy. The evaluation focused on identifying areas of bias and the ability to detect nests (Fig. 1). It also identified ways to analyze the data that give both a more accurate estimate of occupied nests as well as localized population information, which is potentially more relevant to local management decisions. Based on the results of the evaluation, we recommended that two occupancy surveys be performed so that eagle nest occupancy and availability can be modeled more precisely.

Initial implementation of the blad eagle monitoring program began in 2009. Four years of data (2009-2012) from Kenai Fjords were used to evaluate and align methods with management needs and ensure robust survey protocols are used.

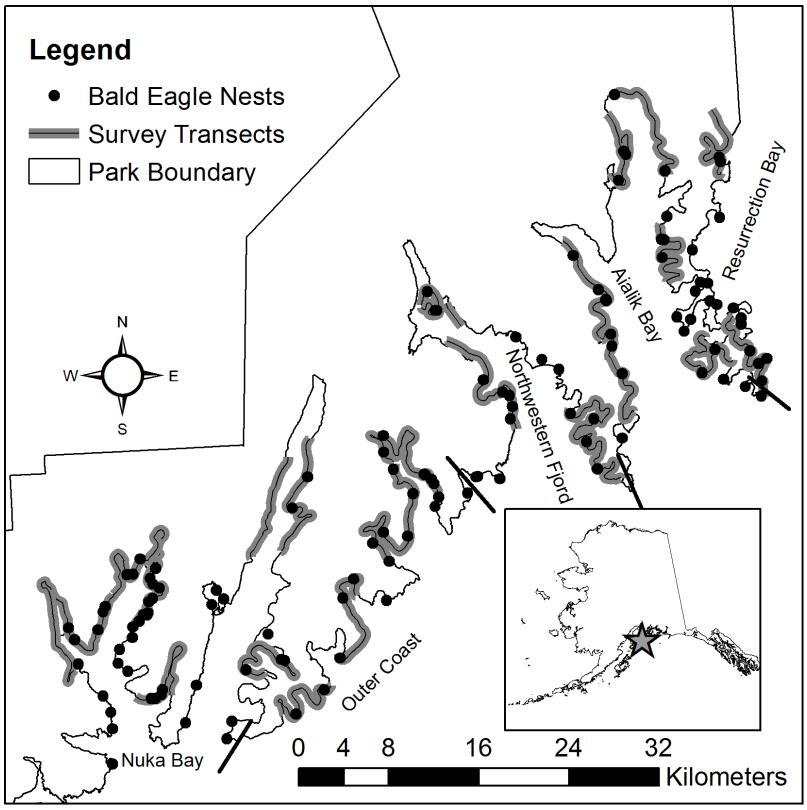


Estimated number of occupied bald eagle nests for each year from 2009-2012 along the coastline of KEFJ. The estimates were derived from the incomplete availability scenario of a Bayesian multistate method used to evaluate protocols. Error bars represent 95% credible intervals for each estimate.

	Total Nests Found	Occupied Nests
Katmai		
2012	54	31
2013	62	20
Kenai Fjords		
2012	74	43
2013	81	29
Lake Clark		
2012	114	50
2013	113	58

Table 1. Bald eagle nest occupancy data for KATM, KEFJ, and LACL from 2012 and 2013.

Surveys are conducted in KEFJ using two observers via helicopter at a speed of 40 to 75 km/h. LACL and KATM both used fixed-wing aircraft to conduct surveys.



Importance

All three SWAN park units support large populations of bald eagles. Bald eagles were once listed as endangered in the contiguous 48 states due to human-caused declines. Populations have since recovered, and they were delisted in 2007. As top predators, bald eagles can serve as indicators of the overall health of local ecosystems and environment. Their breeding success is also influenced by food availability and spring weather conditions. Understanding the status and trends of local populations can assist managers address future questions on impacts visitor access or other human caused disturbances, such as oil spills.

Left: Figure 2. Locations of survey transects and bald eagle nests in KEFJ.

Monitoring Approach

The goal of the long-term bald eagle monitoring program is to develop rigorous survey methods to track nest occupancy and productivity in a standardized manner across all three SWAN park units. Additionally, survey methods are compatible with the methods proposed in the post-delisting monitoring plan for bald eagles. Staff began testing methods in KEFJ in 2009 using two-observer aerial surveys to locate nests and determine occupancy state. Ongoing efforts since then have included an assessment of methods used in KEFJ. This analysis accounted for the ability for observers to see nests, but also identified other potential sources of error related to survey methods. Surveys began in KATM in 2011 after a 20-year break using the draft protocol for KEFJ; LACL has monitored bald eagles for the last 20 years and adapted methods in 2012 to be consistent with the other two parks. One to two occupancy surveys are flown per summer season in each park. In KEFJ, surveys are conducted along the coast. In KATM, they are flown in the Naknek watershed. LACL surveys cover all bald eagle habitat with known nests in the park and preserve.

Bald eagle nests are commonly seen in cottonwood trees, like this one in the twin Lakes area of LACL.

Publications and Reports

Wilson, T. L., J. H. Schmidt, W. L. Thompson, and L. M. Phillips. 2013. Monitoring bald eagle populations in remote landscapes: Are nests available for detection? Journal of Wildlife Management. *In preparation.*

Witter, L. A., and B. M. Mangipane. 2011. Bald eagle nest survey Lake Clark National Park and Preserve, Alaska. Natural Resource Data Series NPS/LACL/NRDS—2011/313. National Park Service, Fort Collins, Colorado.

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http://science.nature.nps.gov/im/units/swan-monitor//wildlife.cfm

Brown Bears

Importance

Brown bears serve important ecological roles as top predators; specifically, they influence population dynamics of other species and transfer nutrients from spawning salmon to the terrestrial system. Alagnak Wild River (ALAG), Aniakchak National Monument and Preserve (ANIA), KATM, and Lake Clark National Park and Preserve (LACL) support high numbers of brown bears. Densities along the coast of KATM are the highest reported in North America. Brown bears are also an economically important resource for wildlife viewing, sport hunting, and subsistence hunting.

Structured decision making efforts for brown bears make progress

In 2012, NPS initiated a project to develop structured decision making models for brown bear populations in Katmai National Park and Preserve (KATM) and Noatak National Preserve (NOAT). The goal of developing structured decision making models for these areas is to give managers quantitative tools to guide decisions about access to habitat areas and harvest of the species. The brown bear structured decision making group met three times in late 2012 and throughout 2013, resulting in a completed model for both KATM and NOAT. During the development process, participants structured objectives, developed models, and then refined and parameterized them during workshops. Along with collaborators at the University of Georgia, the group continues to parameterize and refine the model. They expect the project to be finished in 2014, resulting in a presentation at the Wildlife Society annual meeting, two published manuscripts, and one annual report.

A brown bear den in Katmai as seen from the air. Pilot-observer teams surveyed a total of 490 km² in central KATM in 2012 and 2013 to test new methods for adequately monitoring bear den occupancy in SWAN parks. Photo: Tammy Wilson/NPS

Testing methods for monitoring brown bear den occupancy

In 2012 and 2013, the Southwest Alaska Network (SWAN) along with KATM and the Central Alaska Network (CAKN) worked together to test an alternative method of monitoring brown bear dens using observations of dens in a 3,000-km^2 area in central KATM. The survey consisted of a three-visit occupancy design where 40 grid cells (490 km^2 total) were surveyed by pilot-observer teams. Den monitoring was conducted at each grid cell between two and three times during bear emergence. Overall, the ability to detect dens, given that they were there, was about 34%. About 64% of the grid cells in the study area were suitable for bear dens. A rudimentary habitat model fit to the den site data shows that bears preferred sites with steeper slopes for denning. However, some dens were found in sites with low overall slope, so bears sometimes place dens on small habitat features, such as moraines, that are not reflected in the mean slope values of the larger site.

A benefit to using this method is the ability to fit a basic occupancy model with data collected from a single season. By contrast, a population estimate for bears takes several years to fit using line transects due to the amount of data required. In addition to ongoing efforts to test methods, in 2013 NPS was awarded $136,399 through the USGS-National Park Monitoring programs to fund a postdoctoral researcher at Mississippi State University to produce a meta-analysis of available bear monitoring methods.

A sow and her cubs pose for the camera in LACL. NPS photo

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Black Oystercatchers

Graduate students supplement monitoring efforts in Kenai Fjords

Research by two graduate students in Kenai Fjords National Park (KEFJ) is supplementing annual black oystercatcher (BLOY) monitoring efforts. Brooke Carney (University of Alaska Anchorage) used stable isotope analysis of field-collected and archived BLOY blood and feathers as well as known prey species in 2012 and 2013 to assess adult diet throughout the duration of the breeding season. Results show diet consistently includes primarily mussels and limpets over the entire breeding season (Mar to Aug), which closely matches previous results from observation-based studies. Additionally, stable isotope analysis indicates BLOY diet has changed little in the northern Gulf of Alaska over the last 100+ years, further strengthening the justification of BLOYs as an indicator of intertidal ecosystem health (Fig. 1). Brian Robinson (University of Alaska Fairbanks) is intensively monitoring active nests during the 2013 and 2014 breeding seasons to examine the role of intertidal invertebrates in the diet of BLOY chicks and assess the influence of these prey items on their body condition and survival. Brian is using remote cameras and direct observation to monitor nests and record provisioning behaviors and repeat captures to track chick growth patterns. Five territories were monitored in 2013, and adults delivered a wide variety of invertebrate prey to their chicks. Of the 12 chicks that hatched from nests, only two survived to fledge. While nesting success was near normal averages, fledging success was lower than usual in 2013.

A black oystercatcher stands in the intertidal zone near Pederson Lagoon, KEFJ.

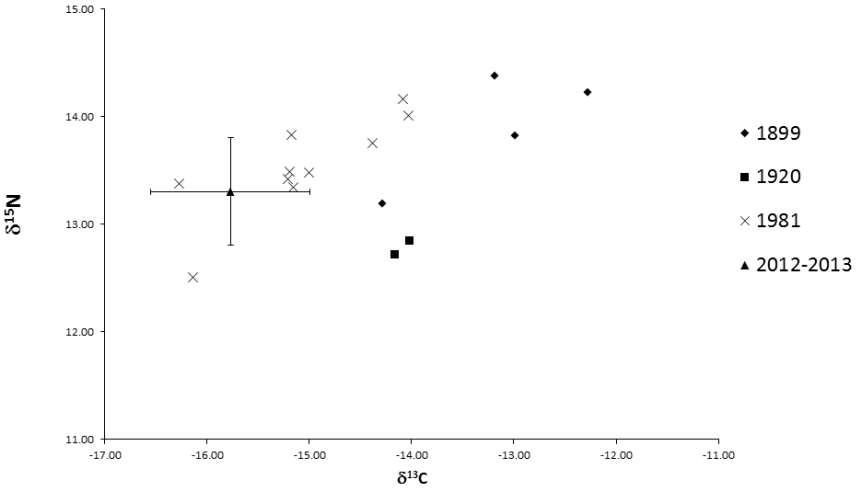


Figure 1. Stable isotope values of black oystercatcher feathers in the northern Gulf of Alaska from 1899 - 2013 indicate the birds have foraged at the same trophic level (^{15}N level) for over one hundered years. This finding provides further justification for black oystercatchers as an indicator of intertidal ecosystem health.

Importance

The black oystercatcher is a common and conspicuous member of the rocky and gravel intertidal marine communities of park shorelines. This species is completely dependent on nearshore marine habitats for all critical life history components, including foraging, breeding, chick rearing, and resting, but is highly susceptible to human disturbance. The black oystercatcher serves as "keystone" species and is important in structuring nearshore ecosystems.

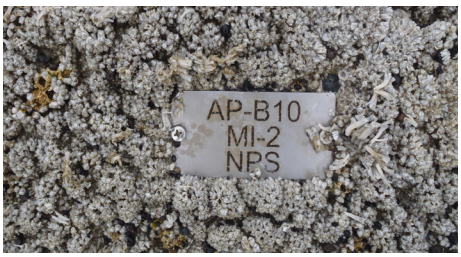
Monitoring Approach

SWAN staff have been monitoring black oystercatcher breeding density, nest productivity, and feeding behavior along the rocky intertidal coast of Katmai National Park and Preserve (KATM) since 2006 and in KEFJ since 2007. Annual boat-based surveys are conducted in early summer to determine breeding density. Nests are located on foot and examined for presence of chicks and/or eggs to determine productivity; shell remains are collected and identified to species to determine chick provisioning habits.

Intertidal Communities

Changes in Mussel Dynamics

Since 2006, we observed substantial changes in mussel dynamics across our study areas in the Gulf of Alaska. We documented reductions in numbers of mussels at mussel sampling sites in Katmai National Park (KATM) and western Prince William Sound (WPWS); however, results vary more for Kenai Fjords National Park (KEFJ) sites. An apparent decrease in percent cover of mussels at the majority of the rocky intertidal sites over the course of our sampling coincided with a decrease in the proportion of mussels in sea otter diets in KEFJ & WPWS during our study period, while remaining low at KATM. Mussel trends suggest decreases in all areas studied, possibly affecting population density and consumption by sea otters and black oystercatchers, a nearshore bird species that relies heavily on mussels as a food resource. Given the high variation we observed in mussels, we initiated studies to try to understand the role mussels play in black oystercatcher productivity and fledging success as well as understand the importance of mussels in sea otter diets.



Barnacle spat covering a mussel bed site in Kaflia Bay, KATM.

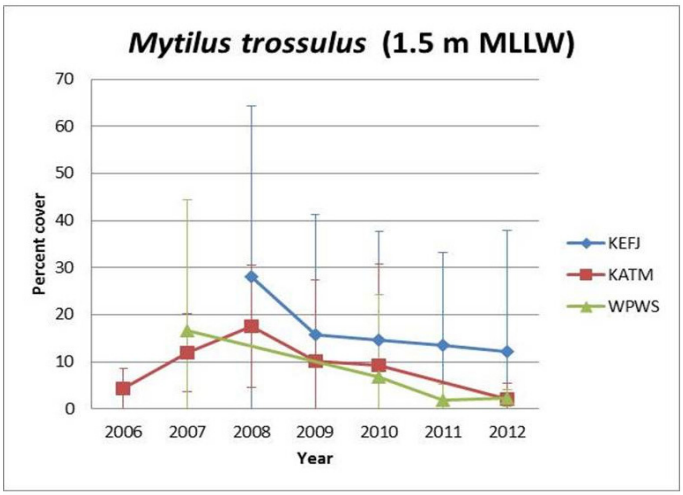


Figure 1. Percent cover of *Mytilus* at the 1.5 m MLLW in KATM, KEFJ, and WPWS, 2006-2012. Error bars indicatd 95% CI.

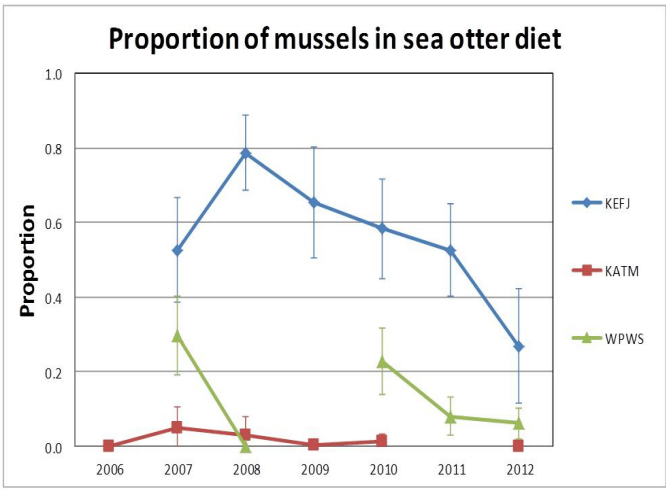


Figure 2. Proportion of mussels in sea otter diets in KATM, KEFJ and WPWS, 2006-2012. Error bars indicate 95% CI.

2008 KATM, Kaflia Bay mussel bed.

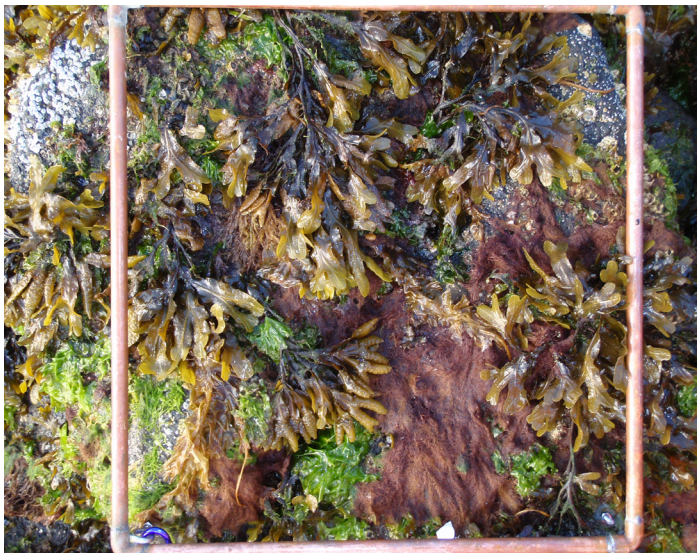
2012 KATM, Kaflia Bay mussel bed site, now covered in barnacle spat.

In our study regions, mussels (*Mytilus trossulus*) are ubiquitous. They serve as an important link in the intertidal trophic web by filtering detrital and planktonic material from the water and providing a food resource for other invertebrates (sea stars, predatory snails) as well as for a variety of birds and mammals that reside in the nearshore environment. Additionally, by forming large mats, mussels provide habitat for other intertidal occupants that reside within or subsurface to mussel beds. Because mussels are so common in the intertidal and are a major food source, mussels can serve as a sentinel species to assess health and environmental change in the nearshore.

Monitoring Approach

SWAN, along with other partners in the Gulf Watch Alaska (GWA) program, monitors several components of the intertidal ecosystem in multiple locations across the Network and Gulf of Alaska in order to gain a holistic understanding of the structure and variation of intertidal communities. SWAN began its partnership with GWA in 2012. GWA is the long-term ecosystem monitoring program of the Exxon Valdez Oil Spill Trustee Council. The current five-year, $12 million program began in February 2012 and is in the first increment of a program anticipated to span a 20-year period. The program is organized into four related ecosystem monitoring components, with data management, modeling, and synthesis projects providing overall integration across the program. SWAN and our partners play a significant role in the benthic component of GWA. Elements of intertidal monitoring efforts include studying invertebrate communities in rocky and soft-sediment intertidal areas, intertidal algal species, blue mussels, and eelgrass. Specifically, intertidal community sampling aims to assess changes in the relative abundance and distribution of algae and sessile invertebrates as well as motile invertebrates in the intertidal zone over space and time. Sampling also includes metrics such as size distribution of limpets (*Lottia persona*) and mussels (*Mytilus trossulus*), the concentration of contaminants in mussel tissue, and intertidal temperature (either sea or air depending on tidal stage). The goal of mussel bed sampling is to assess changes in the abundance of mussels over time. These data are primarily to be used as an indicator of mussel availability as prey for a variety of predators such as sea stars, sea ducks and sea otters. The goal of eelgrass sampling is to assess changes in the extent and density of eelgrass over time.

Sampling intertidal algae and invertebrates in Kinak Bay, KATM 2012.



Quadrat sampling for percent ocover of algae in rocky habitats.

Importance

Intertidal and subtidal communities provide an important source of production; are an important conduit of energy, nutrients, and pollutants between terrestrial and marine environments; provide resources for subsistence, sport, and commercial harvests; and are important for recreational activities such as wildlife viewing and fishing. The intertidal is particularly susceptible to human disturbance including oil spills; trampling by recreational visitors; harvesting activities; pollutants from terrestrial, airborne and marine sources; and shoreline development. Marine invertebrates provide a critical prey resource for shorebirds, ducks, fish, bears, sea otters, and other marine invertebrate predators. Changes in species composition, abundance, contaminant levels, and biomass of intertidal invertebrates can indicate important changes in the coastal ecosystems of which they are a part and can have effects that cascade to other trophic levels. Kelps and eelgrasses are "living habitats" that serve as nutrient filters and provide understory and ground cover for planktivorous fish, clams, urchins, and a physical substrate for other invertebrates and algae. Kelps and eelgrasses also provide spawning and nursery habitats for forage fish and juvenile crustaceans. Kelps are the major primary producers in the marine nearshore and because they are located in shallow water, they are prone to be more impacted by oil spills and other human-related activities.

Eelgrass bed in Kukak Bay, KATM.

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Sea Otters

Growth & Stability: Sea Otter Population Status in KATM & KEFJ

Sea otter population abundance is monitored via aerial surveys, which occur every three years, weather permitting, along the coasts of KATM and KEFJ. Surveys follow a methodology that accounts for incomplete detection. Abundance surveys were flown over KATM in 2008 and 2012, and in KEFJ in 2002, 2007, and 2010. Attempts to conduct the surveys in 2013 were unsuccessful due to inclement weather.

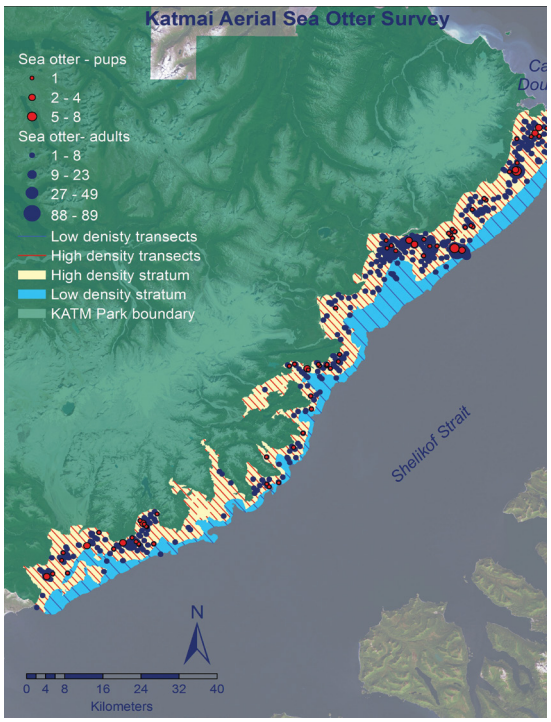
Katmai National Park & Preserve

Abundance estimates from the 2012 KATM survey indicate that the population continues to grow. The estimated sea otter population for KATM is 8,644 individuals, with an overall density of 5.95 otters/km^2. The 2008 population estimate was 7,095 individuals with an estimated density of 4.89 otters/km^2. Within the four years from 2008 to 2012, the estimated sea otter population increased by 22% within the survey boundaries of KATM.

Aerial image of sea otters.

KEFJ		
Year	Adjusted Population Size	*SE*
2002	799	349
2007	1511	625
2010	1322	494
KATM		
Year	Adjusted Population Size	*SE*
2008	7095	922
2012	8644	1243

Table 1. Sea otter population in KEFJ and KATM.



Katmai National Park and Preserve aerial sea otter survey mapped results for 2012.

Kenai Fjords National Park

2010 was the most recent sea otter aerial survey completed in KEFJ. This was the third aerial survey completed since 2002 along the Kenai Peninsula, the second specifically conducted within KEFJ. The estimated sea otter population for KEFJ is 1322 individuals, with an overall density of 0.89/km2. The 2010 population estimate is similar to that of 2007 (1511 individuals, 1.02/km2). The population appears to be stable. Densities of sea otters in KEFJ are slightly less than in neighboring western Prince William Sound where densities range from 0.88 in 2002 to 1.89/km2 in 2009. Sea otter habitat is limited in KEFJ (steep and deep), so sea otter abundance is generally low. To optimize monitoring efforts, another survey will be flown in KATM in 2014. Once completed, SWAN will have 3 surveys from each park and can begin a power simulation to evaluate methods to improve precision of estimates and the ability to detect change.

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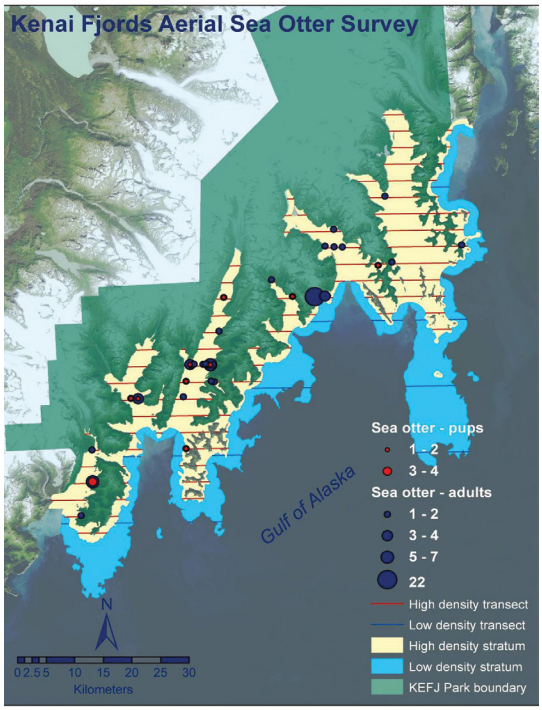


Kenai Fjords aerial sea otter survey mapped results for 2010.

Monitoring Approach

Sea otters are monitored in KEFJ and KATM in several ways. Shore-based observations are conducted using high-powered spotting scopes to monitor foraging success rate as well as prey size and composition. The shore-based surveys are conducted annually during June (KEFJ) and July (KATM). Since monitoring began in 2006, sea otters have been observed feeding on 40 different species of marine invertebrates. In KATM, clams dominate the diet (>60%) while mussels (~61%) dominate the diets of sea otters in KEFJ (Coletti et al. 2014). Sea otter carcasses are opportunistically collected from specified areas along the KEFJ and KATM coasts to develop age-specific survival estimates based on population models. Carcasses are aged and the data is used to estimate the age composition of dying sea otters. KATM has several sea otter haul out areas where large numbers of carcasses can be collected to obtain an adequate sample size; however, KEFJ has more limited sea otter haul out areas, making it difficult to implement the full protocol. No sea otter carcasses were recovered for age composition at death analysis in 2011 from KEFJ. KATM was not surveyed in 2011. In 2012, 22 carcasses were collected. Sixty-two carcasses were recovered from the KATM coast in 2013 for analysis.

A female and pup sea otter resting on a rock as seen through the high-powered scopes used to observe foraging habits.

High-powered scopes are set up to observe foraging dives by sea otters as part of the overall monitoring efforts.

Sea otter in kelp. Photograph by Benjamin Weitzman, U.S. Geological Survey.

Importance

Sea otters are a "keystone" species that can dramatically affect the structure and complexity of the nearshore environment they inhabit. Sea otters prey on sea urchins ('grazers') that feed on kelps resulting in top-down cascading effects on the nearshore community structure. Heavy predation on sea urchins greatly alters the abundance and composition of lower trophic levels (e.g., kelps). Also, sea otters tend to have smaller home ranges in comparison to other marine mammals, require high caloric intake, have an incidence of disease that is correlated with contaminants, and have broad appeal to the public, which make them a prime species for monitoring. In September 2005, the Southwestern Alaska stock of sea otters, which includes the Katmai NP population, was federally listed as threatened.

Sea otters hauled out on a rock.

References

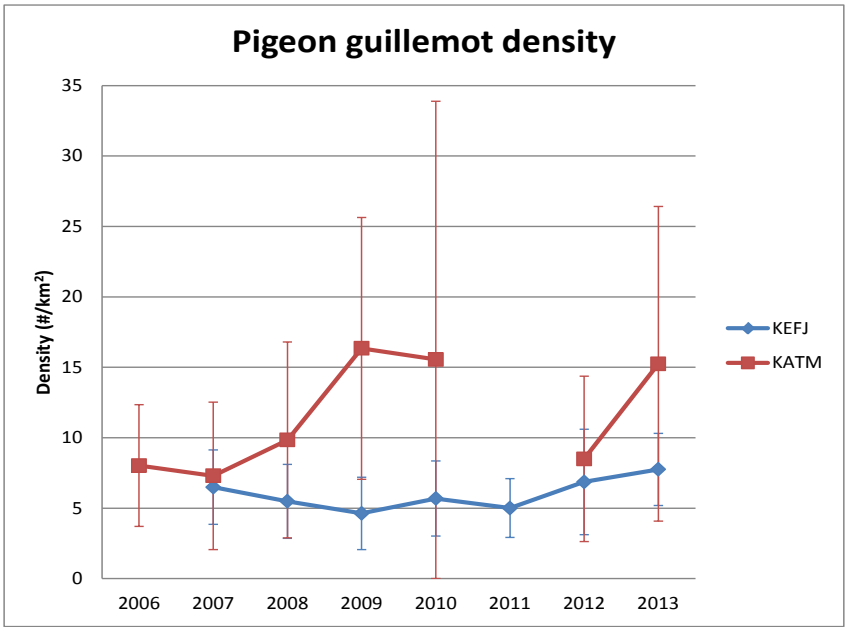
Coletti, H. A., T. A. Dean, K. A. Kloecker and B. E. Ballachey. 2014. Nearshore marine vital signs monitoring in the Southwest Alaska Network of National Parks: 2012. Natural Resource Technical Report NPS/SWAN/NRTR—2014/843.

Marine Birds

Winter and summer surveys completed in both Kenai Fjords and Katmai

Both winter and summer marine bird surveys in Katmai National Park and Preserve (KATM) and Kenai Fjords National Park (KEFJ) were successfully completed in 2012 and 2013. Summer surveys were completed annually in both parks while winter surveys focused on KATM in 2012 and 2013 in KEFJ. The shoreline skiff surveys provide baseline information on species composition, distribution, and density for populations of marine bird and mammal fauna that occur in the nearshore waters of KATM and KEFJ. SWAN is currently in the process of conducting a power analysis to assess the Network's ability to detect trends in density and composition. This exercise is expected to be completed in 2014 and will give the Network greater ability to interpret data from annual surveys.

Marine bird surveys are conducted using three people: an inshore observer, a vessel operator-observer, and a data recorder.



Example data: Density of pigeon guillemots in KATM and KEFJ, 2006-2013. KEFJ was not surveyed in 2006 and KATM was not surveyed in 2011.

Importance

Marine birds rely heavily on habitats and prey associated with the marine nearshore ecosystem of park coastlines. These species are top-level consumers of marine invertebrates, such as mussels, clams, snails, limpets, and forage fish. Because of these characteristics, marine birds are good indicators of change in the marine ecosystem. Monitoring focuses on birds that are trophically linked to the nearshore food web such as sea ducks (harlequin duck, Barrow's goldeneye, and scoters), mergansers, and black oystercatchers as well as various guilds of other marine birds (e.g., pigeon guillemots, blacklegged kittiwakes, and cormorants) that occupy other food webs or habitats. Monitoring these various guilds simultaneously may improve our ability to discriminate among potential causes of change in seabird populations and the nearshore ecosystem. Many of these species were impacted by the Exxon Valdez oil spill as well, and exhibited protracted recovery periods as a consequence of lingering oil in nearshore habitats. Public concern exists for the welfare of marine birds because they are affected by human activities like pollution and commercial fishing.

Monitoring Approach

SWAN uses standardized, boat-based surveys in randomly selected portions of coastline to monitor the species composition, distribution, and density of several species of marine birds along the coasts of KATM and KEFJ. Summer surveys are conducted annually and winter surveys are conducted in each park on alternate years as weather permits. Marine bird surveys have been monitored in KATM and KEFJ since 2006 and 2007, respectively.

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References

Coletti, H. A., T. A. Dean, K. A. Kloecker and B. E. Ballachey. 2013. Nearshore marine vital signs monitoring in the Southwest Alaska Network of National Parks: 2014. Natural Resource Technical Report NPS/SWAN/NRTR—2014/843. National Park Service, Fort Collins, Colorado. In preparation.

Water Quality

Lake Temperature

SWAN has monitored water temperature year-round in Lake Clark (LACL) since 2006 and Naknek Lake (KATM) since 2008. Similar monitoring has occurred in Kijik Lake (LACL) and Lake Brooks (KATM) since 2010. This monitoring relies on the use of programmable data loggers attached at various depths to moored vertical temperature arrays. Data from the temperature arrays allow tracking of freeze-up and break-up dates, lake stratification, and large-scale wind events – all of which influence lake productivity. When comparing temperature data from the Lake Clark and Naknek Lake arrays, variability is evident both between years in a given lake and between lakes in a given year (Fig. 1). The effect of wind events on thermal mixing during the ice-free period is also evident.

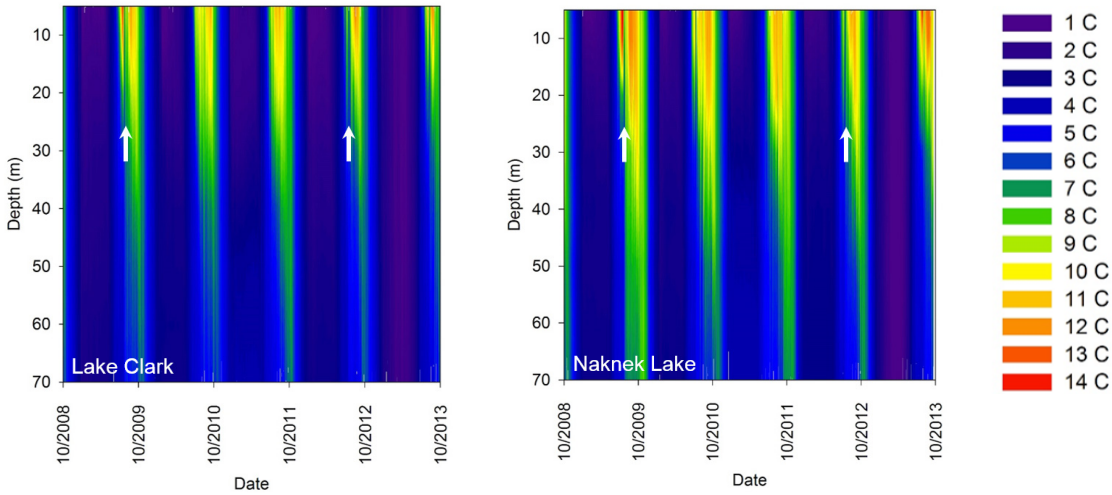

Figure 1. Average daily water temperatures from 5 to 70 m depth in Lake Clark and Naknek Lake, based on temperature array data from 2008 through 2013. Arrows indicate dates of two strong wind events (July 21, 2009 and July 10, 2012) that caused mixing between cool deep and warm surface waters, abruptly lowering near-surface temperatures.

Monitoring Approach

SWAN monitors five core water quality parameters: temperature, pH, dissolved oxygen, specific conductivity, and turbidity. A primary objective of this monitoring approach is to identify trends in the spatial and temporal variablity of core parameters in large lake systems. Several sampling schemes are used to accomplish this objective, ranging from continuous year-round monitoring at targeted locations to synoptic once-a-year sampling at randomly selected sites. SWAN plans to finalize its protocol for monitoring water quality by the end of 2014.

E. Booher and T. Hamon retrieve a temperature array from Naknek Lake, KATM. Arrays consist of data loggers secured to a stationary line at incremental depths up to 100 m. Photo: M. Shephard/ NPS.

Importance

Lakes and rivers function as integrators of water, energy, sediments, nutrients, and pollutants from the landscape and atmosphere. Therefore, water quality parameters can serve as indicators of landscape-level changes that affect aquatic processes. Despite the remoteness of SWAN lakes and rivers, their water quality is subject to alteration due to global anthropogenic influences, such as climate change. Alterations in water quality have the potential to impact the growth, survival, and reproductive success of aquatic and terrestrial organisms.

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Resident Lake Fish

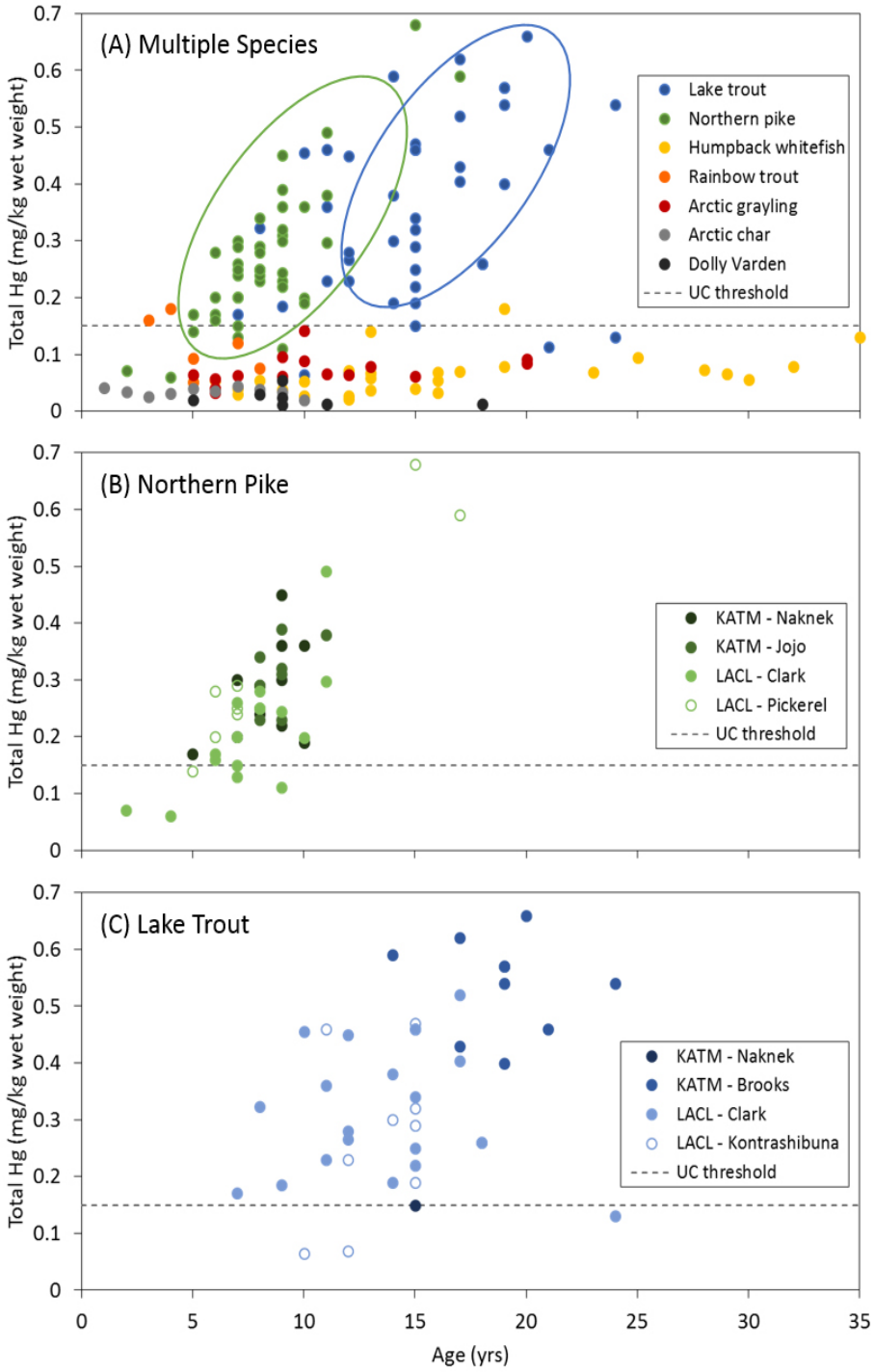


Figure 1. Total Hg levels in resident fish fillets are determined partly by fish age and species (A). However, even when age and species are accounted for, variability in Hg levels exists (B and C, which depict Hg in northern pike and lake trout, respectively). In all three graphs, the dashed line represents the upper limit for unlimited consumption (UC) of Alaska-caught fish, specifically for women of childbearing age, nursing mothers, and children under the age of 12 (Verbugge 2007).

Mercury Levels in Fish Tissue

Monitoring since 2005 has built a solid baseline of tissue samples from more than 250 fish, representing 9 species from 11 lakes in 2 park units. These samples indicate that resident fish in SWAN lakes have acquired elevated concentrations of mercury (Hg), the majority of which is methylmercury (MeHg), a toxic and readily biomagnified form. Why do fish from SWAN – which inhabit some of the most pristine and remote waters in North America – have such elevated Hg concentrations?

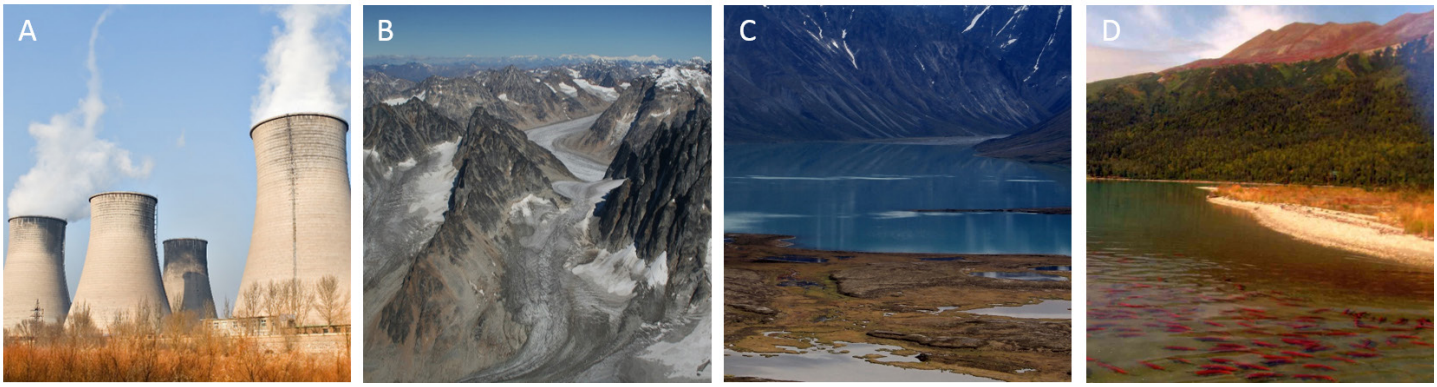
Lake trout collected from LACL in 2011. Photo: S. Huffman/NPS.

Factors driving fish Hg levels can be grouped into two broad categories: distant and local. Distant factors are atmospheric emissions (notably from coal burning), and subsequent long-range transport and deposition. Local factors, such as glaciers, wetlands, and salmon, influence the distribution of distantly derived Hg (Nagorski et al. 2014). Fish age and species also help determine Hg concentrations, in that older piscivorous species tend to have higher concentrations. Understanding the interplay of each of these factors will help make sense of the observed pattern in the Hg levels in SWAN fish (Fig. 1).

Monitoring Approach

Are contaminant concentrations increasing in fish that inhabit SWAN lakes? The first step in answering this question is to define current concentrations, in order to establish a baseline. To this end, biologists began collecting tissue samples of resident lake fish from select lakes within Lake Clark and Katmai National Parks and Preserves in 2005. Since then, the samples have been analyzed for heavy metals (e.g., mercury, arsenic, copper) and persistent organic pollutants (e.g., pesticides and various industrial and combustion by-products). Future monitoring will involve collecting and analyzing additional samples for heavy metals approximately every 5 years. Persistent organic pollutants will be analyzed less frequently (every 10-15 years), primarily due to the high cost of laboratory analysis.

Collecting fish samples on Portage Lake in LACL. Photo (right): D. Young/NPS.



Drivers of Hg concentrations in resident lake fish include both distant and local factors. Distant factors are predominantly atmospheric emissions from industrializing nations (A). Local factors include melting glaciers, which contain latent reservoirs of atmospherically deposited Hg (B); nearby wetlands, which convert atmospherically deposited Hg to MeHg through bacterial respiration (C); and spawning salmon, which import MeHg acquired while at sea (D). Photos: StockFreeImages.com, C. Lindsay/NPS, E. Booher/NPS, and D. Young/NPS.

Day's catch from Lake Brooks in KATM. Photo: A. Shulstad/NPS.

Importance

SWAN consists of five park units encompassing 9.4 million acres. Within this vast area exist hundreds of remote, near pristine lakes. Resident fish inhabiting these lakes play a key role in subsistence and recreational fisheries, so understanding their contaminant levels is crucial.

There is growing concern that fish species in some SWAN lakes have acquired elevated levels of contaminants such as mercury (Hg). Contaminants can bioaccumulate in fish tissue, especially in long-lived, predatory species like northern pike (*Esox lucius*) and lake trout (*Salvelinus namaycush*). When contaminants in fish tissue reach high enough concentrations, fish consumption advisories can be placed on a particular water body or fish species. Given the importance of resident lake fish as a food source for subsistence users, elevated contaminant levels in fish populations have human health ramifications, as well as broader ecological consequences.

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References

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Salmon

Escapement data are critical for the sustainable management of subsistence, commercial and recreational fisheries. Photo: K. Mueller/USFWS.

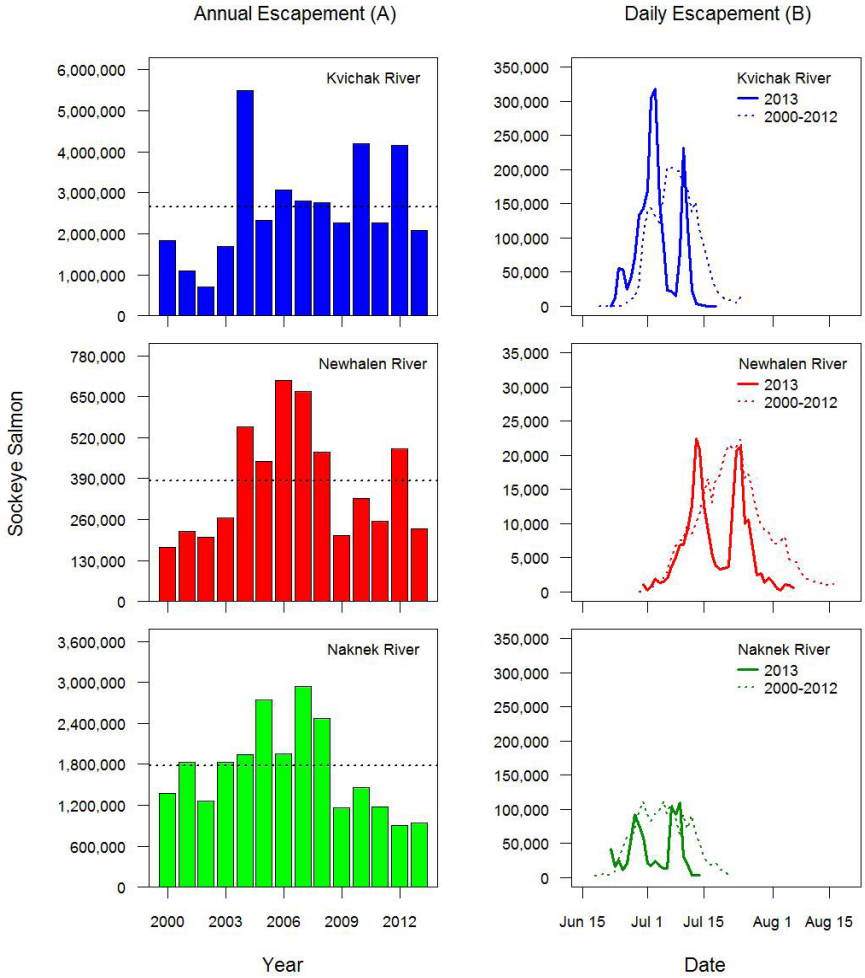

Figure 1. Sockeye salmon escapement estimated annually (A) and daily (B) at counting towers on the Kvichak, Newhalen, and Naknek Rivers. Dotted lines represent the average escapement for the years 2000 - 2012. Note the differences in y-axis scales among the graphs. Kvichak and Naknek data are from http://www.adfg.alaska.gov/.

Recent Trends in Southwest Alaska Salmon Stocks

Overall: Bristol Bay

The number of migrating adult salmon that "escape" the fishery to spawn is commonly referred to as *escapement*. According to the Alaska Department of Fish and Game (ADF&G), the total annual escapement of sockeye salmon (*Oncorhynchus nerka*) to Bristol Bay in 2013 was 7.6 million fish. An additional 15.4 million sockeye salmon were harvested, yielding a total run of 23.0 million fish.

Lake Clark (LACL)

The estimated annual escapement of sockeye salmon for the Kvichak River in 2013 was 2.1 million fish, 22% below the average escapement from 2000 to 2012 (2.7 million fish; Fig. 1A). For the Newhalen River, the estimated annual escapement in 2013 (0.23 million fish) was 40% below the average from 2000 to 2012 (0.38 million fish; Fig. 1A). Salmon counted in the Newhalen River are a subset of those counted in the Kvichak River further downstream, thus the smaller size and later timing of the Newhalen peaks in daily escapement (Fig. 1B).

Katmai (KATM)

The estimated annual escapement of sockeye salmon for the Naknek River in 2013 was 0.94 million fish, or 47% below the average escapement from 2000 to 2012 (1.8 million fish; Fig. 1A). Daily escapement had two distinct peaks in 2013 (Fig. 1B), likely due to a temporary closure in the commercial fishery. This two-peak distribution of escapement was consistent across all three rivers.

Monitoring Approach

In Alaska, salmon are managed by ADF&G, with assistance from the U.S. Fish and Wildlife Service (USFWS). NPS staff supplement ADF&G and USFWS management through salmon-related research and monitoring in parks. Counting towers, aerial surveys, weirs, and sonar are common tools used to estimate escapement. Currently, ADF&G operates counting towers on the Naknek River downstream of the KATM boundary (Fig. 2), and on the Kvichak River downstream of the LACL boundary (Fig. 2). NPS staff operate counting towers on the Newhalen River, upstream of ADF&G's Kvichak tower but downstream of the LACL boundary (Fig. 2). The Kvichak and Naknek watersheds comprise the majority of the land area of SWAN parks draining into Bristol Bay. Thus, monitoring escapement within these systems provides a good estimate of the abundance of salmon returning to large portions of LACL and KATM.

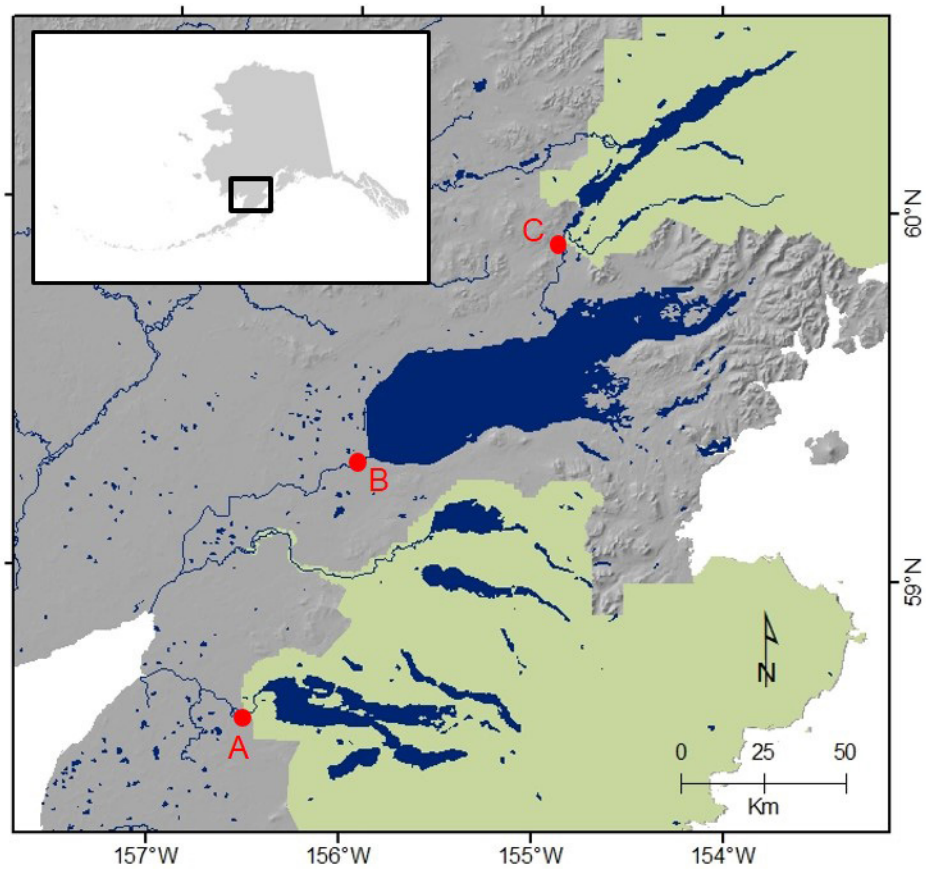

Figure 2. Locations of counting towers on the Naknek (A), Kvichak (B), and Newhalen (C) Rivers downstram of park boundaries in southwest Alaska (map inset).

Yuzhun Evanoff, an intern with the Bristol Bay Native Association, counts salmon migrating upstream on the Newhalen River. Photo: D. Young/NPS.

Sockeye salmon return to natal waters to spawn and die, providing important resources for aquatic and terrestrial ecosystems. Photo: D. Young/NPS.

Importance

Sockeye salmon are the life blood of the Bristol Bay region in southwestern Alaska. This species' importance in structuring the ecological framework of aquatic ecosystems is rivaled only by its storied history in Native Alaskan culture and today's commercial and subsistence fisheries. The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 specifically established LACL for the following purpose, among others: "To protect the watershed necessary for perpetuation of the red salmon fishery in Bristol Bay…" Additionally, ANILCA expanded Katmai National Monument (redesignated as KATM) and created Katmai National Preserve "...to maintain unimpaired the water habitat for significant salmon populations…" Maintaining healthy runs of sockeye salmon is critical to the ecological, economic, and social integrity of the Bristol Bay region.

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Alagnak *Aniakchak* *Katmai* *Kenai Fjords* *Lake Clark*

Visitor Use- Lake Clark NPP

Visitation and Timing

Over the last seven years the number of visitor use days reported by CUA operators (Commercial Use Authorization, i.e. vendors transporting visitors to parks) has more than doubled from approximately 4,000 days to 10,400 visitor use days. Most of this increase is on the Cook Inlet side of the park. In 2013, Crescent Lake, Silver Salmon Creek, and Chinitna Bay were the most highly visited places in the park and preserve, together accounting for over 75% of the reported user days (over 7,530 use days combined) in Lake Clark National Park and Preserve. Crescent Lake has seen a phenomenal growth in visitor use going from less than 250 reported visitor use days in 2007 to approximately 3600 in 2013 (Fig. 1).

The seasonality of the visitor use in Lake Clark can also be viewed via this information. Approximately two-thirds of the visitation occurs in July and August. In spite of the more than doubling of visitation over seven years this ratio has stayed about the same (Fig. 2).

Importance

Understanding visitor use patterns across the parks and across the years lets the park managers assess where rangers and staff need to be deployed, and where impacts (such as trampling or increase in social trails) may need to be monitored or mitigated in the future. Likewise, visitor use patterns may also inform commercial operators by providing insights to the areas visited currently and the timing of visits–details which are helpful when planning guiding operations. Because these remote Alaska park units do not have entrance stations, these data collected from CUA operators are the primary means to quantify and understand visitation patterns and public uses in these vast backcountry areas.

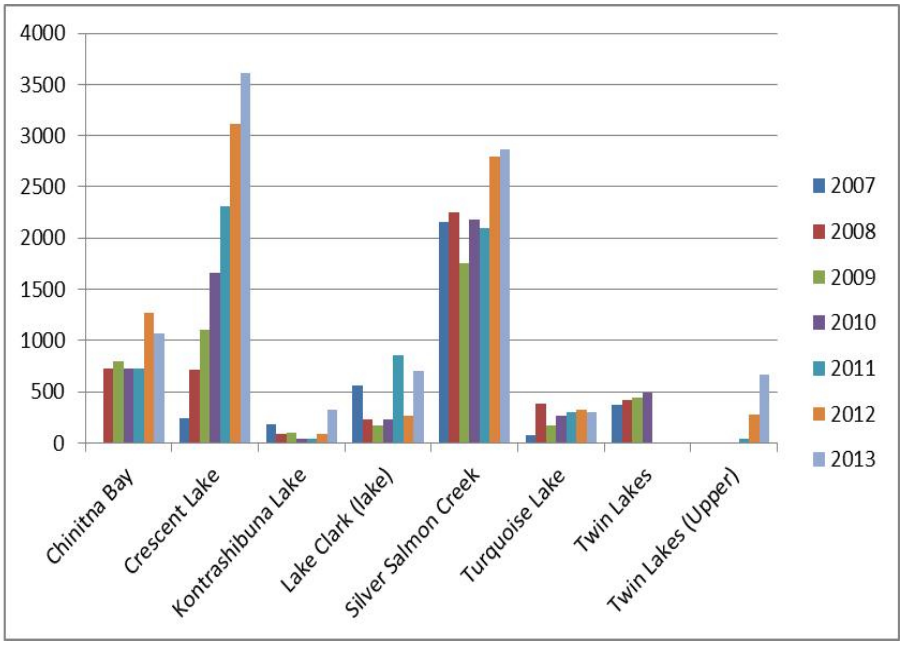


Figure 1. Total User Days by Location (2007-2013) for the three most visited locations on the coast and the four most visited locations in the interior of the park as reported by the commercial use operators. Upper and Lower Twin Lakes were broken out separatelstarting in 2011 resulting in the bar graph gaps. Data from the Lake Clark National Park & Preserve CUA database 03/20/14.

Photographers eyeing a bear near Silver Salmon Creek, Lake Clark NPP.

Activities

Three main activities reported by the commercial operators are bear viewing, sport fishing and photography (Fig. 3). There has been significant growth in the number of visitors coming to Lake Clark for these three main activities. For example, the number of visitor use days reporting bear viewing as their main activity has tripled from approximately 1,000 people (in 2007) to over 3,300 in 2013. The number of reported user days focused on sport fishing and photography has likewise more than doubled in this same period of time. In contrast, the number of reported visitor use days for all other activity categories has stayed relatively constant, although Lake Clark NPP may be seeing both better reporting as well as an increase in hiking tours (over 600 visitor use days for 2013; Fig. 3).

Status and Trends - Lake Clark National Park and Preserve

Visitors to the Park

Visitors to Lake Clark NPP have a choice of numerous permitted CUAs who offer a variety of services within the park and preserve. Visitors may also choose to come to the park utilizing their own plane or boat; however aside from the people who live or have a cabin in or near the park, this is much less common. The vast majority of visitors to the park and preserve utilize a lodge, guiding service, or air taxi operator. The commercial operators pay a small fee for each visitor they bring to the park, and report their usage in the park. This information provides a view of where, how and when the majority of visitors are coming to each park unit. These data are compiled through the CUA reports from each operator.

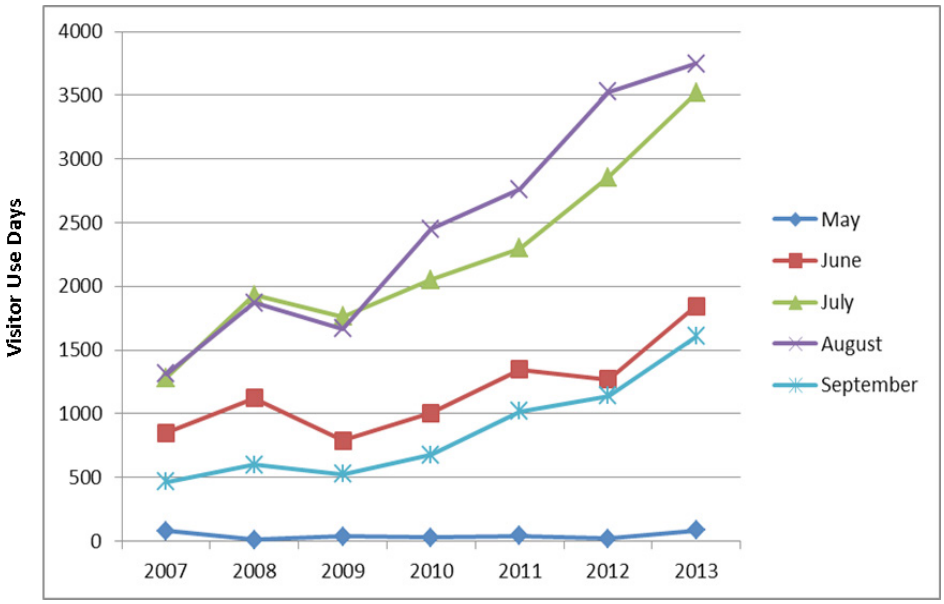
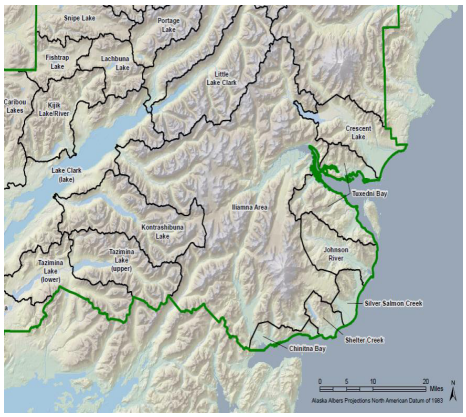


Figure 2. The number of visitor use days for May thru September for 2007 - 2013. Data from the Lake Clark National Park & Preserve CUA database 03/20/14.

User Days & Locations Defined

'User Days' are slightly more than the number of actual visitors to the park, since visitors who spend several days in the park will counted each day they are in the park. This definition of 'User Day' provides the park the best information of the potential impacts by location across the park. This access to broad trends and overall patterns provides the park managers with the information needed to assess potential impacts.

Each park unit is divided into areas (see map), roughly corresponding to watersheds in each park unit. Areas with concentrated use have been sub-divided into smaller areas. When reporting, CUAs choose the area of the visitors' main activity.



There are 33 Visitor Use Monitoring Areas for Lake Clark National Park and Preserve, Alaska, a portion of which are represented. The commercial operators (Commercial Use Authorized operators) report their use in these areas annually, the number of visitors and their main activity.

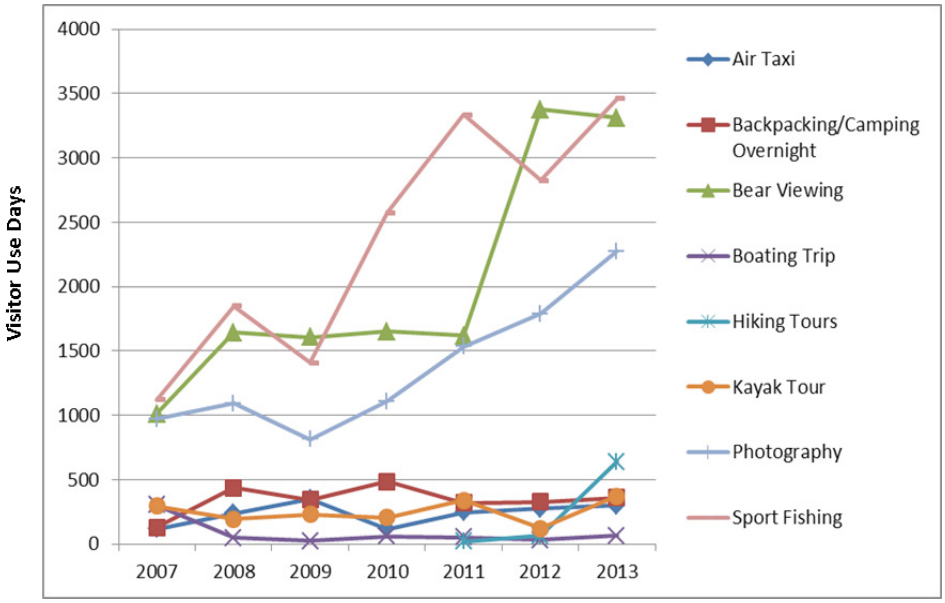


Figure 3. The number of visitors and the main activity for the visitors as reported by the Commercial operators working in Lake Clark NPP from 2007 through 2013. Data from the Lake Clark National Park & Preserve CUA database 03/20/14.

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Southwest Alaska Inventory and Monitoring Program Visitor Use Resource Brief

Alagnak *Aniakchak* *Katmai* *Kenai Fjords* *Lake Clark*

Visitor Use- Katmai NPP

Status and Trends

Over the last seven years the number of visitor use days reported by CUA operators (Commercial Use Authorization, i.e. vendors transporting visitors to parks) has vacillated between 25,000 and 27,000 per year. Visitation patterns are affected not only by sport fishing and bear viewing opportunities but also national events. The national economic downturn in late 2008 affected the visitor use in Katmai for the 2009 season. Visitation for Brooks Camp dropped by almost 2,000 visitor use days, and took three years to recover (Fig. 1).

More detailed review of the specific locations for Katmai NPP show Hallo Bay, Geographic Harbor, Kukak Bay, and Swikshak Lagoon as being some of the most visited locations on the coast of Katmai (Fig. 1). These coastal areas receive over 5,000 visitor use days per year (Fig. 1). Visitation to the other areas in the interior of Katmai and to the Preserve seems to vary more between the years. This probably is due to the change in the strength and timing of salmon runs over different years, and bears usage at these streams providing varying trout fishing and bear viewing opportunities.

Most of the visitation for Katmai National Park and Preserve happens in July and August. About 72% of the visitor use days occur in these two months (Fig. 2). July visitation seems to continue growing (over 10,000 visitor use days in 2013), whereas visitation in June, July and September is declining or flat over the 2007-2013 period (Fig. 2).

Looking only at the most current year, 2013, provides a snapshot of where the visitation occurs in each month. Brooks is extremely busy in July when the bear use of Brooks River is at its peak, and much less in the other months (Fig. 3). Moraine Creek (in the Preserve) has a very high use in August, (with over 2,000 visitor use days), and only 400-500 visitor use days in July and September (Fig. 3). Hallo Bay on the coast has more consistent bear viewing visitation across the summer season by comparison (Fig. 3).

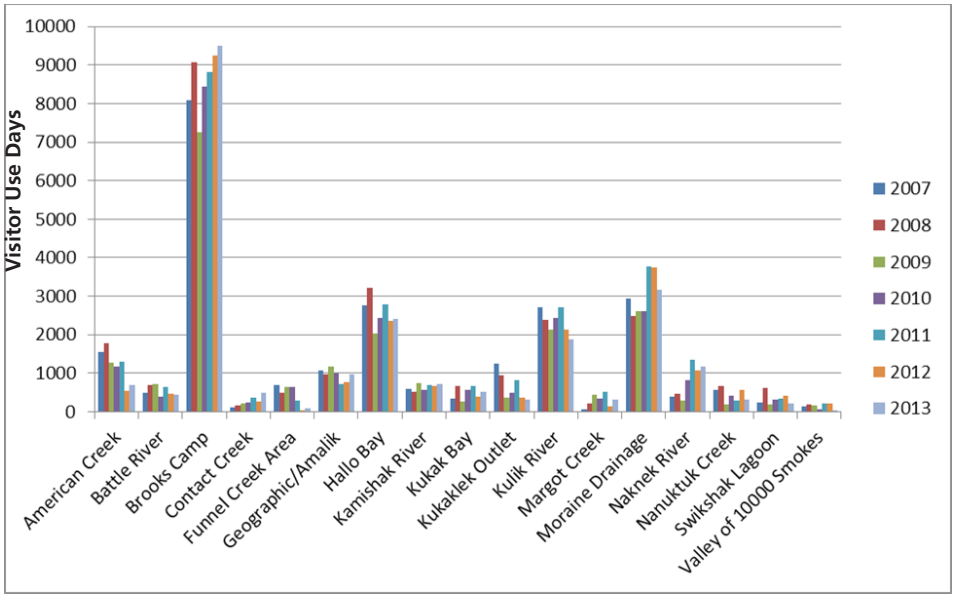


Figure 1. Total Visitor Use Days by Location (2007-2013) for some of the most visited locations in Katmai National Park and Preserve as reported by the commercial use operators. Data from the Katmai National Park & Preserve CUA database 03/20/14.

The main three activities reported by the commercial operators are sport fishing, bear viewing, and air taxi (Fig. 4). These three categories are not mutually exclusive, namely many of the CUA operators report only one activity, where the visitors themselves are focused on both sport fishing and bear viewing. Most of the use reported as 'Air Taxi' is going to Brooks Camp – where people focus on bear viewing as well as sport fishing. Reported other activities, such as big game tranporters, hiking tours, photography etc., continue to make up a very small percentage of visitor use days in Katmai National Park and Preserve (Fig. 4).

Importance

Understanding visitor use patterns across the parks and across the years lets the park managers assess where rangers and staff need to be deployed, and where impacts (such as trampling or increase in social trails) may need to be monitored or mitigated in the future. Likewise, visitor use patterns may also inform commercial operators by providing insights to the areas visited currently and the timing of visits – details which are helpful when planning guiding operations.

Because these remote Alaska park units do not have entrance stations, these data collected from commercial service providers is the primary means to quantify and understand visitation patterns and public uses in these vast backcountry areas.

Photo: Four planes tied up in a small lake in Katmai Preserve, while visitors sport fish and bear view in the stream in the background. July 2013.

Visitors to the Park

Visitors to Katmai NPP have a choice of numerous permitted CUA operators who offer a variety of services within the park and preserve. Visitors may also choose to come to the park utilizing their own plane or boat; however, aside from the people who live or in or near the park, this is much less common. The vast majority of visitors to Katmai National Park and Preserve utilize a lodge, guiding service, or air taxi operator. The commercial operators pay a small fee for each visitor they bring to the park, and report their usage in the park. This information provides a view of where, how and when the majority of visitors are coming to Katmai. These data are compiled through the CUA reports from each operator.

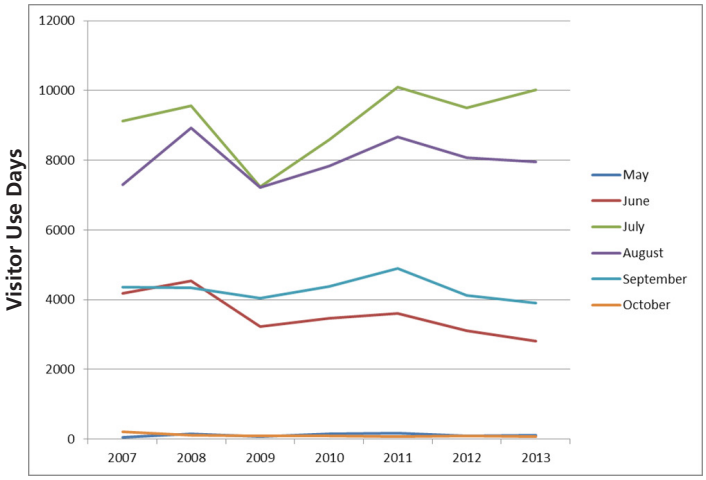


Figure 2. The number of visitor use days for May thru October for 2007 – 2013 for Katmai National Park and Preserve. Data from the Katmai National Park & Preserve CUA database 03/20/14.

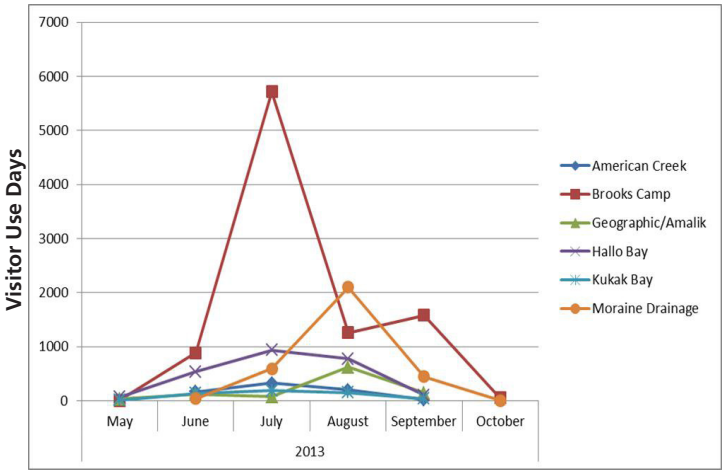


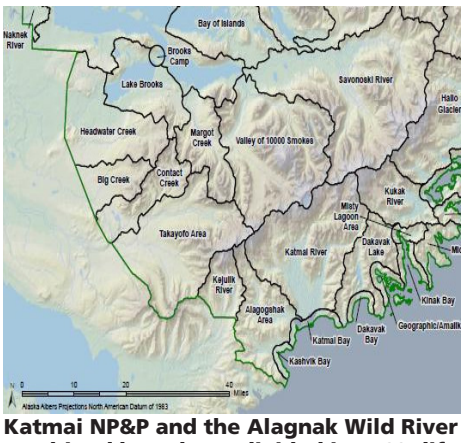
Figure 3. Use patterns across the season for 2013 for some of the most frequently visited locations in Katmai National Park and Preserve. Data from the Katmai National Park & Preserve CUA database 03/20/14.

User Days & Locations Defined

In these cases the number of reported 'User Days' are slightly more than the number of actual visitors to the park, since visitors who spend several days in the park will counted each day they are in the park. This definition of 'User Day' provides the best information of the potential impacts by location across the park. These broad trends and overall patterns of use across the summer and across locations provide park managers with the information needed to assess potential impacts.

Each park unit is divided into areas (see map), roughly corresponding to watersheds in each park unit. Areas with concentrated use have been sub-divided into smaller areas. When reporting, CUA operators choose the area of the visitors' main activity.

Locations in the Parks



Katmai NP&P and the Alagnak Wild River combined have been divided into 60 different use areas, a portion of which are represented. The CUA operators (Commercial Use Authorized operators) report their use in these areas annually, the number of visitors and their main activity.

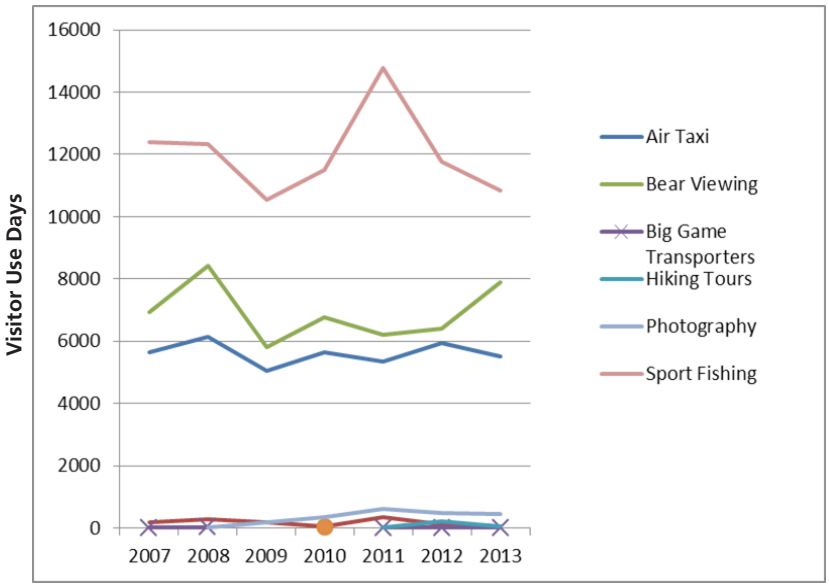
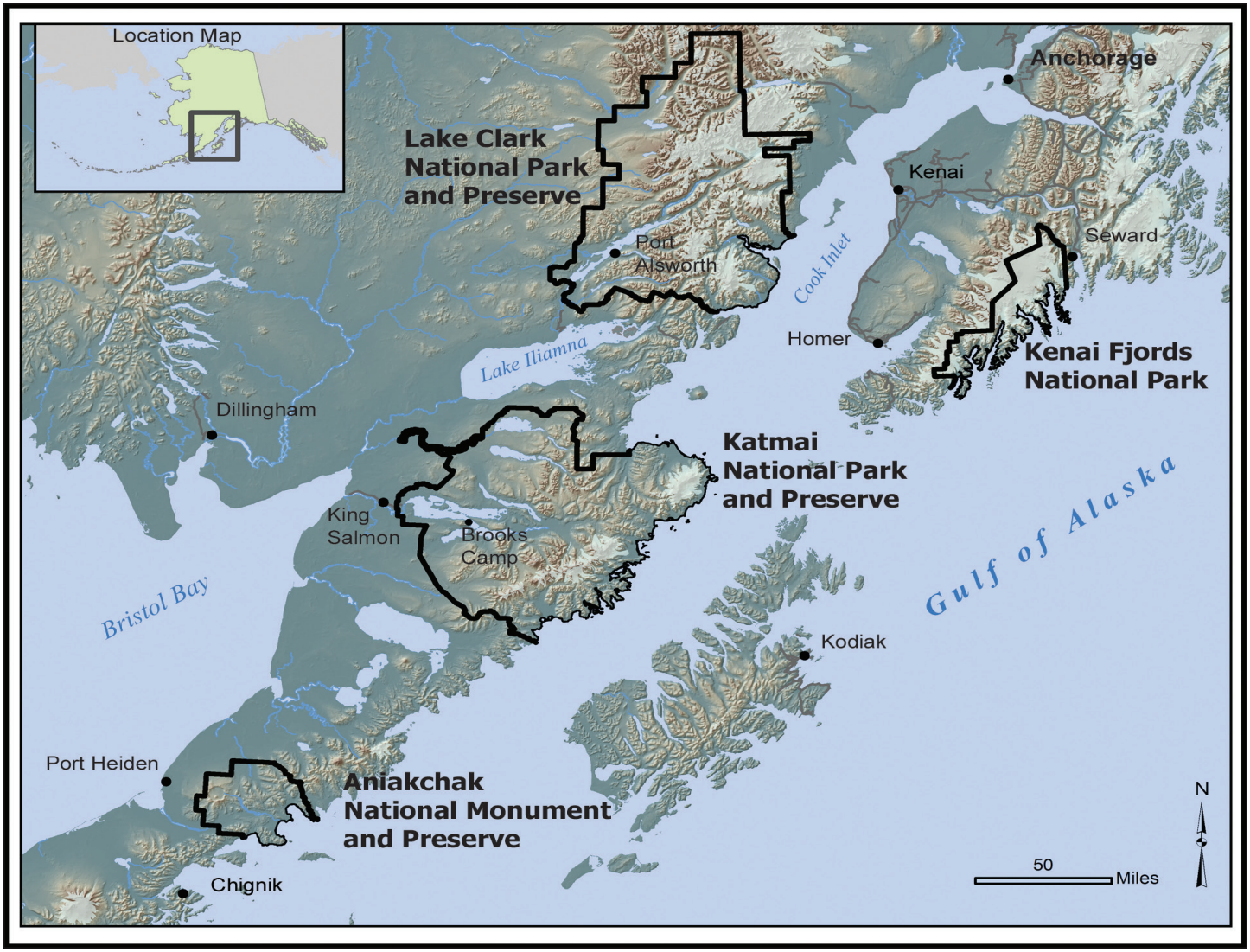


Figure 4. The number of visitors and the main activity for the visitors as reported by the Commercial operators working in Katmai NPP from 2007 through 2013. Sport Fishing, Bear Viewing and Air Taxi continue to dominate reported activities in Katmai. Data from the Katmai National Park & Preserve CUA database 03/20/14.

Contact: Michael Shephard, NPS-SWAN, michael_shephard@nps.gov

National Park Service
U.S. Department of the Interior

Alagnak Aniakchak Katmai Kenai Fjords Lake Clark



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