North Coast and Cascades
Science Learning Network

National Park Service
U.S. Department of the Interior

2012 RESOURCE BRIEF ANNUAL

On the Cover
Top Nicole Bowerman, physical science technician, places a benchmark on Austera Peak, North Cascades National Park. NPS/NOCA.
Bottom Left Mount Rainier National Park. NPS/MORA
Bottom Right Jason Smith and April Lewis bagging non-native yellow iris plants along the Netul River at Lewis & Clark National Historical Park. LEWI/Cole

This Page Bill Baccus (r), Stefan Lofgren (below), and Glenn Kessler (l) sampling snow near Paradise (MORA) as part of the Western Airborne Contaminants Assessment Project. MORA/Lofgren

Opposite Lake Monitoring at North Cascades National Park. NOCA/Welch

contents

What is the Science Learning Network?

The Science Learning Network (SLN) brings science and education together to help preserve and protect areas of national significance. Its mission is to integrate research and education to better communicate park science to the public and other NPS staff.

The Science Learning Network increases the effectiveness of communicating park research, scientific results, and the management of park resources by:

- Facilitating use of parks for scientific inquiry
- Supporting science-informed decision making
- Communicating relevance of and providing access to research knowledge
- Promoting resource stewardship through partnerships

Nationwide, there are 15 “Research Learning Centers,” most located in a single national park. The SLN is a virtual center providing research and education support to all eight NPS areas in the North Coast & Cascades Network.

In 2010, the Science Learning Network launched a website intended to serve as a science information gateway. The website, **www.nwparkscience.org**, highlights research conducted by NPS scientists monitoring park resources, historical research, and featured projects by research partners. Check out our “Science Minute Videos” at **www.nwparkscience.org/video**.

Dr. Jerry Freilich
Science Learning Network Director
Olympic National Park

Jerry Freilich is a Philadelphia native with a masters in Environmental Education from Cornell and a Ph.D. in ecology from the University of Georgia. He’s been a naturalist, law enforcement ranger, and research ecologist at six National Parks since 1978. As director of the Science Learning Network his job is blending science, education, and the media to protect Northwest National Parks.

Dean Butterworth
Education Specialist
Olympic National Park

Upon graduation from the College of the Holy Cross in Worcester, MA Dean Butterworth obtained a commission in the US Navy and served as a communication officer and navigator. After completing his naval service, he obtained an elementary teaching credential through the State of Connecticut’s Alternate Route to Certification program. His NPS career began in 1998 and includes assignments as an interpreter and district interpreter at five other National Parks.

Dr. Mark Huff
Inventory & Monitoring Manager
North Coast & Cascades Network

Mark Huff is Inventory and Monitoring Program Manager for the North Coast and Cascades Network. He worked for five federal and state agencies during his career ranging from to Branch Chief of Science and Decision Support to Interagency Conservation Biologist of the Northwest Forest Plan. Mark received his M.S. from Duke University and Ph.D. from the University of Washington.

SLN Steering Committee

Jacqueline Ashwell
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Mount Rainier National Park

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Greg Shine
Chief Ranger and Historian
Fort Vancouver National Historic Site

David Szymanski
Superintendent
Lewis and Clark National Historical Park

Jerald Weaver
Chief of Integrated Resources
San Juan Island National Historic Site

north coast and cascades **parks**

U.S. Department of the Interior
↓
National Park Service
↓
Pacific West Region
↓
North Coast and Cascades Network
↓
- **Science Learning Network**
- Inventory and Monitoring

The National Park Service is responsible for 392 park units across the United States. These parks are divided into regions and further still into networks. Each network contains parks that share common ecological and cultural features.

The eight North Coast and Cascades parks are in the mountains and lowlands of the Pacific Northwest, from the Pacific Ocean to the east slope of the Cascades Range. Tall mountains and a maritime climate produce a tremendous environmental gradient, varying in elevation from sea level to glaciers, and in annual precipitation from almost 200-inches to less than 20-inches per year. These environmental patterns shape the variety and distribution of plant and animal communities and ecosystems encompassed within the parks.

Four historic parks preserve snapshots of significant cultural milestones in the development of the Pacific Northwest. Three larger parks showcase the variety of terrestrial and aquatic ecosystems native to this region and exemplify pristine Pacific Northwest Wilderness areas.

PARK NAME	TYPE OF PARK UNIT	ACRONYM	ACREAGE	2009 VISITATION
Ebey's Landing	National Historic Reserve	EBLA	19,333	NA
Fort Vancouver	National Historic Site	FOVA	194	1,017,326
Klondike Gold Rush- Seattle	National Historical Park	KLSE	<1	54,219
Lewis and Clark	National Historical Park	LEWI	1,575	225,846
Mount Rainier	National Park	MORA	236,380	1,151,654
North Cascades	National Park Complex	NOCA	504,780	349,934
Olympic	National Park	OLYM	922,650	3,276,459
San Juan Island	National Historical Park	SAJH	1,751	274,642

Style Guide

How to Write and Submit a Resource Brief

Resource Briefs are 1-3-page synopses summarizing resource topics and are updated annually. They are intended to be starting points, where readers can quickly learn about issues and then find links to web and print sources for further information. These briefs succinctly explain why the monitoring of a particular resource is critical, its status and trends, and a discussion of ecological or management implications.

One goal of the Science Learning Network is to have briefs written for every network Inventory and Monitoring Vital Sign as well as a number of critical park-specific topics. The SLN is committed to maintaining these briefs on an annual basis and to adding other briefs on relevant topics.

The primary audience for this communication product is park managers and interpreters. Interested members of the public will also be able to download these briefs from www.nwparkscience.org.

Specifications

- Fits onto one to three 8½" x 11" pages
- Contains one or two relevant photos, maps, charts, graphs, etc.
- The text consists of three parts as summarized below, for a total of about 1,000 words.

- **IMPORTANCE** A short explanation of why the resource matters. This could refer to its ecological role or its importance to humans, and should specifically pertain to the North Coast and Cascades Network. 200-250 words

- **STATUS AND TREND** A summary of the current status and how the resource has changed over a specified period of time. This may also include an event of interest that monitoring data have captured. Depending on what is relevant to current management of the resource and which data are available, this may be only the last five years, or it may cover the last century. Indicate what is being monitored and include specific data where possible, but not data that require extensive explanations. 200-300 words

- **DISCUSSION** The discussion section should provide concise, insightful comments on the monitoring results. The discussion could include patterns and relationships in the data, predictions, emergence of new questions, explanation of unexpected results, inconclusive nature of the data, comparisons with existing literature, and any other major findings not included in the status and trends section. A discussion also could include how management decisions were made using monitoring data, how trends or changes may impact other monitoring topics, ecological implications of an event or change, and key reason(s) for any changes that have occurred. 100-150 words

- **GRAPHICS** The text should be accompanied by eye-catching graphics: photos, maps, and/or graphs (with captions)—that are relevant. For topics for which data are available, include graphs to show the most important trends over a relevant period of time.

To create a new resource brief, please contact Jerry_Freilich@nps.gov

Resources

What is Inventory and Monitoring?

Park managers are charged with keeping our National Parks "unimpaired for the enjoyment of future generations." To do this they need to understand which resources are actually present in the parks and their condition. To document status and trends of natural resources, a national program of inventory and monitoring (I&M) has been under development since 2001. The North Coast & Cascades network of parks was one of the first to begin implementing this program. I&M is designed to characterize trends in the status of the park ecosystem, to assess the efficacy of management practices, and to provide early warning of impending threats.

The I&M program is based on monitoring carefully selected "Vital Signs," chosen as sensitive indicators of the overall health of park resources. Vital Signs are physical, chemical, and biological measurements, each selected for its ability to inform park managers in a timely and cost-effective way. Vital Signs monitoring will help define the normal limits of natural variation in park resources and provide a basis for understanding future changes. Monitoring results will also be used to identify problems, to give early warning of impairment, and to suggest areas where management practices need change. Results from Vital Signs monitoring are assembled nationally and reported to Congress annually in the form of an ecological health "scorecard."

National

The National Park Service:	*www.nps.gov*
Explore Nature in the NPS:	*www.nature.nps.gov*
Research Learning Networks	*www.nature.nps.gov/learningcenters*
Inventory and Monitoring	*science.nature.nps.gov/im/index.cfm*

North Coast and Cascades Network

Science Learning Network	**www.nwparkscience.org**
Inventory and Monitoring	*science.nature.nps.gov/im/units/nccn*
Intranet I&M website (available only to NPS computers)	*www.nccn.nps.gov/im/default.aspx*

National Park Units

Ebey's Landing	*www.nps.gov/ebla*
Fort Vancouver	*www.nps.gov/fova*
Klondike Gold Rush *(Seattle)*	*www.nps.gov/klse*
Lewis and Clark	*www.nps.gov/lewi*
Mount Rainier	*www.nps.gov/mora*
North Cascades	*www.nps.gov/noca*
Olympic	*www.nps.gov/olym*
San Juan Island	*www.nps.gov/sajh*

Additional Resources

Greater Yellowstone Science Learning Center	*www.greateryellowstonescience.org*

Climate

Ebey's Landing, Fort Vancouver Lewis and Clark, Mount Rainier, North Cascades, Olympic, San Juan Island

I & M RESOURCE BRIEF

Importance

Climate can be described as the prevailing weather conditions of a region averaged over a series of years. A region's climate acts as a "system driver," an over arching set of ecological and physical phenomena including wind, precipitation, temperature, and other variables associated with the global movements of vast air masses.

Climate is a primary factor regulating all biological processes and it ultimately controls the distribution of plant and animal species. For example, climate controls the elevation of treeline, the location of prairies and rainforests and all of their associated species. Climate affects the behavior and reproduction of individual organisms. These effects can be subtle, pushing a bird's breeding season forward or back by days or weeks. Or they can be dramatic, for example a stream's temperature may rise above a threshold eliminating certain species of fish. In addition, extreme weather, an aspect of a region's climate, can result in windthrow clearings, forest fires, avalanches, and floods.

The North Coast and Cascades Network (NCCN) monitors climate to understand variations in other park resources being monitored. Comparing current and historic data helps us to understand long-term trends and provides the means for modeling impacts to park facilities and resources in the future. The NCCN climate monitoring program compiles data from over 40 weather stations in and adjacent to the parks, 12 of which are actually operated by the National Park Service. Compiled weather data for individual water years (Oct 1 to Sept 30) is published in five NCCN reports annually.

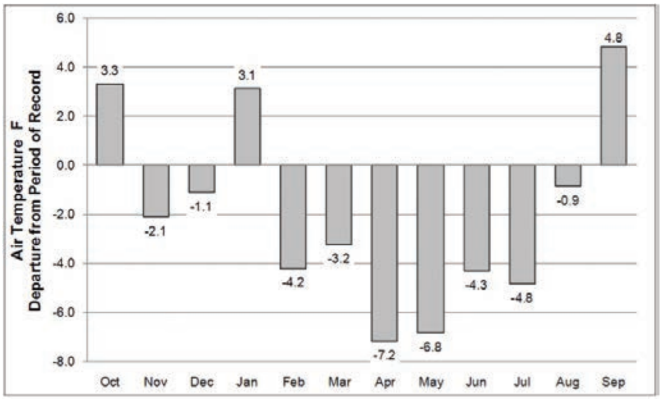
Status and Trends

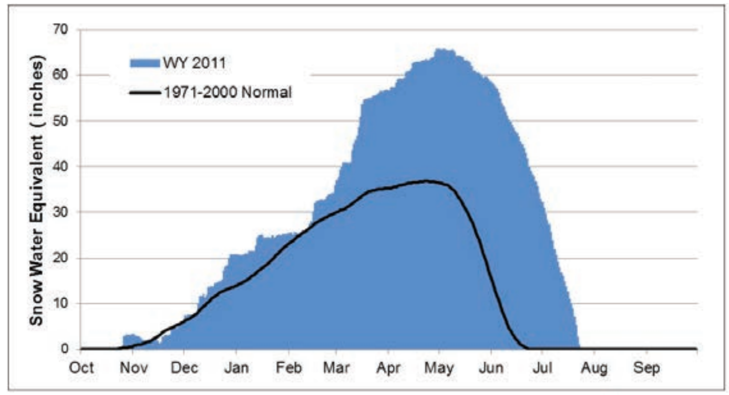
Water years 2010 and 2011 were characterized by cool and wet springs, followed by colder than normal summers. This was particularly true in the spring and summer of 2011. The mean statewide temperature for Washington State from April through July 2011 was the second coldest in a record extending back to 1895. This temperature anomaly is well illustrated when comparing 2011 temperatures at Paradise in Mount Rainier National Park (MORA), with the nearly 100 year record from this site (Opposite L).

Cold temperatures and above normal precipitation during spring and early summer months of both years also resulted in unusually deep and persistent snowpacks in the mountainous NCCN parks. In the summer of 2011, June 1st snowpack was over 200 percent of normal at the Waterhole SNOTEL near Hurricane Ridge in Olympic National Park (Opposite R). At Paradise, in Mt. Rainier, the record for the maximum snow depth was broken for eight consecutive days beginning on August 7th and ending on August 24th. Snow finally melted at the Paradise weather station on August 25th, missing the record for latest snow on the ground by 2 days, which was set in 1974.

Recent climate trends, especially the cool springs and persistent snowpacks of the last two years, directly influenced the ecosystems and research activities within the NCCN mountain parks. In 2010 and 2011, Nisqually and Emmons glaciers on Mt. Rainier exhibited positive mass balances (i.e., the glaciers grew) for the first time since monitoring began in 2003. All four glaciers monitored by the NPS at North Cascades National Park had positive mass balances in 2011, the first time in 12 years.

In 2011, ice out dates for mountain lakes were the latest since monitoring began. Study lakes at Olympic National Park remained frozen an average of 300 days, 51 days longer than normal (Opp Bottom). The abbreviated season of open water in these lakes likely had a profound short term effect on aquatic organisms and influenced the physical and chemical measurements recorded.





Discussion

These climate observations had biological ramifications. In 2010, Roosevelt Elk herds in the western valleys of Olympic National Park remained out of their traditional count areas until mid-April, well after the annual census was conducted. In 2011, spring counts were abandoned as GPS locations of radio collared animals indicated that they had not yet descended into the survey count areas. That same year, fall counts of elk herds in high country areas were delayed until mid-September, as herd movement indicated a six week delay in their migration to high country habitat.

Annual efforts to monitor migratory and resident landbirds during spring and early summer of 2011 were stymied by a persistent snowpack blanketing high country areas. At the three mountainous parks, field crews were unable to access some of the higher elevation survey transects. Preliminary results from surveys indicated a change in the elevation distribution of some bird species.

A mid-January rain event observed across the Cascades and Olympics created a widespread and persistent crust in the mountain snowpack. This crust was responsible for numerous large avalanches in 2011 which in turn created large areas of forest disturbance.

Climate models project an increase in average temperatures in the Pacific Northwest, while projected changes in precipitation are less certain. In 2010 and 2011, NCCN parks were largely influenced by the presence of strong La Niña conditions, caused by an atmospheric response to cooler than normal Pacific Ocean temperatures. La Niña conditions are associated with cooler and wetter than normal weather patterns in the Pacific Northwest. The below-normal temperatures of the past two years are simply part of natural climate variation. Future data collections will tell how these trends mesh (or clash) with long-term patterns.

Contact: Bill_Baccus@nps.gov

Opposite Park Technician Bill Baccus replaces electronics on an automated rain gage. NPS/OLYM/Warrick

Above Left Comparison of average monthly temperature (°F) for the Paradise COOP Station in Water Year 2011 against monthly averages 1916-2011.
Above Right Comparison of daily snow water equivalent (inches) for the Waterhole SNOTEL (OLYM) in Water Year 2011 against the climate normal (1971-2000). Note snowpack's extreme departure from normal beginning in March and continuing into mid-summer.
Right Remnants of the previous winter's ice cover in mid-October, 2011. Milk Lake, Olympic National Park. NPS/OLYM/Baccus

Glaciers

North Cascades, Mount Rainier

I & M RESOURCE BRIEF

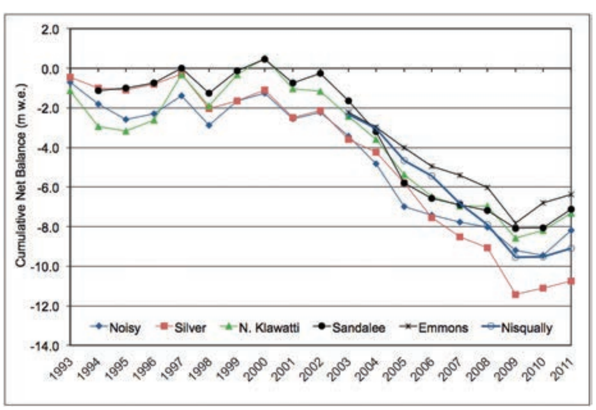
Importance

Glaciers have continued to shape the dramatic scenery and ecosystems of the Pacific Northwest Mountains since the end of the last ice-age. They currently cover a combined area of 235 km^2 in the three large national parks in Washington State, and are integral components of the region's hydrologic, ecologic, and geologic systems. Each summer glaciers provide billions of gallons of freshwater for drinking, irrigation, hydroelectricity, fishing, water-based recreation, and wildlife. Glacial melt water comes at a critical time of year when the weather is relatively hot and dry, providing late-season buffering to the region's lakes and streams. On the Skagit River alone glaciers provide 8-12% of total summer runoff, or about 120-180 billion gallons. The glacial influence on the Skagit is likely the main reason why it is one of the few rivers in Puget Sound to host all five native species of salmon. The sensitive and dynamic response of glaciers to variations in both temperature and precipitation in all seasons makes them excellent indicators of regional and global climate change.

Status and Trends

The National Park Service began long-term monitoring of extent and volume of four glaciers at North Cascades National Park Complex (NOCA) in 1993 and two glaciers at Mount Rainier National Park (MORA) in 2003. Monitoring includes spring field measurements of snow depth and density on the glaciers, while snow and ice melt are measured in late summer. These measurements are used to calculate volume change or "mass balance." Mass balance is the difference between winter accumulation (growth) and summer melt (loss).

Our monitoring program has observed significant reductions in glacier mass balance at both parks. Since 1993, glaciers monitored at NOCA have a combined volume loss equivalent to nearly 9.6 billion gallons of water, while at MORA glaciers have lost 35.8 billion gallons of water equivalent since 2003. This is a continuation of long-term glacial retreat started in the early 1900's. Since that time, NOCA glaciers have shrunk about 53 percent in the last 100 years.



In 2010 and 2011, wet springs and cool summers helped glaciers build small increases in mass balance. At NOCA, all four monitored glaciers had slightly positive net mass balances for the first time in twelve years. At MORA, both Emmons and Nisqually glaciers were slightly positive in 2010 for the first year since monitoring began. In 2011, five of six glaciers monitored had positive mass balance, while Emmons glacier was slightly negative. This small gain in volume, however, is unlikely to reverse the long-term decline.

Glacier contributions to the four watersheds within NOCA averaged 165.0 billion gallons in 2010 and 2011 comprising between 3 and 24 percent of the total runoff depending on the year and watershed. At MORA, glacial contribution to the Nisqually and White River watersheds averaged 53.1 billion gallons, and 12-10 percent of the total runoff, respectively.

For more information see the North Cascades Glacier Monitoring Program website (http://www.nps.gov/ noca/naturescience/glacial-mass-balance1.htm).

Discussion

Rapid loss of glaciers in this network is unambiguous evidence of global warming, and reflects a pattern observed in mountain ranges around the world. Loss of this resource and the late summer water it provides is already affecting lakes, streams, municipalities and hydroelectric projects. Continued loss of glaciers will complicate efforts to protect threatened and endangered species such as Chinook salmon and bull trout. Research using glacier monitoring data indicates that the loss of glaciers during the last century in Thunder Creek watershed at NOCA has resulted in a 25% decline in late summer stream flow. During the next century, glacier loss in this basin could reduce summer stream flow an additional 30%.

Contact: Jon_Riedel@nps.gov

Opposite Cumulative net mass balance of six glaciers monitored at North Cascades and Mount Rainier national parks. Units are meters water equivalent (m w.e.). Water equivalent expresses the different water contents of snow, ice and firn as a single value

Above Jeanna Wenger and Rebecca Lofgren take glacier measurements at Ingraham Flats, Mount Rainier National Park. Little Tahoma Peak in the background. MORA/Bowerman

Landscape Dynamics

North Cascades, Mount Rainier, Olympic, Ebey's Landing, San Juan Islands, Lewis and Clark

I & M RESOURCE BRIEF

Importance

Each year natural disturbance events such as avalanches, landslides, floods, fires, and clearcuts alter the landscape in and around the parks in the North Coast and Cascade Network (NCCN). These landscape changes vary in duration, size, and severity, from a sudden small flood in a riparian zone to a fire that burns thousands of acres over several weeks.

Although considered a natural process, landscape change inside the park can have lasting effects on park ecosystems and can significantly impact natural and cultural resources. Changes outside the park, such as clearcuts and development, alter the ecological connections that tie resources within the park to the broader ecosystem in which the park is located.

The NCCN landscape dynamics monitoring program was developed to track the location, type, severity and duration of common landscape changes. Observations from the program will provide both a broader context for changes observed in other NCCN monitoring programs and a baseline against which to compare the natural frequency of changes with those under future-anticipated climate regimes.

Methods

Due to recent advancements in satellite imaging and remote sensing technology, landscape changes can be efficiently detected over large areas at a relatively low cost. Our program uses satellite imagery, Geographic Information Systems (GIS), and statistical analyses to map and categorize change events in and around NCCN parks. The study area for each park was designed to include all watersheds inside and within 10 miles outside of park boundary, as well as areas of particular interest to parks (Figure 1). The specific objectives of the monitoring program are:

1. To detect and map areas within the NCCN study areas larger than 2 acres (0.8 ha) that have experienced a minimum 10% loss in cover.
2. Using aerial photography and/or classification models, to map and categorize landscape change types of interest to the NCCN.

The landscape dynamics monitoring program compares yearly sets of images from Landsat satellite system to detect significant landscape changes. The process of identifying changes has been automated by a computer program called LandTrendr, developed by a group of scientists at Oregon State University. Each year, the Landsat images undergo LandTrendr statistical analysis to detect all new areas that have changed compared to the previous years. Each area then passes through a size and magnitude filter, resulting in a map that shows change events that are larger than 2 acres (0.8 ha) and where at least 10 percent of vegetative cover was removed. Figure 2 shows how LandTrendr detects a Mass Movement at North Cascades National Park (NOCA).

Above Western Washington University Intern Ian Oehler evaluates his position using a GPS while Nathan Schaller records data. NPS/NOCA
Below Wind thrown trees in the Quinault Valley, Olympic National Park. OLYM/Warrick

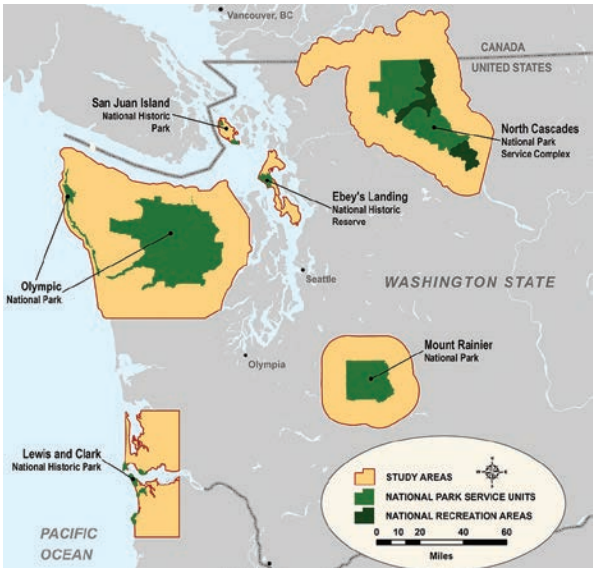


Figure 1

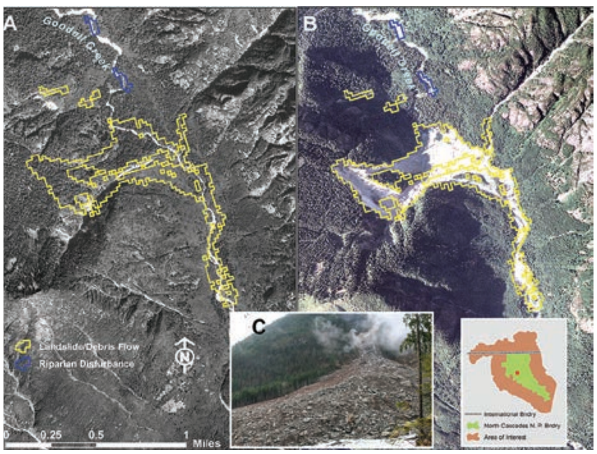


Figure 2

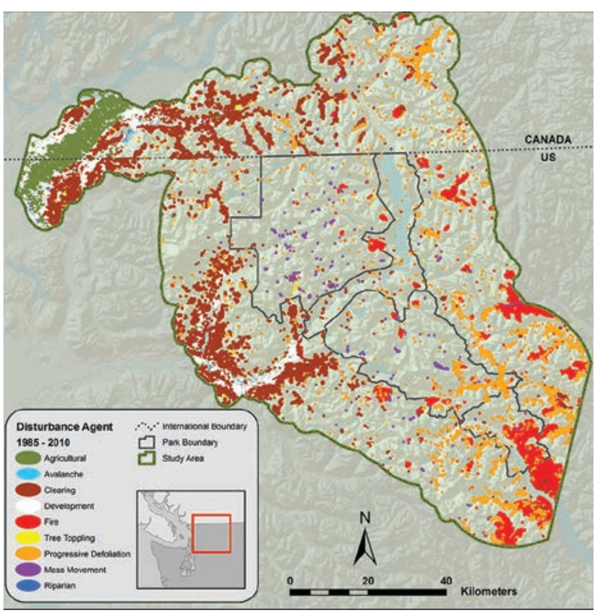


Figure 3

Once individual change events are delineated, we apply a statistical model to the data to label the event with a landscape change type. The statistical model combines information about the event's shape, size, and location on the landscape with the information about the event's duration and magnitude from the LandTrendr algorithm. For example, the irregular shape, location on a valley wall, and full removal of vegetation are all factors that would lead to the event shown in Figure 2 receiving the Mass Movement category label. Maps showing the location of the landscape change events inside and outside NCCN parks are then created (Figure 3).

Discussion

The NCCN's landscape dynamics monitoring program launched at NOCA in spring of 2011 using Landsat images from 1985 to 2010. Future analyses will investigate the links between the frequency and timing of landscape change and Pacific Northwest weather patterns, potentially leading to more accurate predictions of certain changes over time.

Researchers predict that in the Pacific Northwest, global climate change may cause some types of landscape changes, such as fires and floods, to increase in frequency and severity. Evidence to evaluate these predictions will come directly from this monitoring program and similar projects around the region. With this study, the NCCN parks will serve as frontiers for some of the most expansive and detailed natural resource monitoring in the Pacific Northwest.

Contact: Catharine_Thompson@nps.gov OLYM
Natalya_Antonova@nps.gov NOCA

Intertidal Monitoring: Sand Beaches

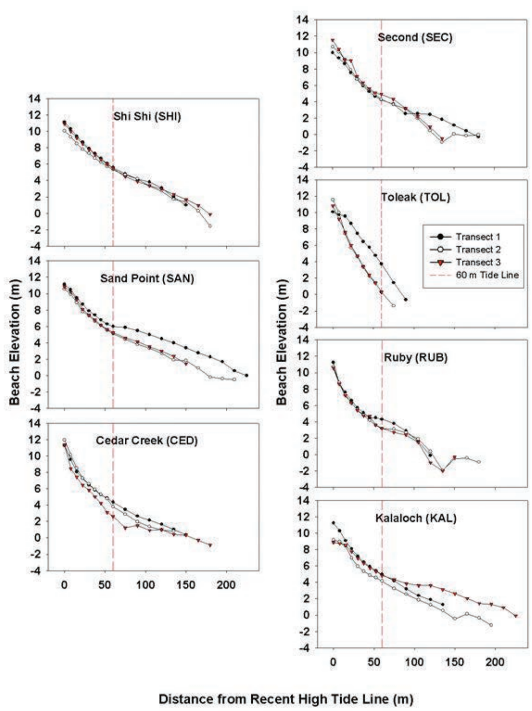
Lewis and Clark, Olympic, San Juan Island

I & M RESOURCE BRIEF

Importance

The North Coast and Cascades Network (NCCN) of parks provide refuge for a vast reservoir of marine resources in the intertidal zone, an area inundated and exposed twice daily by the tide. The hallmark of NCCN intertidal areas is the incredible productivity and diversity of the rocky, cobble and sandy beach habitats, with over 750 species of marine invertebrates and seaweeds and 65 species of intertidal fish. This richness represents the highest diversity of intertidal biota found along the entire west coast of North America. The intertidal zone represents a transition between terrestrial and marine environments. Intertidal and nearshore ecosystems are tightly linked via nutrient cycling, dispersal of organisms and the opportunistic use of intertidal areas by nearshore organisms when it is flooded. The productive nearshore waters of the Pacific Northwest are strongly influenced by oceanographic processes, such as upwelling of deep nutrient-rich water on open coast. Most intertidal organisms have life stages that live and disperse through the nearshore coastal ocean and contribute to its high productivity.

The sand beaches of Olympic National Park are a major intertidal habitat. These beaches make up approximately 30% of the 70 mile Olympic park coastline and play a key role in nutrient cycling and nearshore ocean productivity. Invertebrates living in the sand are important food resources for migrating shorebirds. Sand beach organisms have evolved many adaptations to life in a harsh, wave swept, shifting sand environment. However, sand beach ecosystems are susceptible to the effects of global climate change, including increased warming, increased frequency and magnitude of storm events, sea level rise, and ocean acidification. Direct human impacts, such as shoreline modification and oil spills can also affect sand beach ecosystems.



Status and Trends

Seven sand beaches spanning the length of the Olympic coast are monitored annually as part of the NCCN Intertidal Monitoring Protocol. On each beach the vertical profile, sand size composition, and invertebrate community structure are measured at three different locations. Sampling from the 2010 field season showed that all beaches, with the exception of Toleak beach, were composed of fine sand with shallow beach face slopes. This beach structure dissipates wave energy across the beach face, delivering nutrients and food resources to organisms that live in the sand. These fine sand beaches also had similar animal community structures. Toleak beach was characterized by a steeper beach face composed of sand and gravel. This beach structure reflects wave energy and the coarser sediments create a harsh environment for animals living in the sand. This phenomenon was illustrated in the Toleak beach community structure, which was depauperate relative to the other beaches, with an average of 8.3 taxa present compared to the 11 taxa found on the other beaches.

Discussion

The array of similar sand beaches along the Olympic coast allows for the detection of environmental change impacts along a latitudinal gradient. In addition, they comprise a network of comparable sites for use in assessing the impact of oil spills along the coast. Like all of the NCCN marine parks, Olympic is situated along major travel routes for commercial shipping traffic, including oil tankers, bound for the ports of Vancouver (Canada), Seattle, and Portland. Sampling from the 2010 field season provided baseline conditions for this array of beaches. Future work will focus on the analysis of trends in physical and biological structure across time. Toleak beach may be dropped from the monitoring program if it proves consistently different from the other beaches.

Opposite, Beach face profiles of Olympic sand beaches. Note that Toleak beach is significantly steeper than the others.

Above Left Olympic National Park sand beach monitoring sites.
Above Right NPS scientists conducting Above beach sampling on Shi Shi beach (OLYM). OLYM/Fradkin

Contact: Steven_Fradkin@nps.gov

Landbirds

Lewis and Clark, Mount Rainier, North Cascades, Olympic, San Juan Island

I & M RESOURCE BRIEF

Importance

Landbirds are vital to every Pacific Northwest ecosystem. They are critical components in a complex food web, eating millions of seeds and insects and in turn, providing food for other creatures. Because they have specific requirements for food, nest sites, and habitats, they respond to subtle changes to their environment. For these reasons, birds are among the most sensitive indicators of ecosystem health and monitoring them is one of the most efficient ways to take the ecological pulse of an area. Bird populations are widely used as indicators of ecosystem health, and monitoring methods have been standardized, giving scientists a relatively low cost and statistically rigorous monitoring tool. Whether year-long residents or spring and fall migrants, birds bring color and song to our national parks. They have high and growing public interest and are the most visible faunal component of many park ecosystems. This broad public interest in birds ensures that landbird information gathered over time will be relevant to the public and to resource managers.

Despite many international treaties, domestic laws, and initiatives protecting resident and migratory bird species, landbird populations continue to decline. Because national parks provide relatively stable and protected habitat for birds, parks are among the few remaining places to study regional and global effects on bird populations. North Coast and Cascade Network parks represent excellent reference sites for comparison with more heavily managed lands. Monitoring landbird populations in Pacific Northwest national parks fills gaps in other regional monitoring programs, for example, collecting information in high elevation subalpine habitats which are virtually unmonitored by other programs.

Trends

The NCCN Landbird Monitoring Program completed its fifth year of long-term landbird monitoring in 2011. During the first five years of sampling, we documented over 100 bird species breeding in the five parks. The six most commonly detected breeding species include pine siskin, dark-eyed junco, red crossbill, varied thrush, winter wren, and Townsend's warbler.

Discussion

In 2007, NPS biologists working with The Institute for Bird Populations and the US Geological Survey established a Landbird Monitoring Protocol for national parks in the NCCN. The NCCN Landbird Monitoring Program has completed five successful years of sampling with the comprehensive, field-tested protocol.

Preliminary results indicate the monitoring program will provide a robust dataset for evaluating a 5-year trend analysis to be completed in 2012-2013, and that the monitoring program is detecting substantial annual fluctuations in bird populations. These fluctuations, when analyzed in the context of annual weather variation and perhaps other factors, should yield interesting and useful findings about the drivers of population dynamics in birds of Pacific Northwest forests.

Contact: Robert_Kuntz@nps.gov

Top Left Rufous hummingbird on Nest GLAC/Hayden
Top RIght Red crossbill male. OLYM/Freilich
Below Landbird crew members in spring training. NPS/NOCA

Mountain Lakes

Mount Rainier, North Cascades, Olympic

I & M RESOURCE BRIEF

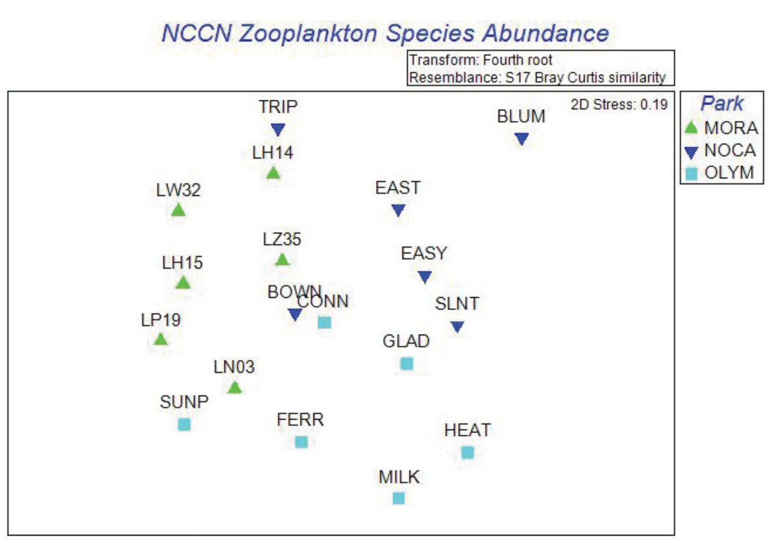
Importance: Petri Dishes of the Pacific Northwest

Shrouded by clouds, mist, and snow for much of the year, high mountain lakes are ideal locations to assess environmental change affecting the high country of the Pacific Northwest. With over 1500 high elevation lakes, the mountainous parks of the North Coast and Cascades Network (NCCN) are exposed to both global stressors, such as climate change, and regional stressors, such as air pollution and visitor impacts. These parks, Olympic, Mount Rainier, and North Cascades, span a gradient of urban influence from the sparsely populated West Coast across Puget Sound and into Eastern Washington. Each park has its own landscape setting, with different geology, climate and connectivity to other mountain systems. Like living Petri dishes, each mountain lake is essentially a pristine membrane accumulating and responding to the chemical and biological influences of the surrounding area.

Zooplankton are monitored annually in NCCN mountain lakes. They are ubiquitous animals living in the water column of lakes worldwide. These organisms are a central link in lake food webs, eating microscopic plants and bacteria in the water, and being eaten themselves by amphibian and fish predators. Zooplankton community structure – the body size, number and density of distinct species, provides valuable insight into environmental perturbations affecting lake ecosystem function. Changes in zooplankton community structure can be linked to nutrient enrichment, sedimentation, and altered foodweb interactions, particularly changes in the presence and density of fish and amphibians.

Status and Tends

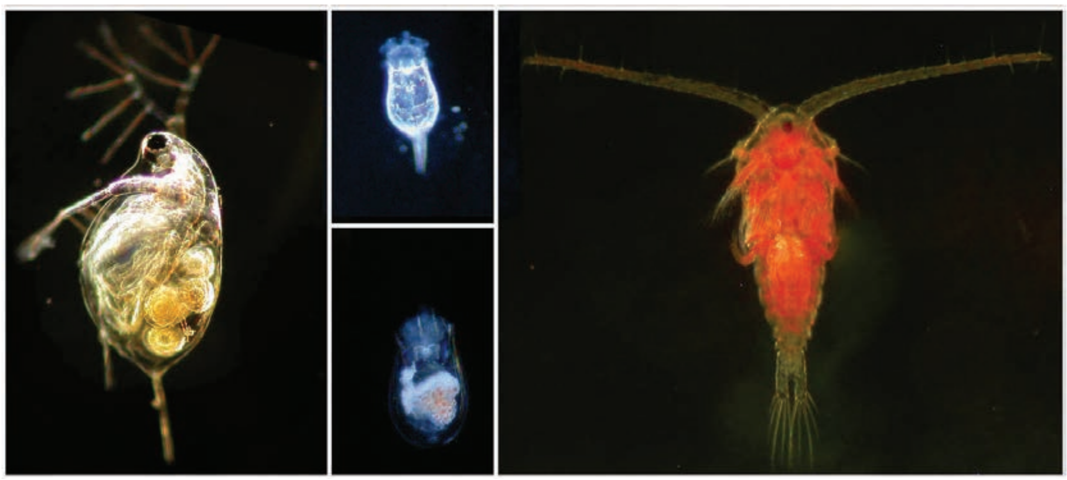
In 2009, Zooplankton communities of 18 subalpine lakes, six at Mount Rainier, six at North Cascades, and eight at Olympic were sampled between August and September. Samples were identified to the lowest possible taxonomic level and community data were analyzed via multivariate techniques. A key finding of this analysis illustrated that the zooplankton



This Page A non-metric multi-dimensional scaling plot of the zooplankton community structure of 18 NCCN lakes from 3 parks. Each symbol represents the community structure of a lake. The clustering of like park symbols illustrates the distinct nature of the park zooplankton communities.

Opposite Above Evergreen State College Intern Samantha Sadoski sampling zooplankton at Lake Louise, Mount Rainier National Park. NPS/MORA

Opposite Below Representative NCCN zooplankton clockwise from left: a cladoceran *Daphnia rosea;* rotifer *Hesperodiaptomus kenai;* copepod *Notholca michiganensis*; and rotifer *Keratella cochlearis.*



community structure of each park was distinctly different (graph below). Mount Rainier and North cascades communities were dominated by high densities of rotifers, whereas the Olympic communities were dominated by high densities of cladoceran crustaceans. Mount Rainier had the highest zooplankton richness with an average of 11.2 taxa, whereas Olympic had the lowest richness with an average of 7.2 taxa. North Cascades had an average of 9.0 taxa. These data suggest that regional differences exist in environmental conditions that structure zooplankton communities within the NCCN. Future analyses will examine lake physical and chemical parameters along with multi-year zooplankton data to determine the robustness of park differences and trends in condition.

Management Applications

This monitoring Program will provide information to:

- Better understand the impacts of global climate change
- Better understand impacts of atmospheric pollution
- Develop criteria for restoring lake impacted by non-native species
- Identify impacts associated with backcountry visitation

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Elk

Lewis and Clark, Mount Rainier, Olympic

I & M RESOURCE BRIEF

Importance

With their large size and wide-ranging movements, elk play an influential role in Pacific Northwest ecosystems. From coastal sloughs and lowland rain forests up through subalpine meadows, these majestic herbivores affect plant growth and species composition, play a role in nutrient cycling, and are prey for predators such as bears and cougars. Outside park boundaries, elk viewing and hunting opportunities are valued recreational activities and are important for the regional economy.

Elk protection was a key reason for the establishment of Olympic National Park, and elk are important ecological and cultural components of other North Coast and Cascades Network (NCCN) parks. Biologists with NCCN and the US Geological Survey (USGS) have developed an improved methodology for elk monitoring at Lewis and Clark National Historical Park (LEWI). The NCCN and USGS also worked with the Muckleshoot Indian Tribe, the Puyallup Tribe of Indians, and the Washington Department of Fish and Wildlife to increase the accuracy of surveys in subalpine habitats of Mount Rainier (MORA) and Olympic (OLYM) national parks.

Status and Trends

Biologists monitor elk populations using a variety of methods. On the ground at LEWI, NCCN and USGS biologists, other park staff and community volunteers search for elk fecal pellets in plots throughout the Fort Clatsop park unit every March and November. Pellet counts provide an accurate index to population size. At LEWI, biologists also monitor elk groups that are seen from road survey routes in and near the Fort Clatsop unit.

At the larger parks, biologists conduct aerial counts using helicopters. Even from this vantage, not all elk in a surveyed area can be detected. One goal at OLYM and MORA is to estimate how factors such as group size, and the amount and type of vegetation in which the group is located influence an elk group's 'sightability,' which is the probability of detecting an elk group that is in the surveyed area. From 2008-2010 biologists at MORA used radio-collared animals to gather data and develop a model that allows the estimation of sightability during the aerial surveys. If a radio-collared animal was not seen during a survey, the radio-transmitter was used to find where it was when the survey occurred, and determine if the animal was missed, or if it was not in the surveyed area. A sightability model was developed for elk monitoring in MORA, and is currently under development at OLYM. In 2011 we flew five fall surveys at OLYM and three fall surveys at MORA.

Discussion

Because topography and vegetation reduce visibility of elk, estimating elk 'sightability' can only be conducted with radio-collared elk. From 2008-2010 in surveys at MORA, biologists were able to track elk with radio collars supplied by the Muckleshoot Indian Tribe and Puyallup Tribe of Indians. During surveys this led to observations of 97 elk groups with at least one radio collar. At OLYM, elk that were fitted with radios in 2008, 2009 and 2010 will be available for future sightability flights. GPS units on seven of the collars have been broadcasting four location points per day to NPS and USGS biologists, greatly increasing our understanding about movement patterns of this keystone species in the park ecosystem.

Above A herd of Roosevelt Elk, from an aerial survey, September 2011. OLYM/Happe
Right Note elk standing on the snow has a radio collar. OLYM/Happe

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Fish Populations

Olympic

I & M RESOURCE BRIEF

Importance

The free-flowing and unregulated rivers that originate in Olympic (OLYM), Mount Rainier, (MORA) and North Cascades (NOCA) national parks are among the most protected corridors in the lower 48 states, and represent some of the largest tracts of contiguous, undisturbed aquatic habitat for several key fish species. Fish populations that inhabit OLYM are being monitored annually in ten park rivers. Olympic National Park contains 31 native and five non-native freshwater fish species throughout 12 major watersheds. The park also protects nine Pacific salmonid species, 70 unique populations, and five federally threatened species.

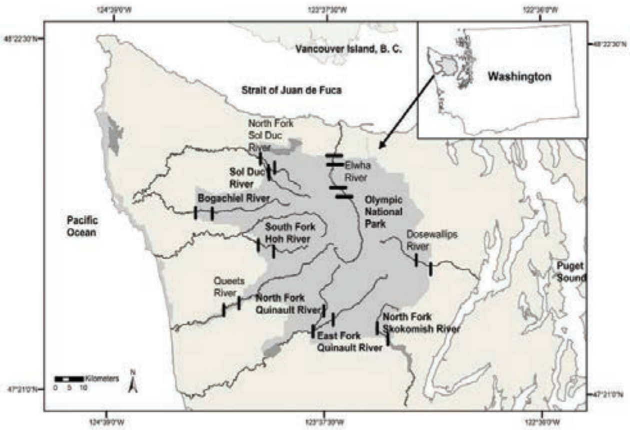
Salmon are anadromous and link freshwater, marine, and terrestrial ecosystems. Studies have shown that Pacific salmonids provide food for over 130 species of aquatic and terrestrial wildlife species and that 20 to 40% of the phosphorus, nitrogen, and carbon in freshwater systems derive from their carcasses.

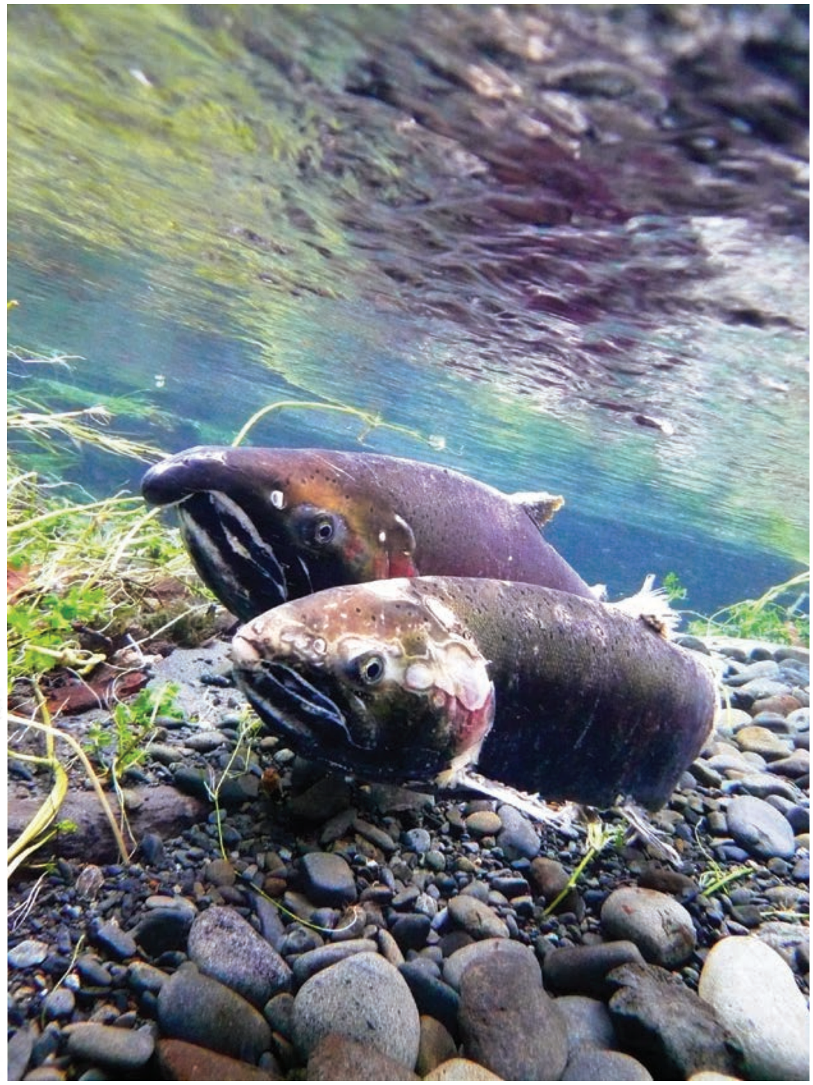
Salmon and steelhead are ecologically, economically, and culturally important to the Pacific Northwest and they contribute significantly to recreational, commercial, and tribal fisheries in rivers that drain from OLYM. Native fish face several in-river threats including overharvest, habitat degradation, and competition from hatchery and non-native fish. Despite the vital importance of native anadromous and resident fish populations, there has been no integrated monitoring program for these populations in the North Coast and Cascades Network.

Status and Trends

The use of snorkeling allows biologists to determine seasonal and annual trends in: 1) fish species composition, 2) relative abundance, 3) migration timing; and 4) extent of non-native and hatchery fish invasions within and among the ten rivers.

From 2005 to 2010, park biologists completed 350 snorkel surveys in ten rivers from June to September each year. These surveys covered over 1,400 river kilometers where biologists observed 129,500 individual fish. Adult summer steelhead and Chinook salmon were found to be at critically low levels of abundance in all rivers during those years. Snorkelers also detected stray hatchery summer steelhead, coho and Chinook salmon in park rivers. In the South Fork Hoh River, there were surprisingly high levels of hatchery fish, particularly since that river does not receive plantings.





Opposite Winter steelhead at Sol Duc Cascades, Olympic National Park. NOAA Fisheries/McMillan

Above Left Fish population monitoring sites at Olympic National Park
Above Right Coho pair spawning in Taft Creek, Olympic National Park. OLYM/Preston

Discussion

The addition of this monitoring program designed by the National Park Service has allowed fisheries managers to detect trends in high priority management species. The scientific information obtained through this protocol has multiple applications for management, research, education, and promoting a better understanding of park fishery resources.

Park managers can now evaluate the number of fish species increasing and decreasing in abundance. Biologists can also determine trends in federally threatened fish such as the bull trout. The protocol also provides information on magnitude of abundance of each fish species and timing of migration of adult fishes. Additionally, the detection of non-native and hatchery fish provides an early warning signal for alien fish invasions in park waters.

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Vegetation Mapping

Olympic, Lewis and Clark,
Mount Rainier, San Juan Island

I & M RESOURCE BRIEF

Importance

The North Coast and Cascades Network (NCCN) is developing vegetation maps for Mount Rainier (MORA), North Cascades (NOCA), Olympic (OLYM), Lewis and Clark (LEWI) and San Juan (SAJH) national parks. Conserving the biodiversity in the parks requires knowledge of the variety and extent of plant species and communities. Exotic species, insect outbreaks and diseases present challenges to the resilience of our park ecosystems. To address these challenges, park managers need accurate, up-to-date maps. Vegetation maps help park managers better understand relationships between vegetation and wildlife, wildland fires and other managed resources. The new NCCN vegetation maps will aid park managers to document and preserve the wealth of vegetation diversity within the parks.

Vegetation Maps

The National Park Service (NPS) mapping program has established a set of standards for mapping which dictate the scale, resolution, accuracy and vegetation classification scheme to be used.

Steps in the mapping process:

1. Create polygons. Draw boundaries around distinct vegetation types seen in aerial photographs or satellite imagery.
2. Field sampling. Visit selected sites identified in the polygon creation process and assign a vegetation type using a field key.
3. Map classification. Classify all sites using computer program that assigns vegetation types to all defined areas that share similar characteristics to those sampled in the field.
4. Accuracy Assessment. Evaluate the accuracy of each mapped vegetation class using extra field data held specifically for error checking.

How are vegetation types assigned?

The NPS adopted the National Vegetation Classification (NVC) System, a hierarchical system that uses both structural and floristic information to define existing vegetation types. There are eight levels in the NVC hierarchy. The topmost levels are general and separate vegetation types based primarily on structure, specifically whether they are dominated by trees, shrubs, or herbaceous plants. The middle levels of the NVC hierarchy incorporate biogeographic range, climate, substrate and dominant or diagnostic species. The NPS selected the second-finest level, called the Alliance level, of the hierarchy as the target for vegetation mapping. Map users will find the vegetation alliances on the maps intuitive because the dominant canopy vegetation determines the alliance. Within the region, over 30 forest alliances, 15 shrub alliances. 20 herbaceous alliances, and 50 wetland alliances have been identified. Alliances are selected in the field using dichotomous keys and descriptions which have been created for these projects.

Project Status

Mapping projects at LEWI, MORA and SAJH are nearing completion. Field sampling to collect data for the map classification has been completed for OLYM. In 2012 mapping cooperators will perform an accuracy assessment on the OLYM map. A NPS field crew will conduct field sampling at NOCA during summers of 2012-2014.

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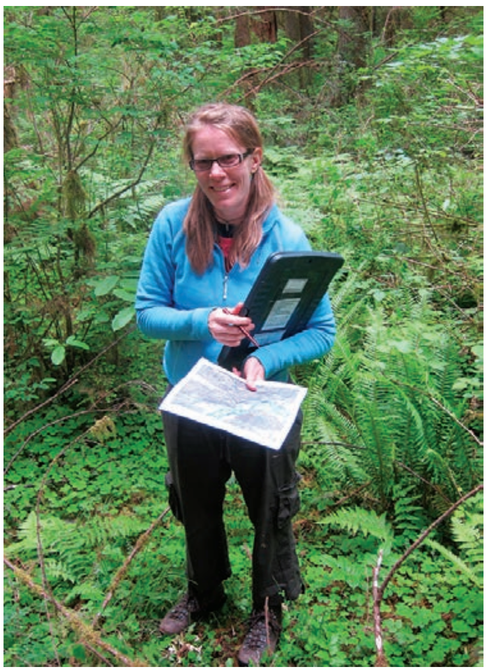

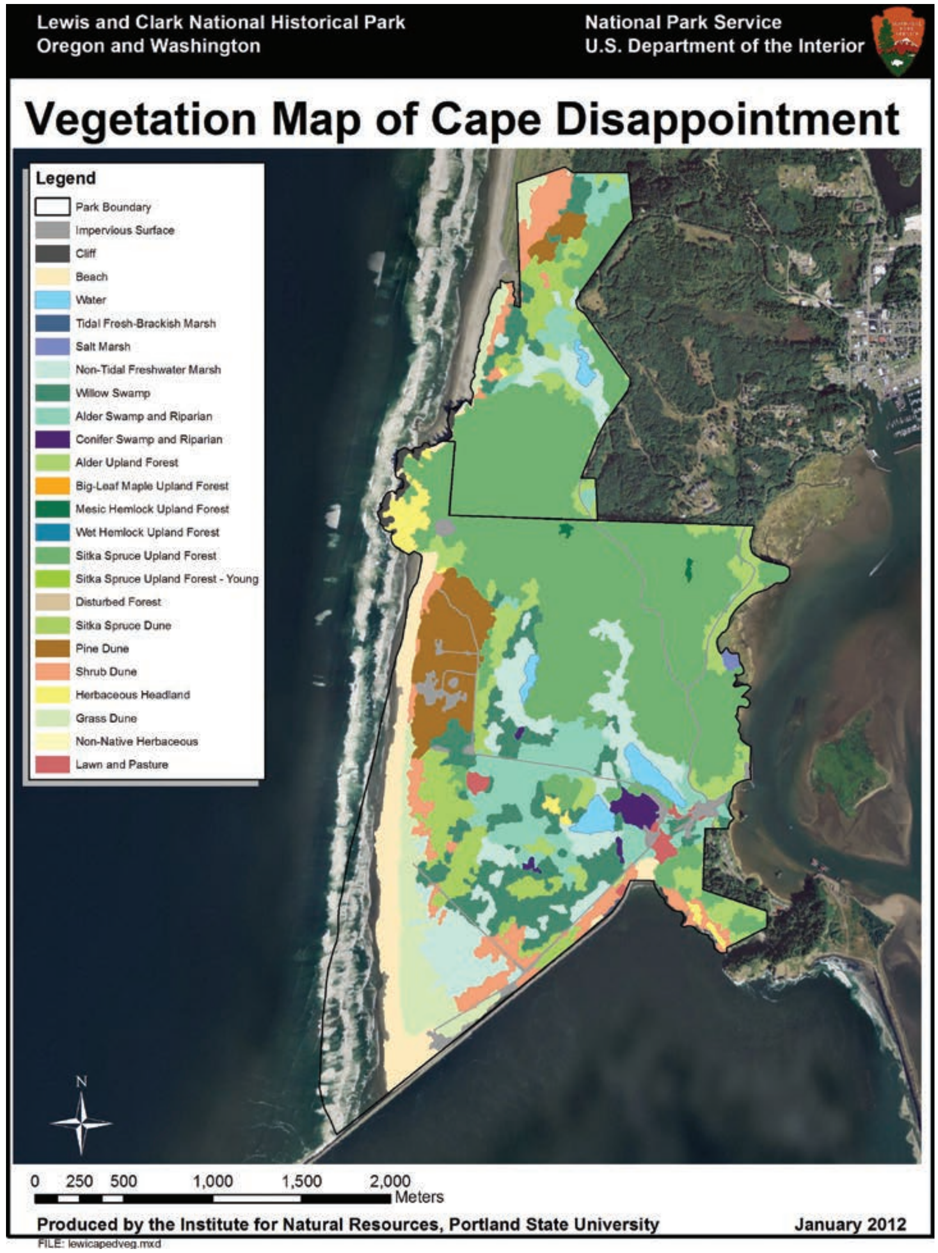

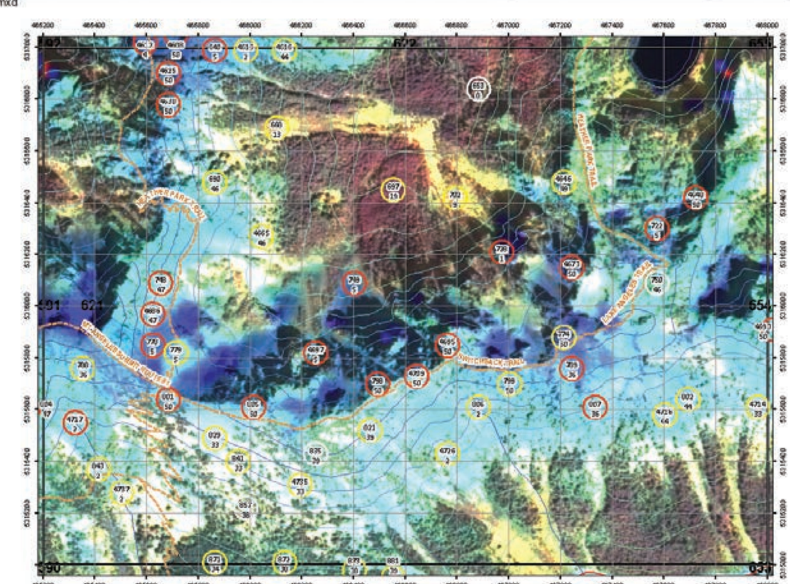

Above Left NCCN Vegetation Inventory Crew Lead Stacy McDonough displays the field maps used to direct the collection of training data for the Olympic map. NPS/OLYM

Above Right A close-up of a field map used in training data collection for NCCN mapping projects. Yellow, red and white circles are target areas for sampling.

Right Map of the Cape Disappointment unit at Lewis and Clark National Historical Park.

Forest Vegetation

Lewis and Clark, Mount Rainier
North Cascades, Olympic,
San Juan Island

I & M RESOURCE BRIEF

Importance

Mature and old-growth forests are icons of the Pacific Northwest. In the parks of the North Coast and Cascades Network (NCCN) forests range from coastal rainforests with massive trees draped with mosses and ferns and surrounded by dense understories; to areas with drought-adapted Ponderosa pines; to high-elevation subalpine fir forests interspersed with meadows just below treeline. These forests, in turn, are the foundation for other biotic communities constituting Pacific Northwest ecosystems. Climate change, air pollution, invasive species and other stressors threaten forest structure, species composition and abundance, thereby threatening the quality and quantity of habitat for terrestrial birds and wildlife. In particular, climate change and air pollution are expected to be the greatest threats to national parks in the Pacific Northwest. Changes in forest structure and composition will also alter the chemistry of water moving from terrestrial to aquatic systems. Consequently, forest monitoring is a fundamental part of the overall monitoring plan for the parks of NCCN. Tree recruitment, growth, and mortality are sensitive indicators of ecological change that can only be documented and understood through detailed, long-term observations. Increases in tree mortality have recently been reported for western North America, demonstrating the utility of long-term forest monitoring.

Status and Trends

The NCCN monitoring program has established 45 permanent forest plots at Lewis & Clark (LEWI), Mount Rainier (MORA), North Cascades (NOCA), and Olympic (OLYM), at elevations from sea-level to 1800 meters. The plots at LEWI are 0.25 hectares (0.6 acres); the plots at the other three parks are one hectare (2.5 acres). Plots established to date include 23 tree species, representing most of the diversity of species in the parks. Additional plots will be established at San Juan Island (SAJH) in the next few years. The specific forest types selected capture the extremes and the middle of the temperature and precipitation gradients for forests in the network. Sitka spruce forests at OLYM and LEWI comprise the warm and wet end of the gradient. These forests are important winter feeding grounds for Roosevelt Elk. The cold and dry end of the gradient consists of subalpine fir forests at NOCA and MORA. The middle of the gradient is represented by western hemlock with a salal and/or Oregon grape understory, measured at MORA, NOCA, and OLYM. These forest types are common throughout the region and monitoring results will provide benchmark information for managed forests. Target vegetation communities for SAJH have not yet been identified.

Tree mortality will be assessed annually and tree recruitment and growth will be recorded every five years. Thirty-five of the plots were established in 2008, allowing for the first evaluation of mortality trends in 2011. Most of these plots (25) showed no consistent trend in tree mortality, with five plots each showing decreasing and increasing trends. Trends in tree recruitment and growth will be reported after 15 years and trends in stem densities and tree basal area will be reported after 10 years.

Discussion
A recent report in the journal Science estimated that in recent decades the rate of tree mortality in old-growth forests in the Pacific Northwest has doubled every 17 years, probably due to regional warming and consequent stress caused by drought. This could lead to fewer large trees, less carbon storage, and forests predisposed to abrupt dieback. Forest monitoring in the NCCN will determine whether or not the recently-observed trend in tree mortality is continuing. It will also provide information about:

- Changes in historic conditions
- Types of habitat the forests provide for other plants and animals
- The forest's ability to capture CO_2
- Susceptibility to pests and pathogens.

This and other information will assist managers in protecting the forests and related park ecosystems.

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Opposite Biological science technician Shea McDonald and project lead Steve Acker review procedures while establishing a new forest monitoring plot in the Carbon River drainage of Mount Rainier National Park. NPS/NCCN

Above Rachel Brunner and Mark Anderson in a monitoring plot at Mount Rainier National Park. O'Brien/Rejman

Whitebark Pine

Mount Rainier, North Cascades

I & M RESOURCE BRIEF

Importance

Whitebark pine (*Pinus albicaulis*) grows in three mountain parks within the North Coast and Cascades Network (NCCN). These trees grow on cold, dry sites above 5,000' (1524 m) on the east side of North Cascades National Park (NOCA) and the northeast corner of Mount Rainier National Park (MORA). Small, disjunct populations are found on the west sides of both parks. In Olympic National Park (OLYM), whitebark pine is limited to three populations east of Mount Olympus and trees are often found in a clumped formation where individuals are difficult to distinguish.

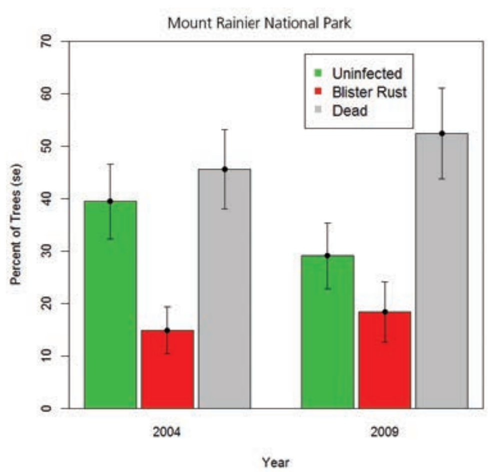
Often the first tree species to establish in subalpine meadows or alpine ridges, it influences snowmelt patterns, soil development, and provides important micro-sites for establishment of other plants. Whitebark pine seeds are a valuable food for birds, squirrels, and bears. Clark's nutcrackers, red squirrels, and Douglas squirrels extract seeds from the closed cones and then cache them in subalpine meadows for future retrieval.

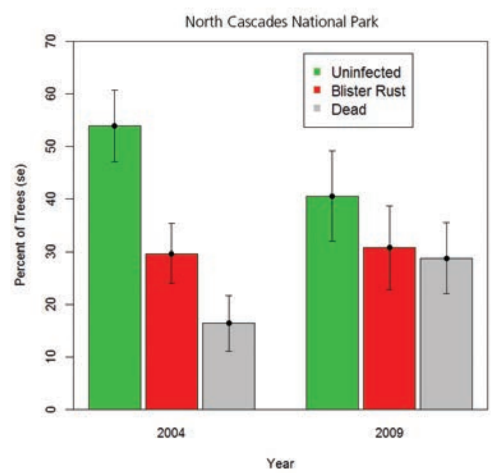
Status

Today, white pine blister rust (*Cronartium ribicola*) and mountain pine beetles (*Dendroctonus ponderosae*) threaten the long-term survival of whitebark pine. Blister rust is a Eurasian fungus that was introduced to North America in 1910. Currently whitebark pine is a candidate for listing by the U.S. Fish and Wildlife Service seeking to protect whitebark pine under the Endangered Species Act

Long-term monitoring of whitebark pine was initiated in MORA and NOCA national parks in 2004. Whitebark pines were tagged in permanent plots allowing park scientists to document changes in tree growth, rates of blister rust infection, mortality, and presence of mountain pine beetles.

Evaluation of long-term plots in 2009 revealed disappointing trends in mortality and infection rates. In MORA, the proportion of uninfected trees (>2.54 cm diameter at breast height, dbh) decreased from 37% to 22% while infection rates rose from 15% to 26% and mortality increased from 48% to 52%. In NOCA, the proportion of uninfected trees decreased from 54% to 32% and infection rates increased from 29% to 39% while mortality increased from 17% to 29%. Infection rates in saplings (individuals taller than 50 cm but <2.54 cm dbh) increased in both parks (25% to 43% in MORA and 17% to 21% in NOCA), although live sapling density remained stable. Incidence of mountain pine beetle was fairly low in each park (3% of sites in NOCA and < 1% of sites in MORA).





Opposite White pine blister rust on a whitebark pine. As the fungus fruits, cankers develop causing the bark to become rough and broken. NPS

This page Top A healthy whitebark pine group. Photo US Forest Service: http://www.fs.fed.us/r6/dorena/photos/whitebark-pine/view/PA00008704/ Sniezko

This page Below White pine blister rust incidence at Mount Rainier and North Cascades national parks in recent surveys

Discussion

NCCN scientists recently collaborated with US Forest Service geneticists to describe patterns of genetic diversity in whitebark pine across Washington and Oregon. In addition, they are also screening populations to quantify levels of genetic resistance to blister rust. In 2007, initial results of the genetic resistance screening indicated that seedlings grown from Mount Rainier parent trees have the highest levels of rust resistance of any seed source in the Pacific Northwest, as tested by the US Forest Service. In future years, results of research and monitoring will be used to develop site specific restoration and climate adaptation strategies.

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Prairie Monitoring

San Juan Island

I & M RESOURCE BRIEF

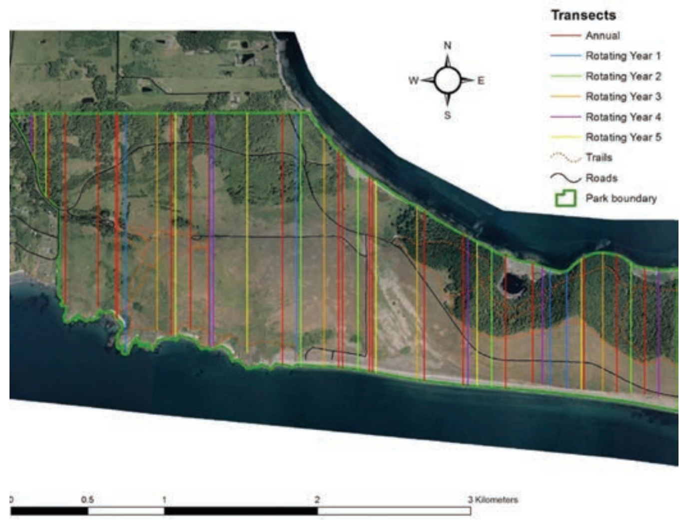
Importance

Prairies and Garry oak woodlands were once extensively distributed across the lowlands of western Washington and Oregon. Today, it is estimated that less than 3% of these areas still exist and many are severely degraded. These communities are an important component of landscapes in Ebey's Landing National Historical Reserve (EBLA) and San Juan Island National Historical Park (SAJH). Historically, prairies provided an important visual and biologic component of the matrix of landscapes that today comprise the cultural landscape. The landscape in San Juan National Historical Park included large treeless areas prior to the arrival of Europeans in the 1800's. During the historic period of the Hudson Bay Company (1853), Bellevue Farm was established in the area now called American Camp and over 4,000 sheep, cattle, horses, and hogs grazed on much of the area. Additionally, farming and the introduction of rabbits altered the native prairies. Despite the past alteration of these landscapes, significant remnants of native prairies and oak woodlands remain in SAJH. Currently about 281 hectares (694 acres) of prairie remain at American Camp and 26 ha (64 acres) at English Camp. Recent surveys documented at least 87 patches (34 ha or 84 acres) of native prairie distributed across the American Camp landscape. Protection of prairie remnants and restoration of degraded prairies to native plant communities will increase connectivity among prairies across the western Washington landscape. Increasing connectivity will increase the adaptive capacity of native biota of prairies ecosystem which are increasingly threatened by anthropogenic development and climate change. Monitoring of prairie conditions is important because it provides park management with the status of native and exotic plant distributions and this information can guide annual work plans regarding exotic plant control and restoration.

Status and Trends

Monitoring of prairies in San Juan Island National Park will begin in 2012. Our monitoring program uses a two-stage sampling design:

- First stage sampling is conducted along parallel transects to detect changes in physiognomic cover classes. The physiognomic cover classes we use are: trees, shrubs, herbaceous vegetation, unvegetated, and developed zones. Observers walk along transects (Figure opposite) and record each cover class they encounter and whether the vegetated cover classes are predominately native or exotic vegetation. Transects were drawn using a Generalized Random Tessellation Stratified (GRTS) sample.



- Second stage sampling focuses on composition of herbaceous communities. One-meter square quadrats are placed systematically along transects and all plant species within each quadrat are identified and recorded along with an estimate of percent of the quadrat that they occupy.

Results of monitoring will be summarized in annual and five-year reports and in an Ecological Integrity Scorecard. Pilot data from 2008 are summarized in a scorecard. Today, the landscape distribution of forests and prairies is very similar to the scene during the historic period of the mid 1800's. Forests are dominated by native tree species, but the integrity of shrub and prairie communities are threatened by introduced plant species that are displacing native species. Exotic shrubs such as Himalayan blackberry (*Rubus discolor*), cutleaf blackberry (*Rubus laciniatus*), and oneseed hawthorn (*Crataegus monogyna*) are spreading rapidly with shrub and prairie communities. Exotic grasses such as velvet grass (*Holcus lanatus*), quackgrass (*Elymus repens*), and cheat grass (*Bromus tectorum*) dominate many areas of prairie and the Garry Oak woodland. Monitoring results will be used by the park to inform priorities of the NCCN Exotic Plant Management Team and prairie restoration plans.

Discussion

The vast, open prairie landscape of San Juan Island National Historical Park's American Camp unit and the oak prairie woodland at English Camp are integral to the history of the park, which was originally established to interpret the story of the Pig War. Landscape distribution of the plant communities (trees, shrubs, and prairies) tells the story of human use and protection of these unique ecosystems. Oral histories indicate that prehistoric and historic native peoples once had winter villages and summer camps on the prairies. They gathered edible plants and promoted growth of some, such as camas, through the use of fire, in addition to hunting deer and fishing for salmon in adjoining waters. Today, the prairie monitoring protocol will provide important scientific data on the distribution and condition (i.e. biodiversity) of prairies, forests, and shrub communities that will be used to inform development of the Prairie Stewardship Plan, update the Fire Management Plan, and guide Exotic Plant Management activities.

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Opposite Vegetation group refining prairie monitoring procedures. NPS/SAJH

Above Left Native prairie patch composed of Roemer's fescue (*Festuca roemeri*), western buttercups (*Ranunculus occidentalis*), common camas (*Camassia quamash*), and chocolate lily (*Fritillaria affinis*). NPS/SAJH
Above Right Monitoring transects at American Camp, SAJH.

Alpine and Subalpine Vegetation Monitoring

Mount Rainier, North Cascades, Olympic

I & M RESOURCE BRIEF

Importance

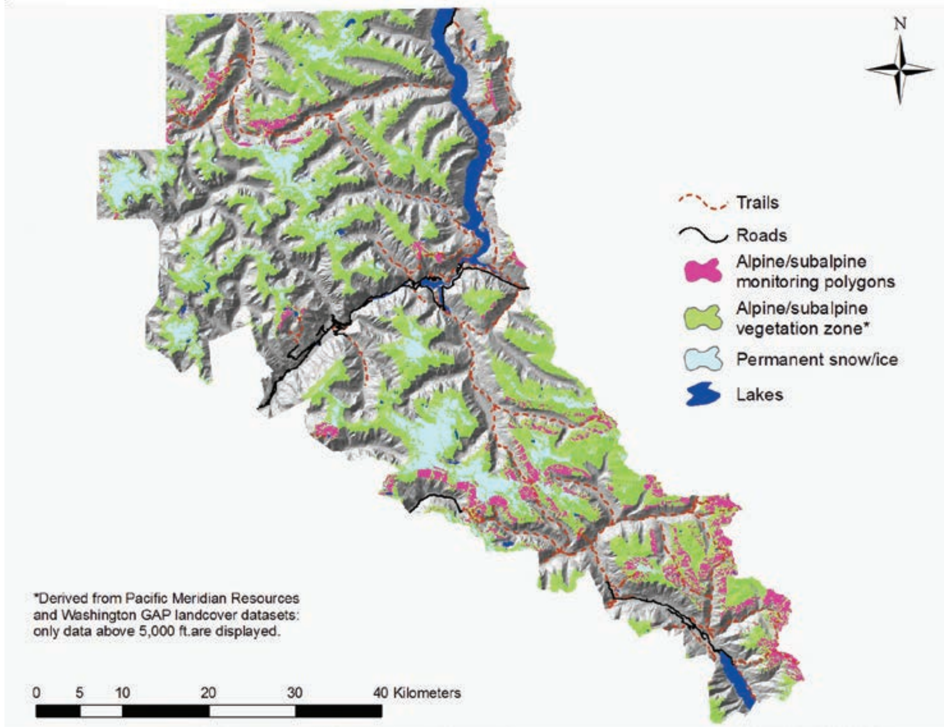
The goal of the alpine and subalpine vegetation monitoring program is to understand the response of vegetation in the alpine treeline ecotone to climate change, within the three mountainous parks of the North Coast and Cascades Network (NCCN). Subalpine and alpine areas are ecologically important zones that provide popular recreational opportunities for visitors to Mount Rainier (MORA), North Cascades (NOCA), and Olympic National Parks (OLYM). The subalpine parkland extends from closed canopy forest (forest line) up to the highest elevation with upright trees (treeline). The alpine zone continues from treeline up to permanent snow and ice on mountain peaks of the Cascades and Olympics. The entire area, from forest line up to permanent snow, is a broad transition zone, often referred to as the alpine treeline. Vegetation composition, structure, and spatial distribution reflect climate's interaction with topography. Because low temperatures are a primary determinant of the distribution of alpine and subalpine areas these areas are particularly sensitive to climate warming. Changing climates may result in significant changes in the distributions of subalpine and alpine meadows of the Pacific Northwest.

Status and Trends

We used a Generalized Random Tessellation Stratified (GRTS) sample drawn from each park to establish a suite of spatially balanced, random sample sites in accessible areas within the alpine treeline ecotone. Subalpine and alpine vegetation monitoring will begin in the summer of 2012 in NOCA, MORA, and OLYM. The objectives of our monitoring are to determine status and trends in:

1. Composition and structure of alpine and subalpine vegetation communities in MORA, NOCA, and OLYM
2. Composition and structure of legacy alpine plots in MORA
3. Soil temperature and snow cover in vegetation plots
4. Structure and condition of Whitebark pine stands in MORA, NOCA, and OLYM

Pilot surveys of Whitebark pine in MORA and NOCA between 2004 and 2009 revealed disappointing five-year trends in the condition of Whitebark pine stands. In MORA, the proportion of uninfected trees (>2.54 cm diameter at breast height, dbh) decreased from 37% to 22% while infection rates rose from 15% to 26% and mortality increased from 48% to 52%. In NOCA, the



proportion of uninfected trees decreased from 54% to 32% and infection rates increased from 29% to 39% while mortality increased from 17% to 29%. Infection rates in saplings (individuals taller than 50 cm but <2.54 cm dbh) increased in both parks (25% to 43% in MORA and 17% to 21% in NOCA), although live sapling density remained stable. Incidence of mountain pine beetle was fairly low in each park (3% of sites in NOCA and < 1% of sites in MORA).

Discussion

Climate models project warmer summers and lower snowpacks for the Pacific Northwest. Lower snowpacks may mean earlier snowmelt and longer, drier growing seasons. Altered climate patterns will in turn influence patterns of vegetation cover and phenology (growth patterns and flower timing). In some cases, changes will be dramatic – including more tree growth in the subalpine parkland or more shrubs growing in subalpine and alpine meadows.

Changes in distribution of grasses (which may increase) and forbs (which may decrease) will be more subtle and difficult to notice in the short term. Some species, such as Whitebark pine (*Pinus albicaulis*) will have a more complicated response to climate. Whitebark pine is an importance species in subalpine areas because it is an early successional species, establishing on alpine ridges or after disturbance, often facilitating the establishment of other plant species (see page 28). Today, the survival of this species is threatened by an introduced fungus, white pine blister rust (*Cronartium ribicola*) and native mountain pine beetles (*Dendroctonus ponderosae*). Warmer winters and summers have allowed the mountain pine beetle to survive and spread at higher elevations and in the NCCN we are beginning to see mortality of Whitebark pine from mountain pine beetles. Changes in vegetation distribution and plant phenology (flowering times) will influence recreational opportunities as well as habitat for wildlife.

Opposite Alpine zone detail showing white (American bistort) and blue (lupine) forbs and purple shrubs (heather). NPS/NOCA

Above Map of North Cascades National Park illustrating alpine and subalpine zones (green) and sampling polygon locations (purple). NPS/NOCA

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Water Quality Monitoring

Mount Rainier, North Cascades, Olympic, Ebey's Landing, Lewis and Clark

I & M RESOURCE BRIEF

Importance

The North Coast and Cascades Network (NCCN) contains over 5,300 miles of rivers and streams within its boundaries. The abundance of fresh, cold, and free flowing water is one of the defining characteristics of the NCCN, making water quality a high ecological, management, and legal priority for the network. These resources sustain 39 native fish and 17 native amphibian species as well as provide for human use, including recreation and domestic water supply. Due to their position in the landscape, rivers and streams integrate the physical, chemical, and biological characteristics of the watersheds they drain. This puts them at increased risk to a variety of environmental stressors, including changes in flow regimes due to climate change, atmospheric pollution, and more localized disturbances related to land management activities and recreational use.

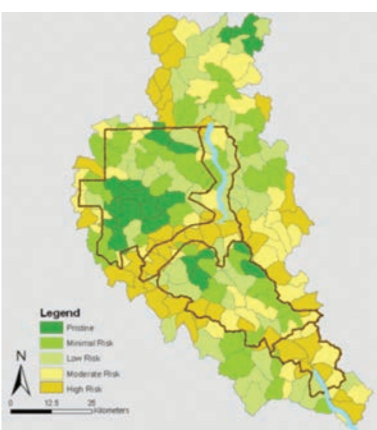
Status and Trends

To gain an understanding about the nature of the threats facing water quality in the NCCN, we conducted a watershed condition assessment to evaluate the impacts of roads, land development, mining, and trails in 465 watersheds. Since water flows into the NCCN from areas not managed by the National Park Service (NPS), the assessment covered 5,500 square miles, an area almost twice the size of NPS-managed lands. By ranking and mapping the watersheds, we were able to identify the areas that are at the greatest risk of impairment.

The NCCN Water Quality Protocol will sample 27 locations that are at the highest risk of impairment. The sample locations will be distributed among Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, Mount Rainier National Park, North Cascade National Park Service Complex, and Olympic National Park. Ten indicators of water quality and riparian habitat condition will be measured at each location.

The primary goals of the NCCN water quality monitoring project are to:

1. Determine the status and trends in the ecological conditions for a selection of wadeable rivers and streams throughout the NCCN at high risk of impairment.
2. Provide timely and high quality data to park managers.
3. Identify and detect new and emerging threats to water quality.
4. Improve the understanding of the basic chemical, physical, and biological processes that affect environmental quality of these surface waters and determine if they are within their natural chemical and biological ranges.



Measurable Objectives

1. Determine the status and trends of the ecological condition in NCCN wadeable rivers and streams listed as impaired under section 303(d) of the Clean Water Act.
2. Determine similar status and trends in waters at a high risk of impairment. These waters are believed to be some of the most imperiled water bodies in the NCCN; many have little or no water quality information that can be used to ascertain their ecological condition. These waters will typically require the initiation of monitoring by the NCCN.
3. Compare water temperature data against state standards for chronic exceedance on a weekly, monthly, seasonal, and annual basis.
4. Compare indices of biological integrity against state standards for chronic exceedance on an annual basis.
5. Compare measurements of dissolved oxygen and pH against state standards for chronic exceedance on an annual basis

Discussion

Water is the issue of the century and will likely be the issue of the millennium. The Pacific Northwest has an abundance of fresh, clean water making it easy to overlook the fact that 3.575 million people worldwide, a population equal to the City of Los Angeles, will die this year from a water related disease.

The cleanest water in the United States flows from its protected forests, and it is estimated that 50% of Americans in the West depend on federal forests for their drinking water. The US Forest Service estimates that approximately $7.2 billion a year is generated from water leaving federal lands. With its considerable freshwater resources, many of which are of likely the best quality in the region, the NCCN is of critical importance to the region-wide conservation of water quality.

The National Park Service's ability to track the water quality within the NCCN will improve management and protection of this valuable resource.

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Opposite Results of the watershed assessment for North Cascades National Park.

Above Students observe a redside shiner at Ross Lake, North Cascades National Park. North Cascades Institute Amy Brown

Network Air Quality

I & M RESOURCE BRIEF

Importance

Visitors to national parks expect clean, clear air. The health of park ecosystems and the integrity of cultural resources depend upon clean air. Air pollutants can impair visibility, harm human and wildlife health, injure trees and other vegetation, acidify streams and lakes, leach nutrients from soils, and erode buildings and monuments. The NPS Organic Act provides the basis for air resource protection in all units of the National Park System. In addition, the Clean Air Act amendments of 1977 designated 48 national parks and wilderness areas as Class I—including Mount Rainier (MORA), North Cascades (NOCA) and Olympic (OLYM) national parks – affording them the highest degree of protection.

Park managers have an affirmative responsibility to protect air quality and sensitive resources called "air quality related values" (AQRVs) from the adverse effects of air pollution. To fulfill these responsibilities, the NPS monitors air quality, assesses effects on AQRVs, communicates information about air quality issues; advises and consults with regulatory agencies; partners with stakeholders to develop air pollution management strategies; and promotes pollution prevention practices in parks.

Status and Trends

Air quality and AQRV data are two of the Inventory and Monitoring (I&M) Program's 12 basic inventories. There are few air quality monitors in parks and there is limited understanding of thresholds for pollutant effects on park resources. Given current information, the air quality and AQRV inventories provide our best estimates of pollution levels and effects in North Coast and Cascades Network (NCCN) parks. In 2010, the NPS Air Resources Division (ARD) estimated average values and trends for visibility, ozone and wet nitrogen (N) and sulfur (S) deposition. They assigned parks to one of three condition categories—good, moderate or significant concern—for each pollutant. Visibility is in moderate condition in all NCCN parks. Ozone is in good condition in all NCCN parks except MORA, where the condition

PARK	VISIBILITY (dv)	OZONE (ppb)	WET N DEPOSITION (kg/ha)	WET S DEPOSITION (kg/ha)
EBLA	6.3 ↔	52.2	0.42	0.43
FOVA	6.4	60.7 ↔	1.23	0.84
LEWI	6.0	60.9	1.71	1.54
MORA	5.0 ↑	62.5 ↔	2.23 ↓	2.03 ↑
NOCA	4.3 ↔	54.5	2.24 ↔	1.80 ↑
OLYM	6.3 ↑	54.9	1.20 ↔	3.45 ↔
SAJU	6.0	51.7	0.48	0.53

dv = deciview
ppb = parts per billion
kg/ha = kilograms per hectare

↑ = improving air quality trend
↓ = degrading air quality trend
↔ = no air quality trend

Air quality condition is good
Air quality condition is moderate
Air quality condition is of significant concern

is moderate. Deposition is of significant concern at MORA, NOCA and OLYM, all of which have high elevation lakes and vegetation that are sensitive to N deposition (Table opposite).

The AQRV inventory is available from the NPS ARD website at http://www.nature.nps.gov/air/Permits/ARIS/index.cfm. The website identifies stressors to AQRVs and describes resources at risk from air pollution. For example, an ozone injury risk assessment uses sensitive species, ozone concentration and soil moisture data to assess the risk of foliar injury. The assessment predicts that vegetation in all NCCN parks is likely to be at low risk from ozone exposure. Risk assessments have also been completed for nutrient enrichment associated with N deposition and for acidification from N and S deposition. Of the 32 I&M networks, NCCN is ranked second highest for risk of nutrient enrichment based on pollution exposure, ecosystem sensitivity and park protection (Class I or wilderness designation warrant greater protection). The NCCN ranks fourth highest for risk of acidification. A risk assessment for mercury deposition and a multi-pollutant risk assessment map will be completed in 2012.

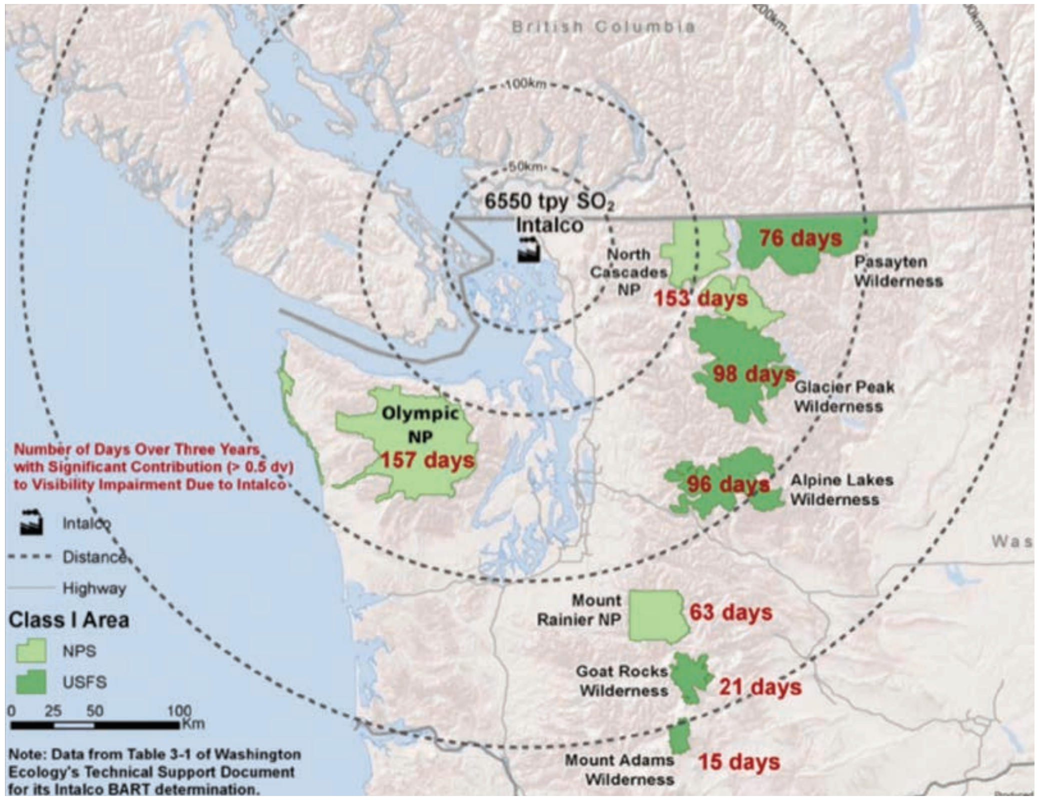
Opposite Average Air Pollutant Concentrations (2005-2009), Trends* (1998-2008) and Condition Categories (2009) for NCCN Parks (*trends are only available for parks with long-term data)

Above Don Campbell USGS sampling snow as part of the Western Airborne Contaminants Assessment Project (WACAP).

Continues...

Network Air Quality

I & M RESOURCE BRIEF



Above Number of days over a three-year period that Alcoa's Intalco Works Aluminum Smelter in Ferndale, Washington, significantly impacts visibility in Washington's eight Class I air quality areas

Opposite Processing a sediment core collected from Stiletto Lake, North Cascades National Park, for diatom analysis as part of a nitrogen deposition study. USGS/Foreman

Discussion

It is often assumed that national parks have pristine air quality. Data showing the extent of air quality degradation in parks enable the NPS to make a strong case for EPA and states to develop management strategies that improve air quality in parks. The following example illustrates the use of park air quality information.

In 1999, in response to data showing haze caused by air pollution is impairing visibility in parks nationwide, EPA issued the Regional Haze Rule which requires states to develop a plan to restore visibility in Class I areas to natural conditions by 2064. The State of Washington submitted its Regional Haze Plan (Plan) to EPA in January 2011. In its Plan, Washington used visibility monitoring data collected at NPS and US Forest Service (USFS) areas, combined with atmospheric modeling, to assess the impacts of individual pollution sources on air quality. They determined Alcoa's Intalco Works Aluminum Smelter in Ferndale, Washington, significantly impacts visibility in OLYM, NOCA and MORA, and in five USFS Class I areas, many times a year (Above). Nevertheless, Washington's Plan includes no additional pollution controls for the Intalco facility. The EPA must decide whether or not to approve Washington's Plan by the end of 2012. Our visibility monitoring data enable NPS and USFS to make a strong case that Intalco should be required to reduce emissions.

Continued monitoring and research are essential to improve our understanding of air pollution effects and provide valuable information that can inform NPS management decisions and be shared with regulators and the public.

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Cultural Landscapes

EBEY'S LANDING NATIONAL HISTORICAL RESERVE

Importance

Ebey's Landing National Historical Reserve, on Whidbey Island in Washington State provides the nation a vivid and continuous record of Pacific Northwest history. The land appears much as it did a century ago. Patterns of settlement, historic homes, pastoral farmsteads and commercial buildings are still within their original farm, forest, and marine settings. A visitor can experience a variety of diverse physical and visual landscapes within a small geographic area. The community of Ebey's Reserve is a healthy, vital one that allows for growth and change while respecting and preserving its heritage.

The cultural landscape of the reserve is made of historic settlement, development patterns, and natural features. Collectively, landscape patterns and their relationship over time imprint and reflect human history in the land and give it its unique Northwest character. A few examples of the unique attributes of this place include:

- Unique geography of naturally formed prairies surrounded by wooded ridges and shorelines.
- How settlers responded to the natural environment in their development, farming and homestead choice.
- Vegetation related to land use such as the formation of hedgerows in historic farm boundaries.
- Road systems charting the paths of wagon roads and bearing the names of early and present day farm families
- Historic farmstead cluster arrangement representing the periods of farm use and technology over the past 150 years.
- Archaeological resources including over 40 seasonal and permanent camps of Native Americans, some going back 9,000 years.
- Views and other perceptual qualities where one can imagine what it was like to be here hundreds if not thousands of years ago.
- Coupeville and Ferry Landing – Intact sites that connect farmland to all of Puget Sound.

The Reserve was set aside in 1978 to "preserve and protect a rural community which provides an unbroken historic record from nineteenth century exploration and settlement of Puget Sound up to the present time." Approximately 85% of the Reserve is privately held. Of the historic structures listed on the National Register of Historic Places, 98% are privately owned. Because of this, the preservation and sustainability of the Reserve's cultural landscape requires a strong local stewardship commitment, through partnership and from local residents. Recognizing that the pressures facing the Reserve are more complex now than 33 years ago, the Trust Board and its partners are establishing a set of programs and collaborative strategies to provide technical and fiscal support to more effectively cultivate and sustain the Reserve's deep tradition of local stewardship.

Cultivating Local Stewardship: Cultural Landscape Preservation Grown Here

Conservation easements to prevent future development and help support viable agriculture are the highest priority and most effective way of protecting the Reserve's unbroken historical record and rural character. Working in coordination with the Whidbey Camano Land Trust, and The Nature Conservancy to secure Land and Water Conservation Funding (LWCF), among other sources, remains an essential tool to protecting the last remaining heritage farmsteads dating back to the Donation Land Claim Law of 1850. In the absence of LWCF funding, the San De Fuca Uplands area of the Reserve remains threatened by subdivision and incompatible development.

In addition to these land protection efforts, it is also essential for citizens to have their own tools available. Many citizens, especially those who have recently moved into the community are unaware that they live within or near a protected historic reserve. The following are tangible strategies and new tools to help empower private property owners to continue to nurture the deep tradition of local stewardship grown at Ebey's Landing National Historical Reserve.

Ebey's Landing is America's first historical reserve and is a living classroom where new tools in historic preservation are being developed to address the issues of today and the future. These tools include:

Field School and Conference

An annual Historic Preservation Field School that provides a hands-on, four-week preservation experience for locals and visitors. The school illustrates application of the Secretary of the Interior's 'Standards for the Treatment of Historic Properties' on National Register heritage buildings.

Continues...

Opposite Freeman Boyer, owner of the Boyer Barn and the 2010 Preservation Crew of Ebey's Landing 3rd Historic Preservation Field School - comprised of members of the Coupeville Lions Club, the NPS and other community volunteers. Photo is in front of the Boyer Barn, circa late 1800's.

Above Ferry House, Front Porch Reconstruction and stabilization underway. Funded through NA Trust, American Express Partners In Preservation Grant, NPS, Coupeville Lions Club, Island County Historical Society, local residents, and visitors

Cultural Landscapes

EBEY'S LANDING NATIONAL HISTORICAL RESERVE

Above Jacob Ebey House Rehabilitation Project – completed. Now open seasonally, with a core of 40 volunteer docents, as Reserve's 1st Visitor Contact Station

Opposite Kineth Water Tower circa 1896. Exterior rehabilitation, window restoration, and stabilization. During and after.

The Ebey's Forever Conference includes field trips, workshops and panels featuring leading local, regional, and national voices in cultural resource management, sustainable agriculture, and interpretation.

Design Review
Review is a legal process of applying context-specific design guidelines to proposed construction and remodeling projects within the Reserve. A tool to help property owners care for and conserve the overall character and appearance of the Reserve, this unified program and guidelines encourages compatible rehabilitation and site planning, and ensures that new development is sensitive to the character of the surrounding neighborhoods and landscape. Members of the New Historic Preservation represent the Town of Coupeville, Island County and the Reserve when considering building applications through the cultural landscape lens.

Ebey's Forever Fund and Grants Program
The Ebey's Forever Fund was established by the Trust Board in 2009 to provide direct fiscal support to the owners of historic properties in the Reserve through its Ebey's Forever Grant Program. A community-based entity based on the Washington Heritage Barn Program, the Fund offers matching grants to these owners to help preserve the Reserve's most historic structures for traditional uses and uses yet to come. In 2012, $62,000 in grant funding was awarded to eleven contributing historic properties for preservation work – helping property owners achieve the highest standards for historic preservation.

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History and Hoppers

FORT VANCOUVER NATIONAL HISTORIC SITE

Above Oregon State University PhD candidate Martin Adams examining a Fort Vancouver grasshopper. NPS/FOVA

Right Male Brown-spotted bush cricket, (*Tessellana tessellata*) NPS/FOVA

IMPORTANCE

Although known for its cultural resources, Fort Vancouver's natural resources are an essential part of the site's unique story. Located near a major river and a protected wetland, yet still within the city limits of Vancouver, WA, the park is home to a host of plant and animal species. As an archaeological site, we need to not only study and understand the flora and fauna currently living, but to uncover and study past environments, whether the same or different from those present today.

Discussions of faunal remains at an archaeological site are generally biased toward vertebrates or marine invertebrates. Often, archaeologists pay little or no attention to insects and their relationship with humans. Not only can insects provide information about past environments, but the type of insect or arthropod found at a site may be directly related to whatever function is taking place there (food processing or storage, burial, etc.) and can often be used to indicate more about human lifestyles and living conditions than might be gleaned from artifacts.

Though much of archaeoentomology, the study of insect remains at archaeological sites, concerns the remains of beetles (Coleoptera), other insect taxa are also known. For this particular study, emphasis is placed on the Orthoptera (grasshoppers, katydids, crickets, and locusts), which have received some attention in the anthropological literature. The purpose of this study is to list and describe the different types of Orthoptera currently found at Fort Vancouver, to briefly describe the natural history and ecology of the taxa in question, and to examine any instances where Orthoptera remains might be found at Fort Vancouver and what one could interpret from those remains.

TRENDS

Sampling methods for Orthoptera were intended simply as a presence or absence survey, and not to quantify population or abundance. Over the course of several seasons (2004, 2010, and 2011), and using several different collecting and trapping techniques, only four species of orthopterans were found. These include the red-legged grasshopper (*Melanoplus femurrubrum*), the meadow grasshopper (*Chorthippus curtipennis*), the brown-spotted bush cricket (*Tessellana tessellata*), and the camel cricket (*Ceuthophilus* sp.). True grasshoppers made up the most numerous suborder of orthopterans at Fort Vancouver, and this could be due to a bias in the collecting techniques. Pitfall traps, for example, would be useful for collecting ground-dwelling crickets, but their use at Fort Vancouver is limited by the possibility of disturbing cultural materials. Surprisingly, while Fort Vancouver does fall within the distribution ranges of 14 of the true grasshoppers (Suborder Caelifera), only two species were found (*M. femurrubrum* and *C. curtipennis*), emphasizing the need for additional Orthoptera sampling.

DISCUSSION

The possibility exists that orthopteran remains might be found in archaeological contexts at Fort Vancouver. In general, the most common current use for grasshoppers, crickets, katydids, and locusts is as a source of food, and they are known to be eaten by modern human populations worldwide. It has been reported that over 1,500 species of edible insects have been recorded from nearly 3,000 ethnic groups in over 120 countries. Orthoptera is one of the most frequently consumed insect orders, regularly eaten in parts of Africa, Asia, and Central and South America.

Archaeologically, there are several sites in western North America where Orthoptera have been consumed. The cooked remains of crickets have been found in hearth features in Wyoming and California's Mojave Desert, and caches of stored Orthoptera have also been recovered in Wyoming, Colorado, and Nevada. Furthermore, native peoples on the western shores of the Great Salt Lake in Utah were able to mass-collect thousands of grasshoppers that were windblown onto the shore of the lake, where they were sundried, salted, and ready to eat. Though not a primary food source, they became an important supplement to the diet at times when other, non-insect game was scarce.

During the Hudson's Bay Company (HBC) occupation of Fort Vancouver as a fur trading post, the cultural composition of Fort Vancouver's Village is known to have included Native Hawaiians, Europeans, Métis, and representatives of over 30 different native tribes. Many indigenous groups – including Chinook, Cowlitz, Klickitat, and Kalapuya – were known to converge in the Vancouver/Portland Basin to take advantage of annual salmon runs and trade with other native peoples who lived along adjacent valleys and tributaries. Some of these groups were among those living in the Village during the fur trade era (1825 – 1860). Among them, the Kalapuya of Oregon's Willamette Valley were well known for their use of controlled fires in the savannas and meadows, specifically for the cultivation and collection of plant foods, deer hunting, and the collection of edible insects, including grasshoppers. Field burning would probably not have been allowed at Fort Vancouver after its establishment, but this did not mean these insects were not consumed here. Furthermore, other native groups east of Fort Vancouver, including Shoshone and Paiute, were known to consume grasshoppers and crickets, and while these groups may not necessarily have resided in the Village during the early half of the 19th-century, trade and kinship ties with these people may have made Orthoptera consumption at Fort Vancouver a possibility.

Of the four species currently collected at Fort Vancouver, only *T. tessellata*– an introduced species from central and southern Europe – would probably not be found in HBC-era cultural deposits. Furthermore, some Orthoptera species that were not collected today could be found in historic contexts. Currently, no Orthoptera remains have been found in Fort Vancouver excavations, but this could be due to past sampling. In recent years, archaeologists have transitioned to a more robust sampling protocol which focuses more attention on microartifacts such as pollen, phytoliths, and small faunal remains. If found in an archaeological context in future, orthopteran remains can enlighten archaeologists on subsistence practices and influences among the native people occupying Fort Vancouver, and also speak to the vegetation and environmental make-up in the area.

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Discovering Elwha History

Olympic National Park

Importance

The Elwha Act was passed as a fisheries and ecosystem restoration bill but it has had the effect of substantively adding to the local and regional archeological knowledge base through regulatory compliance actions undertaken in the last 15 years. These include archeological survey, testing, construction monitoring and limited data recovery. While it remains largely an ecosystem restoration project, just about any member of the Lower Elwha Klallam Tribe will tell you there is an equally important cultural restoration occurring.

Archeological resources—those non-renewable, tangible, and quantifiable materials that allow us to piece together the past—form an important linkage between the larger scale cultural resource restoration that encompasses intangible aspects associated with memories, oral history, and spirituality and the realm of Western empirical science.

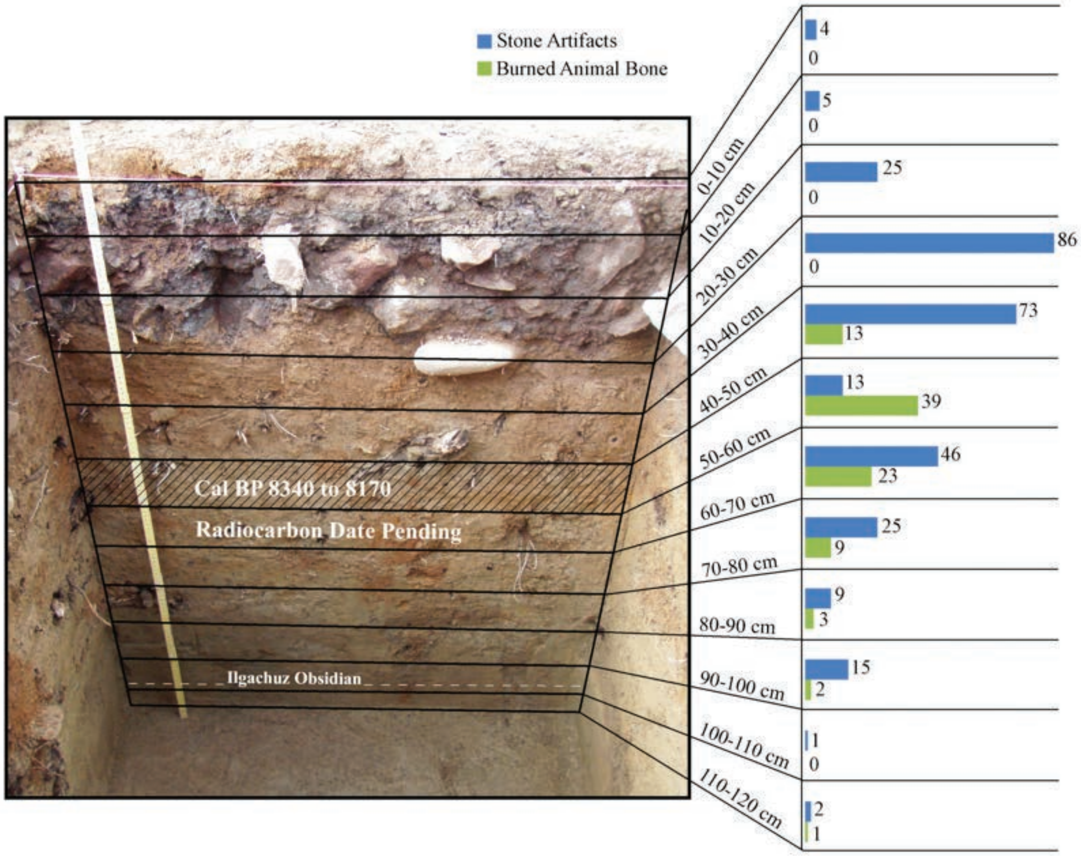
Status

If you look at archeological site distributions across the Olympic Peninsula prior to the Elwha Project, you will find that the lowland river valleys are not well represented. During the 15 years leading up to dam removal, archeological investigations associated with the project have revealed a long and complex archeological record within the Elwha Valley.

Archeological sites in the valley have been documented during all phases of the project and reveal an intensity of use that may surprise many people. These sites are typically comprised of lithic debitage (chipping debris) and flaked stone tools, though several sites have provided limited assemblages of faunal remains including burnt animal bone, fish bone, and marine invertebrate remains. These materials have allowed us to complete radiocarbon analyses confirming human use of the Elwha Valley back nearly 8,000 years.

Discussion

The focus of archeological investigations has now shifted from survey, testing, and evaluation of sites prior to deconstruction to monitoring and treatment of sites during deconstruction activities. Soon the focus will narrow to monitoring river erosion/meander as the river re-establishes its free flowing regime. Analysis and interpretation of data are ongoing.



Archeological excavation has been completed at six pre-contact archeological sites within the valley. A large assemblage of flaked stone artifacts has been recovered that is being analyzed and will contribute to our understanding of stone tool technological organization and raw material procurement. The limited faunal remains—rare in most open, lowland archeological sites—provides a much needed avenue for chronometric dating. Radiocarbon dates range from 3,200 ± 40 years Before Present on marine gastropod remains found in an upriver location, and associated with flaked stone tools and a hearth feature, to a date of 7,420±40 at a large site that was probably an upriver fishing location. This latter date is the oldest radiocarbon result from an archeological context within Olympic National Park and the second oldest date on the Olympic Peninsula. Quantitative analysis of an obsidian artifact that was recovered from a stratigraphic position beneath (presumably older than) the 7,420 date suggests early, well developed trade networks between the Olympic Peninsula and central British Columbia.

Combine this information with the recently documented location of the Lower Elwha Klallam creation site and it becomes clear that the Elwha Restoration Project has contributed to a better understanding of when, where and how people have used the watershed during the Holocene, but perhaps more importantly it gives confirmation and validation to the Lower Elwha Klallam as they reestablish cultural patterns and ties to the river that has sustained them since time immemorial.

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Opposite Archeologists excavating ca. 8,000 year old sediment from a site along the Elwha River. NPS/OLYM

Above Preliminary results from archeological testing, note radiocarbon dated layer.

Estuarine Restoration

LEWIS AND CLARK NATIONAL HISTORICAL PARK

Importance

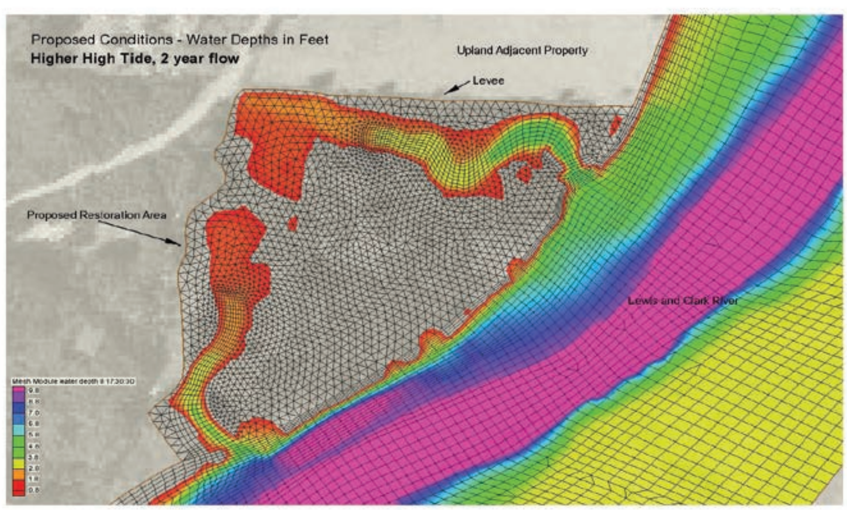
In selecting a site for the 1805-06 winter encampment, William Clark wrote that the Corps of Discovery decided on “a rise about 30 feet higher than the high tides.” With extensive marshes along the river, this higher elevation made the site a prime choice for Fort Clatsop. Over time, the look of the cultural landscape has been largely lost due to diking, draining, and filling of the adjacent wetlands, including Otter Point.

An estimated 95% of former wetlands in the Youngs Bay watershed have been similarly drained. These estuarine areas form important habitat for numerous species, including threatened and endangered salmon that rear and seek refuge on their migration out to sea. Re-establishing a tidal connection between the 34 acres of Otter Point and the Lewis and Clark River is part of an effort to restore 16,000 acres of wetland habitat throughout the watershed and a broader Recovery Plan for federally listed Columbia River salmon species.

Otter Point Restoration

LIDAR data and ground surveys revealed two channels that had existed prior to being filled by dredge material in the 1960’s. Starting in the fall of 2010 and continuing in the summer of 2011, heavy equipment recreated these channels by excavating 5,000 linear feet out of the dredge material. An additional five acres also were excavated down to marsh elevations.

Restoration crews set large woody debris and willows into the banks of the channel to increase habitat complexity, to provide cover for juvenile salmon,



ANCHOR ENVIRONMENTAL, L.L.C.

Figure A-19
Proposed Conditions, Water Depths, 2 year flow, Higher High Tide (t=17:30:00)
Otter Point Restoration Project

and to enhance macroinvertebrate recruitment. In the fall of 2011, park staff, contractors, and volunteers planted 45,000 plugs of native wetland emergent species into the tidal zone, planted 3,400 shrubs in the upland areas, and sowed the entire area with native seed harvested from the park and neighboring lands.

In 2012, construction will finish on a new 1,400 foot long cross-levee to protect adjacent property owners from floods. Once the new levee is in place, the existing levee will be breached in several locations to allow full tidal connectivity to the channels and floodplain.

This restoration project was accomplished through partnerships with the Columbia River Estuary Study Taskforce, Bonneville Power Administration, Lower Columbia River Estuary Partnership, and Oregon Watershed Enhancement Board.

Opposite Left Large woody debris is placed into the newly excavated south channel. NPS/LEWI
Opposite Right Hydrologic modeling predicts the extent of high tides after the existing levee is breached.

Above A former tidal wetland, Otter Point has been diked, drained, and filled over the past 100 years. Reed canary grass dominated the site before restoration. NPS/LEWI

Monitoring the South Clatsop Slough

One-half mile upstream of Otter Point, the park and its partners replaced a tide gate with a 46 foot bridge span, allowing tidal inundation to former pasture land at the South Clatsop Slough. Since the bridge was installed in 2007, scientists have been monitoring changes in vegetation communities, fish assemblages, water quality, and macro-invertebrate abundance and diversity. In 2011, they found a total of 736 juvenile salmon – including coho, Chinook, chum, and cutthroat – during bi-monthly sampling.

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Hazard Tree Management

MOUNT RAINIER NATIONAL PARK

Above Fruiting body of the fungus *Armillaria ostoyae*, a root disease pathogen prevalent in Ohanapecosh Campground. MORA/Degerman

Opposite Above Shallow soil depth and fungal root diseases render trees susceptible to windthrow. Both were causal factors for this root failure cluster in Ohanapecosh Campground. MORA/Degerman

Opposite Below The shredded texture of the decayed wood in this tree is symptomatic of rusty red stringy rot, caused by the fungus *Echinodontium tinctorium*. MORA/Degerman

Importance

More than 50 percent of the land area of Mount Rainier National Park (MORA) is covered by coniferous forests characterized by long-lived species such as Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*), which can reach heights in excess of 60 meters (200 ft.). Trees are frequently subject to damage caused by insect infestation, fungal disease, high winds, environmental stressors, heavy snow loads, soil erosion, soil compaction, and mechanical injury resulting from human activities that, with time, can lead to structural failure of a tree. A high proportion of the developed areas in park, such as campgrounds, administrative facilities, and employee housing are situated within forested zones; their location increases the likelihood of a tree failure causing serious injury to visitors and employees, or damage to structures and vehicles. In recognition of this inherent danger, the park's vegetation management staff developed a systematic approach to hazard tree management based on professionally recognized criteria.

Status and Trends

The MORA Hazard Tree Management Plan finalized in 2010 defines the procedures for survey, evaluation and mitigation or abatement of tree hazards affecting both front country and backcountry developed areas in the park. Management actions to reduce hazards can include abatement through planning and restrictions on use within developed areas. Mitigation can range from topping trees to maintain a component of wildlife habitat or full removal of a tree. Most forested front country developed areas in MORA are heavily affected by years of human use; some areas have lost most or all understory vegetation, have severely compacted soil, and have little to no natural regeneration of either trees or understory species. These conditions, in combination with mechanical injuries of natural or human origin, are environmental stress factors that can lead to the decline of the remaining mature trees in these areas. Another component of the problem is that most if not all rated hazard trees in the park are infected with one or more fungal pathogens. While these fungi are native and a natural component of the forest ecosystem, trees stressed by injury or altered habitat conditions are especially susceptible to infection. Of particular concern are the high-use areas of Ohanapecosh and White River campgrounds, where the mature conifers are subject to multiple natural and anthropogenic stressors, and disease centers have already developed. To prevent deforestation of the main campground loops via the combination of tree hazard mitigation and natural failures of diseased trees, actions are needed to improve habitat conditions and reduce the effects of human activities around the remaining trees.

Discussion

While the primary objectives of the MORA Hazard Tree Management Plan are identification and mitigation of tree hazards, the need for resource protection and restoration measures is recognized by the plan, and implementation of those measures is included as part of the plan. Toward this end, downed logs from felled hazard trees will be used to delineate individual campsites, block social trails, and create protected zones around clusters of mature trees for restoration with native understory species. Seed collection from undisturbed habitat adjacent the major campgrounds and picnic areas – Ohanapecosh, White River, Cougar Rock and Paradise –is planned for 2012 and beyond, for both direct seeding and greenhouse propagation for future revegetation efforts. Also, a forest monitoring study will be initiated this year at these sites, both within and outside the footprint of disturbance, to establish targets for restoration and to document the long-term efficacy of our site protection and restoration techniques in protecting tree health in high-use developed areas.

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Mountain Lakes Restoration

NORTH CASCADES NATIONAL PARK COMPLEX

Importance

One of the principal threats facing aquatic resources in mountain lakes can be attributed to the widespread introduction of non-native fish. In the past, people thought they were improving the natural environment by stocking non-native species of fish. But, instead, the result has created many negative impacts to the ecosystem and unhealthy and non-recreationally-rewarding fisheries. The mountain lakes in the North Cascades are naturally fishless due to barriers such as the steep and rugged nature of the glacially carved valleys and abundant waterfalls. Though lacking in fish, the lakes are far from barren of aquatic life. When the glaciers receded following the last ice-age (approximately 11,000 years ago), a wide variety of aquatic organisms gradually colonized the mountain lakes including plankton, invertebrates, and amphibians.

Research conducted here and at other parks has demonstrated that reproducing populations of fish (established through past stocking of lakes with sufficient spawning habitat) can overpopulate a lake and measurably deplete their food base, resulting in negative impacts to native species of amphibians, insects (such as caddisflies) and zooplankton. In addition, fish predation in combination with other factors affecting the suitability of these waters to sustain native species, such as climate change and air pollutant deposition, may dramatically increase the rate of decline in these species. The impacts of non-native trout are not just confined to lakes. Non-native trout are dispersing downstream from lakes and competing or hybridizing with threatened populations of native fish. In particular, the spread of Eastern brook trout (*Salvelinus fontinalis*) from mountain lakes risks placing these non-natives in competition with the native and threatened bull trout.

Status

Prior to 2008, North Cascades National Park Complex had 62 lakes containing introduced fish. Fish populations in 26 of these lakes were maintained by frequent stocking through 2008, and discontinued in 2009, following the signing of the Record of Decision regarding the Mountain Lakes Fishery Management Plan/Environmental Impact Statement. The absence of spawning habitat in these lakes does not allow for successful natural reproduction, so it is expected that future angler harvest and natural mortality will eliminate fish populations in the 26 lakes over the next ten years.

Active restoration measures are required for the remaining 36 lakes that contain reproducing populations of fish. High density populations of fish are found at 27 of these lakes and represent the first priority for restoration. Fish were removed from three of these lakes as a result of recent restoration efforts by park staff using intensive gill netting and application of antimycin, a fish toxicant. Gill net efforts to remove fish from three other lakes are nearly complete. Complete removal of reproducing fish populations from seven of these lakes may never be possible because of their large size and depth.

Discussion

Removal of non-native fish from mountain lakes in various protected areas has yielded very promising results. In Sequoia-Kings Canyon National Park, mountain yellow legged frogs are rapidly recolonizing lakes where populations of non-native trout were recently removed. Long-toed salamanders have recolonized a number of lakes in the Montana's Bitteroot Mountains following the eradication of introduced trout populations. In the Canadian Rockies, large crustacean zooplankton assemblages have recovered following the elimination of fish from mountain lakes, although recovery has taken an average of almost two decades. At Mount Rainier National Park, gill net removal of brook trout from a small lake resulted in significant changes in the abundance and behavior of northwestern salamanders, with adults actively feeding during the day (instead of hiding) and more widely distributed throughout the lake.

These case studies demonstrate that fish removal can lead to recovery of native organisms without further intervention, although recovery for some species can take many years.

The National Park Service will continue efforts to protect native aquatic ecosystems and endangered species in the park. Although some fishing opportunities will be foregone, an abundance and variety of sport fishing opportunities will remain in the park, and many native aquatic organisms will benefit from this effort including some that are currently seriously threatened.

Fish removal efforts at five more lakes will begin in 2012. Restoration plans will be custom-tailored for each lake in response to each lake's particular characteristics of size, depth, and habitat complexity which influence the success of these projects. Results of the eradication efforts will be carefully monitored to evaluate the effectiveness of fish removal efforts and recovery of native species.

Left Removal of non-native cutthroat trout in Upper and Lower Triplet Lakes is almost complete (NOCA). NPS/NOCA

Right Introduced Golden Trout captured at Jeanita Lake (NOCA). NPS/NOCA

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Fisher Reintroduction

OLYMPIC
NATIONAL
PARK

Importance

The fisher (*Martes pennanti*) is a dark, sleek, cat-sized member of the weasel family that once roamed coniferous forests throughout western Washington, including Olympic National Park (OLYM). Because of their prized fur, their susceptibility to trapping, and loss and fragmentation of their preferred low-elevation coniferous forest habitats, fisher populations declined and eventually were extirpated throughout Washington during the mid to late 20th century. Nobody knows when the last fisher disappeared from OLYM, although the last fisher was trapped near the park in 1969.

Any ecosystem is incomplete without all its parts. Because the purpose of national parks is to preserve and protect vignettes of primitive America for future generations, the missing pieces are acutely missed. Consequently, an important goal of the National Park Service (NPS) is to reintroduce extirpated species to their native environments where feasible, and in so doing restore the richness of native plant and animal communities, and the diversity of natural processes that govern how park ecosystems work.

In 2006, NPS and the Washington Department of Fish and Wildlife (WDFW) forged a partnership with several other agencies and conservation groups to return the fisher to its native habitat in OLYM. After lengthy planning and amidst a fresh snow on a cold January morning in 2008, the partners gathered to release the first of 11 fishers transported from British Columbia to their new home in the Park. This marked the first step in restoring a key player to the Park—the fisher—long known for its affinity for large trees, its secretive habits, and as a predator of small and medium-sized forest mammals

Status

Biologists released 90 fishers in seven of the 11 major watersheds that drain the mountainous interior of OLYM. All released fishers had tiny radio collars, and allowed biologists from the NPS, US Geological Survey, WDFW and other agencies to track their movements and fate for up to 2½ years following their release. That work wrapped up in 2011 when the last radio collar reached the end of its battery life. Data from that research are currently being analyzed; consequently results are in most cases too preliminary to draw conclusions.

We know, however, that fishers released into OLYM have dispersed long distances—up to 99 kilometers (about 60 miles) to establish home ranges widely throughout the Park and on adjoining lands. In May 2009 biologists documented the first litter of young fishers (known as kits) that were conceived and born to one of the first fishers released in 2008. By June 2011 seven females were documented to have denned. This provides confirmation that at least several fishers have adapted to their new home by finding a suitable den sites and mates. Because all radio collars have run out of battery power, and transplanted fishers have successfully reproduced, biologists no longer know the exact number of fishers in the reintroduced population.

Discussion

The return of fishers to OLYM is an 'adaptive management' project, a marriage between research and management designed to inform future management. We know that many of the released fishers survived for over two years and that several produced kits. The next phase of the study is to assess if the population is persisting and spreading. We hope to do this through the use of remotely triggered cameras that "trap" images of fishers as they come into bait and boxes that grab samples of hair so that we can do DNA analysis and assess who survived and who reproduced. We hope to start that investigation in 2013. Ultimately that information will be used determine whether the fisher restoration project was a success, and how much of their new landscape fishers are using.

This landmark effort culminates over ten years of interagency and non-governmental cooperation. Key funding and support has been provided by US Geological Survey, OLYM, WDFW, US Fish and Wildlife Service, Conservation Northwest, Doris Duke Foundation, and Washington's National Park Fund. This project also benefits from the support and efforts of many individuals within the US Forest Service, British Columbia Ministry of Environment, Makah Tribe, Lower Elwha Klallam Tribe, British Columbia Trappers Association, Washington Department of Natural Resources, and the University of Washington.

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Opposite Female 65 leaving her den tree, captured by a motion-activated camera. Olympic Fisher Project

Above Fisher kits rescued from a den tree after the mother died. The kits were raised at Northwest Trek and released when fully grown. Olympic Fisher Project/ Manson

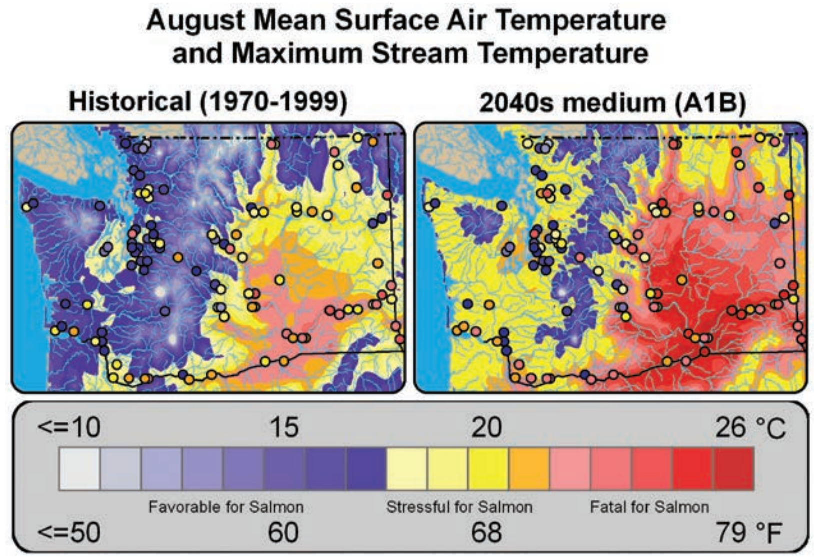
Climate Change and Salmon

North Coast & Cascades Network Science Brief

Importance

Climate plays a crucial role in the freshwater, estuarine and marine ecology of salmon, and projections for a warmer climate in the future have implications for Pacific Northwest salmon populations throughout their complex life histories. Key climate-related factors that affect salmon in the freshwater part of their life cycle include stream temperature and the volume and timing of streamflow. Climate influences estuarine and marine habitat for salmon directly via changes in water properties (e.g. temperature, salinity, water clarity, dissolved oxygen and pH) and indirectly through impacts on food webs, and it is likely that future climate change and ocean acidification will play important roles in altering these salmon habitats. In this brief we focus our discussion on freshwater impacts and the potential for ocean changes to impact early marine survival rates.

Key hydrologic factors coupled with climate that affect freshwater salmon habitat are thermal and streamflow regimes. Because the residence time of freshwater life stages varies considerably among the different salmon species and stocks, the responses of salmon to shifts in these factors depend to a great extent on stock-specific adaptations to local environmental factors and the way that different stocks occupy freshwater habitats in space and time. Because future climate changes are expected to both reduce streamflows and increase stream temperatures in what are already the low flow/warm season, populations with extensive freshwater habitat use in summer are likely to experience significant negative impacts on their freshwater productivity. Steelhead (*Oncorhynchus mykiss*), stream-type Chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*) and coho salmon (*O. kisutch*) are likely to have a greater sensitivity to freshwater habitat changes than those that migrate to sea at an earlier age (ocean-type Chinook salmon, pink salmon (*O. gorbuscha*), and chum salmon (*O. keta*). Resident (and anadromous) coldwater fish like bull trout (*Salvelinus confluentus*), rainbow trout (*O. mykiss*), and cutthroat trout (*O. clarkii*) are also likely to experience a reduction in high quality freshwater habitat in summer. Future climate scenarios also point to widespread increases in the frequency and intensity of fall and winter flooding in many Pacific Northwest (PNW) watersheds, and increases in flooding are likely to negatively impact the spawning success for many fall spawning salmon (all species) and bull trout populations.



Status and Trends

Increased stream temperatures caused by climate change are likely to affect salmon and resident coldwater fish by direct impacts on their physiology, and indirect impacts mediated through altered food webs and disease and parasite environments. Future stream temperature scenarios have been developed from future air temperature scenarios and observed relationships between stream temperature and air temperature. Stream temperature scenarios are predicted to be similar on both sides of the Cascade Range in the early part of the 21st century (above). However, by mid-century the lower elevation streams, particularly on the east side of the Cascades, are forecasted to warm at a greater rate than those at higher elevations. This pattern becomes more striking by the end of the century, when lowland areas on both sides of the Cascades undergo the greatest warming. These projections consistently indicate that shifts to increasingly stressful thermal regimes for salmon will be greatest for eastern Washington, where historic water temperatures are generally warmer than in western Washington.

Warming associated with climate change is expected to increase the distribution, frequency and persistence of thermal migration barriers and thermally stressful waters for salmon. The persistence of summertime water temperatures greater than 21˚C (70˚F) is predicted to start earlier in the year, and endure until later in the year. The critical thermal threshold of weekly average temperatures for salmon was determined as 21°C (70˚F) by the Environmental Protection Agency (2007). Weekly water temperatures exceeding this threshold result in lowered immunity to pathogens, migration barriers and fish kills. The projected increases in stream temperature alone suggest an intensification of thermal stress for Washington's salmon. Stocks with summer adult return migrations in already warm water bodies are likely at the greatest risk from future warming. These include many summer-run steelhead, sockeye and summer Chinook salmon populations in the Columbia Basin.

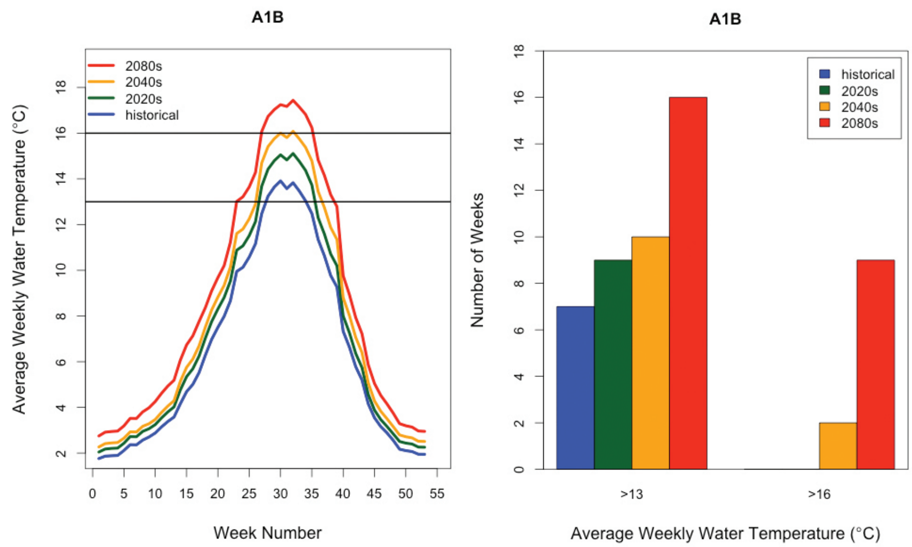
Increased stream temperatures also pose risks to the quality and quantity of favorable rearing habitat for juvenile stream-type Chinook and coho salmon and steelhead (summer and winter run) because these stocks spend at least one summer rearing in fresh water. Reductions in the volume of summer and fall low flows in warmer, low elevation basins will also reduce the availability of spawning habitat for salmon populations early in the fall. Moreover, the lower base flows projected for many western Washington streams in the summer months are expected to exacerbate

Opposite Salmon leap at Olympic National Park. NPS/OLYM

Above Historical and future stream temperatures in Washington. Colored shading shows the historic (1970–1999) mean surface air temperatures for August, and shaded circles show the simulated mean of the annual maximum for weekly water temperatures for select locations. After Mantua et al. 2010. Figure: Robert Norheim

Climate Change and Salmon

North Coast & Cascades Network Science Brief



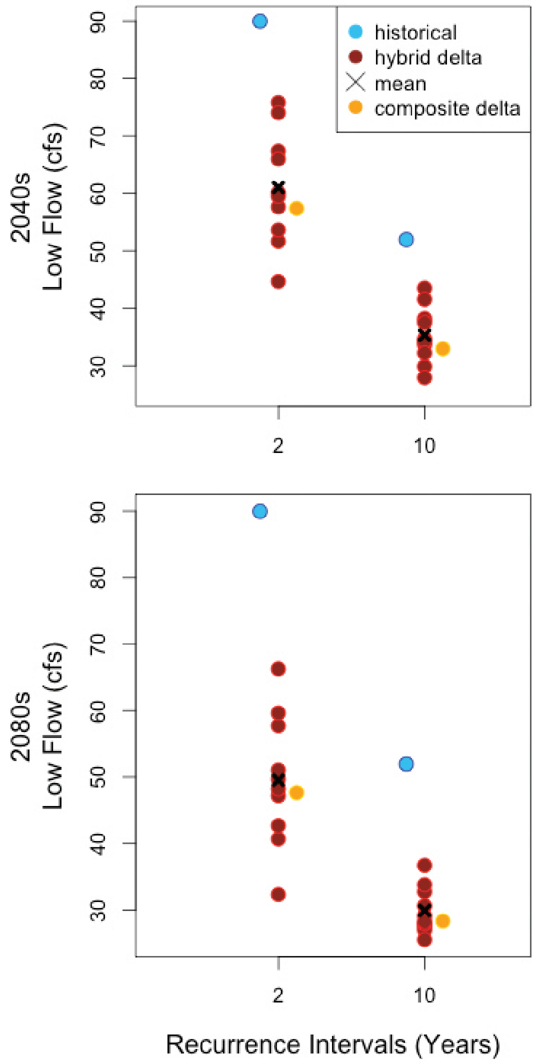
Above Changes in weekly water temperature at Ruby Creek, in the Skagit River basin, under future climate change scenarios (left) and the number of weeks exceeding 55°F (13°C) and 61°F (16°C). After Hamlet et al. 2010.

Opposite Above The 7-day minimum low flow statistics with a 2-year and 100 year return interval for the Ruby Creek gage near Newhalem for historical, for the 2040's (top) and 2080's (bottom) and for two different approaches to future climate model output downscaling: hybrid delta and composite delta means. The results are for the A1B greenhouse gas emissions scenario. The hybrid delta approach allows better simulation of the hydrologic conditions leading to low flows than the composite delta approach because it simulates changes near the extremes of precipitation and temperature better. In all cases, the future low flows are projected to be lower than the historical low flows.
Opposite Below Elwha River peak flow events from 1910-2010. The upward trend is one example of statistically significant changes in winter flow patterns in Pacific Northwest rivers.

the effect of the warmer air temperatures on the stream thermal regimes. (The stream temperature modeling used in the WACCIA report was only based on regressions between air and water temperature and did not explicitly consider the influence of streamflow on stream temperature – for a given amount of heating, temperature change is inversely proportional to the volume of water being heated, so lower flows will result in more warming).

Although cool-season stream temperature changes and impacts are not assessed in this study, it is possible that climate-induced warming in winter and spring will lead to earlier and perhaps longer growing seasons, increased aquatic food-web productivity, and more rapid juvenile salmon growth and development rates that may benefit parts of the freshwater life cycle for some or even many of Washington's salmon. It seems likely that the potential for positive impacts of future stream warming are greatest in Washington's coldest streams, either in the maritime climatic zones of Western Washington or in high elevation stream reaches. Also, warming of temperatures can result in intrusion of previously excluded species such as coho salmon into bull trout spawning habitat where coho may outcompete the bull trout.

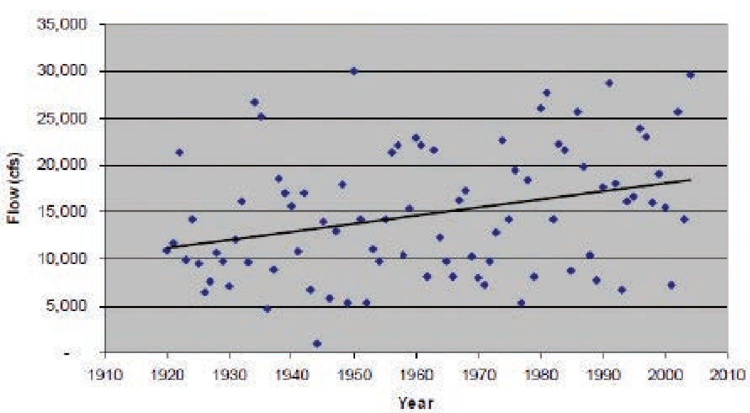
As increased temperatures cause snow lines to rise, a greater intensity and frequency of winter flooding is projected for Washington's mid-elevation basins, where transient runoff currently dominates streamflow on both sides of the Cascades. Increased winter flooding, resulting from a greater contribution of rainfall to streamflow, is likely to negatively impact the egg-to-fry survival rates for pink, chum, sockeye, Chinook, and coho salmon due to an increased intensity and frequency of redd scouring. However, the impact of increasing winter flooding will likely vary among species and populations because redd depth is a function of fish size; deeper redds will be less vulnerable to scouring and the deposition of fine sediments. Parr-to-smolt survival rates will likely be reduced for coho and stream-type Chinook salmon and steelhead because greater peak flows may displace rearing juveniles out of preferred habitats if the habitat lacks side-channels that provide slow-water off-channel refugia. Reductions in spring snowmelt may negatively impact the success of smolt migrations from snowmelt-dominant streams where the timing of seaward migration has evolved to match the timing of peak flows.



Because earlier snowmelt and increased evaporation will reduce surface runoff and deplete shallow soil moisture earlier in the year, most of Washington's rainfall-dominant and mixed rainfed/snowfed river basins are expected to have an extended period of summer low flows.

In contrast, low-flow projections for snowmelt-dominant basins demonstrate that they are less sensitive to rising temperatures. Historically, the lowest flows for snowmelt-dominant basins tend to occur in the winter when precipitation is stored as snow. However as temperatures rise and rainfall contributes more to streamflows in these basins, today's snowmelt dominant basins may experiences increases in winter streamflow. For the mixed rainfed/snowfed basins in particular, the combination of increased summer stream temperatures and reduced summer flow is likely to limit rearing habitat for salmon with stream-type life histories (wherein juveniles rear in fresh water for one or more years), increase mortality rates during spawning migrations for summer-run adults, and reduce the availability of spawning habitat that is most vulnerable to both dewatering and scour.

While there has been substantial work done to use simulation models to evaluate climate change impacts on aspects of freshwater habitat for salmon, very little work has focused on evaluating climate change impacts on coastal estuaries and the nearshore coastal ocean where salmon appear to experience high levels of mortality that then strongly influence total marine survival and adult abundance. However, periods with weak upwelling winds in spring and summer and warmer than average coastal ocean temperatures have been associated with a suite of changes in marine habitat and food webs that contribute to reductions in growth and survival rates for many PNW salmon populations. Specifically, cold periods have tended to favor especially productive food webs for salmon that include larger and fattier zooplankton communities, and fewer predators and competitors for juveniles salmon. The opposite has been true with warm periods. Future climate scenarios point to warming trends in the upper ocean that will increase the stratification of the upper ocean and likely inhibit the upwelling of cold, nutrient rich water that fuels a productive coastal ocean in the PNW region. Warmer surface waters will also favor an influx of subtropical predators and competitors for juvenile and maturing salmon. However, some climate models suggest that this warming may be countered in the coastal zone by an intensification of upwelling favorable winds in spring and summer. At this point, it is not clear if future changes in the coastal ocean will amplify or dampen the impacts of climate change on salmon freshwater habitat, but it will be a critical part of climate impacts on salmon in the future.



Discussion

The impacts of climate change on the life history and long-term viability of coldwater fish species are key considerations for PNW national parks. To the extent that these species are bellwethers of freshwater habitat viability and aquatic ecosystem change, they also serve as indicators of a variety of adverse environmental impacts on pristine ecosystems.

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The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations.

The National Park Service Mission