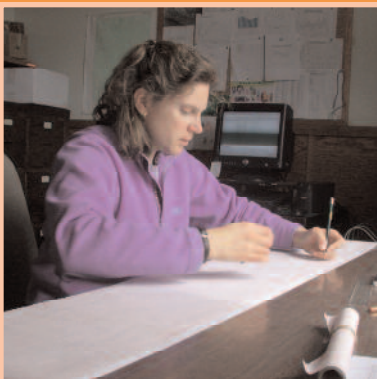




Long-term Silvicultural & Ecological Studies

Results for Science and Management:
Volume 2

Ann E. Camp, Lloyd C. Irland,
and Charles J.W. Carroll

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Of course, we thank all those past foresters and scientists who had the foresight to initiate these re-measurement projects and keep copious, detailed notes; it was often only the existence of those notes that allowed old plots to be discovered and revitalized. We should also recognize all of the landowners and administrators who supported these efforts over the years. And of course we thank those who couldn't bear to toss those old notes and maps!

Most especially we acknowledge the excellent editing skills of Charles J.W. Carroll MFS 2012 who pulled everything together while finishing up his own research. In the midst of graduating and moving to Colorado, Jeff managed to find time to get the project into the hands of the Global Institute of Sustainable Forestry's publications staff before departing New Haven. For that we are in his debt.

We hope that this publication will help readers learn of the work that has been done in the research efforts that are included. Perhaps it will remind someone of some old notes and maps in file boxes, in an attic somewhere, in the study of a retiree, or an old map storage cabinet. Perhaps it will cause someone, somewhere, to pause and think a moment before committing such documents to a dumpster or shredder.

The Editors

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Establishing a Long-term Vegetation Monitoring Program in National Parks of the Pacific Northwest

Regina M. Rochefort¹ & Steven A. Acker²

Introduction

The primary mission of the National Park Service (NPS) is to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations. In 2000, the NPS Inventory and Monitoring Program (I&M) was established to provide scientifically sound information on natural resources by documenting the status and long-term trends in composition, structure, and function of park ecosystems. The program was also established to evaluate how well current management practices are sustaining those ecosystems (National Park Service 2001, Fancy et al. 2009). The national I&M program is organized around 32 monitoring networks including approximately 270 park units. Each network identifies key indicators or "vital signs" to track the overall condition or "health" of park natural resources and to provide early warning of situations that require intervention (Davis 1989, 2005, Fancy et al. 2009).

The North Coast and Cascades Network (NCCN) is composed of seven parks in western Washington and northwest Oregon: San Juan Island National Historical Park (SAJH), North Cascades National Park Service Complex (NOCA), Olympic National Park (OLYM), Ebey's Landing National Historical Reserve (EBLA), Mount Rainier National Park (MORA), Fort Vancouver National Historical Site (FOVA), and Lewis and Clark National Historical Park (LEWI) (Figure 1). In 1997, the NCCN initiated a series of workshops and meetings with park staff and subject matter experts to identify key park

ecosystem components and core indicators prior to development and implementation of monitoring protocols (Weber et al. 2009). During these meetings, climate change and air quality were identified as the greatest threats to national parks in the Pacific Northwest (Weber et al. 2009). Vegetation was identified as one of ten vital signs for the network; the other nine were: landscape dynamics, climate, mountain lakes, glaciers, landbirds, water quality, intertidal, fish assemblages, and elk (NPS 2010).

Spatially, the seven NCCN parks are distributed across a diverse landscape and range of climatic conditions, resulting in a wide range of ecological diversity. Four parks (SAJH, OLYM, EBLA, and LEWI) protect diverse intertidal assemblages along the Washington and Oregon coasts while the three mountain parks (MORA, NOCA, and OLYM) encompass permanent snow and ice fields along the crests of the Olympic and Cascade Mountain ranges. SAJH, EBLA, and FOVA protect important historical prairie landscapes within the Puget lowlands of Washington. While the network topography provides incredible opportunities for field research in a variety of habitats, it also presents challenges for travel to study sites. NOCA (273, 668 ha) and OLYM (373,384 ha) are large wilderness parks with limited road and trail access across their extremely rugged topography (e.g. NOCA has only 128 km of roads and 621 km of trails). Although Mount Rainier National Park (95,354 ha) has more extensive road (236 km) and trail (418 km) systems, its elevation gradient (490 m to 4,393 m) and weather require careful planning prior to monitoring trips.

¹ North Cascades National Park

² Olympic National Park

Vegetation Vital Signs

Vegetation monitoring focuses on documenting vegetation change along the elevation and climate gradients spanned by network parks: lowland prairies, forests, and subalpine/alpine vegetation (Figures 2, 3, 4). Within each broad vegetation category, monitoring objectives were identified after considering stressors to vegetation, management objectives, and indicators of ecological integrity. Once quantitative monitoring objectives were articulated, specific monitoring variables were selected, sample designs were developed, and methods of analyses identified. Pilot monitoring was generally conducted for one to two field seasons in order to test the proposed methods and calculate sample sizes based on our objectives, sampling frequency, and variability in our monitoring variables. Protocols for each Vital Sign were written and peer reviewed prior to implementation.

Three vegetation monitoring protocols have been developed: Prairies, Forests, and Alpine/ Subalpine. All protocols share several basic program characteristics:

- The protocol must allow statistical inference of status and trends within and across parks with sufficient power to provide useful data to park management.
 - This characteristic sounds like common sense, but given the number of parks in our network and the large size of OLYM and NOCA, this was not an easy choice. Prairie habitats were limited to SAJH and very small in size so we could easily make the decision to develop a sample frame that had inference to all prairie habitats in the park. However, when we looked at forests and subalpine/alpine vegetation, we debated whether a small number of reference sites with site level inference (e.g the GLORIA network, Pauli et al. 2004) or a geographically extensive sample frame with broad

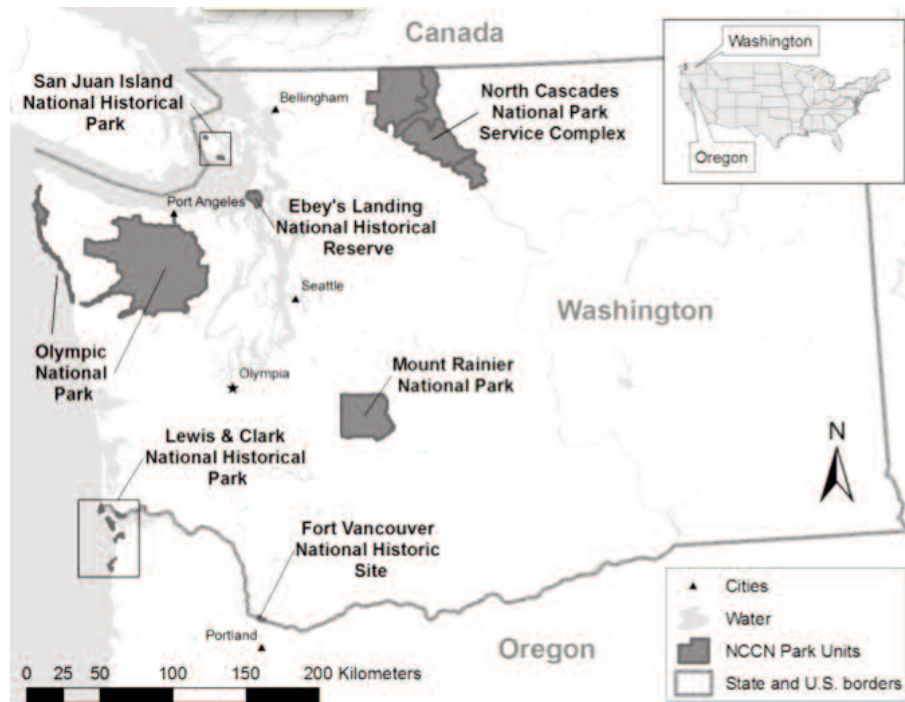


Figure 1. Parks within the National Park Service's North Coast and Cascades Network.



Figure 2. Prairie landscape at San Juan Island National Historical Park.



Figure 3. Douglas fir/ western hemlock stand in Mount Rainier National Park.

statistical inference would better serve our needs. If we selected a small number of sample sites, we would probably be able to visit the sites more frequently and document interannual variation as well as long-term trends. If we selected this approach, we would not be able to capture the diversity within forests or high-elevation vegetation communities and we might not even sample the areas most sensitive to climate change.

- o For forests, we decided to limit monitoring to three forest types, but monitor frequently (annually) to enhance our ability to identify the cause of tree mortality.
- o In subalpine and alpine habitats, we felt that landscape heterogeneity was an important characteristic of this environment and we wondered whether this would decrease (i.e. spatial heterogeneity) with changing climates so, more samples would be important (i.e. rather than indicator sites). We also decided that we needed to insure that our samples were distributed over the range of elevations, aspects, and slopes in this zone so an extensive sample was important. Due to the sensitivity
 - of high-elevation habitats and travel times involved (e.g. some sample sites in OLYM or NOCA would require 8-10 hours of hiking each way), we would only sample once every five years, sacrificing interannual changes for spatial extent.
 - Crew safety and accessibility of plots must be considered because we are monitoring in large wilderness parks with steep terrain and limited trail access.
 - Climatic change will become a profound influence on park ecosystems; protocols should document its effects on landscapes in forest, subalpine, alpine, and lowland prairie areas.
 - o In this regard, we expected the subalpine/alpine areas would be the most sensitive to changing climate and in particular duration of snowpack. We suspected that patterns of tree establishment and proportions of forbs:grasses might be the first indicators of change. Sample designs were developed to document these types of changes.
 - o However, we knew that higher temperatures and changing precipitation patterns (i.e. summer drought) might be problematic for forest



Figure 4. Alpine habitat in Mount Rainier National Park.

trees (van Mantgem and Stephenson 2007, van Mantgem et al. 2009) so, we did not want to ignore this zone. Monitoring was limited to three specific forest associations, but sites are monitored annually so that trends in mortality can be identified rapidly.

- o Prairies presented a different problem – we really were not sure what changes to expect with climate change. Exotic (non-native) plant species are currently a management priority at SAJH and they may respond to changing climates. Monitoring at these sites is fairly intense (spatially and temporally) and we hope it will be sensitive to climate induced changes.
- NCCN study sites should provide a foundation upon which other researchers can initiate short and long-term research to address more detailed questions than we can support.
 - o We know that vegetation response to climate change is often slow (Gonzalez et al. 2010) and the frequency of our monitoring events may not provide early warnings of changes. Additionally our program will document changes but may not provide the mechanisms or casual agents for these changes. For these reasons, we are actively recruiting other researchers to conduct more intense research (e.g. physiologic or genetic research) to increase the utility of these sites to increase our understanding of ecosystem processes and improve our management of national parks.

Lowland Prairies

Prairies and oak woodlands were once extensive in the Puget Lowlands of Washington (Franklin and Dyrness 1988, Dunn and Ewing 1997, Pater et al. 1998). These grass-dominated landscapes developed during the warmer climates of the early Holocene on gravelly, outwash soils that were not conducive to the establishment of woody vegetation (Ugolini and Schlichte 1973, Whitlock 1992). As cooler and wetter climates returned, Native Americans often maintained prairies by burning areas periodically to remove encroaching trees and shrubs and to encourage important food plants such as camas (*Camassia quamash* and *Camassia leichtlinii*), chocolate lily (*Fritillaria lanceolata*),

and Garry oak (*Quercus garryana*) (Kruckeberg 1991, Whitlock 1992, Weiser 2006). After European settlement in the mid 1800s, fire frequency decreased and trees invaded many of these areas (Agee 1984, 1993, Peterson and Hammer 2001). Later, continued agricultural use, grazing, urban development, and invasion by exotic plant species contributed to the decline of prairie habitats (Chappell et al. 2003). Today, less than 3% of these areas remain and many are severely degraded (Crawford and Hall 1997).

Historically, prairies provided an important visual and biologic component of the matrix of landscapes in Ebey's Landing National Historical Reserve (EBLA) and San Juan Island National Historical Park (SAJH) (Avery 2004). For example, during the historic period of the Hudson's Bay Company (1853), Bellevue Farm was established on the open, south-facing, grassy slopes of the American Camp area of SAJH and over 4,000 sheep, cattle, horses, and hogs grazed on much of the area (Rolph and Agee 1993). Surprisingly, despite this use, significant remnants of native prairies and oak woodlands remain in SAJH. Recently, surveys documented approximately 87 patches of native prairie distributed across the 695 acre American Camp landscape (Rochefort and Bivin 2010).

The goal of the prairie monitoring program is to detect and describe changes in the extent and distribution of prairies, oak woodlands, and forests in San Juan Island National Historical Park and the ecological integrity of prairie communities. Four primary objectives are addressed in this protocol:

- 1) Detect change in the extent of physiognomic cover types (i.e. trees, shrubs, prairies) within the park.
- 2) Detect change in the proportion of areas dominated by exotic and native species within each cover type.
- 3) Detect change in the quality of prairie cover types.
- 4) Detect changes in composition and diversity of prairies cover types within the park.

Prairie monitoring follows a two-stage sampling design; the first stage is designed to detect changes

in physiognomic cover classes and the second stage focuses on composition of herbaceous communities. Sampling is conducted along parallel transects drawn at random using a general random tessellation stratified sample (GRTS) (Stevens 1997). Physiognomic cover types and origin of predominant species (i.e. exotic or native) are recorded along transects. Species composition, of herbaceous cover types, is monitored within 1 m² quadrats located systematically along transects. Status and trends of cover types are assessed through changes in origin of predominant species, species richness, and changes in species composition. Annual status estimates will be utilized by park staff in the development of annual work plans regarding exotic plant control. Five and ten year trends in cover types, species composition, and exotic plant distribution will provide feedback on prairie restoration programs and insights on the influence of climate change and management actions on vegetation patterns and the cultural landscape.

Forests

Forest communities in the NCCN parks are quite diverse reflecting the varied precipitation, temperature, and elevation gradients (Franklin and Dyrness 1988, Franklin et al. 1988, Henderson et al. 1989, 1992). Coniferous forests cover approximately 60% of the network parks and range from Sitka Spruce (*Picea sitchensis*) coastal rainforests, to low-elevation, old-growth Douglas Fir/ Western hemlock (*Pseudotsuga douglasii*/ *Tsuga heterophylla*), up to the subalpine fir (*Abies lasiocarpa*) forests near the Olympic and Cascade crests, and down to the low-elevation, drought-adapted Ponderosa pine (*Pinus ponderosa*) forests in eastern areas of North Cascades National Park. Several global and regional stressors (i.e., anthropogenic climate change, atmospheric and precipitation chemistry, introduced pests, pathogens, invasive species and forest harvest) threaten forest structure, species composition and abundance, thereby changing the quality and quantity of habitat for terrestrial birds and wildlife.

Our protocol was developed based on our assumption that climate change and air quality may cause significant changes in structure of NCCN forests in

the future. Recently, a number of studies have reported increased tree mortality in unmanipulated forests of western North America over the last several decades (e.g. van Mantgem and Stephenson 2007, van Mantgem et al. 2009). While tree mortality occurs throughout the life of forest stands, mortality in early successional stages tends to result from competition with other trees rather than external environmental factors (Franklin et al. 1987, 2002, Oliver and Larson 1990). We are interested in monitoring mortality caused by environmental drivers, therefore we are working in late-successional, coniferous forests that represent the range of climatic regimes and elevation in the NCCN (Table 1, Acker et al. 2010).

We are monitoring forests in relatively warm and wet conditions in the Sitka spruce zone (Olympic NP, Lewis and Clark), cold and dry conditions in the subalpine fir zone (North Cascades and Mount Rainier), plus the intermediate western hemlock zone (Mount Rainier, North Cascades, Olympic, San Juan Island). Our fixed strata in each park are 300 m elevation bands within these zones: 0-300 m, 600-900 m, and 1500-1800 m. Six permanent plots are established within each park stratum and their locations are selected randomly using a general random tessellation stratified sample (GRTS) to get a spatially balanced sample (GRTS, Stevens 1997). Tree mortality is evaluated annually in each plot and tree recruitment and growth will be recorded every five years.

Subalpine and Alpine Ecosystems

Subalpine and alpine areas are ecologically important zones that provide popular recreational opportunities for visitors to Mount Rainier, North Cascades, and Olympic National Parks. Spatially, these zones cover approximately 34% of MORA, 36% of NOCA, and 19% of OLYM. The subalpine parkland is a mosaic of tree clumps and herbaceous meadows extending from forest line (closed canopy forest) up to treeline (Franklin and Dyrness 1988). The alpine zone continues from treeline (highest elevation of upright trees) to the peaks of the Cascade and Olympic mountains. Alpine vegetation is generally sparsely distributed across the landscape; patches of sedge-turf communities, sub-

shrubs, or krummholz trees are interspersed between snowfields, talus slopes, and rocky fell-fields. The entire area, from forest line up to permanent snow is a broad transition zone and is expected to respond fairly quickly to projected climate changes and in particular changes in the duration of snow cover (Rochefort et al. 1994, Holtmeier and Broll 2005, Canonne et al. 2007, Loarie et al. 2009).

The goal of the Alpine and Subalpine Monitoring Protocol is to provide staff of the NCCN with an accurate vision of the status and trends of vegetation in the alpine treeline ecotone in order to inform management decisions affecting these areas. We identified four specific monitoring objectives, to determine the status and trends in:

1. Composition and structure of alpine vegetation communities in MORA, NOCA, and OLYM
2. Composition and structure of subalpine vegetation communities in MORA, NOCA, and OLYM.
3. Soil temperature and snow cover period in subalpine and alpine communities in MORA, NOCA, and OLYM and at legacy plots in MORA.
4. Structure and condition of whitebark pine stands in MORA, NOCA, and OLYM
5. Composition and structure of legacy (historic, non-random) alpine vegetation plots in MORA

The monitoring protocol utilizes a general random tessellation stratified sample (GRTS) of monitoring sites distributed within 1.5 km of trails and roads to address the first five goals. This sample frame will provide us with statistical inference across the three parks within this access zone and thus will provide an extensive view of changes in species composition in response to climate change.

Accomplishments to Date

As of January 2011, all three protocols have been peer reviewed. The Forest Monitoring Protocol received final approval September 2010 and the Prairie and Alpine/Subalpine Protocols have been

provisionally approved pending revisions based on the review. At this time, we have established 35, 1-hectare plots in three parks (Mount Rainier, North Cascades, Olympic), at elevations from sea-level to 1800 m. We will establish additional plots at San Juan Island National Historical Park (2012) and Lewis & Clark National Historical Park (2011). Long-term Prairie and Alpine/Subalpine monitoring will begin in 2012 although pilot monitoring has already been conducted to varying extents in each park. For example, whitebark pine monitoring (Alpine/Subalpine) plots were established in Mount Rainier and North Cascades in 2004 and resurveyed in 2009. Evaluation of these plots in 2009 revealed disappointing trends in mortality and rates of infection by white pine blister rust (*Cronartium ribicola*) (figure 5). In MORA, the proportion of infected trees (> 2.54 cm dbh) rose from 15% to 18%, mortality increased from 46% to 52%, and uninfected trees decreased from 39% to 29% (Figure 5). In NOCA, the proportion of infected trees increased from 29% to 31%, mortality increased from 16% to 29%, and uninfected trees decreased from 54% to 40%. 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). Additional plots will be established in Olympic National Park in 2012.

Summary

National parks provide field laboratories where monitoring and research can increase our understanding of the response of unmanaged ecosystems to climate change. Potential changes in vegetation include migration of species ranges within and outside parks, loss of suitable habitat, and competitive exclusion by invasive exotic species. Globally and regionally, evidence of changing climates is visible in species distributions, phenologic patterns, and forest mortality (Parmesan et al. 1999, Cayan 2001, van Mantgen and Stephenson 2007). Within the parks of the North Coast and Cascades Networks, resources are already responding to changing con-

ditions. For example, there are 312 glaciers in North Cascades National Park, comprising approximately one third of all glaciers in the lower 48 states (Porter et al. 1971). Glacial area has declined by 44% over the last 150 years (Granshaw 2001, Riedel 2009). Another example is that of rising forest and treeline. Tree establishment in the subalpine parkland of the NCCN is generally controlled by the duration of snowpack; rates of establishment in Mount Rainier National Park have accelerated during warm, dry summers on the west side of the park and cool, wet summers on the drier east side of the park (Little et al. 1994, Rochefort and Peterson 1996, Stueve et al.

2009). Our challenge is to learn both how to monitor these indicators of climate change frequently enough to document changes and then to develop ways to utilize these results in park management.

National parks and other protected areas are challenged to respond to climate disruptions in proactive ways that incorporate up-to-date science and local ecosystem measurements based on their specific resources, environment, and management objectives (GAO 2007, Millar et al. 2007, Cole et al. 2008, Lawler 2009, USDI 2009). Development of management responses to these changes may

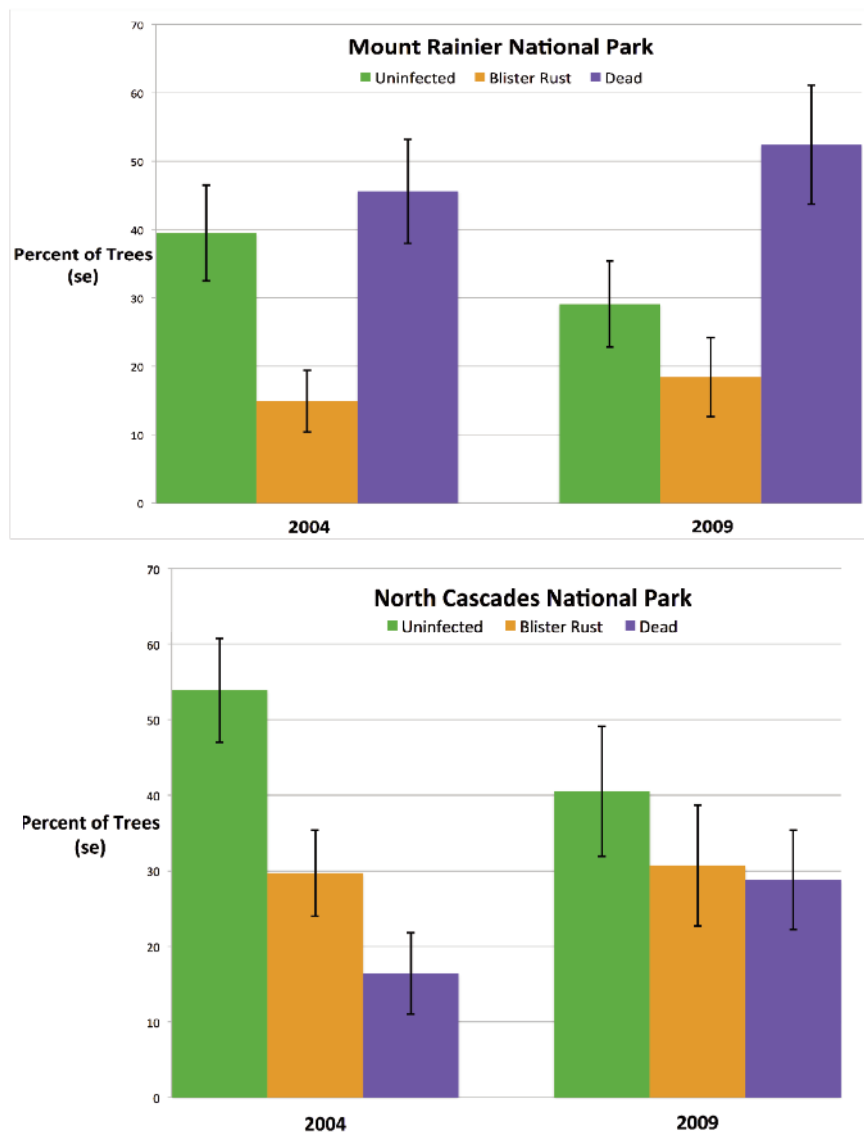


Figure 5. Five year trends in health of whitebark pine stands in Mount Rainier and North Cascades National Parks. Whitebark pine study plots elevations range from 1786 to 1833m in each park.

require the National Park Service to take a more active role (e.g., moving seeds) in managing resources than current policy prescribes. The NCCN Vital Signs Monitoring program has been designed to provide early warning of the types and severity of future changes so that management options can be developed and evaluated in time to be effective. In collaboration with adjacent national forests, the NCCN parks are initiating partnerships to develop adaptation strategies (e.g. www.north-cascadia.org) that will rely heavily on the research and monitoring that is being conducted in these areas.

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