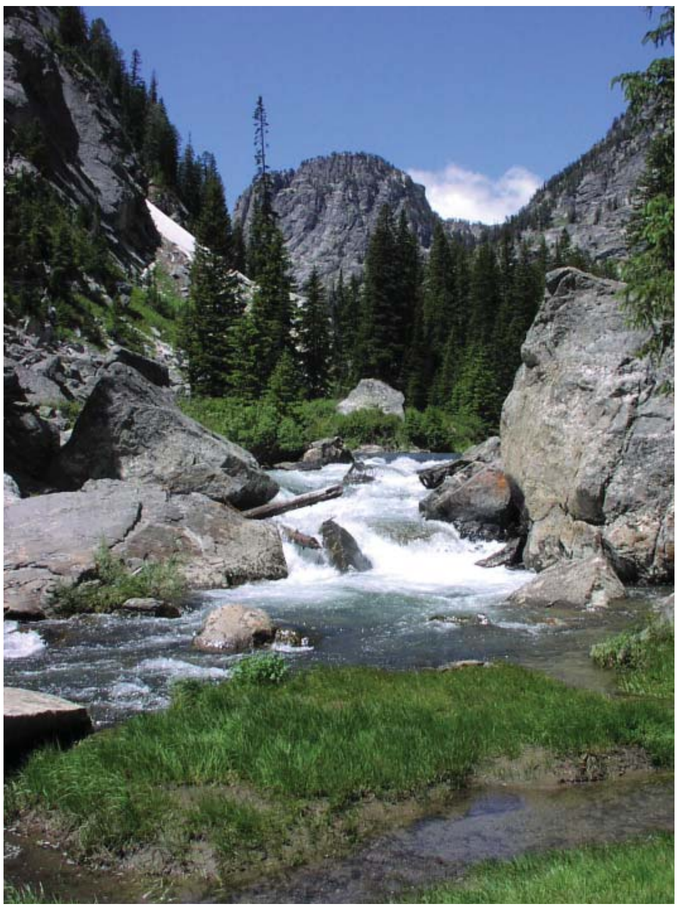
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Enhanced Monitoring to Better Address Rapid Climate Change in High-Elevation Parks

A Multi-Network Strategy

Natural Resource Report NPS/IMR/NRR—2011/285



ON THE COVER

Clockwise from left: Mouth of Death Canyon, Grand Teton National Park; Big Southern Butte, Craters of the Moon National Monument and Preserve; Thunder Lake, Rocky Mountain National Park. NPS photos.

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January 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Natural Resource Publications Management web site, http://www.nature.nps.gov/publications/NRPM.

Please cite this publication as:

Bingham, B., M. Britten, L. Garrett, P. Latham, and K. Legg. 2010. Enhanced monitoring to better address rapid climate change in high-elevation parks: a multi-network strategy. Natural Resource Report NPS/IMR/NRR—2011/285. National Park Service, Fort Collins, Colorado.

NPS 960/106365, January 2011

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Executive Summary

In fiscal year 2010, the National Park Service (NPS) received funding for a new Climate Change Response Program (CCRP). The goals of the CCRP strategy include enhancing the existing natural resources Inventory and Monitoring Program (I&M) to expand the program's monitoring of climate-sensitive indicators. The results from the enhanced monitoring will be used to evaluate and report the status and trends of park resources for the purpose of facilitating adaptation planning and management. The initial I&M priorities for the CCRP goals build upon existing monitoring and strengthen interagency coordination for parks in four categories of high vulnerability to climate change: high elevation, high latitude, coastal/marine, and arid lands. The Department of Interior (DOI) Landscape Conservation Cooperatives (LCC) provided the organizational framework for collaboration on enhanced monitoring. Working with partners within each LCC, the I&M networks established procedures for enhancing existing monitoring to provide more information on ecological response to climate change.

In May 2010, a workshop, titled "Monitoring Ecological Response to Climate Change in High Elevation Parks in the Great Northern Landscape Conservation Cooperative," was held to engage managers from high-elevation parks with agency and university scientists and partners. The workshop had three main objectives: (1) Review current knowledge of the impacts of climate change to high-elevation resources, (2) Evaluate existing monitoring efforts in context with high-priority indicators of ecological response to climate change, and (3) Identify opportunities for enhancing existing monitoring, data management, and analysis to support managers in planning, adapting, and responding to the ecological impacts of climate change in the Rocky Mountains and Upper Columbia Basin. Interest in the workshop was significant, with participation by managers, scientists (including several climatologists), university faculty, and others from the National Park Service, U.S. Geological Survey, Bureau of Land Management, U.S. Fish and Wildlife Service (USFWS) Wildlife Refuge System I&M Program and Ecological Services, State of Wyoming, Colorado State University, Montana State University, Sonoran Institute, National Ecological Observatory Network (NEON Inc.), and others. The results of the workshop were used to establish priorities for enhancing long-term monitoring of climate-change impacts to resources in parks of the Greater Yellowstone, Rocky Mountain, and Upper Columbia Basin I&M networks. These priorities are the basis for a long-term strategy and workplan developed by the three high-elevation I&M networks and their partners within the Great Northern LCC.

Also in 2010, the U.S. Fish and Wildlife Service Refuge System initiated its new Inventory and Monitoring Program. The USFWS has co-located the national staff of their new I&M program with the NPS national staff in Fort Collins, Colorado. The high-elevation NPS I&M networks plan to work closely with the USFWS I&M program to implement monitoring protocols and data management, analysis, and reporting procedures on national wildlife refuges within the Great Northern LCC. Additionally, we will continue to strengthen our monitoring partnership with other agencies and collaborators within the Great Northern LCC.

One of the most effective ways to immediately strengthen our collaboration with partners to address the significant challenges of rapid climate change is to share monitoring protocols, data, and information products. As part of the enhanced monitoring component of the NPS Climate Change Response Program, the NPS is developing an integrated data system using DOI and industry standards to allow efficient searching, discovery, and sharing of data and information across multiple data systems.

The three I&M networks within the Great Northern LCC will use the NPS Natural Resource Information Portal (NRInfo, http://nrinfo.nps.gov) to share data and information products with partners and the general public. In addition, the Greater Yellowstone Science Learning Center and the three network Internet sites will provide our partners within the Great Northern LCC access to high-elevation park and network products. To increase the ability and efficiency of DOI and bureau managers, scientists, planners, interpreters, and others at all levels of the organization to search for, find, retrieve, share, and disseminate available data and information, and for bureaus to communicate information to their constituencies, tribes, and the general public, we intend to establish an information portal targeted specifically at providing federal, state, university and other partners within the Great Northern LCC direct access to data and information products resulting from this work.

The Greater Yellowstone, Rocky Mountain, and Upper Columbia Basin I&M networks developed this document to describe their process for identifying critical monitoring needs and enhancing each park's understanding of the effects of climate change. The process includes identifying existing monitoring in need of enhancement, as well as new monitoring, to improve understanding of the effects of climate change on parks.

Critical to the strategy's successful implementation is an adequate allocation of travel allowance associated with the work. Currently, regional offices are responsible for managing I&M network travel ceilings. For FY2011, the Greater Yellowstone and Rocky Mountain networks require $8,200 and $8,500, respectively, in travel, and the Upper Columbia Basin Network requires $14,100 allocated for travel. Without these travel allocations, the strategy cannot be implemented in FY2011, and any new funding for climate-change monitoring will need to be returned to the Washington Office. The strategy to enhance existing monitoring in the three high-elevation networks includes:

1. Increasing the spatial extent of monitoring alpine vegetation and soils using the Global Research Initiative in Alpine Environments (GLORIA) methodology and network.
2. Increasing the spatial extent of vegetation and soils monitoring in sagebrush-steppe and grassland/shrubland/woodland systems.
3. Expanding monitoring of species known to be climate-sensitive, including the American pika and five-needle pines (whitebark pine and limber pine).
4. Completing and implementing a protocol for consistent reporting of weather and climate data for high-elevation parks.
5. Implementing phenology monitoring (using patterns of "greening" and productivity) and snowpack monitoring through the acquisition, analysis, and interpretation of MODIS (or Moderate Resolution Imaging Spectroradiometer) for high-elevation parks.
6. Delivering peer-reviewed communication products that explain the ecological impacts of climate change and management implications.
7. Strengthening current partnerships with the USFWS I&M program and others to efficiently monitor climate-change metrics in a consistent manner.
8. Looking for opportunities and funding to further develop and apply key monitoring products (e.g., NPScape and the Integrated Resource Management Application) to support collaborative climate-change monitoring across land-management boundaries.
9. Contributing data, reports, synthesis documents, and expertise to the broader Great Northern LCC effort so as to better understand and respond to the consequences of climate change on regional scales.
10. Increasing awareness (and access) within the Great Northern LCC of monitoring protocols, data, reports, and other products useful to our monitoring partners for landscape-scale conservation and management of natural resources.

Acronyms

AAR	annual administrative report
CCRP	Climate Change Response Program
CSC	Climate Science Center
DOI	Department of the Interior
FY	fiscal year
GLORIA	Global Research Initiative in Alpine Environments
GRYN	Greater Yellowstone Network
I&M	inventory and monitoring
IMR	Intermountain Region
LCAS	Learning Center of the American Southwest
LCC	Landscape Conservation Cooperative
MODIS	Moderate Resolution Imaging Spectroradiometer
MP	memorial parkway
NB	national battlefield
NCPN	Northern Colorado Plateau Network
NHP	national historical park
NHS	national historic site
NM	national monument
NMem	national memorial
NP	national park
NPres	national preserve
NPS	National Park Service
NR	national reserve
NRA	national recreation area
Pres	Preserve
PWR	Pacific West Region
ROMN	Rocky Mountain Network
spp.	species
UCBN	Upper Columbia Basin Network
USFWS	U.S. Fish and Wildlife Service

1 Introduction

In response to the growing knowledge and awareness of the effects of climate change on federal lands, the National Park Service (NPS) developed a national strategy to implement the new Climate Change Response Program (CCRP). The CCRP strategy (http://www.nature.nps.gov/climatechange/about.cfm) provides guidance and direction to the NPS for addressing the effects of climate change on park lands. The goals and objectives are described under four main components: science, adaptation, mitigation, and communication. The NPS vision, as described in the national Climate Change Response Strategy, is to adapt to climate change and effectively preserve and restore park resources and opportunities for visitor enjoyment. This vision will be achieved through collaboration among NPS employees, partners, and the public to promote climate-change science and apply best management practices and sustainable behaviors toward reducing climate change and its impacts.

The specific science goals of the national strategy include: (1) developing and applying climate science, (2) collaborating with and among scientific agencies and institutions to advance climate science at the local to national level, and (3) identifying and conducting scientific studies and resource-monitoring activities necessary to support NPS mitigation, adaptation, and communication. In keeping with the main objective of the National Park Service's Inventory and Monitoring (NPS I&M) Program, the NPS Climate Change Response Strategy states that only the best available scientific data and knowledge will be used to inform decisionmaking about climate change.

Secretarial Order No. 3289, of September 14, 2009, established a climate-change strategy to integrate the work of each Department of Interior (DOI) bureau to mitigate and adapt to the effects of climate change in the pursuit of their respective missions. Given the broad impacts of climate change, management responses are expected to be coordinated at the landscape level. The DOI has adopted a framework of 22 ecosystem-based Landscape Conservation Cooperatives (LCCs) to coordinate the Department's efforts to respond to climate change and other stressors. LCCs are management–science partnerships that link science and conservation delivery and inform integrated resource-management actions within and across landscapes. At the core of each LCC will be a scientific and technical staff with an applied resource-management focus, similar to the staff of the I&M networks, who produce data, reports, synthesis documents, and models to inform management and planning.

The National Park Service expects to participate with each of the DOI-proposed LCCs to address climate-change impacts to park resources with an integrated strategy that includes science, adaptation, mitigation, and communication activities. The initial I&M priorities for the CCRP goals build upon existing monitoring and strengthen interagency coordination for parks in four categories of high vulnerability to climate change: high elevation, high latitude, coastal/marine, and arid lands. One of the network groups that received funding from the CCRP includes three networks in the Rocky Mountains and Upper Columbia Basin: the Greater Yellowstone (GRYN) and Rocky Mountain (ROMN) networks within the NPS Intermountain Region (IMR), and the Upper Columbia Basin Network (UCBN) in the Pacific West Region (PWR).

In fiscal year (FY) 2010, the three high-elevation networks, with the input of federal partners and scientists from academic institutions, began reviewing their existing monitoring plans and partnerships in order to meet the goals of the Climate Change Response Strategy and Secretarial Order 3289. This document describes the strategy developed by the networks to monitor climate-change impacts and its effects on NPS high-elevation lands in the Rocky Mountains and Columbia Basin, as well as the vital-sign prioritization and selection process and the final vital signs chosen for new and enhanced monitoring. It includes options for monitoring based on anticipated project budgets (for all three networks combined) ranging from $325,000 to $350,000 annually.

1.1 Objectives and Scope

The objectives of this strategy document are to:

1. Describe the predicted impacts of climate change on aquatic and terrestrial ecosystems in graphic form, using conceptual models;

2. Show, in graphic form, how current and potential monitoring indicators link to these conceptual models and contribute to understanding some of the predicted impacts of climate change;

3. Describe the criteria used for prioritizing potential indicators or vital signs;

4. Define the three networks' priorities for additional monitoring of climate-change impacts on high-elevation resources, including which indicators the networks propose to measure, and which additional indicators should be kept in mind for future consideration; and

5. Identify how the networks will collaboratively work within the Department of the Interior LCC and Climate Science Center (CSC) frameworks and partner with the U.S. Fish and Wildlife Service (USFWS) and other federal agencies, states, and academic institutions to make efficient and effective use of staff and funds and to standardize data collection, analysis, and reporting procedures.

The scope of this monitoring strategy includes 12 National Park Service units occurring at high elevations in the Rocky Mountains and Upper Columbia Basin. The high-elevation units from each of the three I&M networks include:

- Greater Yellowstone Network: Four park units in northwest Wyoming, southeast Idaho, and southern Montana: Grand Teton (GRTE) and Yellowstone (YELL) national parks, John D. Rockefeller, Jr., Memorial Parkway (JODR), and Bighorn Canyon National Recreation Area (BICA).
- Rocky Mountain Network: Four parks units in Montana and Colorado: Glacier National Park (GLAC), Florissant Fossil Beds National Monument (FLFO), Great Sand Dunes National Park and Preserve (GRSA), and Rocky Mountain National Park (ROMO).
- Upper Columbia Basin Network: Four park units in southwest Montana, Idaho, eastern Oregon, and eastern Washington: Big Hole National Battlefield (BIHO), City of Rocks National Reserve (CIRO), Craters of the Moon National Monument and Preserve (CRMO), and Nez Perce National Historical Park (NEPE).

This workplan describes the multi-network strategy for enhancing monitoring activities within parks of the Great Northern LCC. Beginning in 2011, the three I&M networks (GRYN, ROMN, and UCBN) anticipate receiving approximately $350,000 annually to support enhanced monitoring of the ecological response to climate change across the 12 NPS units. The three networks will work collaboratively with the USFWS I&M program and other partners to implement and manage the enhanced monitoring for climate change within the Great Northern LCC.

1.2 Core Team and Working Group

This monitoring strategy was developed by a core team and a broader working group. Core team members included:

1. Bruce Bingham (Intermountain Region I&M Program Manager)
2. Mike Britten (Rocky Mountain Network Program Manager)
3. Lisa Garrett (Upper Columbia Basin Network Program Manager)
4. Penny Latham (Pacific West Region I&M Program Manager)
5. Kristin Legg (Greater Yellowstone Network Program Manager)

The broader working group included the Core Team members plus:

1. Isabel Ashton (Rocky Mountain Network)
2. Rob Bennetts (Southern Plains Network)
3. Scott Bischke (Mountain Works)
4. Nina Chambers (Sonoran Institute)
5. Steve Fancy (Inventory & Monitoring Division)
6. John Gross (Inventory & Monitoring Division)
7. Andy Hubbard (Sonoran Desert Network)
8. Tom Olliff (NPS Great Northern LCC Coordinator)
9. Stacey Ostermann-Kelm (Greater Yellowstone Network)
10. Kathy Tonnessen (Rocky Mountains Cooperative Ecosystem Studies Unit)
11. Cheryl McIntyre (Sonoran Institute)
12. Dave McWethy (Montana State University)
13. Dusty Perkins (Northern Colorado Plateau Network)
14. Tom Philippi (Inventory & Monitoring Division)
15. Ellen Porter (Air Resources Division)
16. Tom Rodhouse (Upper Columbia Basin Network)
17. Billy Schweiger (Rocky Mountain Network)
18. Donna Shorrock (Rocky Mountain Network)

1.3 Approach

Development of this strategy included several steps: First, the ecologists from the core team and working group began two literature reviews and synthesis efforts. One effort focused on past, present, and future climate changes in the region. The other addressed ecological responses to climate changes. The resulting documents provided a common foundation for understanding observed and potential climate-change impacts to high-elevation natural resources. The synthesis also supported the refinement of conceptual models used to describe important predicted effects of climate change on terrestrial and aquatic ecosystems, and potential indicators of ecological response.

As an example, Figure 1 (see page 5) is a conceptual model for alpine/subalpine ecosystems. Current conditions are shown on the left panel, and predicted future conditions on the right. It is assumed that climate change will result in increased temperatures and an overall decrease in precipitation in the Rocky Mountains and Upper Columbia Basin. Precipitation patterns will likely show increased winter precipitation (including more "rain-on-snow" events) and decreased summer precipitation. Under these conditions, it is predicted that forests will shift upslope, tree density will increase at treeline, and temperate forest species will encroach into subalpine areas. Forbs will likely decrease in favor of graminoids and shrubs, exotic weeds may invade high-elevation communities, and wildlife species dependent on alpine habitats will likely decrease.

Second, the core team reviewed each network's list of vital signs and looked for opportunities to enhance existing monitoring and for gaps in existing monitoring that, if filled, would provide valuable information to park managers and others about the ecological impacts of climate change. The product of this step was a table linking management issues with vital signs and recommendations for enhancing or expanding monitoring. Tables were developed for several systems, including riparian/wetland/aquatic, sagebrush-steppe, grassland/woodland, and alpine/subalpine systems. Another table focused on physical resources that included broad-scale processes.

The third step was to conduct a workshop to engage managers and scientists from the NPS, other agencies, and universities to help establish priorities for monitoring ecological response to climate change within high-elevation parks. On May 4–5, 2010, in Bozeman, Montana, the I&M program and Sonoran Institute co-hosted a workshop, titled "Monitoring Ecological Response to Climate Change in High Elevation Parks," that included more than 70 participants. The workshop emphasized opportunities for enhancing ongoing monitoring and data management, and improving information sharing and collaboration within the NPS and with partners. The climate and ecological syntheses, conceptual diagrams, and analysis of opportunities for enhancing existing monitoring and filling climate-related "gaps" were presented. Feedback from the entire group was solicited. Groups examined the tables developed in step 2 and classified each issue according to its responsiveness to climate change, how common the recommendation was for all parks in the Great Northern LCC, cost-effectiveness, and relevance to management (Appendix A). The group was also invited to share additional ideas and opportunities for collaboration. A final workshop report (as well as the climate and ecological syntheses) is available on the Greater Yellowstone Research Learning Center website, http://www.greateryellowstonescience.org/CC_workshops/highElev.

Directly following the workshop, the core team met to reflect on input provided during the workshop and begin drafting this strategy and workplan for the three I&M networks in the Great Northern LCC. The work built on the results (i.e., prioritized vital signs for climate-change response) from the two-day workshop. The core team determined that the highest-priority indicators were alpine, sagebrush-steppe, and grassland vegetation and soils; climate-sensitive species (including high-elevation five-needle or white pines and pika); phenology (patterns of "greening" and productivity); and snowpack monitoring.

Finally, based on input from the workshop and the working group, the core team developed a budget for $350,000 of anticipated additional funding and determined management responsibilities for each network for tracking funds and developing annual workplans and administrative reports. The budget defines the expenses needed to establish and enhance monitoring activities and gather existing data for the proposed high-priority indicators. The entire budget is allocated toward salary, travel, and equipment expenses for field-data collection and analysis. All data management, and some reporting, is currently being absorbed by existing network infrastructure. Additional funding of around $30,000 could be used to further enhance existing capabilities in data management, reporting, and science communication. Any reduction in funding would result in reduced field-data collection from that proposed in this document.

1.4 Multi-network Priorities and Strategy

1.4.1 Priorities

More than 50 potential indicators of ecological response to climate change were considered by breakout groups during the May 2010 workshop. The broader working group met on May 6 to review the results of the workshop. Their efforts resulted in agreement on a high-priority subset of these potential indicators, emphasizing seven vital signs currently monitored in one or more high-elevation parks and with the greatest potential for enhancement as indicators of ecological impacts of climate change. The subset of indicators included five-needle pines, climate, phenology, sagebrush-steppe, grasslands/shrublands/woodlands, alpine wildlife, and alpine vegetation and soils. Table 1 shows the rankings resulting from the workshop for each of these vital signs included in our multi-network strategy for high-elevation parks in the three networks.

Climate-change concerns go well beyond impacts to natural resources. The understanding and acceptance of climate change and its anthropogenic relationships are surrounded by political and socioeconomic apprehension. Consequently, the workshop participants emphasized the importance of clear communication of observed and potential impacts of climate change, both internally among land-management agencies and with the public.

1.4.2 Strategy

Our FY2011 plan and long-term strategy both focus on the seven vital signs selected at the workshop as (1) having high combined potential to serve as good indicators of climate change (e.g., responsiveness to climate change, meaningful spatial scales), (2) being cost-effective in a multi-network approach to enhancing existing monitoring, and (3) being interpreted by managers as having significant value for park management. All seven vital signs received an overall ranking ranging from 4 to 5 and are treated equally as part of a multi-network strategy.

Our approach to implementing the enhanced monitoring is described in the following section and includes the vital signs in Table 1, along with the enhancement of communication products related to the ecological impacts of climate change. Table 2 (see page 10) shows the parks in which this enhanced monitoring will be implemented.

Table 1. Subset of vital signs chosen by the workgroup for enhanced monitoring and the associated workshop rankings from breakout sessions (5 = highest, 1 = lowest).

Vital sign	Responsiveness to climate change	Applicable at appropriate spatial scales	Cost-effectiveness	Relevance to park managers	Average rank
Five-needle Pines	5	5	5	5	5.0
Climate	5	5	4	5	4.8
Productivity/Phenology	5	5	4	4	4.5
Sagebrush-steppe Vegetation	5	4	4	5	4.5
Grassland, Shrubland, and Woodland Vegetation & Soils	5	4	4	5	4.5
Pika	4	5	3	4	4.0
Alpine Vegetation & Soils	5 veg, 4 soil	4	4	4	4.0

See Appendix A for entire set of vital signs considered at the May 2010 workshop.

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Figure 1. Conceptual diagram depicting recent conditions and possible effects of climate change on alpine/subalpine environments in high-elevation parks of the Rocky Mountains and Upper Columbia Basin.

1. **Alpine Vegetation and Soil: Increase the spatial extent of monitoring alpine vegetation and soils using the Global Research Initiative in Alpine Environments (GLORIA) methodology and network ($60,000)**

We propose to expand current alpine vegetation and soils monitoring in high-elevation parks by adding GLORIA sites in GRTE and YELL. Once implemented, the NPS I&M program will provide monitoring information on alpine biodiversity and soils for five GLORIA sentinel sites in the Rocky Mountains along broad latitude and elevation gradients (approximately 11 degrees of latitude and 1,755 m of elevation from GRSA (37°45'15.984"N, at 4,000 m) to GLAC (48°41'45.996"N, at 2,245 m). The ROMN and GRYN staffs will work collaboratively with parks to establish new sites and manage the field work. Data management, analysis, and reporting will be centralized at the ROMN.

Alpine/subalpine communities and ecosystems are fundamentally important to many parks in the Rocky Mountain/Upper Columbia Basin region, including GLAC, GRTE, YELL, ROMO, and GRSA. Reasons why alpine ecosystems are important in high-elevation parks include: (1) they are typified by spectacular scenery and wildflower displays that draw and inspire park visitors; (2) alpine communities support numerous animals of management concern, including bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*), white-tailed ptarmigans (*Lagopus leucura*), and pikas (*Ochotona princeps*); and (3) much of the water resources in the region are derived from snowmelt, and the quality and quantity of this water is influenced by ecosystem processes in the alpine. Because the alpine is particularly sensitive to climate change and atmospheric deposition and is globally distributed, it provides an important indicator for change (Figure 1). Potential impacts from climate change include shifts in forest distribution, tree-line, community composition, increased invasive species, and loss of alpine-obligate species.

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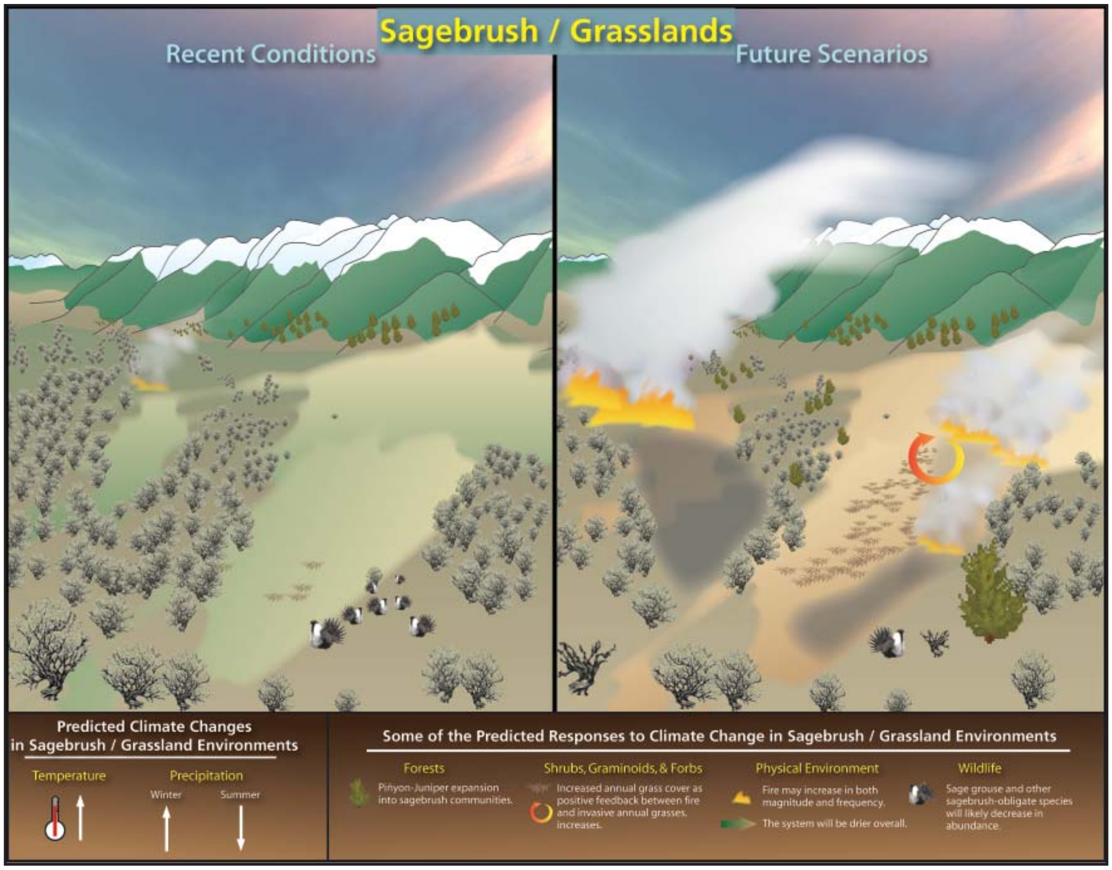

Figure 2. Conceptual diagram depicting recent conditions and possible effects of climate change on sagebrush/grassland environments in high-elevation parks of the Rocky Mountains and Upper Columbia Basin.

2. Sagebrush-steppe and Grassland, Shrubland, and Woodland Vegetation and Soils: Increase the spatial extent of monitoring of vegetation and soils in sagebrush-steppe and grassland, shrubland, and woodland systems (includes ecotones) ($88,000)

We propose to expand current sagebrush-steppe and grassland/shrubland/woodland monitoring in high-elevation parks by adapting existing monitoring protocols used in UCBN and ROMN parks. Enhanced or expanded monitoring will be implemented in parks from all three networks, including sagebrush-steppe monitoring at GRTE, and monitoring of semi-arid vegetation and soils at BICA, GRSA, and ROMO. Once implemented, the NPS I&M program will provide climate-change response monitoring information for seven high-elevation parks in the Rocky Mountain and Upper Columbia Basin regions. This vegetation and soils monitoring at relatively low elevations will complement alpine vegetation and soils monitoring at the high elevations of our GLORIA sites. Data management, analysis, and reporting for sagebrush-steppe monitoring in UCBN parks and GRTE will be centralized at the UCBN. Data management, analysis, and reporting for monitoring of vegetation communities in BICA, ROMO, and GRSA will be accomplished collaboratively between the GRYN and ROMN, depending on the communities monitored.

Sagebrush and grasslands in the region include sagebrush steppe, represented in the western portions bordering the Great Basin and in the Columbia Basin; shortgrass steppe, found in Colorado; Palouse grasslands, limited to eastern Washington and northwestern Idaho; and northern mixed-grass prairie. Other grasslands, such as subalpine meadows and those associated with ponderosa pine, are scattered throughout the foothills and higher elevations of the region.

Sagebrush steppe and grasslands in the region support sensitive wildlife species, including black-footed ferrets, pronghorn antelope, sage grouse, and numerous sagebrush/grassland-obligate songbirds. Sagebrush and grasslands are well represented in the high-elevation parks.

Western shrublands and grasslands have been extensively modified by settlement, domestic grazing, altered fire regimes, and introduced species, causing major—possibly irreversible—changes in ecosystem structure and function. Sagebrush steppe is considered one of the most threatened U.S. ecosystems. Biological invasions by species such as cheatgrass (*Bromus tectorum*), and habitat loss and fragmentation also pose major threats, and climate change will likely exacerbate their effects. For example, there is evidence that warmer temperatures may promote the invasion of woodlands into grasslands, alter species composition and productivity, change herbivore pressure, and alter fire regimes. Scenarios for impacts from climate change (Figure 2) include increases in fire frequency, expansion of pinyon-juniper, and other compositional changes, such as invasions of annual grasses and invasive non-native species.

3. American Pika: Increase spatial extent of pika monitoring ($60,000)

We propose to expand current monitoring for American pika (*Ochotona princeps*) using the existing NPS protocol applied in the UCBN. The pika is a climate-sensitive focal species and, in addition to UCBN parks, the NPS protocol is currently used at GRTE and was pilot-tested this year at YELL. We anticipate continuing the monitoring at YELL and establishing new monitoring at GRSA, ROMO, and GLAC. Depending on funding levels, the new pika monitoring field-data collection may occur in alternating years. All existing and future pika-monitoring data management, analysis, and reporting will be centralized at UCBN.

The American pika is widely considered to be an indicator species for detecting ecological effects of climate change. Results from recent studies suggest that in some areas, pikas are being lost from lower elevations in response to increased warming and, thus, their suitable habitat is being reduced. In models designed to predict these patterns of loss, the importance of climatic factors has risen dramatically over the past decade. Recent habitat and extinction models predict that pikas may disappear from up to 80% of their current range by the turn of the century.

4. Five-needle Pines: Increase spatial extent of whitebark and limber-pine communities ($60,000)

We propose to expand current five-needle pine monitoring by adapting the existing Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem and/or the monitoring protocol being used for limber pine in the Upper Columbia Basin. Enhancement of current monitoring will include additional whitebark-pine (*Pinus albicaulis*) plots in GRTE and YELL. New monitoring of limber pine (*Pinus flexilis*) will include ROMO and GRSA. Data management, analysis, and reporting for high-elevation parks in the IMR will be centralized at GRYN. Data from UCBN will be exported, when needed, from the combined high-elevation whitebark-pine monitoring database that UCBN shares with other PWR networks. Depending on funding levels, new plots may be established in other park units, and/or new data collection may occur in alternating years.

Climate change is hypothesized to affect whitebark-pine communities through three mechanisms: (1) causing a shift in pathogen ranges, which may lead to new regions of hospitable climate for whitebark-pine blister rust and, thus, increase the potential for infection; (2) increasing temperatures, leading to a decrease in suitable environmental conditions for high-elevation whitebark pines; and (3) changes in the frequency of severe fires, which may lead to an overall decrease in whitebark pine numbers through mortality.

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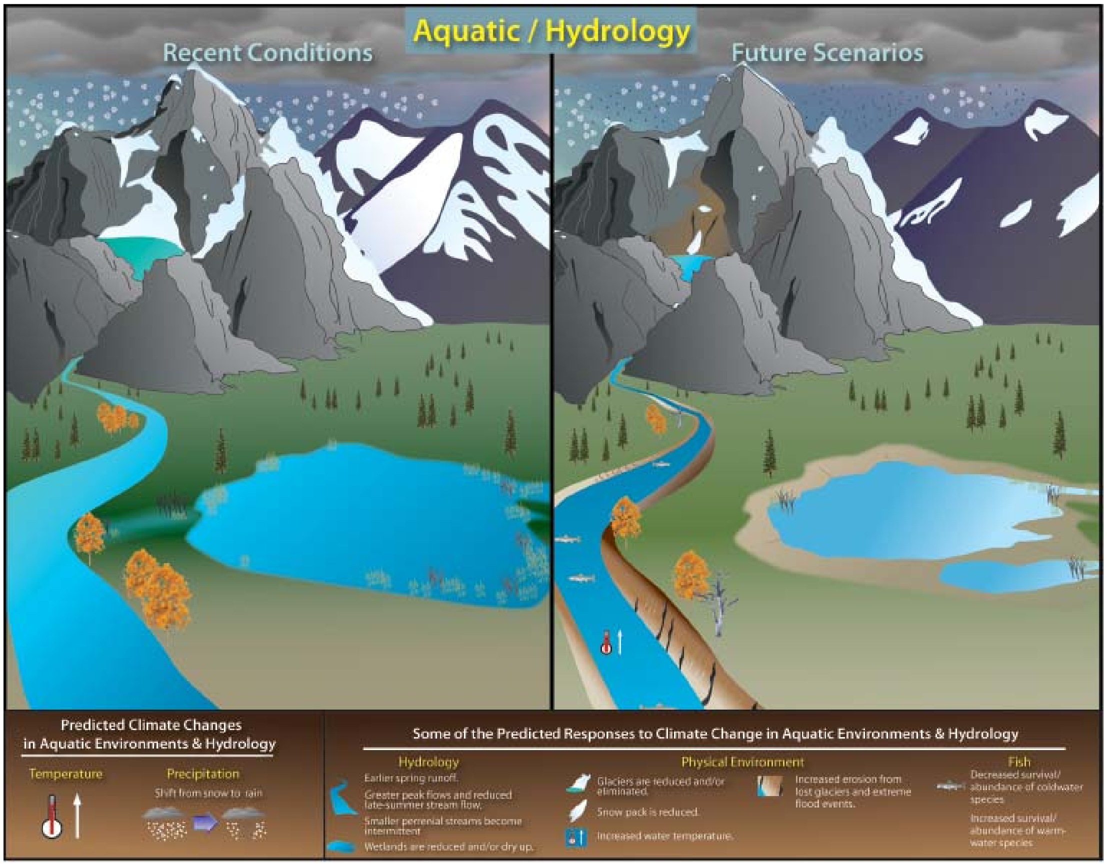

Figure 3. Conceptual diagram depicting recent conditions and possible effects of climate change on aquatic/hydrologic systems of the Rocky Mountains and Upper Columbia Basin.

5. Climate: Implement weather and climate reporting in all Upper Columbia Basin high-elevation units (see item 6).

Currently, ROMN and GRYN share a protocol for summarizing and reporting climate and weather patterns in parks. We propose to adapt that existing protocol to include BIHO, CIRO, CRMO, and NEPE. Data analysis and reporting will be centralized at GRYN.

Climate is one of the primary drivers of the physical and ecological processes that determine the distribution, structure, and function of ecosystems. Moreover, climate is critical to park management and visitor experience, is a driver of change in other vital signs and park resources, and there is evidence that climate has changed in the past century and will continue to change. By accessing and analyzing high-quality climate data for the high-elevation parks included in this plan, park and network staff will be better able to understand and interpret changes in status and trends of other vital signs.

6. Phenology and Snowpack: Implement phenology and snowpack monitoring through the acquisition, analysis, and interpretation of Moderate Resolution Imaging Spectroradiometer (MODIS) data ($40,000).

Phenology and snowpack are widely accepted as indicators of climate change. The I&M program has been working with others to develop methods for tracking changes in seasonal patterns of vegetation "greening," productivity, and snowpack melt. The methods have been applied on the Colorado Plateau, but no data analysis has occurred in high-elevation areas of the Rocky Mountains and Upper Columbia Basin. Expanding this monitoring to include high-elevation parks, refuges, and other lands will enhance our understanding of the impacts of climate change on the cyclic phenomena of seasonal vegetation changes and snowpack. We propose to acquire, analyze, and interpret MODIS data to improve understanding of vegetation phenology patterns and snowpack extent for high-elevation parks by adapting the land condition monitoring protocol developed by the Northern Colorado Plateau Network (NCPN). New funding will be used to support a 0.5 FTE position for acquiring, managing, and analyzing MODIS data. The position will also support the analysis and reporting of weather and climate data from park weather stations. Data management, analysis, and reporting of the MODIS data will be centralized in GRYN.

The Rocky Mountain/Upper Columbia Basin region contains an abundance of snowpack and snowfields, glaciers, lakes, streams, wetlands, and rivers, and managed reservoirs that provide critical water resources to human and wildlife populations and support sensitive plant communities. Snowpack, which varies across the region, is typically greatest in high-elevation forests, peaks in early April, and melts during the summer, contributing an estimated 75% of the water in streams. High-elevation areas feed lower elevations through a network of lakes, streams, groundwater, and wetlands. Aquatic ecosystems—especially lakes, rivers, and streams—in high-elevation parks are very popular with visitors and the public because of their scenic values, recreational opportunities, and contributions to park biodiversity. Predicted impacts (Figure 3) include earlier spring runoff, loss of perennial streams, a reduction or elimination of glaciers, and increased erosion. Analysis of remotely sensed MODIS imagery is important for validating these and other predicted impacts. It will also provide high-elevation parks with spatially and temporally extensive information that will help the networks to understand linkages between climate, snowpack, and field-based water quality and quantity monitoring data.

7. **Communication: Deliver peer-reviewed communication products that explain the ecological impacts of climate change and management implications ($42,000)**

The politics and socioeconomics of climate change complicate our ability to accept, understand, and apply the knowledge we gain from research and monitoring. The products we deliver must not only have scientific integrity, but also meet management needs and convey results in a way that is sensitive to public apprehensions. We propose to use new funding to support writer-editor needs that will provide approximately 0.75 FTE, in total. The UCBN (0.25 FTE) has access to a writer-editor but insufficient funding to fully support the position. The ROMN and GRYN will share a position, with 0.5 FTE being paid out of vital signs funds and 0.5 FTE paid with new climate-change funding.

Table 2. High-elevation parks where climate change-related monitoring will be conducted.

Parks	Alpine vegetation and soils, GLORIA	Sagebrush-steppe and grasslands, shrublands, and woodland communities	American pika	Five-needle pines	Climate	Phenology and snowpack using MODIS
Greater Yellowstone Network						
Bighorn Canyon NRA		X			X	X
Grand Teton NP	X	X	X	X	X	X
John D. Rockefeller, Jr., MP					X	X
Yellowstone NP	X		X	X	X	X
Rocky Mountain Network						
Florissant Fossil Beds NM		X			X	X
Glacier NP	X		X		X	X
Great Sand Dunes NP&Pres	X	X	X	X	X	X
Rocky Mountain NP	X	X	X	X	X	X
Upper Columbia Basin Network						
Big Hole NB					X	X
City of Rocks NR		X			X	X
Craters of the Moon NM&Pres		X	X	X	X	X
Nez Perce NHP					X	X

Funding sources include vital signs, CCRP, and park base

1.5 Partnering

As intended, the LCC framework provides numerous opportunities for NPS I&M networks and other NPS programs to collaborate with other federal and state agencies, as well as with external public and private entities. At this time, the primary partners for the high-elevation climate-change monitoring collaboration include the NPS I&M program networks, the USFWS I&M program (staff in Fort Collins and Denver), individual USFWS refuges, the USFWS Ecological Services Montana Field Office (which, along with NPS, is the co-lead for "standing up" the Great Northern LCC), the USGS field offices, the DOI North Central and Northwest Climate Science Center (Colorado State University and University of Idaho, respectively), the DOI Northwestern Climate Science Center (host location TBD), the USGS Northern Rocky Mountain Science Center, and the Bureau of Land Management.

Specific partnering opportunities for the three high-elevation networks that are planned or currently underway include:

- Engaging with the USFWS to develop and implement monitoring protocols consistently across the USFWS refuges and NPS units wherever possible;
- Engaging with LCC partners by participating on the LCC science committee, charged with determining the LCC-related science needs and priorities; and
- Collaborating on implementing alpine vegetation and soils monitoring using the GLORIA field methods consistently across the networks (USGS currently monitors alpine vegetation and soils in GLAC).

2 FY 2011 Administration, Budget, and Workplan

2.1 Multi-network Collaboration

The enhanced monitoring described in this document will be jointly managed by the UCBN, GRYN, and ROMN program managers, who will meet as needed to discuss work planning, budget, and implementation of monitoring activities. Decisions will be made by consensus. Each year, the networks will collaborate on a single, shared workplan that will be submitted to the IMR and PWR I&M program managers for approval. Where opportunities arise, the three high-elevation networks will interact with staff from the Great Northern LCC, the USFWS I&M program and refuges, the North Central and Northwest Climate Science Centers, other federal or state agencies, and academic partners to collaborate on monitoring, data analysis, and reporting.

For FY2011, the Greater Yellowstone and Rocky Mountain networks require $8,200 and $8,500, respectively, in travel, and the Upper Columbia Basin Network requires $14,100 allocated for travel. Without these travel allocations, the strategy cannot be implemented in FY2011, and any new funding for climate-change monitoring will need to be returned to the Washington Office.

2.1.1 Budget (FY 2011 and subsequent years)

Each of the three networks is implementing vital signs monitoring that will be enhanced as proposed in this document. Based on these current activities, each network will have specific budget-tracking and management responsibilities related to new climate change monitoring funds (Tables 3 and 4):

- The UCBN program manager will manage funds (including salary and travel) for monitoring pika and sagebrush-steppe for all three networks, and funds for UCBN communication products.
- ROMN will manage funds for monitoring alpine vegetation and soils (GLORIA) in ROMN and GRYN, and funds for monitoring grassland/shrubland/woodland systems in the ROMN and GRYN.
- The GRYN will manage funds for monitoring five-needle pines in GRYN and ROMN, and funds for phenology and snowpack monitoring in all three networks, and any reporting associated with this monitoring.
- Management of funds for communication products for the GRYN and ROMN will be determined later, depending on where the position is located. Until then, the funds will be managed by the IMR I&M program.

An annual administrative report (AAR) that describes monitoring accomplishments and the use of CCRP monitoring funds will be generated at the end of each fiscal year. These AARs will be separate from those developed by individual networks for accomplishments using vital signs funds. The UCBN, ROMN, and GRYN program managers will each contribute to the AAR and rotate as lead for the report. The ROMN will take the lead in FY 2011, the UCBN will lead development of the FY 2012 report, and the GRYN in 2013. These annual reports for monitoring accomplishments using CCRP funds will require the approval of the IMR and PWR I&M program managers and the I&M division chief. AAR development will follow the timeline used for individual network annual administrative reports for vital signs monitoring funds.

2.1.2 Protocols

The three networks currently have protocols for alpine vegetation and soils (GLORIA), pika (UCBN), five-needle pines (GRYN, UCBN), sagebrush-steppe (UCBN), grassland/shrubland/woodland systems (ROMN), and climate (ROMN and GRYN). These existing protocols and SOPs will be used where possible and adapted as needed to accomplish monitoring objectives across all 12 high-elevation park units. The existing NCPN MODIS protocol for phenology and snowpack is currently being evaluated with FY2010 funds and will be adapted to accomplish monitoring objectives within the LCC. Where SOPs are shared and field sampling is involved, field crews from the networks will be trained together to ensure that data collection methods are implemented consistently across the networks. Where practical, the three networks will also gain efficiencies through shared purchasing and contract administration.

Table 3. Funding distribution summary for budget management responsibilities.

Network	Account code	Amount
UCBN	2126	$118,000
ROMN	2119	$118,000
GRYN	2120	$114,000

Table 4. New funding allocation, by manager.

Description	Amount
Greater Yellowstone Network	
Five-needle pines (whitebark and limber pine)	$60,000
Field crew salary/benefits	16,300
Field crew travel	3,500
Protocol lead/Ecologist salary/Benefits	38,000
Protocol lead/Ecologist travel	2,200
Phenology and snowpack (salary and travel)	$40,000
Rocky Mountain Network	
Alpine vegetation (GLORIA)	$60,000
Field crew salary/benefits	10,412
Field crew travel	6,000
Protocol lead/Ecologist salary	41,588
Protocol lead/Ecologist travel	2,000
Grassland/shrubland/woodland systems	$44,000
Field crew salary (2 crews)/Benefits	25,054
Field crew travel	8,000
Protocol lead/Ecologist salary	8,946
Protocol lead/Ecologist travel	2,000
ROMN & GRYN (TBD): Climate-change communication (salary)	$28,000
Upper Columbia Basin Network	
Pika	$60,000
Field crew salary/benefits	17,000
Field crew travel	2,400
Protocol lead/Alpine biologist salary/Benefits	38,000
Protocol lead/Alpine biologist travel	2,600
Sagebrush-steppe	$44,000
Field crew salary/benefits	19,000
Field crew travel	5,400
Protocol lead/Ecologist salary	11,000
Protocol lead/Ecologist travel	3,700
Equipment costs	4,900
Climate-change communication (salary)	$14,000
Total	**$350,000**

2.1.3 Staffing

Phenology and snowpack monitoring and reporting for all three networks will be accomplished with a shared 0.5-FTE ecologist or physical scientist. This position will provide some support for analysis and reporting of climate/weather data related to specific objectives for enhanced climate-change monitoring. The support will depend on the available data from parks and specific products required within each network. Meeting objectives outside the scope of enhancing climate-change monitoring may require additional analysis and reporting performed by each network. The position will be duty-stationed at the Northern Rocky Mountain Science Center in Bozeman, Montana. The UCBN will use new funding for climate-change communication by supporting either an NPS position or services secured through a cooperative agreement. The ROMN and GRYN will share a writer-editor position that will be supported by network funds and supplemented with new climate-change monitoring funds.

Five-needle pine (whitebark pine and limber pine) monitoring and reporting in GRYN and ROMN parks will be supported with a shared ecologist not to exceed 0.5 FTE. The position will be located within the Greater Yellowstone Network. Monitoring and reporting for grassland, shrubland, or woodland vegetation in GRYN and ROMN parks will also be supported by a shared ecologist position not to exceed 0.5 FTE. This position will be located within the Rocky Mountain Network.

Pika monitoring and reporting for all three networks will be accomplished with a shared term 0.5 FTE alpine biologist. This position will support analysis and reporting of pika monitoring data from high-elevation parks. The position will be duty-stationed at the discretion of the UCBN program manager, who will supervise this position. The UCBN will support 0.5 FTE of the biologist's salary. A two-person pika-monitoring field crew will be hired to complete annual data collection, with training and database support provided by the UCBN staff.

Sagebrush-steppe monitoring and reporting for GRTE and the UCBN parks will be accomplished by the UCBN ecologist, Tom Rodhouse. Additional funds will be used to support Tom's additional work in the expansion of the UCBN sagebrush-steppe protocol into GRTE. A two-person sagebrush steppe-monitoring field crew will be hired to complete annual data collection, with training and database support provided by the UCBN staff.

The UCBN will use new funding for climate-change communication by securing services through an existing cooperative agreement with the University of Idaho. The UCBN has a science-communication specialist position established and will use additional funds to support the development and dissemination of climate change response reports and briefs.

2.1.4 Data management and reporting

All data management will be conducted using existing network infrastructure. Existing data-management processes across the three networks will be examined to look for efficiencies in sharing data-management resources. Data management and reporting for pika and sagebrush-steppe will occur at the UCBN. Data management and reporting for alpine vegetation and soils will occur at the ROMN, which will also perform data management and reporting for and grassland/shrubland/woodland systems, with additional data-management support provided by the GRYN. Data management for five-needle pines will be accomplished separately for PWR and IMR parks and the data combined as needed for reporting. Data management and reporting for phenology and snowpack will be managed at GRYN. Climate and weather data will be managed cooperatively by the three networks using consistent data structures. Climate and weather reporting may be centralized at the GRYN, or shared by the three networks, depending on product needs.

The three I&M networks within the Great Northern LCC will use the NPS Natural Resource Information Portal (NRInfo, http://nrinfo.nps.gov) to share data and information products with partners and the general public. In addition, the Greater Yellowstone Science Learning Center and the three network Internet sites will provide our partners within the Great Northern LCC access to high-elevation park and network products. To increase the ability and efficiency of DOI and bureau managers, scientists, planners, interpreters, and others at all levels of the organization to search for, find, retrieve, share, and disseminate available data and information, and for bureaus to communicate information to their constituencies, tribes, and the general public, we intend to establish an information portal targeted specifically at providing federal, state, university, and other partners within the Great Northern LCC direct access to data and information products resulting from this work.

2.2 FY 2011 Workplan

Planned implementation activities and schedule for FY2011 appear in Table 5.

Table 5. Activities and schedule for enhanced climate-change monitoring in FY 2011.

Administration: March 2011
Hire and orient new ecologist (0.5 FTE) to support development and implementation of phenology, snowpack, and climate protocol (Term GS-11)
Hire alpine biologist (0.5 FTE) to be the protocol lead for pika monitoring in high-elevation parks
Hire and orient new science writer-editor (GS-9) to be shared by ROMN and GRYN (duty station to be determined)
Protocol development: May 2011
Adapt NCPN MODIS protocol for phenology and snowpack
Adapt ROMN and GRYN climate and weather protocol for UCBN
Adapt GRYN or UCBN five-needle pine protocol for ROMN
Develop sampling frame for GRTE sagebrush-steppe sampling using the UCBN sagebrush-steppe protocol
Adapt ROMN vegetation and soils protocol for GRYN and ROMN
Field work: Summer 2011
Establish GLORIA sites (GRYN candidate sites were identified in summer 2010)
Establish sagebrush-steppe sites (GRTE)
Establish vegetation sites (BICA, GLAC)
Establish rotating pika sites (ROMO, GLAC, GRSA)
Establish 5-needle pine sites (GRSA, ROMO, YELL, GRTE)

Appendix A. Vital Signs Prioritization

Vital Signs Prioritization

On the second day of the workshop, participants broke into six work groups focused on the four conceptual models (Product 3—riparian / wetland / aquatic; sage steppe / grassland; forest / woodland; alpine / subalpine), another group focused on physical resources / broad scale processes, and a final work group looking at partnering opportunities. Each of the first five work groups was tasked with developing a coarse-filtered prioritized list of recommendations associated with monitoring ecological response to climate change in high elevation parks. The process employed follows:

During development of each network's monitoring program, teams created lists of vital signs (through rigorous review, conceptual models, expert input, etc.) that were initially prioritized against the overall program goal of monitoring conditions of natural resources in parks. Prior to this workshop, program and regional managers reviewed these network lists for vital signs that potentially include climate change aspects. They eliminated vital signs that appeared not to be climate change related, plus organized the vital signs based on ability to monitor climate change under the five breakout areas noted above. Each breakout group started their prioritization effort with their section of this managers' monitoring table (note that the table can be found on-line at the workshop website; see www.greateryellowstonescience.org/CC_workshops/highElev).

<u>Prioritization Steps:</u>

1. Each breakout group reviewed the vital sign and potential impact columns (i.e., in the monitoring table) for thought and discussion with emphasis on management implications and management relevance. The groups were free to modify, add to (are there any critical gaps?), or delete the managers' monitoring recommendations as the group thought warranted.
2. Using a subset of prioritization criteria from established to facilitate the workshop process each group rated (via filling in spreadsheet cells) each recommended vital sign against four areas 1) responsiveness to climate change, 2) applicable spatial scale, 3) cost effectiveness, 4) relevance to managers. Groups were told that for this exercise all four areas are weighted equally.
3. Then, each group compiled a list of opportunities, concerns, ideas, and prioritization logic for report to the full workshop. They considered issues of integration across ecosystems, created a listing of critical thoughts and outcomes for the workgroup and selected spokesperson to report back to the entire conference.
4. Groups provided conference facilitators with spreadsheet results for overall compilation and sorting.

The combined results of the breakout groups are presented in the table below. This prioritized list served as input to the Planning Day following this workshop, held by a subset of NPS attendees to this workshop (see Next Steps, below).

From the document, "Summary Report from NPS I&M High Elevation Climate Change Response Workshop," Gallatin Gateway Inn, Bozeman, MT, May 4–5, 2010, presented by the meeting facilitation team from MountainWorks and the Sonoran Institute.

Sorted results of breakout group exercise to prioritize vital signs for monitoring ecological response to climate change in high elevation parks (5 = most important, 1 = least important).

Group	Vital Sign	Responsiveness to Climate Change	Applicable at Appropriate Spatial Scales	Cost Effectiveness	Relevant to Park Management	Average
Alpine	5 Needle Pine	5	5	5	5	5.0
Aquatic / Riparian	Amphibians	3.5	5	3	4	3.9
Aquatic / Riparian	Aquatic Macro-invertebrates	4	5	3	3	3.8
Forest	Aspen	3	5	5	5	4.5
Aquatic / Riparian	Bats	3	5	3	4	3.8
Sage / Grasslands	Bats	3	4	3	4	3.5
Forest	Bats	2	2	3	3	2.5
Alpine	Bighorn Sheep	2	4	3	4	3.3
Forest	Clark's Nutcracker	2	5	2	4	3.3
Physical	Climate	5	5	4	5	4.8
Sage / Grasslands	Disturbance (Fire) Dynamics	5	5	4	5	4.8
Alpine	Forest Insects and Disease	4	5	5	5	4.8
Forest	Forest Insects and Disease	5	5	4	5	4.8
Forest	Forest Structure and Composition	4	5	3	4	4.0
Physical	High Elevation Lakes	5	3.5	4.5	4	4.3
Alpine	Invasive Plants	3 alpine, 4 subalpine	5	3	4	4.0
Sage / Grasslands	Invasive Plants (Early Detection)	3?	5	2	5	4.0
Forest	Invasive Plants (Early Detection)	4	5	3	5	4.3
Aquatic / Riparian	Invasive Plants-(Early Detection)	2	5	3	5	3.8
Forest	Invasive Plants (Status and Trends)	4	5	5	5	4.8
Aquatic / Riparian	Invasive Species	2	5	3	5	3.8

Sorted results of breakout group exercise to prioritize vital signs for monitoring ecological response to climate change in high elevation parks (5 = most important, 1 = least important).

Group	Vital Sign	Responsiveness to Climate Change	Applicable at Appropriate Spatial Scales	Cost Effectiveness	Relevant to Park Management	Average
Alpine	Invertebrate Pollinators	4	5	3	4	4.0
Physical	Land cover and use	5	5	3	5	4.5
Alpine	Landbirds	4	5	3	3	3.8
Forest	Landbirds	2	5	4	3	3.5
Sage / Grasslands	Landbirds	4	4	2	4	3.5
Aquatic / Riparian	Landbirds	2	5	2.5	3	3.1
Forest	Limber Pine	4	5	4	4	4.3
Alpine	Mountain Goats	2	2	3	3	2.5
Aquatic / Riparian	Native fish	4	4.5	3	5	4.1
Physical	Ozone	3	2	3	3	2.8
Aquatic / Riparian	Periphyton (algae & diatoms)	3	5	3	3.5	3.6
Aquatic / Riparian	Physical Characteristics / hydrology / groundwater	5	5	3.5	4.5	4.5
Alpine	Pika Monitoring	4	5	3	4	4.0
Sage / Grasslands	Productivity/ Phenology	5	5	4	4	4.5
Alpine	Ptarmigan	3	3	2	3	2.8
Alpine	Rare Plants	4	4	2	3	3.3
Sage / Grasslands	Sage grouse	4	2	5	5	4.0
Sage / Grasslands	Sagebrush Steppe Vegetation	5	4	4	5	4.5
Aquatic / Riparian	Seeps and Springs	5	2	2	4	3.3
Physical	Snow Chemistry	2	4	4	3.5	3.4
Aquatic / Riparian	Soils	4.5	4	2	3	3.4

Sorted results of breakout group exercise to prioritize vital signs for monitoring ecological response to climate change in high elevation parks (5 = most important, 1 = least important).

Group	Vital Sign	Responsiveness to Climate Change	Applicable at Appropriate Spatial Scales	Cost Effectiveness	Relevant to Park Management	Average
Aquatic / Riparian	Stream / river channel characteristics	3	4	3	4	3.5
Aquatic / Riparian	Vegetation	4	5	2.5	5	4.1
Aquatic / Riparian	Vegetation - Camas Lily	4	1	5	5	3.8
Alpine	Vegetation Composition and Soil Structure: Alpine Tundra	5 veg, 4 soil	4	4	4	4.0
Sage / Grasslands	Vegetation Composition and Soil Structure: Grassland, Shrubland, and Woodlands	5	4	4	5	4.5
Aquatic / Riparian	Water Chemistry	3	5	4	3	3.8
Aquatic / Riparian	Water Quantity	5	5	5	4.5	4.9
Physical	Wildland Fire	5	5	5	5	5.0
Forest	Wildland Fire	4	5	4	5	4.5
Sage / Grasslands	Woodland Ecotone Shift	5	3	2	5	3.8

NPS 960/106365, January 2011

National Park Service
U.S. Department of the Interior

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