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PARK Science

Integrating Research and Resource Management in the National Parks

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
Office of Education and Outreach

SPECIAL ISSUE: CLIMATE CHANGE ADAPTATION & COMMUNICATION

The first of two editions on climate change, this issue explores adaptation and communication strategies, along with public engagement, to address this global phenomenon

• Scenario planning • Policy considerations • Training needs • Carbon sequestration and air quality • Landscape-scale conservation • Citizen scientist involvement • Innovative educational programming •

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Masthead continues on page 9

From the Editor

The water's fine ... (but it's getting deeper)

I felt apprehensive while planning this special edition of *Park Science*. Climate change is such an all-encompassing and complex topic and has so many implications for the future of the national parks that I wondered how we could do it justice in one issue. Short of reducing our carbon footprint what can we really do about climate change? This grand force has decades of inertia behind it, ensuring it will persist for a long time to come, and it operates at global-to-local scales. Its effects are likely to compound the many isolated resource conservation issues we deal with on a daily basis in ways we are not yet prepared or can even possibly imagine. Hence the need for this special issue, but how to get it right? For me the answer was to take the plunge and start my in-depth education on the subject. So, with this issue, we begin our foray into park management in the age of climate change—the "Anthropocene," as some have suggested it be called.

Climate change is not new, and even our response to it in the National Park Service goes back to the early 1990s, as John Dennis illustrates in his article on the NPS Global Change Research Program. That initiative was never fully funded, but now we enjoy the benefits of having a Climate Change Response Program to help develop and integrate climate change coping strategies into our science and management operations. Herein, program manager Leigh Welling shares her understanding of heritage conservation as a landscape-level role for the National Park Service in conjunction with other partners. Through the work of this relatively new program, the National Park Service has illuminated many park management issues related to climate change and has adopted a response framework that emphasizes (1) adaptation, (2) mitigation, (3) science, and (4) communication. We largely follow this approach in organizing the following climate change–related features, case studies, and research reports in order to illustrate these management applications.

As I mentioned indirectly, one issue of *Park Science* is not adequate to cover this huge topic, so we will have two. In this edition we explore the concepts of *adaptation* and *communication*, along with the latter's corollary, *public engagement*. We have one feature article that explicitly addresses *Mitigation*, in the department "Park Operations," in this issue. Other articles touch on mitigation, for example forest carbon sequestration, but are presented under other headings. In fact, the articles under any category may relate to multiple facets of the NPS climate change response strategy. Finally, in a few months we will follow up with our summer issue devoted to the *science* of climate change in national parks.

"Uncertainty" describes one of the primary problems associated with climate change, and this can lead to discouragement and inaction. How can we maintain a healthy, productive perspective in light of this immense challenge? I believe this issue of *Park Science* can help by demonstrating progress and sharing some of the best work to date in the National Park Service on the subject of climate change. We need to feel a sense of mastery over what we do, and having good information helps. So, pick an area of interest, test the waters, and dive in.

—Jeff Selleck

Contents

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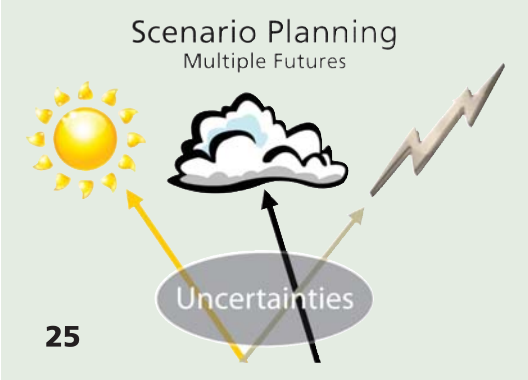
GLOBAL BUSINESS NETWORK

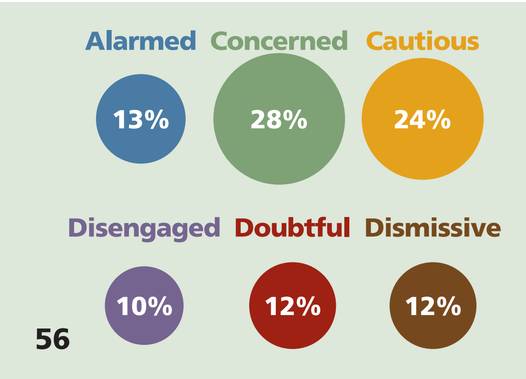


USGS/NATE STEPHENSON

ON THE COVER

Earth's vast oceans and atmosphere are warming, with consequences for landscapes and national parks. The National Park Service is exploring solutions to this global problem through adaptation strategies, such as those that promote ecological resilience, and by how its staff communicates this complex issue with the public.

NASA GODDARD SPACE FLIGHT CENTER, FROM HTTP://VISIBLEEARTH.NASA.GOV



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UPCOMING ISSUES

Summer 2011
Climate change II—Scientific knowledge and research applications. September release. In production.

Fall 2011
Seasonal issue. October/November release. In production.

Winter 2011–2012
January 2012 release. Topical issue: Wilderness research and management. In production.

Spring 2012
Seasonal issue. May release. Contributors deadline: 15 January.

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COMMUNICATION AND PUBLIC ENGAGEMENT

In This Issue

NATIONAL PARKS AND OTHER PROTECTED AREAS DISCUSSED IN THIS ISSUE

Abbreviations

NF	National Forest
NHP	National Historical Park
NL	National Lakeshore
NM	National Monument
NP	National Park
NS	National Seashore

Index

Landscape Conservation

USGS/DANIEL B. FAGRE

National parks and protected area management in a changing climate: Challenges and opportunities

By Leigh Welling

Research ecologist Greg Pederson and field assistant Kali Abel near Boulder Pass in Glacier National Park, Montana, where the U.S. Geological Survey is studying climate change. Tree-ring core samples collected in the park on trips like this reveal that snowpack accumulation over the last five decades is the least of any fifty-year period in about 1,000 years.

GLOBAL CLIMATE CHANGE PRESENTS far-reaching and complex challenges for protecting wildlife, ecosystems, and other treasured landscapes. How we choose to respond to this challenge could set the tone for management and policy approaches for a long time to come. The broad scale at which climate change drivers act (e.g., warming temperatures and sea-level rise) will confound park-level efforts to mitigate and adapt to impacts unless they are coordinated with the actions of other protected area managers. Regardless of how well thought out and innovative response strategies are, they need to be envisioned and implemented with an unprecedented level of collaboration and cooperation across jurisdictional boundaries if they are to be effective in the long term. We have an opportunity now to outline a vision and lay a foundation for managing national parks within a broader protected area context.

The Intergovernmental Panel on Climate Change (IPCC) has established beyond all reasonable doubt that Earth's climate is rapidly changing. The most recent report of the IPCC (2007[1]) states, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."

[1] IPCC. 2007. Climate change 2007: Synthesis report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [core writing team R. K. Pachauri and A. Reisinger, editors]. Cambridge University Press, Cambridge, UK and New York, New York, USA.

National parks and other protected areas are already experiencing impacts from climate change. Warming temperatures are causing accelerated melting of mountain glaciers, reduced snowpack, and changes in timing and amount of streamflow. Melting sea ice along coastlines threatens marine mammals as well as the human communities that depend on them, while thawing permafrost is toppling buildings, roads, and facilities and disrupting the structural basis of large areas of land. We have documented high-elevation species, such as the pika, moving upslope in mountain parks such as Yosemite in California and Great Basin in Nevada.

While some impacts from climate change are already measurable, the long-range effects of climatic disruption on protected natural and cultural resources, infrastructure, and visitor experience are just beginning to be understood. Of potentially greater concern are the complex ways in which climate change will interact with other stressors to produce cascading impacts that cannot yet be recognized or anticipated. This is especially problematic because impacts will vary greatly among different geographic regions. How will rising sea level and changes in weather and water cycles affect our ability to protect wildlife habitat, cultural and historical features, and buildings and infrastructure? And how will species populations, communities, and ecosystems adapt to these new conditions? Not all species will respond in the same way and at the same rate, and the science of simulating the complexities of these interactions is highly uncertain.

Improving our science programs is important to be sure, but we cannot use lack of information as an excuse not to act. The climate change discussion has shifted from awareness and evidence to accountability and action. It has progressed from science to management. As stewards of our natural and cultural heritage we have an obligation to act. As we try to understand the magnitude, scale, and unpredictability of these changes, the question is, What is the most appropriate response for managers of parks and other protected areas?

The climate change discussion has shifted from awareness and evidence to accountability and action. It has progressed from science to management. As stewards of our natural and cultural heritage we have an obligation to act.

Role of national parks and protected areas in climate change response

As we determine our goals for response to climate change—and how they fit in with those of our other land management and science partners—it is useful to consider which qualities inherent in our system of national parks might play a special role in light of climate change. While there are many attributes of parks and other protected areas that are important in this regard, four general categories have special relevance:

1. Conserving biodiversity, ecosystem services, and cultural values
2. Supporting ecosystem adaptation
3. Enhancing scientific knowledge
4. Communicating relevance

Conserving biodiversity and other values
National parks and protected areas have been the centerpiece of conservation strategies for decades as hot spots for biodiversity; for protecting such essential ecological, social, and economic services as clean water, carbon storage, genetic reservoirs, disaster mitigation, soil stabilization, recreation, and solace; and for preserving our cultural heritage. However, protected areas that were set up to safeguard particular resources, conditions, or qualities generally were established assuming a constant climate. Under climate change we know that species ranges will shift and many systems will be altered by increased disturbance. Cultural resources face a particular challenge in this regard because they are fixed in place, and most cannot be moved except at great cost and by incurring damage and loss of integrity. The consequences could be that some protected areas will end up with very different habitat and species assemblages than they were initially designed to protect, and with very different conditions under which resources that cannot adapt still must be protected. So, while the need for resource and ecosystem protection will intensify in a changing climate, accomplishing conservation goals will be increasingly challenging. Future conservation efforts will require reevaluating management goals and expectations under different climate change scenarios to establish realistic targets and ensure the intended conservation results can be delivered.

Promoting ecosystem adaptation
National parks and other protected areas can be among the most effective tools for adapting to climate change, if managed within the context of larger landscapes. Natural areas such as forests or riparian environments often exhibit greater resilience to change than human-altered systems, thereby allowing species to adapt. Several characteristics of natural protected areas can support ecosystem adaptation:

- Availability of climate refugia or habitats that persist as climate changes
- Landscape connectivity that allows plants and animals to move to more suitable locations
- Viable populations with sufficient genetic diversity to adapt

National parks and other protected areas can be among the most effective tools for adapting to climate change, if managed within the context of larger landscapes.

- Areas of natural habitat large enough to be resilient to large-scale disturbances and long-term changes
- Lack of additional threats and stressors.

A management approach that supports these elements for ecosystem adaptation cannot be accomplished without collaboration, and the National Park Service is actively engaged in creating and sustaining science-management partnerships toward this end (see sidebar, next page). Several articles in this special edition of *Park Science* describe how we are beginning to frame this issue. This will require a broad and bold vision that goes beyond the current system of lands to identify and connect key features and processes through additional protection measures that include refugia, corridors, and buffer zones. Networks of these areas within large landscapes can provide the highest level of resilience to climate change by carefully defining and managing connections or corridors between protected areas, removing or preventing barriers such as roads or monoculture forests or crops, and creating stepping-stones for particular species. No single entity or level of government can effectively adapt to climate change alone, but collectively, as a conservation community, we can.

Enhancing scientific knowledge

Conserving biodiversity and ecosystem function while allowing species to adapt to climate change will require readily available, high-quality scientific information. National parks and other protected areas offer unique opportunities for research on climate change because these ecosystems represent some of the most pristine lands, those least modified by humans. Such areas have immense and increasing value to civilization as laboratories for basic research. In many cases they are the best baselines from which to understand the complex interactions of natural systems.

Protected areas are also important to the conservation sciences as we become more aware that they are not islands but interact substantially with their surrounding environments. The longevity of these invaluable resources will depend heavily on management recommendations and restoration efforts guided in turn by high-quality research and monitoring information. In this way management actions can be flexible and adaptive to changing conditions and trends. A second thematic issue of *Park Science*—to follow in a few months—will delve into the scientific research and observations of climate change in national parks and the kinds of management considerations they are helping to inform.

Communicating relevance

In a future in which more people will be vying for fewer resources, and where climate change is likely to cause a greater strain on people's livelihoods and the availability of resources, expanding the network of protected ecosystems will require a high level of public support. To gain that support, the relevance of protected areas must become more apparent to the human communities that live in or depend on them. As discussed in several articles in this issue, many opportunities exist to engage citizens of all ages in experiencing the wonders of these areas and witnessing the changes that are taking place. Through direct experience in these natural classrooms or a wide range of interpretive and educational media, the public can come to understand how climate change is affecting the planet's resources and how they can adapt their behavior to promote resource stewardship.

Conclusion

Many issues compete for the attention of park managers, and climate change has often been perceived as a future, rather than an immediate, threat. The variables associated with climate change compound our ability to plan for and respond to it. These include the scientific uncertainties mentioned earlier in this article, as well as questions about how visitor experience will be impacted, what kinds of management actions the public will expect and support, and how to build the capacity to respond given current fiscal constraints. The tasks ahead are clearly daunting, but if there is a silver lining it is that climate change requires us to think with a systems perspective and this necessitates collective action and problem-solving.

Our work with climate change has been described as "building the bicycle while riding it." We are developing ideas and applying them in real time. Though the challenges are difficult, we are making progress through commitment, teamwork, and thoughtful exploration and application of creative solutions. Over the past several years we have made strides to define and structure the critical issues presented by climate change, decide how we should respond, and begin to cultivate interactive and flexible processes for reasoned action. Some of the best and most current work on climate change science, adaptation, planning, and communication is discussed in the articles that follow in this (spring) and the next (summer) issue of *Park Science*. Out of need, landscape conservation is coming together over climate change

A few words about Landscape Conservation Cooperatives and Climate Science Centers

By Melanie Wood and Cat Hawkins Hoffman[1]

In September 2009, Secretary Salazar issued Secretarial Order 3289, "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources." This directive established cooperatives for public-private partnerships among departmental bureaus and their partners to collaborate in responding to climate change and other stressors. As a result the Department of the Interior has established a national network of 21 Landscape Conservation Cooperatives (LCCs) that support and enhance on-the-ground conservation efforts by facilitating the production and dissemination of applied science for resource management decision makers. Now at various stages of development, the LCCs consist of federal, state, tribal, local, nonprofit, and private stakeholders working with existing partnerships and programs, and establishing new partnerships, to facilitate communication, share the results of research, and strategically target and implement additional research and actions to meet shared conservation goals. In addition to these cooperatives, eight university-based, regional Climate Science Centers (CSCs) ultimately will be established to support the LCCs and other partnerships by providing scientific information, tools, and techniques to land managers as they respond to climate change.

The National Park Service fully supports and participates in these initiatives through park, regional, and national participation in the Landscape Conservation Cooperatives, and by staffing full-time positions at five of the LCCs and three of the CSCs. The Park Service is colead with the U.S. Fish and Wildlife Service of the Great Northern LCC and has recently hired a cultural resource specialist and a socioeconomic adaptation coordinator, to be stationed at the Pacific Islands LCC and South Atlantic LCC, respectively. The two remaining NPS LCC positions will provide such expertise as coastal ecosystems and geomorphology for the North Atlantic LCC and urban landscapes in the National Capital Region, which will work across parks and LCCs that have urban landscapes. The three NPS CSC positions are expected to be filled in FY 2012 in Alaska, the Pacific Northwest, and the Southwest.

For further information please contact Cat Hawkins Hoffman, NPS National Adaptation Coordinator, Climate Change Response Program, in Fort Collins, Colorado. She can be reached by e-mail at cat_hawkins_hoffman@nps.gov.

[1] See table 1, page 11, for author contact information.

and this opportunity will make the National Park Service a more proactive and effective caretaker of our national heritage and a strong partner for linking science with resource conservation at all scales.

About the author

Leigh Welling *has been involved in climate change research and education since the mid-1980s when she began her graduate work in paleooceanography at Oregon State University. She is manager of the Climate Change Response Program, National Park Service, Fort Collins, Colorado, and can be reached at leigh_welling@nps.gov.*

PS

PARKScience

Park Science is a research and resource management bulletin of the U.S. National Park Service. It reports the implications of recent and ongoing natural and social science and related cultural research for park planning, management, and policy. Seasonal issues are published usually in spring and fall, with a thematic issue that explores a topic in depth published annually in summer or winter. The publication serves a broad audience of national park and protected area managers and scientists and provides public outreach. It is funded by the Associate Director for Natural Resource Stewardship and Science.

Articles are field-oriented accounts of applied research and resource management topics that are presented in nontechnical language. They translate scientific findings into usable knowledge for park planning and the development of sound management practices for natural resources and visitor enjoyment. The editor and board review content for clarity, completeness, usefulness, scientific and technical soundness, and relevance to NPS policy.

Article inquiries, submissions, and comments should be directed to the editor by e-mail; hard-copy materials should be forwarded to the editorial office. Letters addressing scientific or factual content are welcome and may be edited for length, clarity, and tone.

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At Your Service

An integrated approach to climate change response in the National Park Service

By Melanie Wood, Angie Richman, and Leigh Welling

THE CLIMATE CHANGE RESPONSE Program (CCRP) works to foster communication, provide guidance, and promote scientific information to support stewardship of our natural and cultural heritage in the face of climate change. Established in 2009 and led by Dr. Leigh Welling, the CCRP coordinates with all national park units and central offices, as well as partners in other agencies and organizations. The program includes a staff of diverse individuals with a variety of backgrounds and experience who serve the National Park Service (NPS) in climate change science and modeling, interpretation and education, resource management, landscape connectivity, monitoring, planning, coastal hazards, cultural anthropology, and renewable and efficient energy use (table 1).

An important milestone was marked on 10 September 2010, when Director Jarvis released the *NPS Climate Change Response Strategy*, a guide for the Service in addressing the unprecedented challenge of climate change. The strategy describes goals and objectives to guide NPS actions through four integrated components: science, adaptation, mitigation, and communication. The National Park Service is beginning to implement elements of the strategy, working with partners to develop methods for assessing resource vulnerability, monitoring change, adapting management strategies for natural and cultural resources and facilities in climate-sensitive areas, and including climate change in NPS planning frameworks. Through the 2010 Service-wide Comprehensive Call, the CCRP funded over $2.5 million in park climate change projects, ranging from the dynamics of carbon cycling, to changes in flow regimes, to the impacts of climate change on pollinators and species such as the Shenandoah salamander, Karner blue butterfly, American pika, and desert bighorn sheep.

The National Park Service continues to be a leader in greenhouse gas reduction and energy efficiency. The Sustainable Operations and Climate Change Program (SOCC) provides the tools and technical support to measure and mitigate greenhouse gas emissions, and promotes climate change education and facilities adaptation to climate change. Approximately 190 parks are completing greenhouse gas inventories using the Climate Leadership in Parks (CLIP) tool, and more than 70 parks are now participating in the Climate Friendly Parks Program, reducing their carbon footprint and communicating the effects of climate change through interpretive programs and materials. The SOCC works alongside the CCRP to mitigate climate change and lead by example in sustainability. The NPS Green Parks Plan, led by the SOCC and finalized in 2011, is an integral component of the larger *NPS Climate Change Response Strategy*. For more information, go to www.nps.gov/climatefriendlyparks.

Products designed to keep NPS staff informed on change in the national parks and the NPS response now include 11 bioregional "talking point" documents, a monthly webinar series, and a monthly newsletter, available on the Climate Change SharePoint site (http://nrpc sharepoint/climatechange/). The CCRP launched a public Web site (www.nps.gov/climatechange) in spring 2010, and is developing a training module on climate change interpretation, as well as several park-specific education resources, through a National Science Foundation-funded grant. The CCRP also provides career development opportunities through the George Melendez Wright Internship and Fellowship Programs, which placed 26 interns and 33 fellows in parks and offices across the country in 2010 and 2011.

To advance the collective knowledge of climate change response across land and resource managing entities, the CCRP plays a key role in larger Department of the Interior (DOI) climate change initiatives. The program will provide three positions in DOI Climate Science Centers to work closely with university researchers to develop management-relevant climate change science. Additionally, the National Park Service participates in all the DOI Landscape Conservation Cooperatives

To advance the collective knowledge of climate change response across land and resource managing entities, the CCRP plays a key role in larger Department of the Interior climate change initiatives.

PHOTOS: NPS

Table 1. Staff of the NPS Climate Change Response Program

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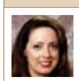	Maria Honeycutt	Coastal Adaptation Specialist (on assignment)	(202) 513-7256 maria_honeycutt@partner.nps.gov
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(LCCs; see sidebar, page 9), which focus on multijurisdictional science-based conservation across landscapes, and the CCRP supports five full-time positions working to support the LCCs.

The CCRP currently leads development of an Action Plan to build on the goals and objectives of the Strategy to identify actions that parks, regions, and national offices can take to meet the NPS mission in a changing climate. This Action Plan will be completed and available as a key resource for NPS staff and partners in 2012. The NPS and a wide range of partners continue to support science, adaptation, mitigation, and communication at all levels of the NPS to further understand, respond to, and communicate climate change in the National Park System.

About the authors

***Melanie Wood** is program assistant, **Angie Richman** is communication specialist, and **Leigh Welling** is program manager, all with the NPS Climate Change Response Program in Fort Collins, Colorado.*

Looking Back

The National Park Service and the U.S. Global Change Research Program: 1990–1993

By John G. Dennis

THE NATIONAL PARK SERVICE HAS been concerned about the effects of climate change on park natural and cultural resource preservation for more than two decades. In October 1988, the Service helped sponsor a World Wildlife Fund conference on the greenhouse effect on biological diversity (National Park Service 1989; Peters and Lovejoy 1992). Working proactively and cooperatively under the aegis of the Department of the Interior (DOI), the Service joined the United States Global Change Research Program (USGCRP) at the end of that year.

Experienced in working collaboratively and involving parks, the NPS representative to the Departmental Working Group on Global Climate Change in January 1989 solicited information about existing NPS activities to show how they related to USGCRP interagency science elements, what issues of concern they addressed, what funding existed for each, and how augmenting them could increase their value to the larger climate change research effort. The outcome was authorization for the National Park Service to prepare a draft budget proposal for integrated inventory, monitoring, and research in 12 geographic areas.

NPS research program takes shape

The resulting NPS program contributed to four interdisciplinary science elements: (1) ecological systems and dynamics, (2) earth system history, (3) human interactions, and (4) solid earth processes. As integrated into the U.S. Global Change Research Program, the NPS investigations focused on learning ecological histories of participating parks and using that information together with ongoing park research and results of downscaled climate models to assess how changing climate might cause ecological change in parks.

Drawing from years of experience with the interdisciplinary Man and the Biosphere Program and its partnership-oriented biosphere reserve network, the National Park Service concentrated its global change research program on areas that grouped parks according to biogeographic region, with some parks serving as core research areas and other parks and ecologically associated areas acting as cooperating research areas. Biogeographic regions involved "a special combination of physiography, climate, vegetation, characteristic species, natural processes, human populations and resource uses" (Gregg and Comanor 1992).

Given collaborative enthusiasm from across the Service, the NPS director announced the NPS Global Change Program (GCP), established a GCP committee of scientists and managers to assist in program development, invited parks interested in participating to develop biogeographic area program proposals, and established a process for both administrative and peer review. By the end of August 1990, the Service had appointed a GCP coordinator; articulated purpose, structure, and components of the NPS program; and issued guidelines and calls for interested parks to prepare capabilities and interest statements and, for successful parks, follow-up global change operations and conceptual research plans. Proposal development, review, and selection thus involved three increasingly focused stages:

1. ***Capabilities and Interest Statement:*** described the biogeographic area's sensitivity to global change, identified its related research interests, and discussed its operational capabilities for supporting those research interests.
2. ***Global Change Operations and Conceptual Research Plan:*** identified relevant research questions, presented preliminary research proposals, and described the base operating program and several more substantial levels for carrying out the proposed research.
3. ***Research Proposals:*** provided detailed descriptions of proposed research project designs, work plans, and implementation requirements to enable obligation of funds.

Interested groups across the National Park Service submitted 27 Capabilities and Interest Statements that the GCP committee ranked with the aid of a cadre of outside experts. The top 11 groups and a separate Coastal Systems–themed initiative were asked to produce Global Change Operations and Conceptual Research Plans. Each accepted plan was scheduled to receive one full-time employee and approximately $60,000 to initiate its base program and start preparing detailed research proposals. The National Park Service issued a second call for Capabilities and Interest Statements from previously unselected areas with the hope that there would be opportunity to increase the number of funded biogeographic programs in the FY 1992 budget.

Denouement

In May 1991, the Service provided base funding to six biogeographic areas and first-year funding for 14 of their research

The National Park Service concentrated its global change research program on areas that grouped parks according to biogeographic region.

projects. These collaboratively conducted projects were designed to be multiyear, multiscale (local to international) efforts drawing on outputs of global climate models to contribute predictive understanding of global change effects on parks. Principal investigators came from parks, Cooperative Park Studies Units, other universities, and other agencies. By mid-1992, 10 biogeographic areas and two thematic programs were funded or approved for requested FY 1993 funding and some also received project contributions from partners. Research areas and themes included ocean and coastal regions, Ozark forest, grasslands, western Great Lakes, southwestern desert, Rocky Mountains, Sierra Nevada, and the Olympic Range. They encompassed 15 core and 31 cooperating national parks and 26 research projects.

Although direct NPS involvement in this first phase of U.S. global change research ended 1 October 1993 with transfer to the newly formed National Biological Survey of all NPS biological research, including the $3 million and 12 full-time staff of the global change research program, excitement and enthusiasm for the initiative continued. Elements of this former NPS Global Change Program can be found today in U.S. Geological Survey (USGS) global change research activities, such as the Western Mountain Initiative (USGS 2008). Additionally, the interdisciplinary and landscape-scale approach continues in the research of many of the federal and academic scientists who were then involved. The experience of parks cooperatively coming together into joint, landscape-oriented programs lives on in the National Park Service's Inventory and Monitoring networks, Research Learning Centers, and involvement with the interagency and interdisciplinary Cooperative Ecosystem Studies Units.

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[1] In author's possession. National Park Service, Washington, D.C.

[2] See the online version of this article for the full list of memoranda related to the USGCRP.

PS

Information Crossfile*

SUMMARIES

The changing face of park management: Stewardship in an era of global environmental change

A LONG-STANDING PRINCIPLE OF CONSERVATION IS waning in the face of unprecedented ecological stress, and the inevitable dilemma looms: For what values are we managing parks and other protected areas? "Naturalness," despite (or because of) a plethora of meanings and interpretations to choose from, can no longer guide conservation planning and decision making. In a treatise on the future of protected area management, Hobbs et al. (2010) argue that as national parks and other protected areas are subject to innumerable human influences, resource managers ought not labor solely under this vague and impractical notion. Resource managers should shed the singular goal of attaining naturalness—an essentially meaningless concept from a management perspective—and embrace multiple goals and approaches, which potentially may involve increasing intervention.

As the effects of climate change make themselves known, wholesale reliance on the goals of historical fidelity (parks as we have known them), autonomy of nature (reluctance to control or actively manage nature), and aesthetic preservation are being called into question. Instead, a broader list of conservation goals is emerging, to include ecological integrity, resilience, and protection of biodiversity. Traditional principles of protected area management need to be supplemented by more robust concepts that may be better able to accommodate climate change, forming the basis for a "more focused but pluralistic approach to park and wilderness management." Indeed, past conditions are no longer "benchmarks for the future," the authors state, and carefully crafted management goals and planned intervention appear to be the best path forward. Historical fidelity, for instance, is still a valid management objective, not to mention an important principle of the park aesthetic, but it simply can no longer be a resource manager's only desired outcome.

Along with the need for a shift in guiding principles, the authors reason that policies for protected area management must also evolve. Going back to 1916, the National Park Service Organic Act states that the fundamental purpose of parks is "to conserve the scenery and the natural and historic objects and the wild life therein … unimpaired for the enjoyment of future generations." And even now NPS *Management Policies 2006* (section 4.1, National Park Service 2006) are premised on the goal to preserve "components and processes in their natural condition." Though, as the authors note, NPS policy illustrates some cases where intervention may be appropriate, managers will need guidance in setting meaningful and realistic management goals.

*Information Crossfile synopsizes selected publications relevant to natural resource management. Unless noted, articles are not reviewed by reference source author(s).

Resource managers should shed the singular goal of attaining naturalness … and embrace multiple goals and approaches, which potentially may involve increasing intervention.

Climate change, invasive species, and altered fire regimes have affected even the most remote park and wilderness ecosystems. Hobbs et al. (2010) discuss why intervention in the physical and biological processes for the sake of maintaining historical conditions in perpetuity is increasingly problematic. They urge that prescribed burns, controlling ungulate populations, thinning forests, and assisting species migration be evaluated on the basis that ecosystems are dynamic and the values of park ecosystems to be protected must be clearly and specifically articulated. "The major challenge to stewardship of protected areas is to decide where, when, and how to intervene in physical and biological processes, to conserve what we value in these places," write the authors.

Thus, Hobbs et al. (2010) vouch for the conservation of nature to cease as the guiding management goal, and be replaced by a suite of guiding principles including ecological integrity, historical fidelity, and resilience, among others. Ecological integrity, a concept already embraced by Parks Canada, focuses on retaining native biodiversity and ecosystem function. Thresholds of acceptable change are set and monitored, and when exceeded trigger management action. Furthermore, human involvement is fully acknowledged and park managers may even try to mimic past human interventions when a system has coevolved with a human component. This concept, the authors explain, "shifts the focus from cause to effect and from past to future."

Another useful principle, resilience, defined as the capacity of a system to absorb change and persist without undergoing a state shift or fundamental loss of character, is useful when dealing with dramatic but uncertain change. "It might require letting go of the way landscapes look today," the authors explain, while deciding which key processes and functions to work to retain. Indeed, attempting to prevent or resist change will only increase the risk of greater change in the future (e.g., historical fire suppression).

Ecological integrity and resilience are just two of many possibilities that Hobbs et al. (2010) propose that would allow for and support uncertainty in the environment and provide opportunities for change and adaptation. In the face of rapid environmental change, deliberate and meaningful experimentation, public involvement in the decision-making processes, and flexibility in operational objectives are options for resource managers to be more adaptive than previously thought.

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—Jonathan Nawn, Amy Stevenson, Jeff Selleck, and Susan Johnson

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Adapting to climate change in the changing climate of resource management

THE BEATLES SANG, "NOTHING'S GONNA CHANGE MY world." As witnesses to such climate change effects as sea-level rise, reduction in glacier mass, and timing of snowmelt and plant growth, protected area managers know otherwise. As the climate changes, so does the world, and so must protected area management style. In a presentation of general guidelines for the management of national parks and protected areas under climate change, Baron et al. (2009) highlight an unavoidable fact: "Climate patterns of the past will not be climate patterns of the future." Though science will continue to play a fundamental role in understanding climate change, to help increase resilience of some resources, the authors urge natural resource professionals to embrace new ways of thinking about resource protection that incorporates planning for uncertainty about rates, magnitude, and specific kinds of change that are plausible. They indicate that experiments in management style are at least as important to adaptation to climate change as advances in science. "Adaptation to climate change, not resistance to it, is the best option," the authors stress, and they recommend adaptive management "wherever possible."

Much of the authors' review of scientifically based principles for natural resource management under climate change will sound familiar to *Park Science* readers. For example, assessing and prioritizing resources at risk based on expert opinion, workshops, literature summaries, and targeted research, and the role of monitoring to detect change in high-priority resources, are all well-established strategies. However, establishing climate-related thresholds for ecological change probably represents new thinking for some, as this activity requires sorting out acceptable versus unacceptable levels of change and evaluating the degree to which change can be controlled or not. Methods for adapting to climate change can be more focused if the standard against which current and future conditions can be compared—the reference conditions—are well defined. When they are defined clearly, a goal for protection or restoration can be better executed. If reference conditions cannot be retained as climate changes, they can help managers focus on planning for adaptation to conditions that are sustainable.

The authors urge natural resource professionals to embrace new ways of thinking about resource protection that incorporates planning for uncertainty.

Adaptation to climate change is about adapting to uncertainty. Scientific uncertainty revolves around our ability to (1) foresee or predict changes with enough certainty so as to be able to begin planning for their occurrence, (2) imagine possible changes that are hard to predict with certainty, and (3) prepare for unknown and therefore surprising changes, possibly caused by climatic interactions with other human activities. One approach the authors describe is the development of management plans that do not aim for a specific outcome, but instead embrace the complexity of landscapes and ecosystems. This strategy depends on the magnitude and kind of uncertainty, and on the degree to which ecological processes can be controlled. Planning for uncertainty could involve several approaches. For example, when uncertainty is low and ecological processes are highly controllable, traditional planning (desired future conditions) may suffice, whereas when uncertainty is high amid controllable processes, adaptive management is recommended. This latter approach allows managers to move ahead with imperfect knowledge and refine management actions as new information comes to light. The authors also review the utility of scenario planning when uncertainty is high and controllability is low, and "hedging" for when controllability and uncertainty are low. They stress the importance of public involvement in the "scenario building" process for its ability to generate management support.

Uncertainty not only complicates management choices but also affects the social realm in which public agencies practice resource management. As resource risk rises, managers need to be empowered to take nontraditional, "reasoned management risks without concern for retribution," the authors say. That is, in order to be as effective as possible in dealing with the uncertainties of climate change, the decision process should be what is most important rather than the decision itself. Working in this paradigm, the authors argue, will require that management actions be based on public involvement and transparency in discussions. Given the indication for adaptive management, this dynamic of stakeholder collaboration will make it necessary to reevaluate those actions frequently.

Adaptation, the authors contend, can be enhanced by taking action to minimize human-caused stressors to park and protected area ecosystems. Reducing pollution, habitat fragmentation, poaching and resource exploitation, and the spread of disease can all improve an ecosystem's resilience to climate change. Revisiting policies from time to time as new findings from science come to light is another idea that will help the National Park Service adapt. Finally, because the climate operates at local, regional, continental, and global scales, so too must management of ecological processes be directed at appropriate levels. Bird and mammal migrations are examples of the need for broader, cooperative management to help species adapt to climate change. Ecosystem-based management "consortia" such as those used at Yellowstone and Great Smoky Mountains national parks are good models for building cooperation across multiple jurisdictions.

In conclusion, Baron et al. (2009) lay the groundwork for resource managers to develop "a robust and diverse set of strategies . . . to confront the uncertainties and complexities of climate change." As they demonstrate, effective adaptation will require new thinking about park management that embraces uncertainty and continually integrates new science. Planning will need to change, too, to include different scenarios, and the rationale for particular actions should be discussed publicly and transparently in order to increase understanding of and support for park management.

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—Jeff Selleck, Jonathan Nawn, and Amy Stevenson
Reviewed by J. Baron

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Bracing for climate change in the U.S. National Wildlife Refuge System

HOW SHOULD THE LARGEST SYSTEM OF WILDLIFE REFUGES in the world preserve its biological integrity in the face of climate change? The answer: begin adapting immediately. Glibness aside, the authors of a recent management review probe this question with genuine concern and offer many effective solutions. In a thorough exploration of the National Wildlife Refuge System's (NWRS) options, Griffith et al. (2009) suggest that the U.S. Fish and Wildlife Service, which manages 635 units in the refuge system, begin making changes on both small and large scales, organizationally and managerially.

Encompassing more than 60 million hectares (150 million acres) in tundra, wetlands, tropical rain forests, coral reefs, and many other habitats, the NWRS faces the very serious threat of climate change and all the accompanying impacts: changes in precipitation, cloud cover, diurnal temperature extremes, biome boundaries, and ocean chemistry and sea-level rise. The authors note that habitat specialists—animal and plant species that do not adapt easily to change, but are tied to a certain type of habitat—are especially vulnerable. Also likely to be affected are those populations that exist at the edge of their range, species that are hampered in colonization or dispersing, and those that occupy fragmented or restricted ranges. These kinds of species commonly come under the stewardship of the U.S. Fish and Wildlife Service at refuges created to protect them individually or as groups, and climate change could marginalize some of these specialized habitats.

As various species adapt to meet or accommodate new conditions, so must NWRS managers. Griffith et al. (2009) suggest they adjust priorities of their actions and account for uncertainties in future impacts of climate change. Developing a vision of conservation targets in a dynamic future, extending budgeting and planning horizons, and rewarding effective responses to climate change are all put forward. In particular, the authors call attention to the relatively small size of refuges and their inability to continue providing certain benefits under climate change for which they were designated. Therefore, they recommend "expanding the conservation footprint" of refuges either by increasing their number, size, and redundancy or by improving their "functional connectivity" and distribution through cooperative conservation measures. Managers should prioritize prospective land acquisitions and conservation partnerships based on models projecting where the most valuable habitats are likely to be located under a warmer climate. The goal of these approaches is to allow for increased resilience, biological integrity and diversity, and environmental health.

Managers must refocus their vision by explicitly identifying the expected threats of climate change and adapting at multiple scales to meet the pervasive and complex conservation challenges.

In addition to climate change, challenges to refuges encompass habitat loss and fragmentation, competition for water, invasive species and species imbalances, urbanization, agricultural activities, natural disasters, transportation corridors, industrial development, and pollution. All of these factors, but especially water quality degradation and availability, disease, and non-native species invasions, are expected to increase and become more complex under the influence of climate change. Of greatest concern for wildlife refuges are the effects of altered hydrology: precipitation and the availability of seasonal surface waters.

The authors argue for adaptation to the challenges of climate change at three operational scales: system-wide goals and strategies, ecoregional planning and coordination (tactics), and proactive and responsive management action by individual refuges. To begin, Griffith et al. (2009) urge managers to complete basic inventories of their refuges and to adjust monitoring to accommodate long-term and variable conditions presented by climate change. Considering multiple scenarios for planning and adaptive management are relevant strategies. Intensive management techniques such as prescribed burning, species translocation, and habitat restoration should also be considered. To implement goals and strategies most efficiently, the authors encourage resource managers to forge partnerships with federal, regional, and local organizations. They also note that multiscale educational training about climate change for all NWRS partners will enable effective responses. In closing, they assert that NWRS managers must refocus their vision by explicitly identifying the expected threats of climate change and adapting at multiple scales to meet the pervasive and complex conservation challenges.

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—Jonathan Nawn, Amy Stevenson, and Jeff Selleck
Reviewed by P. Gonzalez

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Evaluating managed relocation by the numbers

WHEN ATTEMPTING TO MITIGATE NEGATIVE EFFECTS OF climate change in protected areas, the cart may occasionally have to come before the horse. That is to say, the unrelenting surge in climate change scenarios may pressure stakeholders to decide on potential resource management solutions with only partial and inexact information. One such intervention—managed relocation or assisted migration—is foreseen by Richardson et al. (2009) as growing in the coming decades as changes in climate become more distinct and species may be faced with extinction. The authors do not give their outright stamp of approval for widespread use of managed relocation, but propose a multivariate decision-making framework that brings to light the risks and benefits of such a strategy in the context of social values.

Managed relocation is the intentional movement of a species, population, or other defined biological unit from one area of occupancy to another where the probability of future survival may be higher. Ideal outcomes of this strategy are to reduce the threat of diminished ecosystem services or extinction, though undesirable consequences could include disturbing ecological integrity or introducing competition in otherwise functional ecosystems. Richardson et al. (2009) note that managed relocation is typically viewed as a "last-ditch option should other conservation strategies be inadequate" and has been used "sparingly to date" by land managers to negate the effects of climate change.

Evaluation of managed relocation strategies has heretofore consisted of a linear analysis, which the authors concur sufficiently addresses neither the large amount of uncertainty nor the competing interests of social values and scientific reasoning. They stress that as a multifaceted tool, managed relocation raises questions that integrate scientific information, aesthetic and cultural values, public policy and logistical concerns, and many other values that can be exceptionally difficult to codify.

Having qualitatively evaluated three hypothetical cases of managed relocation, Richardson et al. (2009) present their graphical, multidimensional evaluation method, a tool the authors hope will clarify the uncertainties for land managers sufficiently to afford justification for a decision. All three cases allow for the exhibition of uncertainty; indeed the study shows how different stakeholder groups could come to very different conclusions about managed relocation, even with the same information, or how varying levels of scientific information produce varying levels of uncertainty. With their evaluation method, the authors seek to diminish the difficulty in codifying and prioritizing the vast amount of variables land managers face when deciding whether or not to engage in managed relocation or other adaptation measures.

The authors categorize the evaluation of managed relocation into four general classes: (1) impacts of conducting or not conducting managed relocation on a given biological unit ("focal impact"), (2) impacts of this activity on a recipient ecosystem ("collateral impact"), (3) practical "feasibility," and (4) social "acceptability." By assigning general numerical values to each category and transferring that information to a polygonal chart, resource managers have a heuristic tool that incorporates both ecological and social criteria in a multidimensional framework. Furthermore, the authors anticipate that their multidimensional evaluation could catalyze public participation and debate, thereby legitimizing decisions related to the use or nonuse of managed relocation and potentially increasing public acceptability of a particular management decision.

Ultimately, the decision of whether or not to use managed relocation is in the hands of the stakeholders, but as the old adage goes, you cannot win if you do not play. Or as Richardson et al. (2009) write, "A decision of nonaction based on intractable conservation disagreement may often result in a loss of biodiversity."

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—Jonathan Nawn, Amy Stevenson, and Jeff Selleck
Reviewed by P. Gonzalez

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BOOK

Climate Savvy

SINCE THE TERM "ADAPTATION" FIRST APPEARED WITH regard to climate change in the 1992 charter for the United Nations Framework Convention on Climate Change, instances of warmer temperatures, rising sea levels, and climatic variability have only increased in number and magnitude. Unfortunately, many resource management strategies remain the same. "We are at a crossroads—or perhaps a traffic circle—of options about our future, including decisions about how we react to the reality of climate change," authors Lara J. Hansen and Jennifer R. Hoffman say in the very first sentence of *Climate Savvy: Adapting Conservation and Resource Management to a Changing World*. In the context of climate change, adaptation refers to the human efforts to reduce the negative effects of climate change, a field that the authors say is rapidly evolving. The ultimate goals of climate change adaptation are to improve resource resilience, support sustainable development, manage natural resources for ongoing use, and protect human well-being.

This optimistic and pragmatic handbook is written in a popular style, with lots of sidebars and explanations; however, the depth of scientific content makes it worthy of being called an academic text, and reflects the authors' expertise. Hoffman began studying the effects of global change in 1992 as a toxicologist, and this experience influenced her perspective during her PhD work in marine ecology at the University of Washington. Hansen worked as chief climate scientist for the World Wildlife Fund Global Climate Change Programme and as a research ecologist for the U.S. Environmental Protection Agency. Her first climate change–related work emerged during her doctorate at the University of Santa Cruz. Together, these two climate change leaders founded EcoAdapt, a nonprofit focused on adapting conservation and resource management to climate change.

The authors provide numerous suggestions and ideas on how to move toward incorporating the reality of climate change into future planning. "We cannot rest on our laurels, nor can we bury our heads in the sand. We have got to make conservation and resource management climate-savvy. We need to adapt conservation and resource management to climate change," they write. Hansen and Hoffman describe actions and ideas that are needed in order to avoid the worst-case scenarios of climate change, while providing current, sound, and accepted research on climate change to emphasize their points along the way.

In this book they highlight ideas and tools for assessing and reducing vulnerability to climate change, including strategies to strengthen protected areas and protect vulnerable species, and discussions about maintaining connectivity and resource resilience. Other topics include managing for uncertainty, reducing stressors (pollutants, pests, invasive species) that interact negatively with climate change, reducing local and regional effects of climate change, and adapting management strategies for regulating harvests and pollutants while integrating the needs of both nature and people.

The book is written for anyone with an interest in enacting, or the ability to enact, climate change adaptation, either through public policy or private endeavor. The authors encourage politicians, land managers, conservationists, and government agencies to act now. "Scientific understanding of climate change and its effects on physical, chemical, and biological systems is rapidly evolving, and will continue to do so. We need to add this new information to our plans as we get it, but we cannot wait until we get it all because we will never get it all," they say.

In the final pages, the authors call for more cross-sector collaboration and insist that greater creativity is needed to find solutions at a sufficiently rapid pace. "We need to blow the sides off the box and look out to the horizon, appreciating both the magnitude of the challenge and the range of options it presents. When it comes to addressing complex problems like climate change, creativity and the ability to integrate examples from multiple arenas are our best assets."

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—Amy Stevenson and Jonathan Nawn

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TECHNOLOGY

KlimaGuide: The yodeling iPhone application for the Swiss Alps

ANYONE FROM THE SERIOUS HIKER TO THE CASUAL WALKER visiting the world heritage site in the scenic Jungfrau region of Switzerland can now learn about climate change in the Alps with the use of an iPhone "app" called KlimaGuide. This electronic trail guide with zoomable topographic maps is pre-installed on special iPhones, which can be rented at Swiss tourist offices for 15 Swiss francs (CHF, or about U.S. $15) per day. The interactive features are intuitive and allow the user to choose from seven different "climate" hikes in the Bernese Oberland.

The hikes range from 2 to 3 miles long and are generally *wanderwegs* (easy hiking trails) with gradual elevation changes of less than 1,000 feet. The global positioning system (GPS) in the iPhone tracks the user's location and sounds a Swiss yodel as the hiker reaches the next point of interest along the interpretive climate path. For each trail, the KlimaGuide highlights six to seven vistas related to the various climate topics, such as *gletscher* (glaciers), permafrost, avalanches, rockfall, tourism, and skiing. The audio tracks of two to three minutes each are the appropriate length for a short science-learning pause as hikers take in the spectacular alpine scenery: the Eiger's infamous Nordwand (north face) and the 13,642-foot-tall glaciated Jungfraujoch. There are also personal behavior suggestions on how hikers can reduce their carbon footprint, with examples like rail travel, energy efficiency at home, and lowering consumption. Included on the

rental iPhone is a bonus video about the environmental research station located on the summit of the Jungfrau. The main emphasis is on the geologic sciences, with only a small portion on flora: the alpine flower selector. A shorter version of the guide is available for download onto personal iPhones for about $10.

The project is a collaboration of the University of Bern, two local communes, a software developer, and the Swiss energy company BKW FMB. Glaciologists worked with experienced climate journalists on the topics for about a year, and the actual audio-video production took about nine months. KlimaGuide launched in summer 2009, but at the initial price of 20 CHF (now $20), only 300 individuals rented the phones. The lower price of 15 CHF ($15) may increase usage.

As "cool" as this new media device is, especially for tech-savvy youth, it seems that a natural extension would be a traditional (less expensive) printed version of the presentation. Since social science research indicates that many people trust their friends and acquaintances for climate change information, such a booklet could be a useful outreach tool that wanderers could take home and share with friends.

See www.jungfrau-klimaguide.ch for more details.

—Joe Witte, broadcast meteorologist, Washington, D.C.
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Park Operations

Connecting park management with a vision for a sustainable tomorrow: The Integrated Environmental Plan

By Monica Magari

Abstract
Apostle Islands National Lakeshore (Wisconsin) has been a leader in environmental stewardship, participating in numerous programs that foster sustainable practices and promote innovative solutions with environmental benefits. However, managing several different voluntary environmental initiatives and meeting mandatory environmental compliance requirements, together with a desire to enhance sustainability commitments, became time-consuming and complex. The small-park staff looked at creative solutions to address the challenge, and the Integrated Environmental Plan (IEP) is the result. The IEP is a management system … [that] combines, streamlines, and simplifies administration and reporting of the park's many environmental initiatives. As a central repository for the various environmental protocols, the IEP creates more effective data collection and an efficient reporting platform. The IEP also allows scientific input to better support park decisions regarding environmental management and to help discover the synergies among different park priorities, including responding to climate change. Annual updates of goals and reexamination of park visions provide an avenue for management adaptation, mitigation efforts, and communication on multiple environmental issues.

Key words: adaptation strategy, Environmental Management System, Integrated Environmental Plan, mitigation strategy, sustainability management systems, sustainability planning

NATIONAL PARK SERVICE (NPS) responsibilities encompass stewardship of natural and cultural resources and management of visitor amenities and park infrastructure. Each of these elements is involved in the challenge of managing parks under a changing climate. Apostle Islands National Lakeshore (Wisconsin) has made significant strides in fostering sustainable practices and promoting innovative solutions to this challenge. The park's newly introduced Integrated Environmental Plan (IEP) streamlines the processes that allow the park to respond to new scientific research and understanding of climate change and to focus management actions on evolving guidance related to climate change.

The IEP is an adaptive management system guided by the park's visions and goals for the future. It is fueled by the legal reporting requirements and voluntary sustainability initiatives of the park and managed by staff in clearly defined roles and responsibilities. It proactively addresses park sustainability, providing a long-term decision-making framework. Thus, the IEP is adaptive and provides a means for the park to focus on both mitigation and adaptation strategies to address climate change.

Projected benefits from the IEP are (1) less time spent administering environmental actions and more time devoted to accomplishing them, (2) more effective data collection and reporting, (3) a conduit for scientific input into park decisions regarding priorities for environmental management and sustainability, and (4) discovery of synergies among different park program areas. The IEP also serves as a platform for communicating climate change–related initiatives in the park. Finally, while it principally directs mitigation actions, it also helps the park adapt to climate change in a standardized manner.

Program development

In 2008, Apostle Islands underwent a routine environmental audit of the NPS Midwest Region conducted by PRIZIM, Inc., an environmental and energy management consulting firm that has been assisting the National Park Service for more than 10 years. Federal directives, including presidential Executive Orders, Department of the Interior policy, and NPS Director's Orders, require national parks to implement an environmental management system (EMS) that mitigates environmental impacts of park operations and activities such as hazardous materials use, energy consumption, and transportation. PRIZIM was impressed by park efforts to integrate sustainability priorities into daily practices; however, the park's EMS needed to better document all the park's environmental programs, procedures, and achievements.

At the time of the audit, park protocols addressing sustainability and environmental management were outlined in (1) an EMS, (2) documented best management practices, (3) Superintendent's Orders, and (4) a Climate-Friendly Park Plan. The park complied with numerous reporting requirements, such as annual updates on energy and fuel usage, and also participated in various environmental initiatives, from community to national levels. Many goals of these initiatives overlapped, but each program was run separately. Administrative requirements were time-consuming and complicated, adding more work

Director's Order 13A: Environmental Management Systems

The purpose of this Order is to provide the foundation for implementing a Service-wide [Environmental Management Systems] approach to guide environmental decision making and actions at all levels. . . .

to already overburdened park staff, who felt their energies were fragmented and inefficient.

In response to these challenges, a team of park employees, supported by PRIZIM staff, developed the IEP, a system that combines, streamlines, and simplifies management and reporting of sustainability and environmental management endeavors. The IEP performs the same functions as a traditional EMS, but takes it a step further, encompassing all the park's long-term, ongoing environmental management activities (except compliance activities governed by the National Environmental Policy Act). The IEP also distributes management responsibilities throughout the park to ensure the most effective and efficient use of staff and budget resources in line with management priorities.

Key components

The IEP comprises several key components:

- **IEP Procedures:** Provides overarching guidance for, and links to, supporting workbooks that constitute the IEP.
- **Impacts and Future Visions Workbook:** Identifies significant environmental impacts of park activities, the key operational controls to mitigate impacts, and long-term goals of environmental performance—future visions—that park staff hopes to attain.

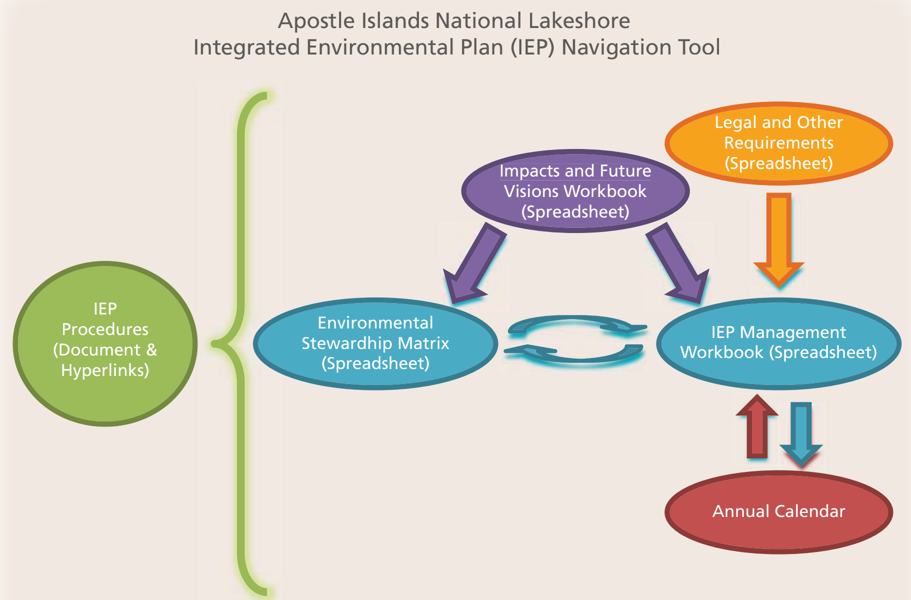

Figure 1. Systems diagram of Apostle Islands IEP.

- **IEP Management Workbook:** Tracks progress on annual goals, objectives, and targets that lead to the park's future visions. Organizes sustainability initiatives, regulatory compliance documents, records, and reports associated with the IEP in distinct spreadsheet tabs.
- **Environmental Stewardship Matrix:** Captures ideas for future projects, identifies environmental best management practices instituted in park functions, and catalogs past achievements. On an annual basis, ideas are drawn from the matrix and developed into goals with objectives and targets in the IEP Management Workbook.
- **Annual Calendar:** Identifies tasks and specifies responsible parties for managing the IEP, achieving annual goals and objectives, and fulfilling environmental compliance requirements.

Conclusion

Apostle Islands is fully implementing the IEP in 2011 and will continue to revise it as part of annual management reviews. Currently, the focus of the park's environmental management is on mitigation efforts. However, the IEP provides a solid foundation for greater attention to changing management priorities as detailed guidance becomes available in support of the NPS Climate Change Response Strategy. The hope is that the IEP will continue to evolve as a tool to improve sustainability and environmental performance and aid in the park's mission to protect the valuable resources of this Lake Superior archipelago.

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In Focus: Policy

Climate change policy challenges in the National Park Service

By Susan Johnson and Jeff Mow

Abstract

We examine and provide a brief overview of the applicability of NPS management policies to climate change in parks. Climate change impacts to park resources should not be considered "impairment" for purposes of management action; rather managers should focus on preventing impairment from in-park activities and engage in cooperative conservation to address impacts from external sources. To maintain resources in a "natural" condition remains a broad management goal, but it is not possible for managers to shield or protect park resources from climate change impacts. We identify some broad policy questions, and stress the importance of consistency in policy interpretations within the context of climate change and the need for a deliberate approach to stewardship action. Policy interpretations and potential changes, as well as stewardship approaches to address climate change, continue to evolve.

Key words: climate change, impairment, National Park Service, natural condition, policy

THE SHENANDOAH SALAMANDER (*Plethodon shenandoah*) lives only in a 6 km^2 (2.3 mi^2), high-elevation area in Shenandoah National Park, Virginia (fig. 1). Survival of this federally endangered species depends on unique habitat conditions of this mountaintop island (NPS 2010a). Moisture and temperature changes projected to occur with climate change would adversely impact the already small salamander population (NPS 2010a). Park managers[1] must decide what action, if any, is warranted to "save" the species in the face of climate change.

Service-wide, new problems such as this will face NPS managers as the rate of climate change accelerates and associated impacts become increasingly evident. In many coastal areas, for example, rising sea level and changes in storm frequencies will challenge managers' ability to maintain infrastructure and park natural and cultural resources. Iconic values and species will not be immune: glaciers, Joshua trees, and giant sequoias are already affected, or are predicted to be affected. How the National Park Service will respond, what response is even possible, and how we should prioritize our duties are questions whose answers must be supported by the best science possible. The answers, however, are ultimately policy questions that must be carefully analyzed in the context of our mission.

NPS Director Jon Jarvis described climate change as "fundamentally the greatest threat to the integrity of our national parks that we have ever experienced" (NPS 2010b). The NPS *Management Policies 2006* (MPs, chapter 4, introduction) recognize that ecosystems are dynamic and subject to continual change (NPS 2006). At the same time, these policies presume a context of relatively stable environmental conditions and somewhat predictable, gradual changes. This allows our paradigms for resource protection, park planning, and natural and cultural resources management to rely on historical conditions and the historical range of natural variability as a frame of reference. However, with climate change continuing to create novel conditions and associated, unprecedented impacts on our resources, the past is no longer a reliable guide for predicting the future. Consequently, current policy may require clarification or "evolution" to guide decision makers and best conserve NPS resources and the national heritage they encompass.

The policy challenge

The NPS *Management Policies 2006* "set the framework and provide direction for all management decisions. This direction may be general or specific; it may prescribe the process through which decisions are made, how an action is to be accomplished, or the results to be achieved" (NPS 2006).

Current management policies direct that decisions use the best available science, carefully considering other pertinent factors and public input, and be transparent via a complete administrative record. Policy does not require what is impossible, economically infeasible, or likely ineffectual.[2] To accommodate site-specific variables, management policies tend to be flexible and broad. They are also practically silent with respect to climate change, mentioning the term "climate change" only twice[3] and providing minimal, if any, guidance for prioritization or triage for park resources affected by climate change.

[1] The park is working with the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the Smithsonian Institution, the University of Virginia, and Towson University on this case.

[2] *MP* section 1.4.3 directs managers to minimize adverse impacts "to the greatest extent practicable."

[3] "Earth's climate has changed throughout history. Although national parks are intended to be naturally evolving places that conserve our natural and cultural heritage for generations to come, accelerated climate change may significantly alter park ecosystems. Thus, parks containing significant natural resources will gather and maintain baseline climatological data for reference" (*MP* 4.7.2). Also, NPS interpreters and educators should take opportunities to explain to visitors and other audiences "the influence of global climate change" on the parks (*MP* 7.5.1).


USGS/MATTHEW STOVER

Figure 1. The Shenandoah salamander is an endangered species whose high-elevation habitat may become less suitable for population persistence under future climate change. The U.S. Geological Survey, the National Park Service, the Smithsonian Institution, and the University of Virginia are cooperatively developing optimal strategies for protection of the species.

How the National Park Service will respond, what response is even possible, and how we should prioritize our duties are questions whose answers must be supported by the best science possible. The answers, however, are ultimately policy questions that must be carefully analyzed in the context of our mission.

Lack of specific guidance regarding resource protection in the context of climate change can promote decision paralysis at times that management creativity and innovation are most needed. In addition to the need for innovative solutions, however, we need Service-wide consistency in interpreting the NPS mission and mandates and complying with relevant legal requirements.

A growing body of literature aggregates some traditional conservation approaches in new ways, suggesting management strategies to adapt to climate change. Many authors emphasize strategies to enhance resilience of existing ecosystems, such as reducing stressors, combating invasive species, and preserving biodiversity, all of which fall under current NPS objectives. We expect, however, that climate change will eventually push some areas to new ecosystem states—changing species associations, community structures, habitat types, and ecosystem functions—in which new management challenges prevail.

Furthermore, in responding to climate change by working with state and federal agencies, tribes, and other partners through the U.S. Department of the Interior's Landscape Conservation Cooperatives, we expect that potential landscape-scale response strategies will include new approaches difficult for parks to consider without policy clarification. For success in the future, park managers need guidance on how to manage ecosystem change and transition.

Upholding our mission into the future

Given uncertainties of future climate change impacts, the diverse array of areas within NPS responsibility, and the importance of learning through adaptive management, adaptation strategies applied in parks should be developed and implemented by design rather than haphazardly. Creativity, innovation, and flexibility at the park level must be balanced with thoughtful and coordinated Service-wide consistency, again highlighting the need for more specific policy guidance.

The need to provide additional policy guidance to field areas is accompanied by broader, complex questions regarding agency mission and management goals, interpreted within the context of climate change. For example, as a premier conservation agency:

- How should the National Park Service define management goals in an era of climate change as our ability to foster and conserve "natural conditions" becomes impractical?
- How do we best manage the potential transition of ecosystems and conserve resources for which we are specifically responsible?
- How do we address the inevitable movement or loss of species from park units?
- How can management policies guide park managers in making decisions despite heightened uncertainty?

Upholding our mission likely requires updating interpretations of policy, mandates, and approaches to resource stewardship.[4] As it has on numerous occasions since being established in 1916, the National Park Service must reexamine its

[4]The MPs will be revised at appropriate intervals to … respond to new … understandings of park resources and the factors that affect them (introduction). Director's Orders can clarify or amend current policy to avoid the need to revise *MPs*.

conservation principles, this time against a background of climate change.

NPS climate change response

The NPS Climate Change Response Strategy, developed at the request of the NPS director (2010b), provides an initial road map for our agency and employees to address impacts of climate change. It describes general goals and objectives under four integrated components: *science*, *adaptation*, *mitigation*, and *communication*. The National Park Service will collaborate with partners to identify and monitor climate change effects in parks and to apply accurate and relevant science to management and policy decisions. We will adapt to a changing climate by developing feasible and actionable scenarios and creating flexible frameworks to manage impacts. We will reduce the carbon footprint of NPS activities through energy-efficient and sustainable practices. Finally, through clear, directed communication, the Service will raise employees' and the public's awareness of climate change implications and provide inspiration to address this challenge.

The strategy calls for (but does not supply) an overarching legal and policy framework to ensure the legality, consistency, and appropriateness of management decisions. With establishment of the NPS Climate Change Response Program (CCRP) in FY 2010, legal and policy issues associated with climate change response activities became a focus. The authors of this article lead a Service-wide policy working group that focuses on legal and policy implications of climate change. The group helps frame legal and policy issues, provides initial guidance on specific aspects of climate change adaptation and mitigation, and conducts case study analyses to help develop a framework for management decisions involving climate change.

The Organic Act, the impairment standard, and future natural resource conditions

The mission of the National Park Service in managing parks is familiar:

> to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations. (16 U.S.C. sec. 1)

There have been several efforts both within and outside of the Service to consider our mission as stated in the Organic Act (above) and its relevance in the face of climate change. How do we preserve resources in a "natural" and "unimpaired" condition when significant changes are predicted to occur in many landscapes? Amending the Organic Act is not desirable, feasible, or necessary. The Service has historically been afforded significant deference in defining objectives to carry out its mission. Current management policy provisions discuss potential impairment and response actions from *in-park* activities and sources (NPS 2006, sections 1.4.4, 1.4.7.1). Regarding potential impairment from external sources, managers are directed to work cooperatively with others (NPS 2006, sections 1.4.5, 1.6). Managers are not held accountable for external impacts, however, in the same sense as for impacts from in-park activities.

Additionally, climate change does not negate existing NPS policy direction. In fact the context of resource management remains consistent—that is, resource managers realize that we cannot prevent all impacts to resources. However, we can help guide changes in the near term by emphasizing management goals such as resiliency, removal of external stressors, and maintaining biodiversity and disturbance regimes such that ecosystem structures and processes remain as healthy and "natural" as possible. NPS policy already calls for these actions.

Current management policies define "natural condition" as "the condition of resources that would occur in the absence of human domination over the landscape" (NPS 2006, chapter 4). Chapter 4 of the management policies alone has more than 270 references to the term "natural." Extensive literature and ongoing discussion debate the role of naturalness with or without the context of climate change, and we expect the conversation to continue well into the future. "Natural" in *Management Policies 2006*, out of practical and realistic necessity, refers to a broad goal of preserving protected areas free from anthropogenic impacts. The climate change we are currently experiencing is primarily caused by anthropogenic emissions on a global scale (IPCC 2007). Though we can reduce our carbon footprint within our parks, reducing all harmful greenhouse gas emissions and altering the current temperature trajectory are beyond NPS control.

Managers should recognize that while the impacts from climate change are not "natural" in the traditional sense, and past conditions are not an effective guide for desired future conditions, they should be diligent in preserving resources unimpaired from activities over which they have control. Additionally, managers should commit fully to cooperative conservation and civic engagement to understand, mitigate where possible, and adapt to impacts from external forces to the extent practicable. The relationship between climate change and other anthropogenic effects on resources is complex—potentially synergistic—and the ability to isolate the primary cause of a specific impact may be limited or impossible. But the bottom-line message is, managers cannot, and are not expected to, prevent impairment from global climate change.

Figure 2. The island scrub jay is found only on Santa Cruz Island, the largest of the California Channel Islands. This insular species is thought to have been isolated from its closest relative, the western scrub jay, approximately 200,000 years ago. It is the only bird species in the continental United States never to have ranged to the mainland.

Policy does not require what is impossible, economically infeasible, or likely ineffectual.

An example of how our managers must cope with climate change may be found at Channel Islands National Park, where the island scrub jay (*Aphelocoma insularis*) is a species of bird endemic to Santa Cruz Island (fig. 2). Long-term viability of this species—already with a small population size and insular range—is at stake from emerging disease and climate change threats of habitat stress and fires (Morrison et al. Accepted). Park managers wrestle with opportunities to identify and manage threats, apply principles of conservation best practices, and explore possible actions that may be more manipulative and intrusive than what the Service typically undertakes. While no decisions are imminent and many uncertainties still prevail, possible actions include captive propagation, vaccination, instituting biosecurity measures, and establishing a second free-living population on Santa Rosa Island. Such examples, if found to be consistent with evolving resource policy, could become an example of strategic climate change adaptation.

The CCRP Policy Working Group will continue to analyze the case studies at both Channel Islands and Shenandoah national parks, using these case studies and others to help develop a framework for decision making on resource issues involving climate change. The group has a list of other case studies for analysis and invites submission of additional issues and situations that park managers may face as a result of climate change impacts. Please contact the authors if you should have such a case study.

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Adaptation

Climate change scenario planning: A tool for managing parks into uncertain futures

By Don Weeks, Patrick Malone, and Leigh Welling

The challenge of a changing climate

National Park Service Director Jon Jarvis stated in a recent interview that climate change is "the greatest threat to the integrity of the National Park System (NPS) that we've ever faced" (The BigOutside Blog 2010). Global temperatures are rapidly rising. The National Oceanic and Atmospheric Administration (2011) has announced that for the entire planet, 2010 is the hottest year on record, tied with 2005. And the period 2001 to 2010 is the hottest decade on record for the globe (fig. 1).

Rising temperatures will influence many aspects of Earth's hydrologic systems, such as precipitation, snow, ice, and permafrost, which will in turn affect plant and animal life and processes such as fire. These cascading effects are already impacting the natural and cultural resources the National Park Service is charged to protect. The range of impacts land managers will need to address are unprecedented and most are not well understood. There is much uncertainty about the specific ways in which ecosystems, populations, and species will respond to these changes.

Over the last several years, there has been renewed commitment in the federal government to addressing the important issue of climate change. The National Park Service, in particular, is looking at new ways to think about, and plan for, the effects of climate change. In fall 2010, the National Park Service published its *Climate Change Response Strategy*, which outlines a broad framework for how the agency will address climate change. Planning for climate change within an adaptation framework is a cornerstone of that document. But even before that, the Service had been quietly exploring and testing ways to plan more effectively in this dynamic environment.

Planning with uncertainty

Forecast vs. scenario planning
The NPS Park Planning Program Standards (Director's Order 2.0) were released in 2004 as the new planning road map for park management. This framework represents a series of planning elements, starting with a Foundation Statement that identifies the fundamental resources and values a park is committed to preserving and maintaining based on legislation. These priorities are then carried through the remaining planning framework. The next planning element, the General Management Plan (GMP), defines *desired conditions* for park-specific fundamental resources and values and identifies the preferred alternative for park management to follow. In the idealized framework, the GMP is followed by a Resource Stewardship Strategy (RSS), which quantifies the desired conditions so that park management has measurable targets for establishing specific management goals and generates strategies to achieve them. These strategies then feed into the park's five-year Strategic Plan, which reflects a prioritization of action items the park commits to implement. This approach is one of forecast planning and it is based on expectations for the future, as park management follows a preferred management alternative for the next 15 to 20 years (fig. 2a).

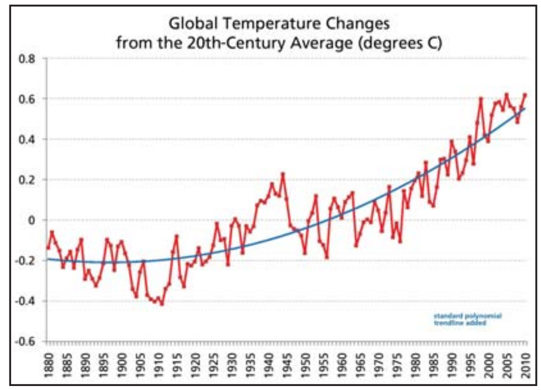


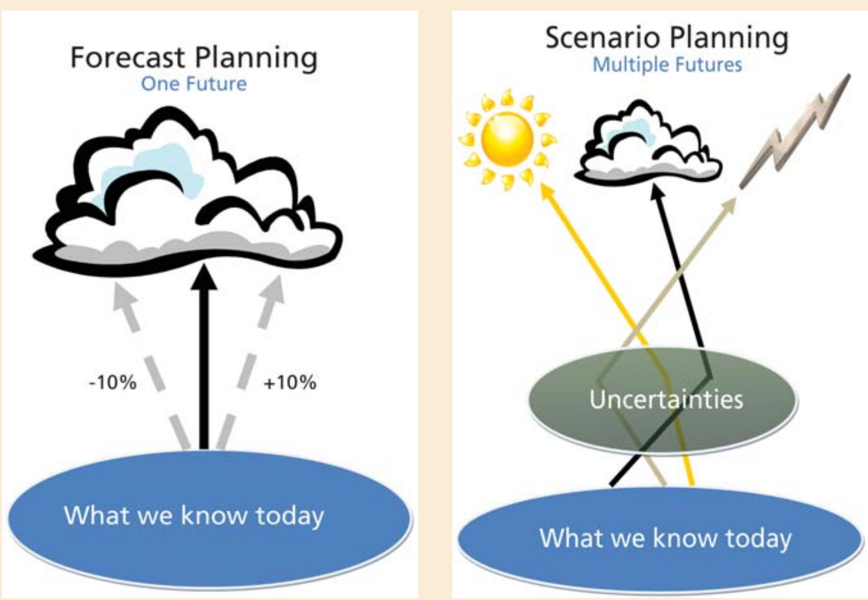
Figure 1. Global temperature changes from the 20th-century average (NOAA 2011).

When considering a changing climate in park planning, the forecast approach is limited by incomplete knowledge of highly consequential factors that are largely unpredictable and outside of management control but influence a park's future conditions. The far-reaching effects of climate change, coupled with high uncertainty about local impacts, produce a range of plausible futures (constrained by the best available science), to which park managers will have to react (fig. 2b). How does the National Park Service identify what future, or potential futures, to plan for? What are the best response options when faced with a range of potential climate futures? These are not easy questions. Exploring the potential consequences of climate change can lead to management paralysis or, if structured correctly, can stimulate new ways of thinking and planning.

Scenario planning
Scenario planning is a process designed for managing into futures with high uncertainty and lack of control (fig. 3). Scenario planning was developed during the Cold War as a way for the United States to

Abstract
Climate change presents unprecedented challenges for the National Park Service (NPS), as science reveals a range of potential climate futures faced by land managers. Such climate-related influences as increases in air temperature; sea-level rise; and changes in precipitation, wind speed, and extreme weather events test traditional park planning and management as parks move toward these uncertain futures. In traditional park planning, a preferred alternative is selected for park management to follow for the next 15 to 20 years, and management works toward that desired outcome. Today, in a world of climate change, new planning processes are needed to manage into uncertain futures. We describe the process of scenario planning, which the NPS Climate Change Response Program is exploring as a tool for park planning and management in an era of uncertainty. We discuss park-specific experiences gained over the past three years from the exploration and application of climate change scenario planning in which managers are presented with a series of plausible futures. Since 2008, the National Park Service has completed five case studies to test the use of climate change scenario planning, with favorable reaction. Under guidance of the Global Business Network, an international pioneer in the evolution and application of scenario planning, the National Park Service has begun to focus on educating its staff and partners on the utility of climate change scenario planning through several training workshops to better assist in its landscape adaptation efforts and other management responses.

Key words: adaptation, climate change, climate variables, impacts, scenario planning

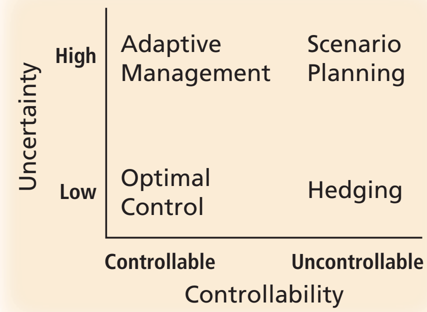


GLOBAL BUSINESS NETWORK (2)

Figure 2. Forecast planning (*a*, at left) vs. scenario planning (*b*, at right).

analyze the relationship between Soviet weapons development and U.S. military strategy (Kahn 1960). The planning approach caught on in the corporate world, starting with Royal Dutch/Shell in the 1970s, and has since led companies from many different industries, such as Microsoft, Nissan, and United Parcel Service, to use scenario planning as a tool for managing into uncertain economic, social, and political futures.

Scenario planning is not a technique for predicting the most probable future.



PETERSON ET AL. 2003

Figure 3. Appropriate management responses based on uncertainty and controllability.

Rather, the objective is to develop and test decisions under a variety of plausible futures. Doing this proactively, essentially rehearsing for multiple futures, strengthens an organization's ability to recognize, adapt to, and take advantage of changes over time (Global Business Network 2009). As such, scenario planning was selected by the National Park Service as a tool to explore for managing parks into a future of climate uncertainty.

Climate change scenario planning in the National Park Service

History

In 2006 the National Park Service began exploring the use of scenario planning in the context of climate change. Over a three-year period, the Service and several partners held workshops to evaluate the utility of a scenario-building technique for helping managers to explore the key uncertainties and park impacts related to climate change and begin to evaluate the most appropriate and effective response strategies. Participants completed five case studies during this exploration phase at Joshua Tree National Park (California), Kaloko-Honokōhau National Historical Park (Hawaii), Assateague Island National Seashore (Maryland), and Wind Cave (South Dakota) and Glacier (Montana) national parks. While several of the case

Scenario planning is not a technique for predicting the most probable future. Rather, the objective is to develop and test decisions under a variety of plausible futures.

studies considered the broader landscape within which parks are located, the Glacier National Park workshop explicitly examined the use of climate change scenario planning in the larger Crown of the Continent ecosystem, which is the transboundary landscape of Waterton-Glacier International Peace Park and more than 20 other state, provincial, and tribal governments in this U.S.-Canadian transboundary region. For each of the five case studies, managers developed several potential climate futures using recent climate data along with model projections, and then evaluated these futures in the context of management challenges and options. Partners involved in this investigative work were the National Interagency Fire Center, the National Center for Landscape Fire Analysis at the University of Montana, the USGS Northern Prairie Wildlife Research Center, the NOAA-funded Climate Assessment for the Southwest at the University of Arizona, and the Global Business Network (GBN).

Building from the favorable reactions and lessons learned during the case studies, the National Park Service teamed with the Global Business Network, a pioneer in the evolution and application of scenario planning, to begin the next phase of scenario planning in 2010. This second stage focused on raising awareness of and building capacity in the scenario planning process within and outside the National Park Service, as well as exploring how scenario thinking may complement landscape adaptation and long-range planning. Thus the National Park Service completed four training workshops in 2010–2011, each focusing on specific bioregional landscapes.

Workshop 1**:** Alaska's Arctic and Coastal bioregions (Anchorage, Alaska, August 2010)

Workshop 2**:** Great Lakes and Atlantic Coast bioregions (Duluth, Minnesota, October 2010)

Workshop 3**:** Urban Landscapes and Eastern Forests bioregions (Shepherdstown, West Virginia, December 2010)

Workshop 4**:** Western Mountains, Pacific Islands, and Arid Lands (Denver, Colorado, February 2011)

These workshops introduced approximately 150 participants to the climate change scenario planning process. The disciplines of the participants ranged from climate change science, to natural and cultural resources and facilities management, to education, planning, and interpretation, and included a variety of land management agencies.

Basic steps

So what is the process for climate change scenario planning? The first step is assembling an interdisciplinary core team to design, facilitate, and bring in the appropriate climate science and management expertise for the planning exercise. According to GBN, participants should include *knowledge holders*, *stakeholders*, and the *curious and creative*. More specifically for the National Park Service planners, educators, scientists, natural and cultural resource managers, facility managers, superintendents, and partnership coordinators, along with representatives from other jurisdictions within the landscape, have important voices in the process.

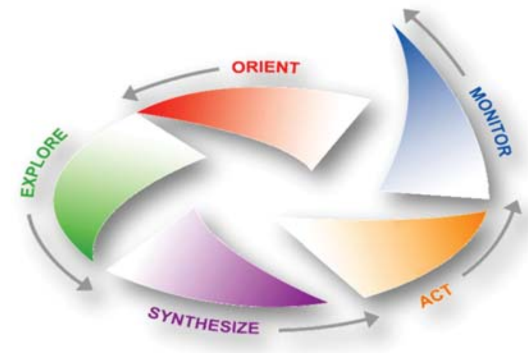


Figure 4. Scenario creation five-step process.
GLOBAL BUSINESS NETWORK 2011

With a variety of approaches available for scenario development, an approach practiced by GBN and applied to the NPS training can be divided into five steps, illustrated in figure 4. These steps resemble a basic adaptive management process and provide a solid framework for NPS scenario planning that is familiar to park managers.

1. ***Orient***: Define the strategic issue and the scale at which to address it. This is framed as a focal question, such as "How will climate change effects impact the landscapes within which management units are located over the next 50 to 100 years?" or "How can managers best respond to long-term change over a 20-year planning horizon?"

2. ***Explore***: Identify the driving forces and major effects that influence the future of the focal question. For climate change scenario planning, a climatologist is engaged to synthesize current science and create a list of relevant climate variables (e.g., temperature, precipitation, storm frequency) along with the projected trend and confidence for

Table 1. Summary of projected climate changes for Alaska

Climate Variable	General Change Expected	Specific Change Expected and Reference Period	Size of Expected Change Compared to Recent Changes	Patterns of Change	Confidence	Source and Context
Temperature	Increase	2050: +3°C ± 2°C 2100: +5°C ± 3°C	Large	More pronounced in north and in autumn-winter	>95% (sign) Very likely	IPCC 2007, SNAP 2010
Precipitation	Increase	2050: 10–25% ± 15% 2100: 20–50% ± 20%	Large	Greater overall percentage increase in north	>90% (sign) Very likely	IPCC 2007, SNAP 2010
Relative humidity	Little change	2050: 0% ± 10% 2100: 0% ± 15%	Small	Absolute humidity increases	50% About as likely as not	SNAP 2010
Wind speed	Increase	2050: +2% ± 4% 2100: +4% ± 8%	Small	More pronounced in winter and spring	>90% (sign) Likely	Abatzoglou and Brown[1]
Pacific Decadal Oscillation (atmospheric circulation)	Decadal to multi-decadal circulation anomalies affecting Alaska	Unknown	Large (comparable to climatic jump in 1970s)	Major effect on Alaskan temperatures in cold season	Natural variation, essentially unpredictable	Hartmann and Wendler 2005
Extreme events: Temperature	Warm events increase, cold events decrease	2050: increase 3–6 times over present conditions for warm events; decrease 1/5–1/3 of present conditions in cold events 2100: increase 5–8.5 times present conditions in warm events; decrease 1/12 to 1/8 present conditions in cold events	Large	Increase in frequency and duration of extreme hot events, decrease in extreme cold events (winter)	Modeled and observed Very likely	Abatzoglou and Brown[1], Timlin and Walsh 2007
Extreme events: Precipitation	Decrease/Increase	2050: –20% to +50% 2100: –20% to +50%	Large	Increase in frequency and contribution, especially in winter	Modeled and observed Uncertain	Abatzoglou and Brown[1]
Extreme events: Storms	Increase	Increase in frequency and intensity	Any increases exacerbated by sea ice reduction and sea-level increase	Increases at southern periphery of Arctic; little information for central Arctic	>66% Likely	Loehman[2] 2007
Sea ice	Decrease	2050: 40–60% loss in Bering Sea (winter/spring); 20–70% loss in Chukchi/Beaufort (summer)	Comparable to recent changes	Nearly ice-free summers by 2050 with ice-free summers by 2100; less loss of sea ice in winter than in summer	>90% Very likely	Wang and Overland 2009
Snow	Increased snowfall during winter, shorter snow season	Winter snowfall 2050: 10–25% 2100: 20–50%	Recent changes not well established	Cold-season snow amounts will increase in interior and north of Brooks Range; increased percentage of precipitation will fall as rain (especially in spring and autumn)	Large uncertainty in timing of snowmelt (warmer springs, more snow to melt)	AMAP 2011
Freeze date (freshwater lakes)	Later in autumn	2050: 10–20 days later near north coast; 5–10 days later elsewhere 2100: 20–40 days later near north coast; 10–20 days later elsewhere	Large		>90% (sign) Very likely	SNAP 2010

CONTINUES ON PAGE 30

Table 1 (continued)

Climate Variable	General Change Expected	Specific Change Expected and Reference Period	Size of Expected Change Compared to Recent Changes	Patterns of Change	Confidence	Source and Context
Length of ice-free season for rivers and lakes	Increase	2050: 7–10 days longer than present 2100: 14–21 days longer than present	Large	Greatest near coasts where sea ice retreats; open-water season lengthens	>90% Very likely	IPCC 2007, SNAP 2010
River and stream temperatures	Increase	2050: 1–3°C 2100: 2–4°C	Large	Consistent with earlier ice breakup and higher air temperatures	>90% Very likely	Kyle and Brabets 2001
Length of growing season	Increase	2050: 10–20 days longer 2100: 20–40 days longer	Continuation of recent changes	Greatest near coasts	>90% Very likely	IPCC 2007, SNAP 2010
Permafrost	Increased area of permafrost degradation (annual mean temperature > 0°C)	2050: ~100–200 km northward displacement 2100: ~150–300 km northward displacement	Large	Permafrost degradation primarily in area of warm permafrost (southern and interior Alaska)	>90% (sign) Very likely	SNAP 2010, Romanovsky et al. 2010
Sea level	Increase	2050: 3 inches to 2 feet 2100: 7 inches to 6 feet	Large	Large uncertainties, especially at upper end of range; complicated by isostatic rebound, especially in southeastern Alaska	>90% (sign, except in areas of strong isostatic uplift)	IPCC 2007

Source: John Walsh, professor of climate change and chief scientist, International Arctic Research Center, University of Alaska–Fairbanks.

Note: Projected changes are for midrange forcing scenario (A1B). Ranges of projected changes would be wider if low-emission (N2) and high-emission (A2) scenarios were included.

[1]Abatzoglou, J. T., and T. J. Brown. Results extracted from nine climate models from Field et al. 2007 (see references). Values based on SRES A1B. See table 1a: Drivers of external change for Joshua Tree National Park (Loehman 2007, below).

[2]Loehman, R. 2007. Table 1a: Drivers of external change for Joshua Tree National Park. Climate Change Scenario Planning Workshop for Joshua Tree National Park and Kaloko-Honokōhau National Historical Park. 13–15 November. National Park Service, Joshua Tree National Park, California. (Table data synthesized from Field et al. 2007 [see references]).

Table 2. Certainty of climate change variables in Assateague Island National Seashore case study

Climate Variable	Predetermined	Critical Uncertainty
Temperature increase	X	
Precipitation		X
Sea-level rise		X
Drought		X
Snow cover decrease	X	
Extreme events: Storms		X

each (table 1). The ability to synthesize climate data and projections into a form that is both accurate and easily understandable by nonscientists is a critical factor upon which many other steps in the process depend. Once the important variables are identified, they must be understood and ranked within the dual context of "uncertainty" and "importance." The objective is to narrow down the list to those variables that are most important and most uncertain to further explore. A variable that does not meet the criteria of important and uncertain may become a "predetermined" variable that is a factor in all scenarios or may not be considered at all (table 2). It is useful at this stage to explore what kinds of conditions may be associated with the extreme uncertainties of a given variable (e.g., would a 10% increase in precipitation result in very different conditions from a 20% decrease?). The NPS approach also develops a table of known and potential resource impacts during the exploration stage, which is drawn upon in the next step.

3. ***Synthesize***: Participants combine information from select climate variables in a way that allows them to envision

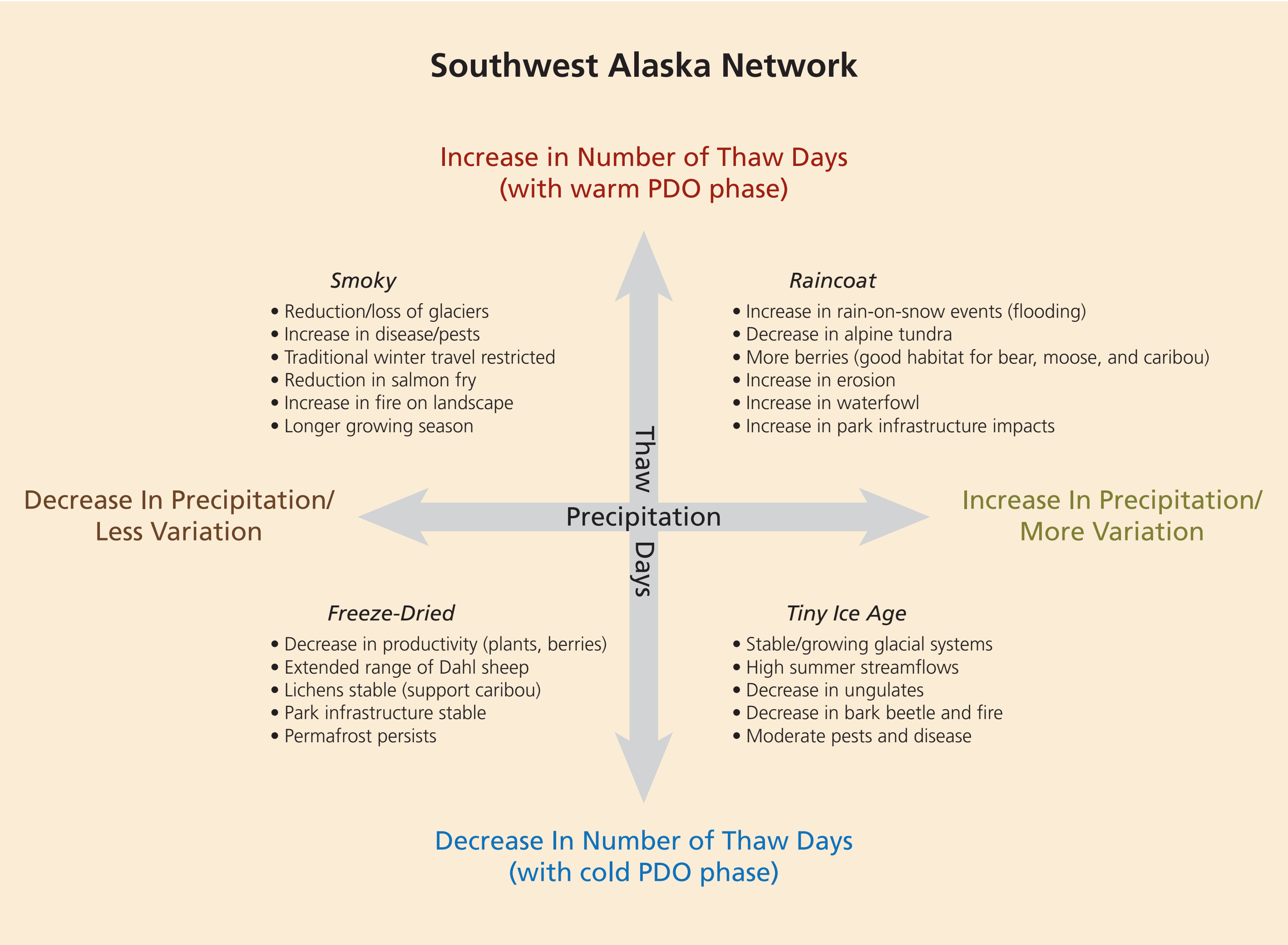


Figure 5. Climate variable framework example from the Southwest Alaska Network workshop. The *x* axis depicts changes in precipitation; the *y* axis shows changes in the number of thaw days per year (above freezing), taking into account the compounding effect of the Pacific Decadal Oscillation (PDO), an oscillating pattern of warm and cool water in the northern Pacific Ocean that shifts about every 20–30 years, influencing air temperatures in Alaska.

different future conditions (scenarios) that may result. We used a 2 × 2 matrix approach with climate variables represented on the axes. For example, *precipitation* and *thaw days* may be selected as two axes for generating four different climate futures (fig. 5). Several scenario matrices can be constructed by trying different combinations of two axes, each generating a set of four scenarios. Selected axes are combined in this way until participants settle on one matrix that best fits the criteria of *plausible*, *divergent*, *relevant*, and *challenging*, which are important for capturing a robust set of scenarios that will allow participants to consider a wide array of potential actions. Once the scenario matrix is selected, participants describe each scenario in detail, using the table of impacts that was created during the exploration phase. The group then identifies the implications of these four climate futures (fig. 5) and the actions needed to respond and adapt.

4. ***Act***: Implement effective management actions. Managers may choose to act on one scenario that appears to represent the most probable future or they may identify several actions that are common to all scenarios (often termed "no regrets" actions). It is also important to identify current practices that are "no gainers" and need to be discontinued. An example of a no-regrets action for southwestern Alaska parks is to improve connectivity across landscapes and jurisdictional boundaries. A no-gainer action at Assateague Island National Seashore, Maryland, would be to build permanent structures on the island despite

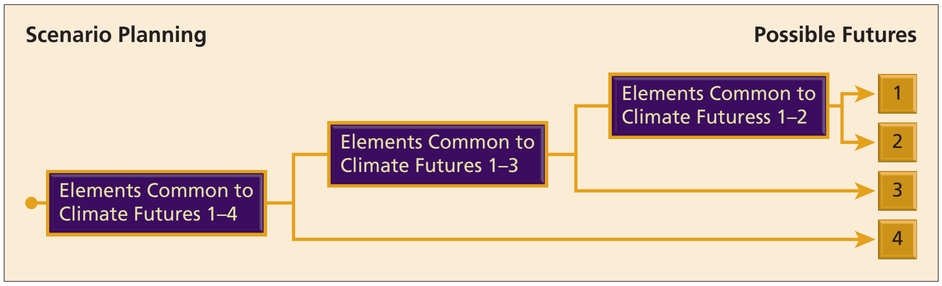


Figure 6. Management through a range of plausible climate futures.

high confidence in a climate future of sea-level rise.

5. ***Monitor***: As new information unfolds, managers should continue to validate the scenarios and evaluate the effectiveness of their response. Is there evidence of moving toward one or a select group of scenarios? Can decisions and actions be adjusted to incorporate new information? While continuing to monitor key indicators, managers should look for signals that a particular scenario is becoming a reality and adjust decisions as necessary (fig. 6).

Nested scenarios: Considering the sociopolitical landscape

The 2 × 2 approach can be used with other types of variables besides climate, such as social, political, and economic variables, which are also uncertain and highly consequential to decision making. When exploring different types of scenario matrices for the same focal question, a method known as "nesting" can be very useful, whereby one matrix is embedded in another. For the NPS-GBN workshops, we created a sociopolitical matrix to describe the broader decision environment within which climate change will manifest, yielding an even broader array of possible futures to consider.

NPS role in climate change response

The National Park Service can, and does, play an important role in the national and global responses to climate change. Protected lands help to conserve biodiversity, support ecosystem adaptation, provide laboratories for fundamental and applied research, and offer many opportunities to engage communities in learning and environmental stewardship (see articles in the "Communication and Public Engagement" section beginning on page 56). Scenario planning is an important tool in the Service's four-pronged Climate Change Response Strategy (i.e., science, adaptation, mitigation, and communication). It allows managers to synthesize the information and potential implications from climate change in a way that is relevant to the conservation of park resources and landscape values.

With its flexible approach to accommodating changing circumstances, scenario planning is one way in which the National Park Service could change its planning paradigm. It is a process that encourages collaboration with other federal land management agencies, climate scientists, and academic institutions. As Director Jarvis said at the conclusion of his interview with The BigOutside Blog (2010), "If there's any silver lining, climate change is forcing us to think and act at the landscape scale. No longer can we think of parks as islands."

Clearly the challenge of managing resources in the face of climate change is daunting. As George Black (2011) points out in a recent magazine article published by the Natural Resources Defense Council, "Adapting to climate change is a singularly complex challenge. It requires money, new technology and infrastructure, institutional capacity, accurate data, different ways of producing and consuming energy, changes in culture and lifestyle, and the nimbleness to adjust to constantly shifting and uncertain circumstances." The National Park Service has made a commitment to addressing these challenges and will continue to take a leadership role in navigating the uncertainties of climate change, exploring and using a variety of scenario planning techniques and other tools to enable effective management response. After all, perpetuity is part of our mission, and that means we are in it for the long haul.

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How does the National Park Service identify what future, or potential futures, to plan for? What are the best response options when faced with a range of potential climate futures? These are not easy questions.

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RESEARCH REPORT

Climate-Friendly Park Employees: The Intermountain Region's climate change training assessment

By Gregg Garfin, Holly Hartmann, Mabel Crescioni-Benitez, Theresa Ely, John Keck, James W. Kendrick, Kristin Legg, and Janet Wise

Abstract

The National Park Service Intermountain Region (IMR) partnered with the University of Arizona to assess climate change training needs for more than 5,000 IMR employees. We identified baseline climate knowledge characteristics: ability to discern between climate variability and trends, understanding of key phenomena (e.g., El Niño), correct identification of observed impacts, but little knowledge of climate projections for the region. Employees identified challenges for implementing a training program: adequate communication technology, adequate funding, clear guidance on actions and policy changes, and communicating with climate change skeptics. Employees recommended that training connect global changes to regional impacts and local solutions and demonstrate relevance to job duties. Interviewees preferred interactive, hands-on learning experiences, but agreed to use electronic media given budget constraints. They identified information overload as a problem, suggesting information be packaged in frequently asked questions, briefs, and videos. We recommend a modular program, leveraging existing, well-vetted information resources. We evaluated more than 150 Web sites and found online training for climate change literacy, but a lack of training on mitigation and adaptation. We present a training decision tree and sample curricula.

Key words: climate change literacy, communication, Intermountain Region

THE INTERMOUNTAIN REGION (IMR) OF THE NATIONAL Park System is one of the most diverse areas administered by the National Park Service (NPS), with more than 90 park units encompassing coastal, desert, mountain, and prairie ecosystems. Climate change and vanishing landscapes were among the top five IMR challenges enumerated in an internal report (NPS 2009). To prepare for these challenges, the Intermountain Region engaged University of Arizona scientists to assess needs for workshops and training to provide IMR employees with information they could use to manage resources, mitigate greenhouse gas emissions, and plan for adaptation to climate changes. University and NPS investigators refined the project scope and agreed upon the following goals: (1) assess the climate change knowledge of a sample of IMR employees; (2) determine the content, design, and communication media of potential training modules for employees; (3) develop a road map linking current and expected climate change information needs; and (4) determine how best to leverage existing climate change information resources and reconcile information from different sources.

Methods

To evaluate climate change literacy and training preferences, the team codeveloped a 21-question structured online survey, using Likert-scale, multiple preference, and open-ended questions, followed by an 18-question semistructured interview protocol. The interviews were conducted after analysis of the survey, and interview questions were informed by survey results and knowledge gaps. Out of 5,379 IMR employees who were invited to participate, 609 (12.6%) responded to the survey. The sample represented 31 workforce roles, defined by amalgamating 166 unique NPS occupational series. Some roles, such as facilities management, interpreters, and natural resources IMR personnel, were overrepresented, whereas responses from IMR administrative assistants, motor vehicle employees, park guides, and park rangers/law enforcement were underrepresented. Our survey analysis does not account for the effects of nonresponse bias; thus, caution should be applied when extrapolating the results to the entire population of IMR employees.[1] For the interviews (n = 15), NPS team members selected key informants across a spectrum of job roles to fill in gaps in the surveys and to provide input from senior management. Interview questions focused on aspects of a training program, including recommendations on how the Intermountain Region should fund climate change training, and major challenges faced by NPS with respect to climate change.

[1] The sample used in this study did not account for bias created by self-selection of survey respondents. To evaluate the representativeness of the sample, we compared the percentage of the full IMR workforce in each of the 31 workforce roles with the percentage of the sample in each of the 31 workforce roles. We found that 23 of the 31 workforce roles (74.2%) in our sample were within 3% of the full workforce, a reasonable representation of the workforce categories. For the following workforce roles, there were differences greater than 3% between the full workforce and our sample: administrative assistance/office support (4.6%), facilities management (–7.3%), interpreter (–12.5%), laborer (3.9%), motor vehicle/automotive (14.2%), natural resources (e.g., biologist, ecologist, geologist, meteorologist) (–3.7%), park guide (3.4%), park ranger/law enforcement (13.6%). (Negative numbers indicate that we oversampled in these workforce roles.) Caution should be applied when extrapolating the sample results to the entire population; results are least robust in representing workforce categories with large differences.

Table 1. Number and percentage of IMR survey respondents identifying climate change definitions

Definition/Answer Option	Adaptation	Exposure	Mitigation	Resilience	Vulnerability	Percentage Correct
An intervention to reduce the rate of emission or increase the rate of absorption of greenhouse gases	33	8	**535**	2	2	92
An adjustment in natural systems in response to a changing climate in order to moderate adverse impacts	**528**	8	27	15	1	91
Degree to which a system can rebound or recover from a disturbance or stimulus such as climate change	15	5	5	**546**	8	94
Degree to which a system is susceptible to and unable to cope with adverse effects of climate, including climate change, climate variability, and extremes	2	11	4	9	**554**	96
Degree, duration, or extent to which a system is in contact with a climatic disturbance	4	**553**	4	5	14	95

Notes: Correct responses are in boldface type. Sample size = 582.

Table 2. Number and percentage of IMR survey respondents identifying adaptation and mitigation examples

Example/Answer Option	Adaptation	Mitigation	I don't know	Percentage Correct
Replacement of an agency's fleet of conventional vehicles with gas-electric hybrids	113	**430**	10	78
Maintain healthy, vigorous trees and minimize severe disturbance by fire, insects, and disease in order to keep carbon stored in forests	**226**	304	18	56
Passage of cap-and-trade legislation to limit greenhouse gas emissions	62	**451**	34	82
Putting additional resources into preserving and protecting cultural landscapes from climate-related degradations	**239**	286	23	44
Changing home lawn-watering schedules to conserve water	**328**	215	8	60
Restoration of streamside vegetation to enhance groundwater infiltration and increase base flow	**210**	325	14	38
Promote connected landscapes to aid species in migration	**320**	203	27	58

Notes: Correct responses are in boldface type. Sample size = 553.

Survey and interview results

Climate literacy

Most respondents (83%) rated themselves as having fair or good knowledge of climate change. Poor or very poor climate literacy self-ratings suggest areas to which IMR should devote special attention; the majority of these came from administrative assistants, office staff, budget and accounting, contracting and purchasing, facilities management, human resources, park manager, park ranger, and law enforcement. Most respondents correctly identified climate change impacts observed in the Intermountain Region, but could not correctly identify projected changes for the region. More than 90% of respondents correctly identified definitions of key terms, such as "greenhouse effect" and "mitigation of and adaptation to climate change" (table 1); far fewer correctly matched seven examples of actions with the terms "mitigation" and "adaptation" (table 2).

Survey results also indicate the need for training on distinctions among climate variability, climate trends, and weather. For example, weather includes atmospheric phenomena and changes on timescales of minutes to days, such as thunderstorms, weather fronts, and tropical storms. Climate variability describes phenomena and changes on timescales of months to decades; examples of variability include seasonal drought caused by recurring phenomena, like La Niña, or multidecade wet or dry periods caused by long-term variations in ocean-atmosphere circulation, such as the Pacific Decadal Oscillation (Mantua and Hare 2002). Climate

Table 3. Climate change training job categories, rationales, and abbreviated curricula

Job Category	Training Rationale	Sample Curricula
Operations and administration	Inform mitigation behavior; prepare for casual public engagement	Basic climate literacy; NPS climate change policy and actions; workplace mitigation actions; procedures for addressing questions from the public
Interpretation and education	Primary public interface; support mitigation compliance efforts; train other employees	In-depth climate literacy; NPS climate change policy and actions; workplace mitigation actions; adaptation planning and actions; in-depth procedures for addressing questions from the public
Research scientists	Inform research practice and methods; inform development of science information for mitigation and adaptation decision making; lay groundwork for collaboration with other scientists; prepare for casual public engagement	Technical climate literacy; science to support mitigation planning; adaptation planning and actions; procedures for addressing public questions
Planners and engineers	Inform mitigation compliance and development of adaptation strategies; inform approaches for addressing uncertainty in decision making; prepare for casual public engagement	Technical climate literacy; mitigation planning and compliance regulations; in-depth adaptation planning and actions; frameworks for addressing uncertainty in decision making; procedures for addressing public questions
Managers	Depending on level of management: inform mitigation and adaptation strategy, policy, and program development; inform approaches for addressing uncertainty in decision making; prepare for public engagement; prepare for partnerships and collaboration	In-depth climate literacy; mitigation planning and compliance regulations; in-depth NPS climate change policy and actions; adaptation planning and actions; frameworks for addressing uncertainty in decision making; in-depth procedures for addressing public questions

trends would include phenomena such as regional or global temperature increases; when, for example, a sustained trend of increasing temperatures is overlaid on variability, the severity of multidecade droughts can increase through earlier melt of winter snowpack and increased evapotranspiration.

Training and information communication preferences

Given federal budget constraints, we examined employee training and communication preferences with respect to cost limitations. We found, in general, that employees prefer in-person training, if cost is not an issue. To maximize training effectiveness, interviewees recommended mixed-method training programs that involve hands-on learning components and interaction with fellow employees. Few employees advocated online training, unless cost limits choices. Only 7.4% of IMR employees felt their Internet access or connection speed would limit use of online training; given current resources, online training is an attractive option for initial development of a training program. These and other considerations suggest the need for a flexible program, with options that accommodate work schedule constraints, the remote locations of some employees, and technology limitations. Interviewees suggested that information overload is an issue; thus information must be tightly packaged (e.g., frequently asked questions, briefs, targeted presentations).

Survey and interview participants suggested well-sourced information that relates global to local phenomena in a manner that is relevant to job duties and individual parks. Participants urged the National Park Service to (1) provide information consistent with other federal agencies, (2) avoid duplicating training materials or classes that are already available outside the Intermountain Region or National Park Service, (3) connect with existing training and agency conferences, and (4) obtain funding for a climate change training program but not by diverting existing park budgets.

Challenges

Interviewees identified key challenges for an IMR climate change training program: inadequate information-dissemination technology and communication networks, lack of funding, need for clear guidance on actions and policy changes, developing clear and consistent messages, and communication with climate change skeptics. From 299 responses to the question "What information do you most urgently need to address climate change in your work?" we found employee disagreement on whether a climate change training program should be mandatory; resistance to a mandatory program creates an additional challenge.

Training and resources

We first assigned NPS jobs in broad categories as follows: operations and administration, interpretation and education, research scientists, planners and engineers, and managers. We then developed several tools for targeting climate change training with associated employee categories and their work-related needs. These include training rationales, core topics, and curricula that outline key concepts (tables 3, 4, 5); decision trees that associate topics

Table 4. Core topics and course descriptions for IMR climate change training

Topic and Course	Brief Course Description
Climate Literacy	
Climate Literacy 1	Climate change: linking global change to local impacts
Climate Literacy 2	In-depth evidence of change and projections of the future
Climate Literacy 3	Climate change science for scientists
Communication	
Communication 1	Procedures for addressing questions from park visitors
Communication 2	Procedures for addressing questions from policymakers, public officials, skeptics
Responses	
Adaptation 1	How can we adapt?
Adaptation 2	Adaptation strategies for implementation
Mitigation 1	What can I do (in my job)?
Mitigation 2	What can we do (NPS, region, society)?
Mitigation 3	Mitigation compliance and planning
Decisions	
Climate Change Decisions 1	Uncertainty and decision frameworks
Climate Change Decisions 2	Science to support decision making
Parks	
Parks 1	What's going on in my park?
Parks 2	What's going on in the National Park Service and in other parks?
Parks 3	In-depth information on policies, actions, and collaborations in my park and throughout the National Park Service

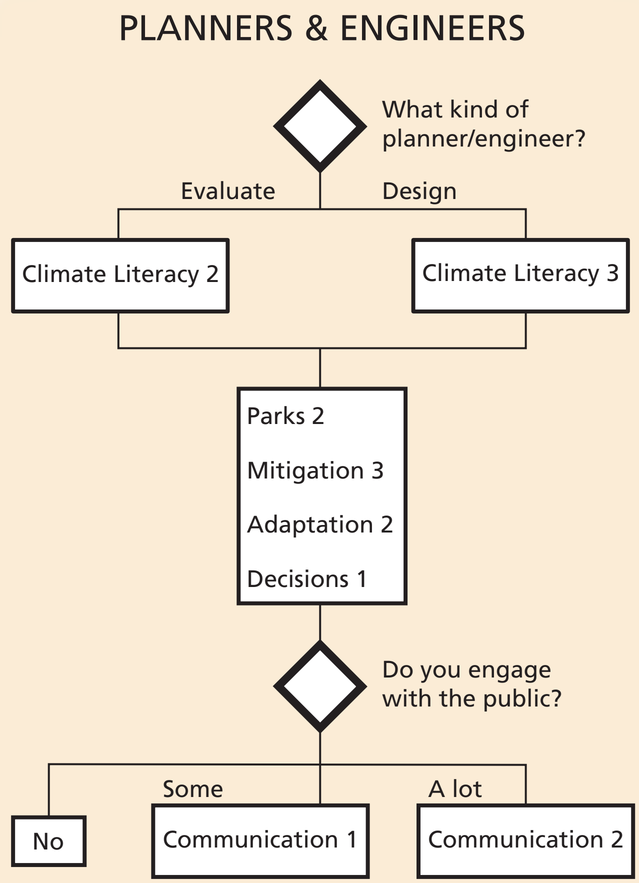

Figure 1. Sample climate change training decision tree for the planners and engineers job category.

with employee categories and suggest pathways for training (fig. 1) and criteria for vetting climate change training resources (table 6).

We recommend that all employees receive training in the core topics of basic climate literacy, NPS policies and actions in their park, and the essentials of mitigation actions that relate to their job duties. If employees interact with the public as part of their work, we recommend training in communicating climate change information.

Additional training recommendations reflect the needs of specific job categories. For example, park interpreters and educators serve as the primary NPS interface with the public and may provide climate change training to other employees. Thus we recommend that interpreters and educators receive training in more topics, including adaptation to climate change, and at a deeper level in order to effectively communicate climate change principles and answer questions from the public and fellow employees. In contrast, planners and engineers may design infrastructure, evaluate mitigation compliance actions, and develop adaptation strategies. They also may need to prepare for casual public engagement, depending on their job duties. Therefore, we recommend that planners and engineers receive deeper training in the core topics and training in adaptation and decision making under uncertainty (fig. 1), including scenario planning (Mahmoud et al. 2009) and other decision frameworks (National Research Council 2010). Climate literacy for planners and engineers includes a technical understanding of uncertainties in climate and hydrology model projections and implications for flood frequency estimation. Similarly, planners and engineers need a more technical understanding of federal regulations for compliance with environmental standards. Providing information at these deeper levels might require in-person or online training that allows for real-time interaction with the instructor.

We found substantial gaps in training on vulnerability assessment, climate change adaptation planning, and making decisions under high uncertainty.

Table 5. Sample climate literacy curricula outlines

Course	Curriculum Outline

Climate Literacy 1
 	
Rationale: Basic climate change science for laypeople that highlights the connections between global-scale climate system changes and their local conditions
	Climate change: Global to local
	• What changes climate?
	  ▪ Natural factors, greenhouse effect, past climates
	• Evidence of change
	  ▪ Global temperature, oceans, snow and ice, drought, ecosystems, greenhouse gas emissions
	• How sure are scientists?
	  ▪ Observations, paleoclimate, models, confidence
	• Local historical context
	  ▪ Local and traditional knowledge of historical climate and extremes
	• U.S. initiatives
	  ▪ National Park Service, Department of Interior
	    ◆ Landscape Conservation Cooperatives
	    ◆ Climate Science Centers

Climate Literacy 2
 	
Rationale: More in-depth examination of climate change science, for those needing extra depth, and to support knowledge for public engagement
	In-depth evidence of change and projections of the future
	• Build on Climate Literacy 1 by adding depth and climate system detail, such as
	  ▪ Global carbon cycle
	  ▪ Climate system feedbacks (e.g., ice-albedo)
	  ▪ How global atmospheric circulation affects regional climate
	    ◆ Teleconnections (e.g., El Niño)
	  ▪ Fundamentals of global observation networks
	• Basics of projected climate changes and impacts for the U.S.
	  ▪ Regional and local observed climate change impacts and the certainty of connections between them
	  ▪ Climate extremes and sea-level rise
	  ▪ Why small changes matter

Climate Literacy 3
 	
Rationale: Greater depth for those needing to apply climate science to research, planning, and infrastructure design
	Climate change science for scientists
	• Build on Climate Literacy 1 and 2
	• Tools and resources
	  ▪ Climate change projections and probabilities
	  ▪ Monitoring: local and regional networks and data
	  ▪ Climate science and service programs
	• Models
	  ▪ Deconstructing the black box: How do global climate models work?
	  ▪ Basics of integrated regional-scale modeling
	    ◆ Hydrologic and land surface models
	    ◆ Terrestrial processes and feedbacks
	  ▪ Assumptions and uncertainties
	• Projected extremes in contrast with historical observations
	• Climate and hydrologic change and methods for dealing with change
	• Statistical and dynamic downscaling
	  ▪ Methods and limitations
	• Monitoring issues
	  ▪ Global, national, regional, and local networks
	  ▪ Informal observations and citizen science

Web site assessment

We evaluated 155 Web sites containing climate change training, information, and resources with a focus on climate literacy, mitigation, and adaptation planning. We made a distinction between resources for training and those for information transfer. The former has a well-defined and consistent structure geared toward education, is self-contained, and provides a structured flow from topic to topic. The latter usually consists of loosely organized information and lacks a clearly defined structure for guiding users through related materials. We initially screened Web resources based on whether or not they provided training. We next evaluated Web sites and training materials using criteria (table 6) modified from a checklist developed by the Climate Literacy and Energy Awareness Network (http://cleanet.org), national leaders in climate science education. Our criteria addressed scientific accuracy, pedagogy, usability and technical quality, alignment with our audiences, and an overall rating.

Most online climate literacy *training* is geared toward the public and would be suitable for "Climate Literacy 1" (table 4). We found substantial gaps in training on vulnerability assessment, climate change adaptation planning, and making decisions under high uncertainty. This suggests that the Intermountain Region should target resources toward subject areas for which there is little online training. That is, the region should develop courses and train-

Table 6. Criteria for climate change training resources

Criteria
Educational quality
Are prerequisite skills and understandings accurately indicated?
Is there any indication that common preconceptions or misconceptions are addressed?
Is there testing on the material learned?
Does the resource provide a vehicle for asking questions or seeking further information beyond the activity?
Does the resource provide clear and comprehensive guidance for teachers to effectively teach the activity? [ONLY for training the trainer]
Ease of use and technical quality
Is the resource free of distracting or off-topic advertising?
Has the Web site won any relevant awards?
Are hyperlinks functional and up-to-date?
Do hyperlinks take the learner off-site for any components of training?
Are training materials and tools freely available?
Does the resource meet technical criteria that make it ready for use?
Is necessary material available in printable handout form?
Audience
Operations and administration
Interpreters, education specialists, trainers
Planners, designers, engineers
Research scientists
Resource “on-the-ground” management
Upper management (users of executive summaries)
Overall rating of relevance
High priority (resource likely to be included in collection of excellent resources)
Medium priority (resource meets basic standards)
Low priority (resource meets basic standards, but is of lower priority)
Hold for later review (keep in pool for another review at later stage)
Excellent but incomplete (excellent and relevant, but needs improved activity sheet)
Do not include (resource does not meet basic standards)

The region should develop courses and training related to adaptation and decision making under uncertainty, rather than devote resources to basic climate literacy, for which there is abundant information and adequate training resources.

ing related to adaptation and decision making under uncertainty, rather than devote resources to basic climate literacy, for which there is abundant information and adequate training resources. Additionally the region may consider using *information* and materials from diverse sources rather than relying on structured training to meet the needs of some job categories.

Conclusions

Based on survey results, which reasonably represent close to three-fourths of the 31 workforce categories surveyed but should be applied with caution when extrapolating to the entire population of IMR or NPS employees, we found that most IMR survey respondents have a reasonable grasp of observed climate impacts and some key phenomena, but climate literacy training must emphasize distinctions between climate variability and trend-driven change, future projections for IMR parks, and nuances in terminology essential to the NPS Climate Change Response Strategy. Given time and budget constraints that limit regionwide in-person training, survey results and interviews with a selected group of IMR employees lead us to recommend flexible, low- or no-cost, modular climate change training with an initial emphasis on existing online resources. We found adequate online training resources for addressing basic climate literacy, but a lack of online training in topics such as adaptation to climate change. We developed several tools for designing climate change training, including key topics, curriculum outlines, and decision trees for matching content with job duties.

Survey and interview results, and our observations of the rapid proliferation of climate information on the Internet and in the National Park Service, suggest the need for structures to organize information in a way that relates closely to employees' work-related duties. Challenges for implementing climate change training include keeping pace with changing information in this dynamic environment and producing IMR-specific materials. We note several opportunities to leverage federal and NPS efforts to produce, implement, and maintain information and training. These include the NPS Climate Change Response Program, Department of the Interior Landscape Conservation Cooperatives and Climate Science Centers, NOAA's Climate Service initiative, and insights produced by George Melendez Wright Climate Change Fellowship research. The upcoming U.S. National Climate Assessment (http://assessment.globalchange.gov), conducted every four years as mandated by the Global Change Research Act of 1990, will bolster the development of region-specific and up-to-date materials.

Acknowledgments

We thank the employees of the NPS Intermountain Region for their enthusiastic response to our survey and for making time for interviews during spring and summer 2010. We thank Lisa Graumlich, Jonathan Overpeck, Chris Hansen, Kiyomi Morino, Zack Guido, and Mike Crimmins for their insights and suggestions.

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SCIENTIFIC AND MANAGERIAL COLLABORATION

The Strategic Framework for Science in Support of Management in the Southern Sierra Nevada, California

By Koren Nydick and Charisse Sydoriak

Abstract

Accelerated climate change is projected to interact with existing agents of change and pose unprecedented challenges for the protection of native species and ecosystem services. Responding to this challenge calls for extraordinary levels of collaboration across the landscape and partnership among scientific researchers and resource managers. The Strategic Framework for Science in Support of Management in the Southern Sierra Nevada Ecoregion was collaboratively developed by federal agencies to face this challenge head-on. The framework will be carried out by the Southern Sierra Conservation Cooperative, a collaborative group of government agencies and nonprofit organizations in the Southern Sierra Nevada Ecoregion. The framework contains four goals: understanding where and why changes occur, anticipating possible futures, developing tools required to take effective action, and providing easy access to and delivery of information to target audiences.

Key words: landscape-scale collaboration, science framework, Southern Sierra Conservation Cooperative

IN 2008, FEDERAL MANAGERS AND scientists in the Southern Sierra Nevada Ecoregion (fig. 1) challenged themselves to develop and carry out a strategic science framework to help mitigate impacts from, and adapt to, climate change. The group took a landscape approach, which transcends jurisdictional boundaries and is reflected in the Department of the Interior Landscape Conservation Cooperatives and the U.S. Forest Service (USFS) All Lands Approach. Initial collaborators were Sequoia and Kings Canyon National Parks, the U.S. Geological Survey Western Ecological Research Center, the USFS Pacific Southwest Research Station, Sequoia National Forest, and Giant Sequoia National Monument. The agencies held a science symposium to review the current state of scientific research. Then, an interagency team of managers and scientists crafted the framework. This document (NPS et al. 2009), released in June 2009, centers on four overarching questions: (1) What ecosystem changes are happening, why are they happening, and what does it mean? (2) What is a range of plausible futures we could face? (3) What can we do about it? (4) How can relevant information be made available to all who need or desire it? Under these four questions, broad goal statements express the desired results. Each goal is subdivided into objectives and tasks, which are expanded upon by focused questions (table 1).

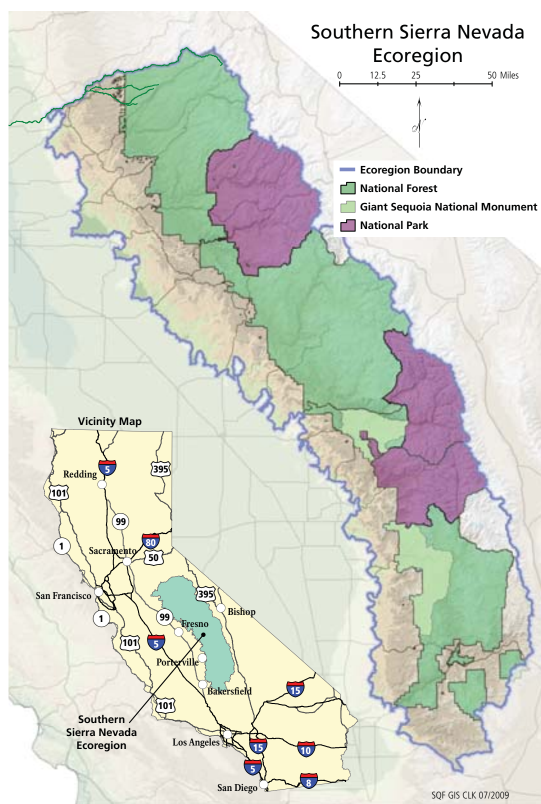

Figure 1. The Southern Sierra Nevada Ecoregion as defined by the Strategic Framework for Science in Support of Management.

Table 1. Examples of focused questions in the strategic framework

• How does each agent of change (e.g., climate, fire, air quality) affect important ecosystem elements?
• What is a plausible range of ecosystem responses to agents of change?
• Which agents of change can be mitigated and how?
• What tools and approaches further ecosystem resilience, resistance, realignment, and response to known agents of change?
• What tools support prioritization of management response (i.e., triage approaches)?
• How can we strategically identify parts of the landscape for different management actions?

To apply the framework, federal and state agency representatives met several times in 2010. They were joined by nonprofit organizations engaged in climate change adaptation planning and formed a public-private science conservation partnership. The National Park Service and the U.S. Forest Service crafted an interagency agreement to fund a science coordinator to lead the effort. The collaborative group

Table 2. Southern Sierra Conservation Cooperative founding members and observers

Federal agency members
• Bureau of Land Management: Central California District
• National Park Service: Devils Postpile National Monument (pending), Sequoia and Kings Canyon National Parks
• U.S. Forest Service: Inyo National Forest, Sequoia National Forest/Giant Sequoia National Monument, Sierra National Forest
• U.S. Geological Survey: Western Ecological Research Center (pending)
Nongovernmental organization members
• Conservation Biology Institute
• Sierra Business Council
• Sequoia Riverlands Trust (pending)
State of California member
• Sierra Nevada Conservancy (pending)
Observers
• NPS Sierra Nevada Network Inventory and Monitoring Program, Stanislaus National Forest, The Nature Conservancy, Yosemite National Park

Table 3. Initiatives proposed by the cooperative and their alignment with the goals of the strategic framework

Goal 1: Detection and attribution
• Coordinated regional monitoring strategies—tree population dynamics and Pacific fisher populations
Goal 2: Forecasting future conditions
• Alternative fire management futures (in progress; see the following article on page 44)
• Comparison and integration of climate adaptation projects
Goal 3: Tools and actions
• Both projects under goal 2 also address goal 3
• Kaweah Watershed coordinated restoration initiative
• Enabling forest restoration goals via ecologically managed biomass generation, a cost-benefit analysis
Goal 4: Communication
• Information clearinghouse for shared learning
• Education and outreach initiative
Integrative across goals
• Reevaluate invasive plant programs and practices under alternative climate futures
• Investigate the vulnerability of blue oak woodlands to climate change and develop adaptive management guidelines

became the Southern Sierra Conservation Cooperative ("the cooperative," see table 2). The mission of this cooperative is to leverage partners' resources and efforts to conserve the regional native biodiversity and other key ecosystem functions in the Southern Sierra Nevada Ecoregion in the face of accelerated agents of change. These agents of change include climate change, habitat fragmentation, encroaching urbanization, shifting fire regimes, invasive species, and increasing air pollution. Managers, scientists, and stakeholders in the cooperative have complementary expertise, capabilities, land bases, fund sources, and more, which when added together have great synergistic power. The cooperative's geographic scope is loosely defined by the boundaries of the Southern Sierra Nevada Ecoregion as defined in the Strategic Framework for Science in Support of Management (fig. 1), but may shift depending upon the scope of initiatives and membership. To avoid jurisdictional conflicts, the cooperative will not make resource management decisions or forward an agenda of any particular management action. Rather the cooperative will provide and exchange information to better inform decision makers. It will assess ecological and societal vulnerabilities due to agents of change and the associated costs and benefits of potential management actions, but will not make a recommendation to select a preferred alternative.

The cooperative meets twice annually for two-day workshops and holds conference calls every two months between workshops. Many of the founding members have signed the initial memorandum of understanding (others are pending as this article goes to press) and an administrative framework has been developed. Importantly, members and observers have generated a list of initiative ideas to provide critical knowledge, understanding, and tools regarding agents of change and potential response actions (table 3). Several of these ideas have been crafted into formal funding proposals. The "alternative fire management futures" initiative described in the following article is in progress.

Of particular priority is the establishment of an information clearinghouse for shared learning. Scientists, resource managers, decision makers, and members of the public involved in landscape-scale conservation and climate change adaptation planning and implementation need to access, translate, evaluate, and share information ranging from raw data to vulnerability assessments, decision-support tools, reports, technical syntheses, and nontechnical summaries. Existing online clearinghouses offer data specific to agencies, states, and research programs, and can include file sharing and spatial information capabili-

The cooperative will not make resource management decisions or forward an agenda of any particular management action. Rather the cooperative will provide and exchange information to better inform decision makers.

ties. Despite these resources, no effective means yet exists to collectively serve this range of information on the geographic scale most needed for on-the-ground conservation. Our goal is to determine the most efficient and effective way to design an information resource for landscape-scale conservation that provides multiple levels of accessible, high-quality information appropriate to different audiences while also facilitating collaboration among users. We will not reinvent services already provided by other clearinghouses, but will utilize and connect existing resources into a shared "one stop" landscape-scale portal. A working group was formed, composed of several cooperative member representatives and additional collaborators and in-kind supporters, such as the University of California–Merced's Sierra Nevada Research Institute, U.S. Fish and Wildlife Service, California Department of Fish and Game, and Environmental Systems Research Institute (ESRI) Conservation Program. The group crafted a proposal to conduct a formal needs assessment and feasibility study, develop an implementation plan, and produce a Web-based prototype that could easily be shared with other landscape conservation partnerships.

The cooperative faces many challenges and already has learned important lessons. First, we have seen that it is critical to quickly move past start-up administrative tasks to keep interest among members and momentum focused on implementing the Strategic Framework for Science. Second, in order to do so we have learned that membership should grow slowly, as educating new members takes time. Third, progress can be significantly slowed by something as simple as turnover in staff, especially in leadership positions. Fourth, the cooperative must be explicit in stating that its focus is on generating information, tools, and management options, and that it does not make policy decisions or forward an agenda of any particular management recommendation. Last, education and outreach are critical components of any climate change adaptation project and are especially necessary to enable the individual members to engage in efficient management decision-making and implementation efforts.

See the following links:

- http://www.nps.gov/seki/naturescience/sscc.htm (general information on the cooperative and download of documents)
- www.fs.fed.us/r5/spotlight/2009/snfframework.php (USFS's overview of the Strategic Framework for Science in Support of Management)
- www.fs.fed.us/psw/southernsierrascience (proceedings of the 2008 Southern Sierra Science Symposium)
- A virtual science learning center Web site, including cooperative information, in development now

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REGIONAL FIRE PLANNING

Alternative futures for fire management under a changing climate

By Koren Nydick and Charisse Sydoriak

Abstract

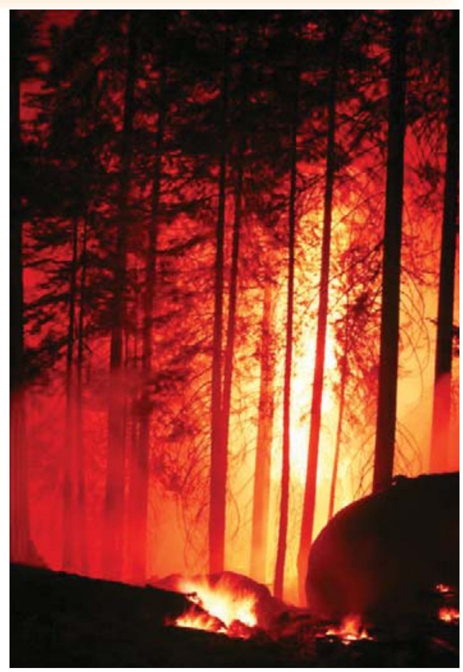
The Alternative Fire Management Futures initiative is the first test of the Strategic Framework for Science in Support of Management in the Southern Sierra Nevada Ecoregion. The goal of this project is to develop critical information, processes, and tools to evaluate and create realistic and flexible fire management objectives based on plausible future environmental conditions in the Southern Sierra Nevada Ecoregion. The project is a collaboration among resource managers, fire managers, and scientists and uses a landscape approach. We combine existing tools (scenario planning, climate change vulnerability assessment, a climate change adaptation "toolbox," and structured decision making) to provide both qualitative strategic and spatially explicit operational management decision support. Results from this project will provide inputs to a National Park Service (NPS) resource stewardship strategy and NPS and U.S. Forest Service (USFS) fire management plans.

Key words: climate change adaptation planning, fire management, Sierra Nevada

THE SOUTHERN SIERRA NEVADA Ecoregion contains extensive forests that depend upon periodic fire for their persistence (fig. 1). This includes fire-adapted giant sequoia trees, which not only depend on but also thrive with frequent fire. As a result of a century of fire exclusion, however, many otherwise protected landscapes have developed unnatural species compositions and forest structure with heavy fuel accumulations. In recent decades, warming temperatures and a shift toward earlier snowmelt have interacted with these changes in forest structure, resulting in more frequent lightning ignitions, more area burned, more frequent large wildfires, greater extent of stand-replacing high-severity fire, longer wildfire durations, and longer wildfire seasons (Westerling et al. 2006; Miller et al. 2008; Lutz et al. 2009). With projections of continued warming, fire activity and severity are expected to keep rising in the Sierra Nevada, increasing the risk of catastrophic wildland fire to human safety, property, communities, giant sequoias, and ecosystems. For example, four climate change scenarios forecast an increase in probability of large wildfires from 100% to 400% by 2070–2099 (Westerling and Bryant 2008).

Park managers increasingly recognize that climate change affects their abilities to appropriately manage fire and conserve valued ecosystem elements and services. Southern Sierra Nevada resource managers have decided to approach the challenge head-on to prepare for, reduce, and respond to these impacts. Sequoia and Kings Canyon National Parks, Sequoia National Forest, and Giant Sequoia National Monument are working together on a pilot project to develop the capacity to manage fire under a "new lens" and to revise fire management objectives, tools, and methods so that valued resources sensitive to climate change can be conserved at an appropriate scale. This is the first application of the *Strategic Framework for Science in Support of Management in the Southern Sierra Nevada Ecoregion* (NPS et al. 2009), described in the previous article. Importantly, the project seeks not only to understand which resources are most vulnerable to changes in climate, fire regimes, and other interacting stressors, but also to identify where these vulnerable resources are located and describe where and how fire management activities may need to vary in the future under different scenarios. Our specific project objectives are listed in table 1.

This effort is an experiment reaching into uncharted territory, an iterative process that will be repeated and refined over time. Anticipated initial outputs include the



USGS/NATE STEPHENSON

Figure 1. Climate change adaptation strategies include prescribed burns like this fire in Sequoia National Park, which was also planned to learn about the effects of fire on hydrology and water chemistry.

Table 1. Project goal and objectives

Project Goal:	Develop the capacity to manage fire successfully under a "new lens" and to revise objectives, tools, and methods so that valued resources that are sensitive to climate change can be conserved at an appropriate scale.
Objective 1:	Define a range of plausible future scenarios with relevance to potential changes in climate, focal resources, and management policies.
Objective 2:	Identify *which* resources are likely to be most vulnerable to the interacting effects of changing climate, fire regimes, and other agents of change.
Objective 3:	Describe *where* biodiversity and other selected values are most likely to (a) remain stable without intervention, (b) survive if current fire management objectives and prescriptions are applied, and (c) suffer losses unless new fire management strategies are developed.
Objective 4:	Identify *what* fire management objectives and prescriptions (coping strategies) should be to enable the conservation of valued fire-dependent ecosystems and to protect fire-sensitive focal resources.
Objective 5:	Identify *how* and *where* fire management efforts may need to vary in the future as a consequence of changing climate.
Objective 6:	Share lessons learned from this project with the public and other federal land managers.

development of a range of plausible future scenarios of climate, fire, and vegetation; spatially explicit resource vulnerability assessments; a decision support framework; and expertise and knowledge required to effectively and efficiently revise fire management objectives, prescriptions, and techniques.

The pilot project is an initiative of the newly formed Southern Sierra Conservation Cooperative (also described in the previous article). In addition, the project team will work collaboratively with the Southern Sierra Fire Science Integration Work Group. The information, tools, and management options developed as a result of this exercise will inform the five-year review of the parks' Fire and Fuels Management Plan scheduled for 2013, as well as upcoming U.S. Forest Service fire management plans.

Project approach

The alternative fire management futures project incorporates multiple complementary climate change adaptation approaches and tools. The National Park Service has been experimenting with a climate change scenario planning approach that overcomes the paralysis of uncertainty by using system drivers to create a range of plausible futures (Peterson et al. 2003; NPS 2011) (see article, page 26). Scenario planning is a strategic process in which managers and scientists describe divergent science-based future scenarios with the objective of revealing potential surprises and producing leaps of understanding. The goal is to make strategic decisions that will be sound for a range of plausible futures. Thus, scenario planning is a structured way of developing "what if" questions and analyses. Additionally, new guidance on climate change vulnerability assessments is now available, shedding light on methods to describe the exposure, sensitivity, and adaptive capacity elements of vulnerability (Glick et al. 2011). Also, the U.S. Forest Service has developed a toolbox approach that focuses on flexible, ecosystem-based management using an array of "no regrets," hedging, triage, proactive, and reactive tools to enhance resistance, resilience, response, and realignment of ecosystems (Millar et al. 2007; Peterson et al. 2011). Case studies of climate change preparedness planning using the scenario, vulnerability assessment, and toolbox approaches often describe strategic planning recommendations or species- or habitat-based vulnerability rankings, but they do not necessarily provide the on-the-ground spatial context sought by operational managers (but see Cole et al. 2011 for a spatially explicit treatment of the Joshua tree).

The alternative fire management futures exercise is a hybrid process that attempts to combine these approaches to address both strategic and operational preparedness. By combining approaches, our project team faces three key challenges: (1) linking the out-of-the box, big-picture thinking that scenario planning fosters with the spatial context that a geospatial vulnerability assessment provides, (2) communicating uncertainty in geospatial products and avoiding false precision and map misuse, and (3) translating climate change exposure and resource sensitivities into decision-support tools that will facilitate managers' abilities to increase resistance, resilience, and adaptive capacity of natural and human systems. Similar to the other approaches, this project has steps to orient, synthesize/analyze, consider management actions, and share lessons learned (see fig. 2, next page). While most of the steps in the project are collaborative (purple arrows in fig. 2), it is important that certain elements fall into the domain of scientists and that others are the responsibility of managers (blue and red arrows, respectively, in fig. 2).

Scenario and vulnerability assessment workshops

A core team of agency scientists and managers, a university science cooperator, and an agency science coordinator to facilitate communication among them is engaged throughout the process. The first workshop was held on 20 January 2011 to gather this core team, provide background information, and review/revise the project objectives and process ("orient" in fig. 2). On 23–24 February we invited additional

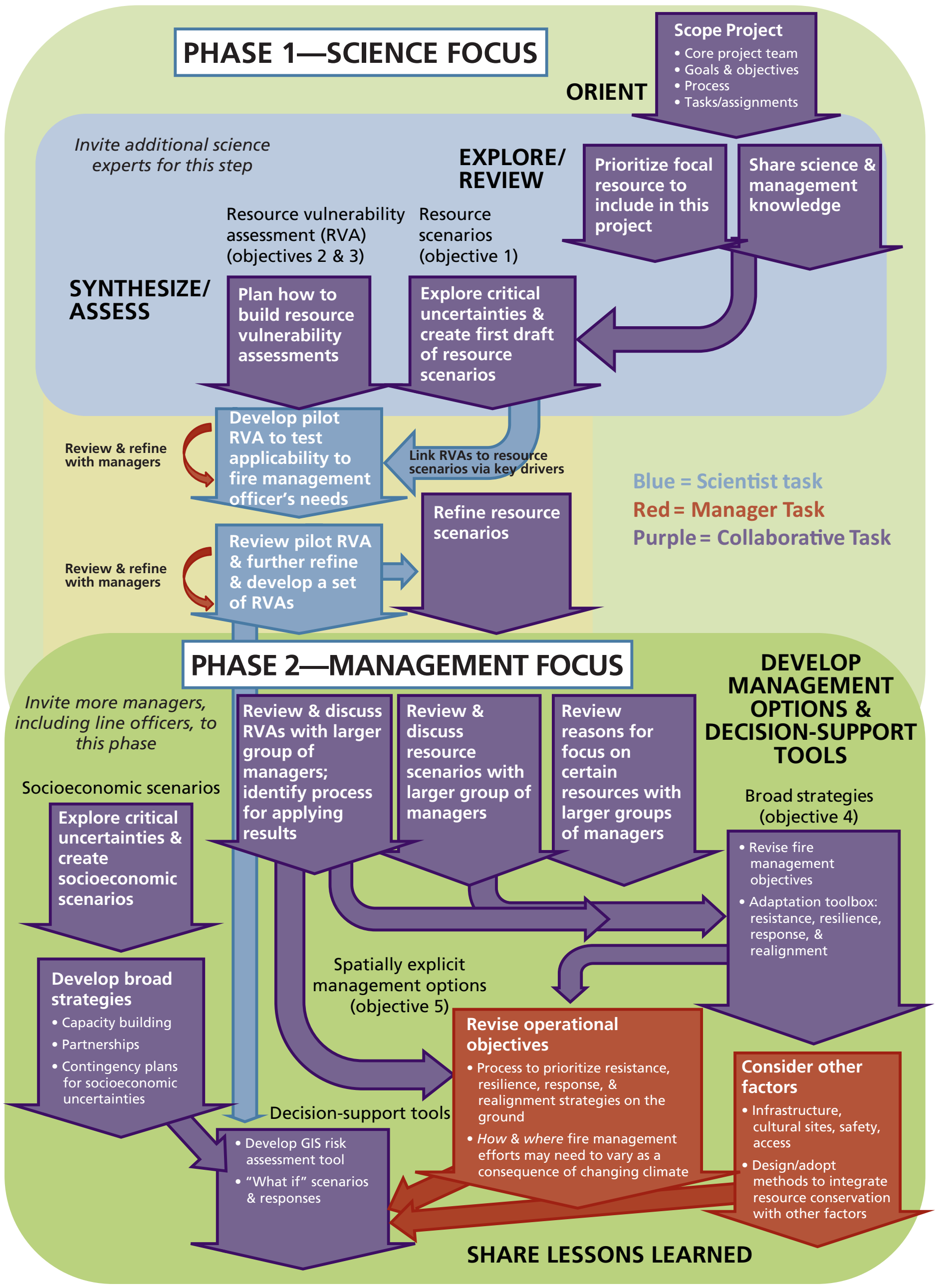


Figure 2. The fire management alternative futures project process is a collaborative approach that combines elements of scenario planning, climate change vulnerability assessments, and the climate change adaptation toolbox.

subject-matter science experts to a second workshop to help us kick off the *explore/review* and *synthesize/assess* steps. First, scientists shared knowledge about climate-fire-vegetation interactions. Then fire managers shared how fire is managed strategically and operationally and described challenges they face, especially in relation to climate change. On the second day, we began developing scenarios. The team identified climate water deficit (which integrates climate and water availability) and fire ignitions as two key uncertain yet important system drivers and used them to delineate four future scenarios. Smaller groups began refining the climate, fire, and vegetation responses for each scenario. To close the meeting, we discussed how to geospatially assess resource vulnerability. The small work groups continued refining scenarios via e-mail and the project leaders developed a conceptual plan and initial ideas for the vulnerability assessment.

The core team reconvened on 2–3 May to revisit the scenarios and produce a work plan for the vulnerability assessment. We found that the scenarios were not divergent enough and stepped back to parse out the important differences in hypothesized resource responses. We also embedded a second axis in the major axis-system. This secondary axis depicted the interannual variability versus seasonality of system drivers. We selected a plausible quadrant in the secondary set of axes to assign to each of the four original scenarios. This resulted in four "hypotheses of future change" scenarios titled "fire burnout," "mega mosaic," "fuel buildup," and "slow change." We added a fifth scenario called "landscape die-off" that could co-occur with any of the other scenarios. Because of the steep elevation gradient in the Sierra Nevada (about 500–14,495 ft [153–4,421 m] above sea level), we considered resource responses separately at low, mid, and high elevations. A small group has been assigned to continue developing the scenarios to ensure scientific robustness, internal cohesiveness, and divergence.

For the geospatial vulnerability assessment, we decided to take a climate envelope modeling approach (using downscaled data) to identify areas of hypothesized climate stability and stress for the major vegetation assemblages. We would then overlay modeled fire exposure, existing sensitivity of the landscape to fire, and various other indices of sensitivity for key valued resources. We will partially link the vulnerability assessment to the narrative scenarios by using four combinations similar to the narrative scenarios but formed by crossing two global circulation models and two greenhouse gas emissions scenarios. Using both the narrative sce-

Sequoia and Kings Canyon National Parks, Sequoia National Forest, and Giant Sequoia National Monument are working together on a pilot project to develop the capacity to manage fire under a "new lens" and to revise fire management objectives, tools, and methods so that valued resources sensitive to climate change can be conserved at an appropriate scale.

narios and the vulnerability assessments, we plan to identify important thresholds of concern that may drive future management decisions. The next convening of the core team will be a resource consequences and management options workshop, scheduled for January 2012.

In phase two, the management focus, we will invite line officers and staff advisors to a March 2012 workshop to review scientific products, potential management options, and hypothesized consequences, and identify broad management strategies and on-the-ground operational practices. The last steps of the project are to develop and test a decision-support tool, possibly incorporating structured decision-making concepts, and to share lessons learned.

We hope that this project will contribute to the science (and art) of climate change adaptation planning by exploring and testing how to combine various existing approaches, such as scenario planning, vulnerability assessment, climate change adaptation toolbox, and structured decision making, to provide both shorter-, and longer-term (10–100 years) strategic and on-the-ground management decision-making support. Locally in the Southern Sierra Nevada, this project will provide critical information for an NPS resource stewardship strategy and both NPS and USFS fire management implementation plans.

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STATE OF THE SCIENCE

Sustainable fire: Preserving carbon stocks and protecting air quality as Sierra Nevada forests warm

By Leland W. Tarnay and James A. Lutz

Figure 1. Glaciers and fires have influenced the landscape of the Sierra Nevada. Glacially smoothed Mount Starr King rises behind the area burned by the 1991 Illilouette fire. The matrix of different burn severities can be seen within the fire perimeter (red outline) viewed from Glacier Point.

FIRE HAS PHYSICALLY SHAPED THE SPECIES COMPOSITION and structure of Sierra Nevada forests, just as glaciers have shaped the underlying landscape (fig. 1). The long, hot summers that occur in the Mediterranean climate of the Sierra Nevada favor fire, because they dry out vegetation and dead woody debris, creating fuel that readily burns when lightning (also common in the Sierra Nevada) strikes. Fire converts that vegetation—living or dead—into smoke. Smoke from fires contains readily inhalable fine particles that can impair human health, while also obscuring scenic vistas that visitors expect when they visit national parks (Clinton et al. 2006).

Smoke emissions also include greenhouse gases (e.g., carbon dioxide, or CO_2) that derive from the carbon in the combusted biomass. While these emissions temporarily contribute to global warming, carbon is returned to the landscape as vegetation takes up CO_2 post-fire (Hurteau and Brooks 2011). The resulting net "carbon balance" and the amount of carbon left on the landscape as biomass (i.e., the "carbon stock") can vary, depending on the period over which that stock is measured and on whether the post-fire vegetation type covering the landscape contains as much carbon as the pre-fire vegetation.

Fire suppression over the last 130 years has changed vegetation types and likely carbon stocks, leaving large portions of Sierra Nevada parks with forest stands that have not burned in almost a century. As a result, small trees and shrubs have grown in under the larger trees, providing "ladder fuels" that could carry fire into the canopy of the larger trees, which are otherwise quite fire-resistant (fig. 2). Fire entering such an overly dense understory can burn at higher intensity, grow faster, release more smoke, and kill more (potentially all) trees. Preventing fires in one year can make a future fire even more severe, perhaps even leading to post-fire vegetation characterized by shrubs instead of forest. The increased fire risk that is the legacy of fire suppression in the Sierra Nevada endangers not only carbon stocks but also our ability to manage fires in a way that minimizes air quality impacts and preserves clean and clear air for visitors and local communities. Climate change has the potential to add another dimension of urgency to this issue by creating longer, drier, hotter summers in which these higher-severity, faster-growing fires are more likely (Lutz et al. 2009b).

Abstract
Climate change may affect temperature, precipitation, snowpack, and fire in the Sierra Nevada, and the effects on various park resources may range from moderate to extreme. But any level of change has ramifications for the day-to-day work of park managers. One technique used by climate scientists and ecologists is dissecting interannual variability into normal and extreme components (i.e., warmer/cooler and wetter/drier) years and comparing differences between those categories. Because the natural range of variability of climate parameters in the Sierra Nevada is larger than recent trends, recent historical highs and lows give us insight into future conditions. Timing of snowpack melt is a key attribute that varies between hot and cool years, and interannual differences in the timing of snowmelt have been shown to have a significant association with fire activity as well as the amount of vegetation converted to smoke and greenhouse gases by fire. This article reviews the implications of these changes for fire management in the context of our current understanding of climate, historical fire suppression, fire frequency, fire severity, and the effects of climate and fire on air quality. We explore positive feedbacks among climate, fire, and air quality that may threaten forests and forest carbon stocks in the Sierra Nevada. We also discuss the potential importance of fire management as a part of an integrated NPS climate response strategy for mitigating threats to air quality, fire ecology, and carbon stock stability as the projected climate changes become manifest.

Key words: air quality, carbon storage, climate change, fine particles, fire ecology, fire severity, greenhouse gases, Sierra Nevada

This scenario highlights the tension of managing Sierra Nevada forests under a warming climate regime: lightning (and humans) will continue to ignite fires, and each suppressed fire, though minimizing immediate smoke impacts, increases the risk of larger, less manageable fires and smoke impacts in the future. Developing the optimal fire management solution requires that we reconcile what we know about fire, forests, smoke, and projected climate with the objectives of protection of life and property, minimization of smoke impacts, and the need to provide stewardship of these forests.

Forty years ago, the National Park Service realized that fire had been unnaturally excluded from the Sierra Nevada and began allowing fires to burn under prescribed conditions, first in Sequoia and Kings Canyon national parks, and soon after in Yosemite National Park. In Yosemite, NPS fire management and the U.S. Geological Survey have been partnering to develop a more quantitative, science-based approach to managing fire and the ecology of fire-adapted forests. In this article we summarize some of the lessons relevant to fire managers interested in adaptively managing such landscapes.

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Figure 2. The spatial arrangement of forests affects how much carbon a landscape can contain and also its fire risk. Dense forests (left) contain large amounts of carbon, but the horizontal and vertical fuel continuity increases the risk of high fire mortality and large smoke production. Open forests (center) include large trees that store considerable carbon, and the lower density of smaller trees reduces the risk that fire will rise into the canopy. Patchy forests (right) have areas of both high and low carbon storage, and the lack of continuous fuels both horizontally and vertically increases the chances of a mosaic of burn severities.

A science summary

Fires were more prevalent before Euro-American settlement

Our current perception of a normal fire year in terms of area burned and smoke production is very different from what likely occurred in the presettlement era. Prior to Euro-American settlement, the combination of lightning-ignited fires and the American Indian tradition of burning resulted in annually burned areas over 10 times the area burned annually from 1950 to 1999 (Stephens et al. 2007). At presettlement levels of fire activity, fires and smoke would have been prevalent on the landscape for most of the summer—always at low levels, and sometimes at very high levels.

Fire is sensitive to climate

In the Sierra Nevada, the number of lightning-ignited fires is related to the spring snowpack because very little precipitation occurs during the summer and autumn fire season. Snowpack limits fires, but low snowpack does not always imply more fire (fig. 3, next page). Wet years have very few ignitions, but in dry years the number of lightning ignitions depends on the number of lightning strikes. Declining snowpack, a projected consequence of climate change (Mote et al. 2005), could significantly decrease the snow limitation in wet years and lead to a greater number of lightning ignitions, any of which could grow to a large size (Lutz et al. 2009b). At the scale of Yosemite, there isn't yet a time trend with respect to number of fires, area burned, or burn severity.

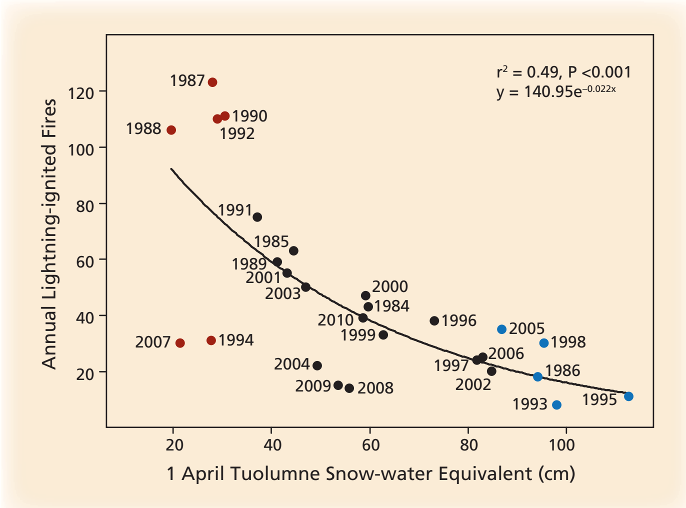


Figure 3. The graph shows the number of lightning-ignited fires of all sizes for each year from 1984 to 2010 and the Tuolumne Meadows 1 April snow-water equivalent for that year. In years with high 1 April snowpack (blue), lightning-ignited fires are less frequent because fuel remains wetter (and secondarily because of fewer lightning strikes). In years with low 1 April snowpack (red), fuel moisture content is permissive of ignition, but depends on the presence of lightning. Years with characteristic 1 April snowpack (black) generally do not feature large numbers of lightning-ignited fires.

SOURCE: ADAPTED FROM LUTZ ET AL. 2009b

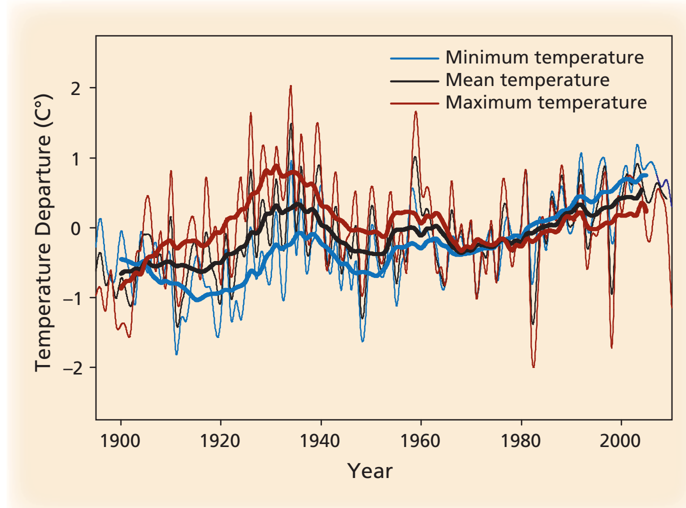


Figure 4. Trends in minimum, mean, and maximum temperatures for the Sierra Nevada from 1900 to 2010. Thin lines represent annual temperatures and thick lines represent 11-year moving averages. From 1981 to 2010, mean temperature in the Sierra Nevada increased at a rate of 2.7°C per century.

SOURCE: CALIFORNIA CLIMATE TRACKER, HTTP://WWW.WRCC.DRI.EDU/MONITOR/CAL-MON/ (ABATZOGLOU ET AL. 2009)

But at regional or continental scales, a trend of increasing fire area (Westerling et al. 2006; Littell et al. 2009) and increasing fire severity (Miller et al. 2008) has already been detected.

Normal is the new cool

Considering moisture persistence and fire behavior, 2010 appeared to local fire managers to be a relatively cool year, with uncharacteristically slow-growing fires and moderate fire behavior. However, compared with the long-term climate record for the Sierra Nevada, 2010 was actually normal from a temperature perspective (fig. 4). Minimum and average temperatures have been higher than the long-term average for each of the 10 years prior to 2010, and maximum temperatures have been higher for 8 of 10 years (Abatzoglou et al. 2009). With cold years becoming less frequent, climate in the Sierra Nevada is coming to resemble a combination of hot and normal years (Lutz et al. 2009b). Projected climate changes may increase water stress on all plants (Lutz et al. 2010) and, by drying out fuel, may increase the area burned (Littell et al. 2009). From a fire management perspective, this only increases the potential urgency for reintroducing fire to densely vegetated, lower-elevation areas when cooler conditions occur—there may be fewer opportunities to treat such areas safely as the climate warms.

Fire-resistant forest structure affects water stress and carbon sequestration

Open-canopy, old-growth forest structure is fire-resistant, and because this ecosystem type is maintained by fire, it thrives where managers are provided opportunities to allow fires to burn, reducing fuel levels and competing vegetation. The resulting open forest structure (figs. 2 and 5) is characterized by large trees—trees that sequester large quantities of carbon and provide habitat for a variety of vertebrate and invertebrate species (Lutz et al. 2009a). Because these fire-maintained forests are in turn fire-resistant, they stabilize landscape-level carbon stores for many years into the future (Hurteau and Brooks 2011). When fire is excluded, these forests experience rapid regeneration of dense stands of smaller trees and shrubs. These small trees and shrubs increase fire severity and compete with larger trees for water, which may in turn decrease the ability of large trees to rebound from fires. Some combination of increased tree densities and climate change has already caused a decline in large-diameter trees (Lutz et al. 2009a), so realizing the goal of burning larger areas at low to moderate severities will be even more important in the future for preserving these forests.

2007 PHOTO BY J. VAN WAGTENDONK

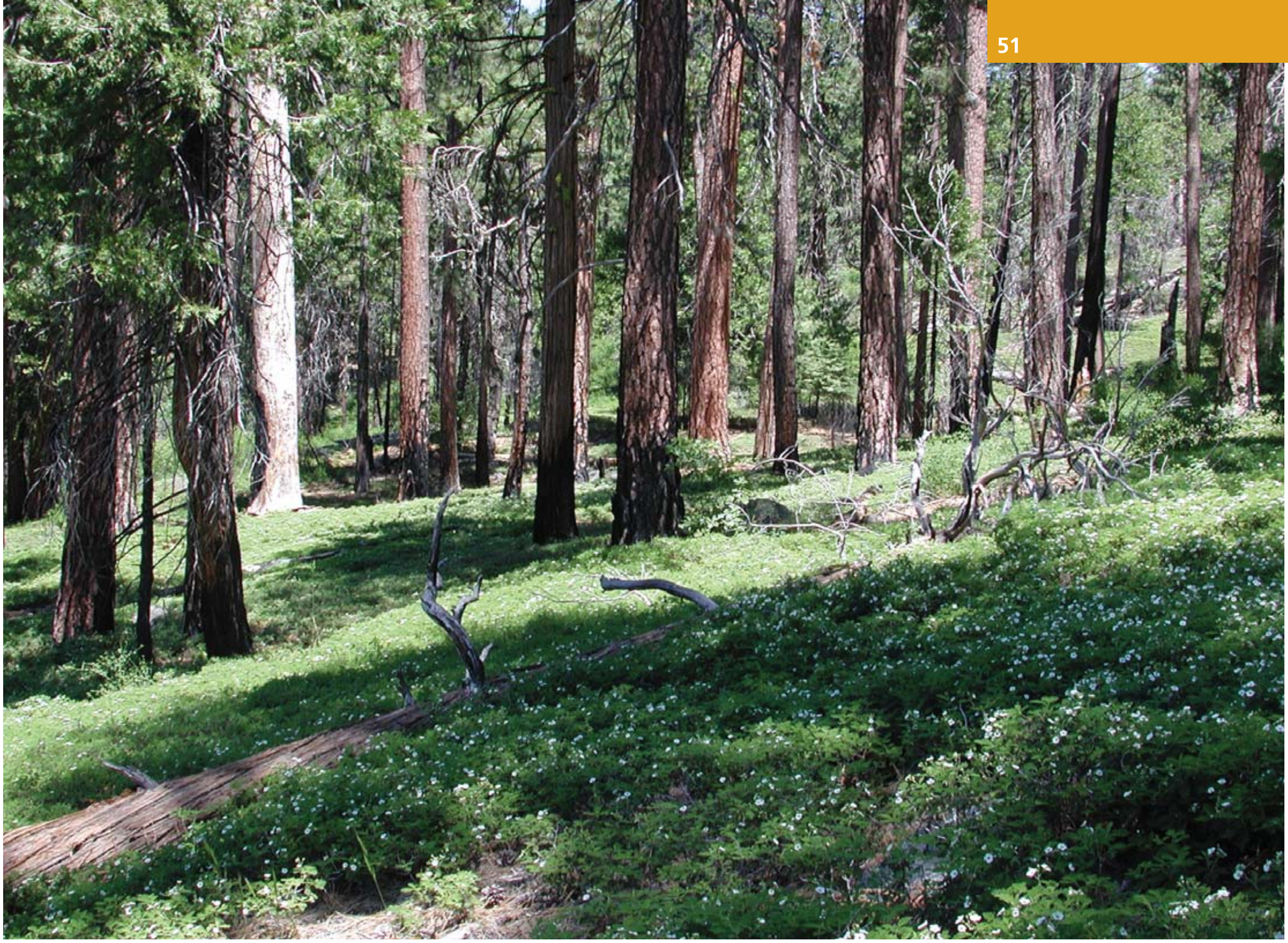


Figure 5. A characteristic open-canopy ponderosa pine–incense cedar forest, burned in 1978 by a prescribed fire and in 1996 by a wildfire.

Forests contain large stocks of carbon, which fire can potentially convert to greenhouse gases

Preliminary estimates based on vegetation plots in Yosemite suggest that the boles (tree trunks) of all medium-sized and large trees in Yosemite contain at least 29 teragrams (Tg, or million metric tons) of carbon, which, if converted directly to CO_2 (CO_2eq, the standard unit of greenhouse gas measurement), is roughly equivalent to 110 Tg. This is more than 1,600 times the amount (0.064 Tg CO_2eq) emitted annually from all vehicles and facilities in Yosemite National Park or about 12 times the amount emitted annually from the entire city of San Francisco (8.8 Tg CO_2eq). Obviously, no fire is likely to completely convert all tree biomass in Yosemite into greenhouse gases at one time, but large fires can and do occur—one large California fire complex of 235,000 ha (580,685 ac) in timber and brush emitted approximately 6 Tg CO_2 over several days (Clinton et al. 2006).

Severity matters

Large amounts of carbon can be released by fire, either immediately through burning or indirectly through the slow decomposition of fire-killed trees. If a fire kills most of the aboveground vegetation, it is considered to have a high severity. In that case, most of the downed wood, litter, duff, small trees, shrubs, and herbs are converted immediately to smoke and greenhouse gases, but only a small portion of larger trees is consumed. If a fire leaves most of the vegetation (particularly the larger trees) alive, it is considered to be of low severity. Although few large trees are killed (fig. 2, previous spread, and fig. 6, next page), the consumption of litter and duff can still be high. In the Sierra Nevada, fires usually burn as complex mosaics of high, low, and intermediate severities. Net greenhouse gas emissions from any one fire (i.e., fire emissions and post-fire decay of fire-killed vegetation minus the incorporation of CO_2 back into biomass) can only be determined decades to centuries later, because pre-fire and post-fire vegetation may differ (Hurteau and Brooks 2011).

Climate will likely affect fire severity and increase risk of high fire severity

Fuel accumulation and longer, drier summers increase the risk that existing carbon stores will literally go up in smoke (and greenhouse gases). However, modeling and analysis show that burning biomass under conditions that preserve the large trees (i.e., low to moderate fire severities) can stabilize total forest carbon, and makes these carbon stores more resistant to future drought and fire (North and Hurteau 2011; fig. 7, next page). Computer model extrapolations show that in Yosemite's mixed-conifer forests, initial fire emissions in a frequent-fire scenario can reduce overall long-term emissions 50% to 60% (not counting post-fire decomposition of dead trees) (Wiedinmyer and Hurteau 2010). Emissions of greenhouse gases and smoke are all reduced in the frequent, lower-severity fire scenario.

Figure 6. Prescribed burn in Yosemite Valley. The prescribed burn reduces fuel and kills smaller-diameter trees while leaving larger-diameter trees alive.

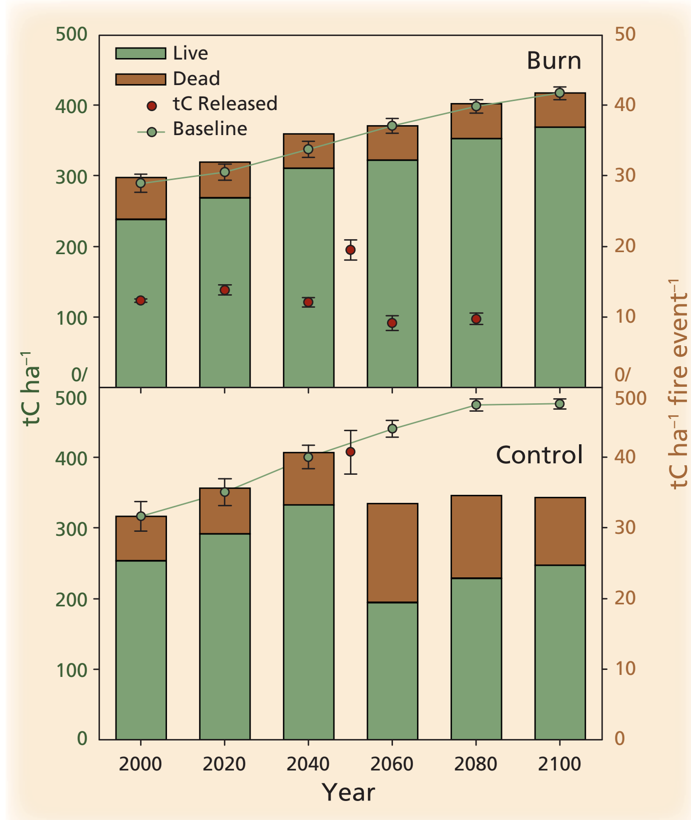


Figure 7. Modeled metric tons of carbon per hectare stored in live- and dead-tree biomass and released by a fire in 2050 in forest plots that were previously burned (top) and not previously burned (bottom).

SOURCE: ADAPTED FROM HURTEAU AND NORTH 2009

Less severe fires reduce the size of subsequent fires

Multiple less severe fires have a short-term emissions benefit and also reduce risk to forests in the long term. Fires consume fuel and limit the spread of further fires for about 10 years (Collins et al. 2009). When areas have not burned for several decades, fires can become 10 times larger than when fuel has recently been consumed (Scholl and Taylor 2010). Allowing multiple smaller fires over decades generates a patch mosaic that reduces the chances that a subsequent fire will burn most of the area at one time. Furthermore, fuel reduction through burning reduces the incidence of large, high-severity patches when fires occur. Forty years after reintroducing fire, portions of Yosemite have apparently returned to this characteristic fire regime (Collins et al. 2009) (fig. 8).

Large enough to be ecologically relevant, but small enough to be manageable

Fire is one of the few landscape-scale tools available to land managers, but those fires have to be greater than about 25 ha (62 ac) in area to be ecologically relevant at these scales. In Yosemite, 91% of lightning-ignited fires from 1984 to 2010 were small (<25 ha), and mostly burned at low severity. However, 97% of the area burned is from moderate-sized fires (>40 ha [99 ac]). Large fires (>2,000 ha [4,942 ac]) are a relatively new phenomenon, coincident with the advent of fire suppression and fuel accumulation in lower-elevation forests and woodlands that previously burned once or twice per decade. The eight largest lightning-ignited fires in Yosemite since 1930 have all occurred since 1990. These large fires have the highest proportion of area burned at high severity and they burned much of that area faster (e.g., >200 ha/day [494 ac/day]) (fig. 9). Fire size is sometimes a poor surrogate for fire effects, because severity of a fire depends much more on the fire intensity and the rate of fire growth. Nonetheless, our experience and working hypothesis are that moderately sized fires that grow at moderate rates yield heterogeneous post-fire landscapes without the type-conversion (forest to shrubland) that can occur in fires that burn at high severity.

Fire growth determines smoke impacts

Fires affect both air quality (human health), due to the release of inhalable fine particles, and visibility (haze) because these same fine particles reduce visual range (for more information see www.nps.gov/air). Tracking and, if possible, managing fire growth are essential for managing air quality during fires because the amount of fuel burned directly affects how much smoke gets into the air on a given day. Since federal land managers have been required under 1990 amendments to the Clean Air Act to minimize smoke impacts from fires, it is important to consider and, if possible, minimize potential impacts on air quality of smoke from fires. Here in Yosemite, emissions estimates of fire growth in the past

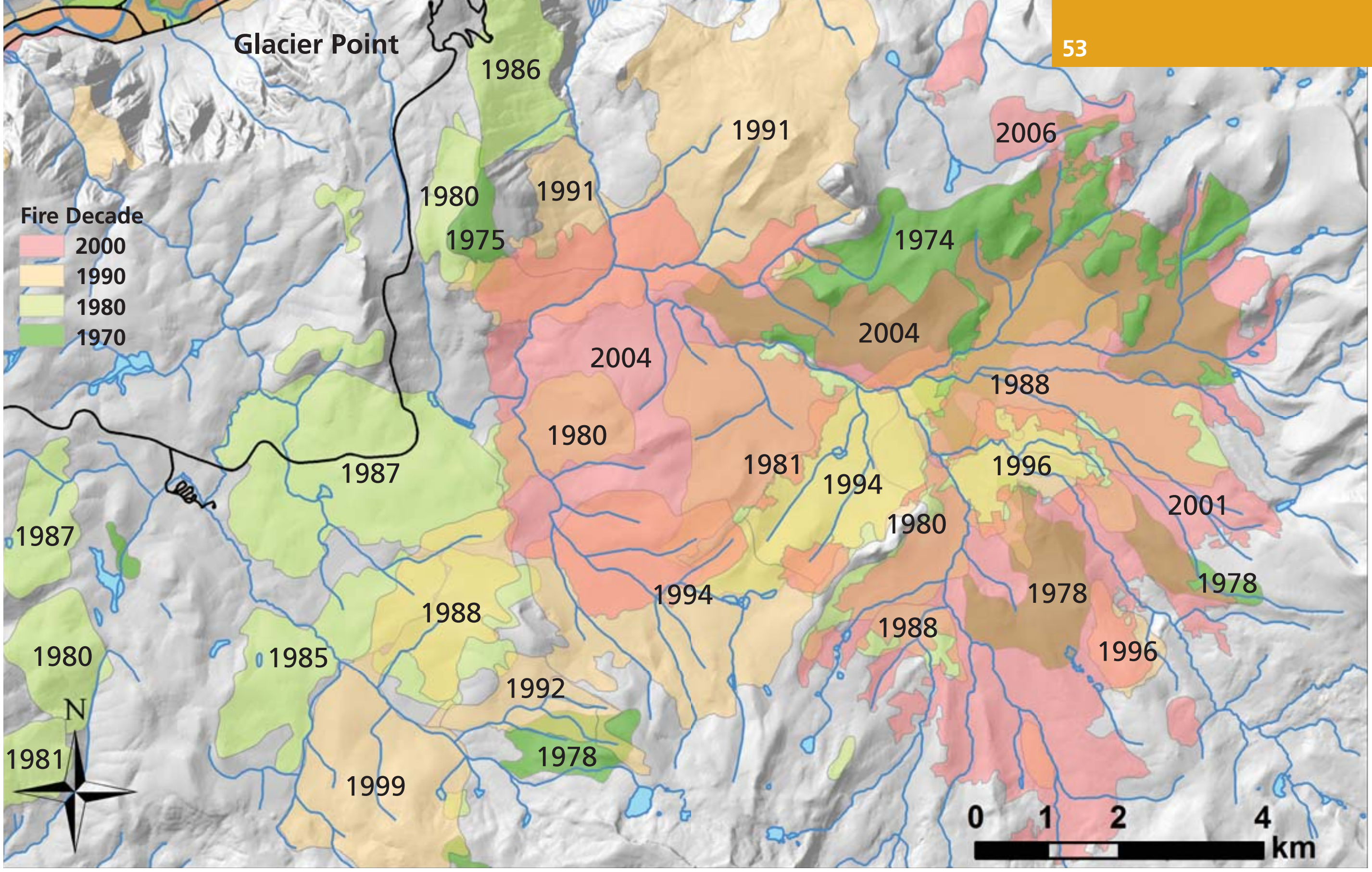


Figure 8. Lightning-ignited fires of greater than 10 ha (24.7 ac) in Yosemite's Illilouette Basin from 1970 to 2009. Much of the basin has burned at least once, and the resulting matrix of forest and fuel densities has greatly reduced the chances of a large wildfire or large smoke production. The Illilouette Basin experiences a large number of lightning strikes that provide ignition.

several years, based on the California Air Resources Board emissions estimation tool (http://www.arb.ca.gov/ei/see/see.htm), show, in general, that small fires rarely emit more than 10 tons of fine particles per day, while moderately sized, moderately growing fires emit 10 to 100 tons of fine particles per day. Our experience so far has been that emissions at these scales rarely produce more than localized impacts. Consistent daily emissions of 100 to 1,000 tons of fine particles are more characteristic of the largest fires, which rarely occur in Yosemite (e.g., Clinton et al. 2006), and result in regional, not just local, smoke impacts (e.g., McMeeking et al. 2006) (figs. 10 and 11, next spread).

Unfortunately, the technology and methods for mapping and forecasting fire growth and associated smoke impacts (i.e., fine particle concentrations) for operational use are still under development (e.g., http://firesmoke.us/wfdss/). Preliminary measurements of fine particle concentrations from a few well-monitored fires in Yosemite support the hypothesis that smoke impacts coincident from these small (<10 ha [<25 ac]) fires are usually not detectable, or are at least minimal. For moderately growing fires (10–100 tons/day), good dispersion also results in minimal smoke impacts. However, under poor dispersion conditions, smoke impacts can be substantial, even unhealthy, especially if the poor dispersion conditions persist for several days. The current smoke minimization strategy is therefore to match emissions to avail-

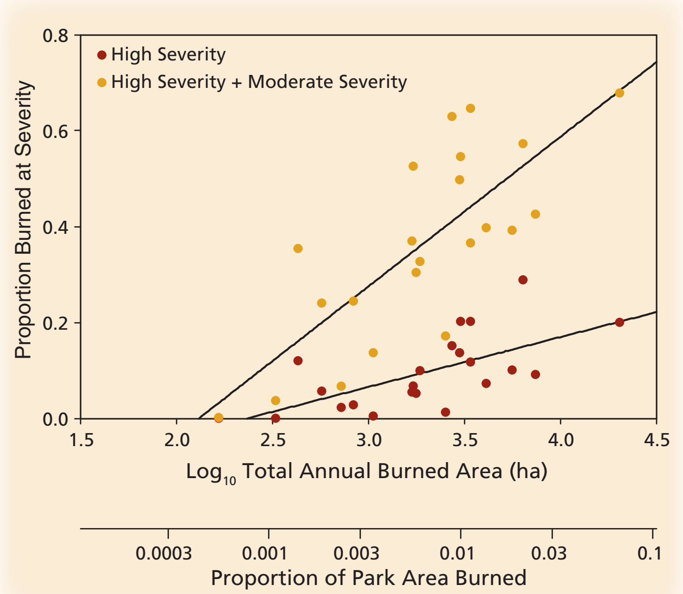
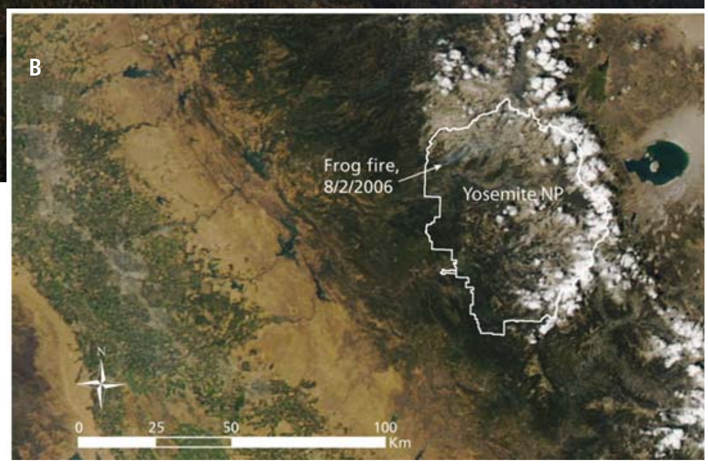


Figure 9. In Yosemite, area burned (ha) at high fire severity (dark red) and high plus moderate fire severity (orange) increases with the total (Log_{10}) annual area burned (1984 to 2005). The years with the most annual area burned show about 20% high severity and more than 60% high plus moderate severity, while the years with the least growth show very little (less than 5%) high or moderate severity.

SOURCE: LUTZ ET AL. 2009b

PHOTO BY L. TARNAY



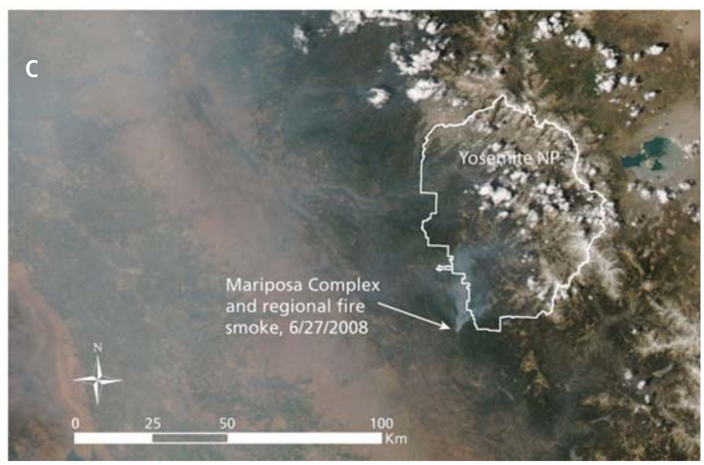


Figure 10. Smoke from the moderate-sized (2,442 ha [6,034 ac]) Frog fire in Yosemite in 2006 (panels A and B) compared with regional smoke impacts from the 2008 Mariposa Complex fires, which were among many large fires burning statewide at the time (panel c). Smoke impacts from moderate-sized fires (panels A and B) can be locally significant but are still relatively small compared with the largest, fastest-growing fires that often occur outside of Yosemite (panel C).

able dispersion, avoiding, where possible, large or moderate fire growth during poor dispersion periods while encouraging growth during periods of good dispersion. Monitoring and data acquisition to refine and evaluate these strategies are ongoing in Yosemite and Sequoia–Kings Canyon national parks, in cooperation with other federal agencies and air regulators.

Conclusion

Forest land managers have few tools with the potential to mitigate the impacts of climate change at landscape scales, but fire is one of them. Response to climate change for Sierra Nevada forests in the coming decades will likely be mediated by fire (McKenzie et al. 2004) and therefore revolve around fire management and fuels issues. The emerging science shows that the benefits of moderately sized, moderate-growth fires can be threefold in that they protect air quality, carbon stocks, and forest ecology. As the climate warms, the ability to realize these benefits hinges on the extent to which land managers can reduce forest fuels to a level that is sustainably resilient to major and minor fires. For land management agencies, this implies a substantial, even unprecedented, fire management response that erases administrative boundaries between land management agencies in favor of treating the most at-risk watersheds with midsized, moderately growing fires. On the downside, delays in restoring appropriate forest structure increase the chances of larger fires "resetting" the ecosystem, on terms that are likely to have severely negative impacts on air quality, carbon stocks, and ecosystems. To the extent that fires can improve forest structure and fire resistance, projected increases in fire activity—if properly managed—may be a way to head off, or at least delay, the worst consequences of climatic warming in the forests of the Sierra Nevada.

2009 PHOTO BY L. TARNAY

Figure 11. The 1,225 ha (3,027 ac) Grouse fire burns a key piece of the Yosemite landscape with minimal smoke impacts, protecting higher-elevation forests from fires that might start at lower elevations.

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PS

Communication and Public Engagement

RESEARCH REPORT

Audience segmentation as a tool for communicating climate change: Understanding the differences and bridging the divides

By Karen Akerlof, Gregg Bruff, and Joe Witte

Abstract
Communicating climate change to 300 million national park visitors each year represents both an enormous challenge and an opportunity for the National Park Service. Informal and formal audience assessment techniques allow communicators to develop strategies and messages that are tailored to certain subsets of the population, or crafted to resonate with all groups, thereby increasing the probability of influencing individuals' attitudes, beliefs, and behaviors. This article reviews audience segmentation research developed by the Yale Project on Climate Change Communication and the Center for Climate Change Communication, and applies it within the context of the National Park Service's designation of communication as one of its four management areas in the Climate Change Response Strategy. A case study on communicating climate change at Pictured Rocks National Lakeshore illustrates some of the ways that one park is already using social science research–based strategies to increase the effectiveness of its outreach programs.

Key words: audience segmentation, climate change, communication, global warming, public opinion, surveys

DUE TO THE IMPACTS OF GLOBAL CLIMATE CHANGE, it has become increasingly challenging for the National Park Service (NPS) to uphold its mission to conserve the nation's most treasured landscapes for future generations. The Park Service has responded by targeting communication as one of four management areas in its Climate Change Response Strategy (NPS 2010). Thus, while the agency is working to expand research on impacts on parks' increasing ecosystem resilience, and assisting species in transitioning to new climate regimes, it is also focused on conveying this information to diverse audiences both in and outside the organization.

This is both an enormous communication challenge and an opportunity for the National Park Service with implications for the almost 300 million people who visit its nearly 400 sites each year. Climate change poses a multitude of inherent problems to communicators: the topic is politically polarizing (Dunlap and McCright 2008), the science is complex (Moser 2010), and most Americans perceive its impacts to be primarily on people and places far removed from themselves (Leiserowitz 2006). Over the past few decades, social science research across many fields—including public health and social marketing (Hornik 2002; Maibach and Parrot 1995; McKenzie-Mohr and Smith 1999)—has begun to determine which communication strategies most successfully engage the public in solving broad societal problems. This research is now being applied to climate change. Over just the last four years, the field of climate change communication, which addresses the issue's communication challenges and how to facilitate social change in related areas such as energy conservation (Moser and Dilling 2007), has developed a rapidly growing academic literature. Yet few studies address the specific problems that public land managers face (Schweizer et al. 2009; Schweizer and Thompson in press).

In reaching out to visitors, NPS interpreters rely on a traditional toolkit of resources and techniques: evening programs, guided walks, roving interpretation, school programs and teacher workshops, multimedia products, publications, and exhibits. Though interpreters and education staff may strive to follow Freeman Tilden's first principle—"Any interpretation that does not somehow relate what is being displayed or described to something within the personality or experience of the visitor will be sterile" (Tilden 1957)—without audience research it is difficult to ascertain information about visitors beyond license plate observations. In this article we offer ideas for evaluating where audiences stand on the issue of climate change, and information on shaping messages that will most appeal to those groups. The data presented here are derived primarily from public opinion research conducted at the George Mason University Center for Climate Change Communication (4C) and the Yale Project on Climate Change Communication, based at the Yale School of Forestry and Environmental Studies.

Global warming's "Six Americas"

Thinking about Americans in terms of a smaller subset of audiences, distinguishable by their attitudes, beliefs, and behaviors, enables communicators to develop messages that resonate more deeply with individuals, whether the topic is politics (Weigel 2006), HIV/AIDS (Yun et al. 2001), or climate change (Maibach et al. 2011b). Moreover, creating tailored programs and materials based on this type of research has been shown to be successful in influencing individual behavior change (Noar et al. 2007), likely by increasing the relevance and salience of the message.

Based on a nationally representative survey of 2,164 adults in the United States that was fielded from 7 October to 12 November 2008, the Yale/Mason team used a statistical technique termed "latent class analysis" to evaluate how people cluster around a set of global warming beliefs, issue involvement variables, behaviors, and societal response preferences. Six distinct audience segments, called "Global Warming's Six Americas," were generated from the study (Maibach et al. 2009). Research by Yale and Mason in the winter of 2009–2010, spring 2010, and spring 2011 is continuing to track these unique audiences. Tools that can be used to segment audiences with sets of either 15 or 36 survey questions are freely available. The Six Americas audience segmentation has been found to be a better predictor of global warming federal policy support than either demographics or political ideology (Maibach et al. 2011b). Indeed, regression analysis of the segmentation as a predictor of a scale derived from nine federal policy options for the reduction of greenhouse gas emissions revealed that it explained as much variance (41%) as a combination of political ideology, demographics, and the segmentation.

The surveys were conducted using Knowledge Networks' online panel of U.S. adults, initially recruited using a random-digit dialing technique. The online panel tracks the U.S. Census Bureau's Current Population Survey (CPS) on demographic variables such as age, race, Hispanic ethnicity, geographic region, and employment. In order to adjust for noncoverage or nonresponse biases, the data were weighted to reflect CPS distributions of age, race, gender, and education. The survey measures were constructed using the term "global warming," as it has been used predominantly in U.S. public opinion surveys over the past few decades (Akerlof and Maibach 2011). The survey defines global warming as "the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result" (Maibach et al. 2011a).

The Six Americas span a spectrum of beliefs about global warming, from the "Alarmed" to the "Dismissive" (fig. 1).

There is a great need at this time for messages that communicate the complexities of climate change and the actions that can be taken.

—National Park Service Director Jon Jarvis, 2009

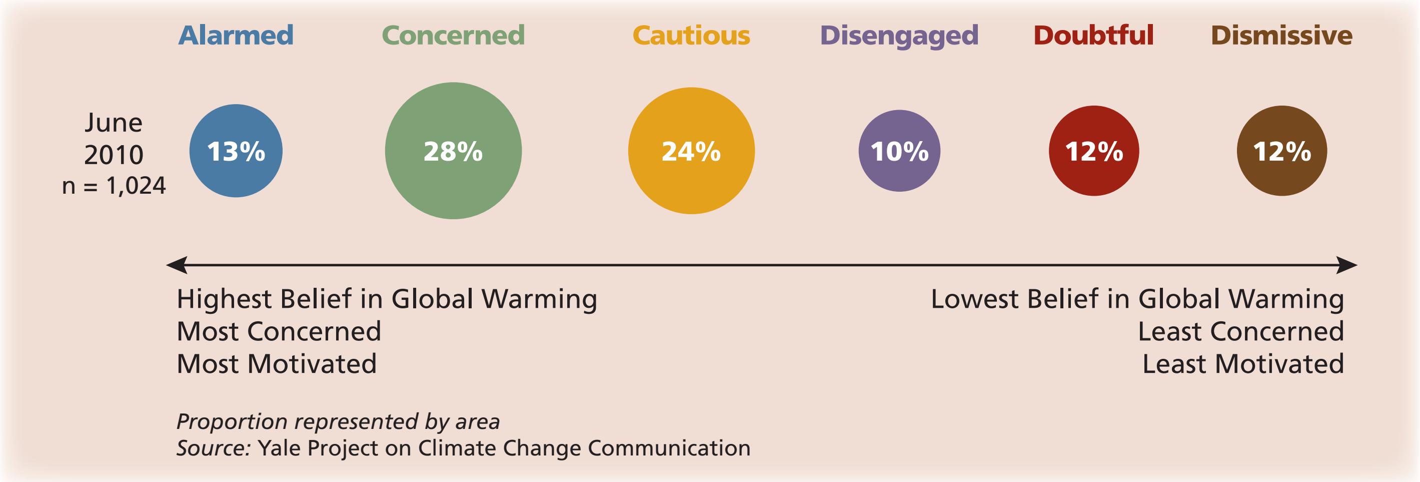

Figure 1. U.S. audiences can be divided into six distinct groups according to their global warming beliefs, issue involvement, behaviors, and societal response preferences. This figure represents the audience sizes as percentages of the American public according to data from a nationally representative survey of adults fielded in May–June 2010 (n = 1,024).
Source: Leiserowitz et al. 2010b

The **Alarmed** are the most concerned about global warming, the most personally involved in the issue, and the most motivated to do something about it. They are certain that global warming is happening, and believe that it is mostly human caused and that there is scientific consensus that it is occurring. The Alarmed view themselves as knowledgeable about the topic and are unlikely to change their minds. This group is the most likely to see global warming as an imminent and severe threat, and to be taking steps both as consumers and as citizens to encourage companies and politicians to respond to the issue. The Alarmed are supportive of a wide range of potential federal policies that would reduce greenhouse gas emissions.

The **Concerned** also believe that climate change is a serious issue and that we need to take action. However, this group is less personally involved than the Alarmed and feels less personally threatened. The Concerned are sure that global warming is happening and that human activities are the main cause, but that it will not harm people for another decade or more. This group is active primarily in using its power as consumers to enact change within the marketplace, but is supportive of policies to lessen emissions.

The **Cautious** are only somewhat likely to say that global warming is occurring, and they are of mixed opinion on whether it is caused by human beings. Regardless, the Cautious see global warming as a removed threat. As a result, they are not likely to be taking action either as consumers or as citizens on this issue, though they are somewhat supportive of potential federal climate and energy policies.

The majority of the **Disengaged** respond "don't know" to whether global warming is occurring and whether it will harm people. They have not thought a lot about this issue, do not feel well educated on the topic, and say they could easily change their minds. This group tends to be of lower income and education levels. The Disengaged are also somewhat supportive of federal climate and energy policy options.

The **Doubtful** are unsure whether climate change is occurring, but if it is, they are fairly sure that it is caused by natural changes. This group perceives global warming as a very distant threat, if it is indeed a real phenomenon. Consequently they do not attach much personal importance to it. The Doubtful believe that scientists are in disagreement on global warming, and that they themselves are well informed about the issue. They say they are unlikely to change their minds, but are supportive particularly of policies that would expand domestic energy sources.

The **Dismissive** believe global warming does not exist and are actively working against policies to reduce greenhouse gas emissions. Like the Alarmed, they have given it a lot of thought, and they are very certain in their views. This group believes it is well educated about global warming, and that there remains much disagreement on the issue among scientists. They support an even more limited range of potential policy options than the Doubtful, primarily increased drilling for oil and the building of nuclear power plants.

For National Park Service interpreters … it is difficult to deduce what any individual's beliefs about climate change are likely to be without first initiating a conversation.

As of spring 2010, the Six Americas' segment sizes ranged from 10% to 28% of the population (Leiserowitz et al. 2010b). The differences among these groups by demographics—gender, ethnicity and race, and age—are not large; the greatest variance lies in the societal values to which they ascribe (Maibach et al. 2009). The Alarmed and the Concerned are more likely to hold liberal, egalitarian views while the Doubtful and the Dismissive are more likely to be conservative and individualistic in their beliefs. For National Park Service interpreters, this means that it is difficult to deduce what any individual's beliefs about climate change are likely to be without first initiating a conversation. Audience analyses to determine the prevalence of the Six Americas among park visitors may be a useful strategy for developing targeted communication materials and programs, but can also be time-consuming and require approval of the Office of Management and Budget. Engaging small groups in open-ended discussions to address two questions is an easy way to roughly ascertain where audiences fall along the spectrum of the Six Americas:

"Do you think that global warming is happening?"

"How sure are you that global warming is (or is not) happening?"

As can be seen in figure 2, the combination of these two questions efficiently captures the spread of the average responses from people across the Six Americas. Addressing a third question, "Do you take actions at home to conserve energy?" may serve to point out similarities across even diametrically opposed audience segments. In doing so, interpreters can quickly ascertain where their audience members may be in the Six Americas, without undergoing a formal survey and recording individual information.

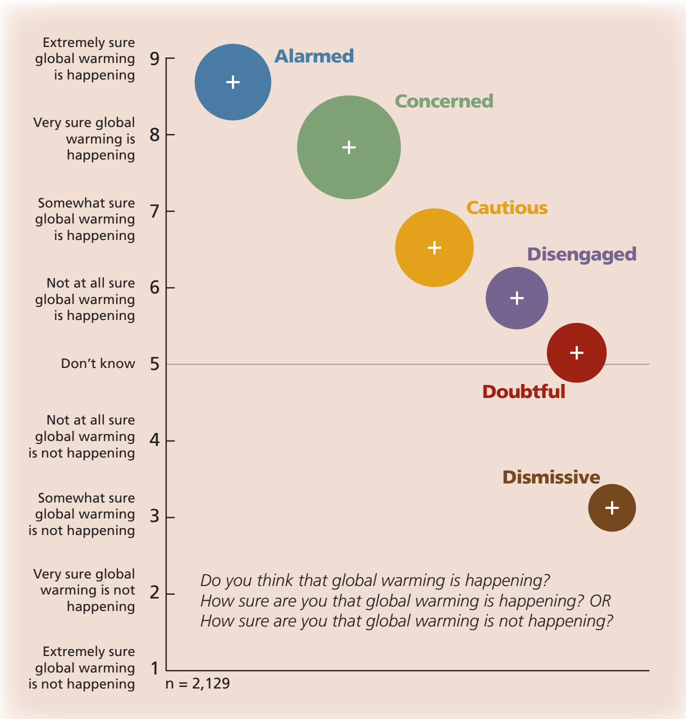

Figure 2. The Six Americas, on average, span from being extremely sure that global warming is happening (Alarmed) to being somewhat sure that global warming is not happening (Dismissive). *Source:* Maibach et al. 2009

For parks or other organizations that are conducting formal surveys, the measures and statistical algorithms used to determine Global Warming's Six Americas may be obtained from the Center for Climate Change Communication and the Yale Project on Climate Change Communication for use in segmenting audiences. A 36-question version places individuals in the correct segment on average 91% of the time, while a 15-item screener is accurate on average 84% of the time (Maibach et al. 2011b). These tools are run using SAS or SPSS statistical software scripts, or an Excel spreadsheet, and are available at http://climatechange communication.org/SixAmericasManual.cfm. Surveys that are conducted, funded, or sponsored by the National Park Service must be processed through the NPS Social Science Program, which assists in determining which types of approval are needed (e.g., the Department of the Interior or the Office of Management and Budget). For more information and review guidelines, see http://www.nature.nps.gov/socialscience/.

What do they know, and what do they want to know?

When the Six Americas were graded on their knowledge of climate change by the Yale Project on Climate Change Communication in 2010, 49% of the Alarmed received a passing grade (70% or above) based on their percentage of correct answers (Leiserowitz and Smith 2010). The other audiences fared worse, with only 33% of the Concerned, 16% of the Cautious, 5% of the Disengaged, 17% of the Doubtful, and 4% of the Dismissive passing. Those least likely to believe that global warming is occurring and attributed to human activities—as concluded unequivocally in the Intergovernmental Panel on Climate Change's 2007 assessment report (IPCC 2007)—did not uniformly score the worst. The Doubtful and the Dismissive were the most likely to know that the greenhouse effect refers to gases in the atmosphere that trap heat (74% and 79% respectively). The Dismissive were also the most likely group to understand that the terms "weather" and "climate" do not have the same meaning (63%).

Stratospheric ozone depletion and climate change have long been confused by the public. The Alarmed and the Concerned were the most likely to misperceive the ozone hole as a significant contributor to global warming (63% and 49%), and to believe that aerosol cans are a significant cause of climate change (49% and 36%).

Unsurprisingly, those skeptical that climate change is occurring—such as the Doubtful and the Dismissive—said they were less interested in learning about it. Less than a third of Dismissives would like to learn more, as opposed to more than three-quarters of the Alarmed. They also have different questions they would like experts to answer (Leiserowitz et al. 2010b). The Alarmed and the Concerned most want to know what the United States can do to reduce global warming, whereas the Cautious, Doubtful, and Dismissive groups want to know how we know it is happening. The Disengaged most want to ask experts what harm global warming will cause.

What are they already doing?

In terms of lessening the impacts of climate change, perhaps even more important than what people know and how people think about the issue is how they choose to act. Individual and household energy consumption in the United States accounts for 30% to 40% of the nation's greenhouse gas emissions (Vandenbergh et al. 2008; Vandenbergh and Steinemann 2007), and thus represents a large source of potential emission reductions. As one of the foci of the Do Your Part! for Climate Friendly Parks initially established by the National Park Service, the Environmental Protection Agency, and private-sector contractor ICF International, and now administered by the National Parks Conservation Association, it also represents a topic that has been a component of NPS outreach programs.

One of the most surprising research results from the October–November 2008 nationally representative survey data (n = 2,129) was the commonality across the Six Americas with regard to their actions on saving energy (Maibach et al. 2010a). Although people across the Six Americas strongly disagreed about global warming, they concurred on the importance of saving energy and demonstrated similar behavior patterns in regard to energy conservation and efficiency (see figs. 3 and 4). When it came to such behaviors as installing energy-efficient appliances and insulating the attic, the Alarmed (mean [M] = 3.35, 95% confidence interval [CI] [3.16, 3.55]) and the Concerned (M = 2.87, 95% CI [2.72, 3.01]) were statistically indistinguishable from the Doubtful (M = 3.17, 95% CI [2.89, 3.45]) and the Dismissive (M = 3.20, 95% CI [2.90, 3.51]). The Cautious (M = 2.62, 95% CI [2.42, 2.83]) and the Disengaged (M = 32.26, 95% CI [1.98, 2.54]) undertook slightly fewer total home improvements than the Alarmed, Doubtful, and Dismissive groups, likely because these audiences tend to be in lower-income groups.

The behaviors of the Six Americas are even more similar in energy conservation habits that require no up-front financial investment. On average, people in all the groups said in fall 2008 that they "always" or "often" practiced two to three behaviors, such as turning off unneeded lights, adjusting their thermostat upward or downward to save energy, or biking instead of driving. For these actions—requiring more of a lifestyle and behavioral commitment than do energy efficiency improvements—the Alarmed reported higher levels of engagement (M = 2.95, 95% CI [2.83, 3.06]) than the other five groups, whose means were slightly, though distinctly, lower (Concerned, M = 2.51, 95% CI [2.43, 2.59]; Cautious, M = 2.32, 95% CI [2.20, 2.43]; Disengaged, M = 2.43, 95% CI [2.27, 2.58]; Doubtful, M = 2.13, 95% CI [2.00, 2.26]; Dismissive, M = 2.38, 95% CI [2.19, 2.56]).

Programs such as Do Your Part! that address changing individual energy behaviors may thus appeal to the entire spectrum of the American public in ways that climate change messages may not, while still engaging people in behavioral changes to lessen greenhouse gas emissions and ameliorate the impacts of climate change. Large majorities of all Americans in the December 2009–January 2010 survey (n = 1,001) said that conserving resources and energy in their everyday activities is important, yet for some behaviors—such as unplugging electronics and using public transportation—the majority have not made those actions habitual (Leiserowitz et al. 2010a).

The significance of Americans' energy efficiency and conservation activities—and their widespread appeal—is that it and other messages that point to a new model of low-carbon living can be framed both as solutions to climate change for Alarmed and Concerned segments and as a way of creating healthier communities for broader audiences.

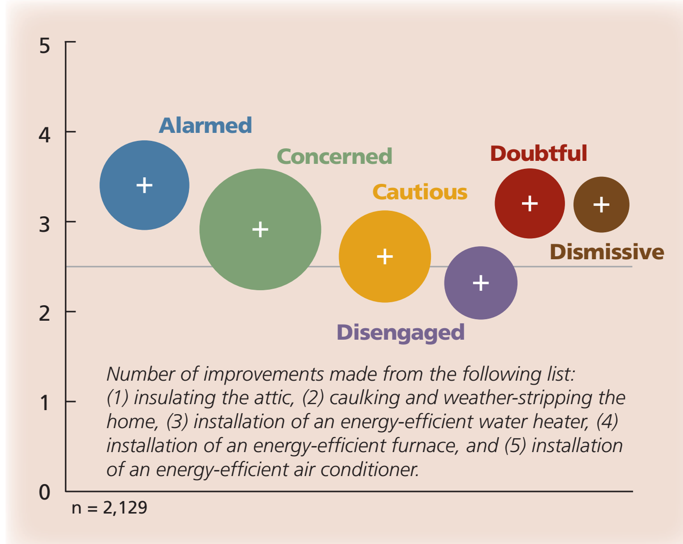

Figure 3. The average total number of home energy-efficiency improvements made by members of the Six Americas ranged from two to four, according to the October–November 2008 nationally representative survey (n = 2,129).
Source: Maibach et al. 2009

What messages work with what audiences?

The following section describes messaging strategies that could be used with the Six Americas based on an interpreter's understanding of his or her audience using the tools described above, or to accommodate a broader range of segments. These messages have not been tested with these audiences, but are based on combining audience segment characteristics with insights from theoretical literature.

The questions about global warming for which members of the Six Americas most want answers reflect the two very *different conversations* about climate change that are currently occurring in the United States. Those who believe strongly that climate change is real want to discuss what to do about it, while those who are less sure or strongly believe it is not occurring prefer to discuss the basis for the science.

Alarmed/Concerned. Messages for the Alarmed and the Concerned therefore may be most effective when they focus on concrete behaviors that individuals and communities can undertake to reduce carbon emissions, perhaps using actions taken by parks as examples: public transportation, low-emission vehicles, and

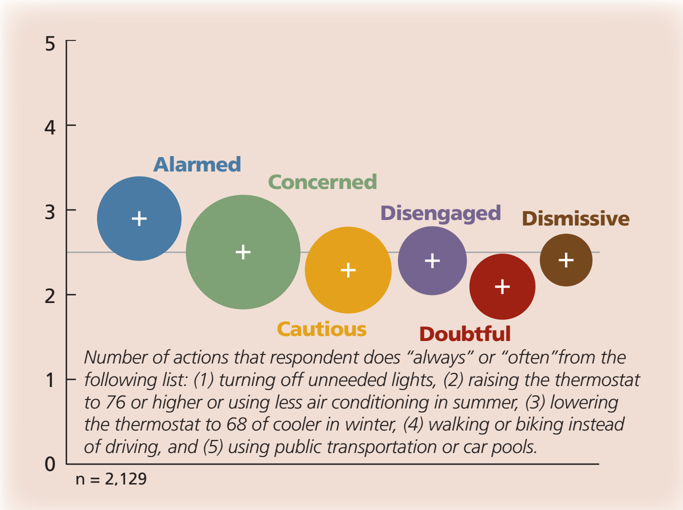

Figure 4. The average total number of conservation actions that Americans take is two to three, according to the October–November 2008 nationally representative survey (n = 2,129).
Source: Maibach et al. 2009

NPS climate change talking points

In its 2010 *Climate Change Response Strategy*, the National Park Service unveiled four core messages to be used Service-wide in external and internal communication. They are as follows:

- Climate change is happening and human activities are contributing to and accelerating it.
- Changing climate has consequences for parks, people, and the planet.
- The National Park Service is responding with practices that address climate change.
- The choices we make now may help to avoid catastrophic impacts in the future.

Similar messaging is also being implemented by the U.S. Fish and Wildlife Service and other organizations. The components of the key points—that climate change is occurring, that we are certain that it is occurring, that it will have negative consequences for people and the environment, that people's activities are a primary cause, and that there are actions we can take to ameliorate its effects—are based on research that suggests that people who hold these beliefs and attitudes are more likely to be convinced of the seriousness of the phenomenon and of the importance of taking action (Krosnick et al. 2006). The study adapted a theoretical model of opinion formation to global warming using two surveys conducted in the mid- to late 1990s. The National Park Service may wish to evaluate the messaging strategy experimentally—as indeed recommended by the study's authors—to assess whether or not providing this factual information increases audience engagement on climate change.

reducing waste. These types of communication fit within the NPS Climate Change Response Strategy goal of "modeling and communicating sustainable practices that lead by example." Many of these same actions can be effectively communicated to the entire spectrum of audiences, by discussing them within other frames than climate change.

Cautious/Disengaged. The Americans who are in the middle of the spectrum—the Cautious and the Disengaged—are less certain in their beliefs about climate change, and feel less informed on the issue (Maibach et al. 2009). These segments have fewer financial resources than either the Alarmed or the Dismissive. Messages that illustrate how to save money by adopting low-carbon lifestyles, and that help individuals to develop the knowledge and skills they need to accomplish these goals, are most likely to be effective in facilitating behavioral change and reducing emissions.

Doubtful/Dismissive. For members of groups who believe the evidence for climate change is not yet conclusive, research suggests that messengers who are viewed as having similar values and who use familiar narrative lines are the most apt to be heard by these audiences regardless of the factual content of their messages, and are able to communicate most effectively (Kahan 2010, Kahan et al. 2011). Interpreters may be able to achieve this by relating stories about the diverse people—spanning political ideology, race and ethnicity, age and gender—who have been involved in researching or combating climate change impacts in the national parks, and the values that motivate them. By using this strategy, interpreters suggest to their audiences that there is a wider sociodemographic and political range of messengers on the seriousness of climate change impacts than they may intuit from traditional mass media depictions, which emphasize issue conflict and polarization (Boykoff and Boykoff 2004). In presenting case stories of people of different backgrounds and sociopolitical views who nevertheless agree in large part on the causes and potential impacts of climate change, audience members are more likely to find at least one of the stories personally resonant.

All audiences. Messages that focus on outcomes that are perceived as beneficial instead of as threatening—such as potential for economic dislocations because of governmental regulation—are likely to be considered more equivocally by all audiences (Kahan et al. 2011). As previously mentioned, energy conservation and efficiency are areas that appeal across all of the Six Americas, including the Doubtful and the Dismissive, likely in part because

The questions about global warming for which members of the Six Americas most want answers reflect the two very different conversations about climate change that are currently occurring in the United States. Those who believe strongly that climate change is real want to discuss what to do about it, while those who are less sure or strongly believe it is not occurring prefer to discuss the basis for the science.

of their salience to those who value thrift. Research also has shown that highlighting the human health benefits of addressing climate change tests well across the Six Americas (Maibach et al. 2010b). Many of the same activities that result in healthier people and communities—such as reducing air pollutants by burning less fossil fuel and using forms of active transportation like biking and walking—also result in decreased greenhouse gas emissions. A survey of residents in the gateway communities of Pictured Rocks National Lakeshore, Michigan, suggested that a large percentage (73%) associated taking action on global warming with improving people's health (76%) and protecting national parks, forests, and wildlife refuges (Akerlof 2010). As places where Americans engage in physical activities such as walking, find places for quiet reflection, escape the stress of normal daily life, and spend time with family members, the national parks could serve as important places to engage in conversations about ways to improve our communities that will make our everyday lives healthier.

Importance of place and trusted messengers

The national parks are iconographic places to the American populace, and the National Park Service is one of the most trusted federal agencies (Wilkinson 2002). Images of Glacier, Mesa Verde, and Yosemite national parks are known across the country, even by people who have never visited them. Visible impacts of climate change on these treasured places may serve to heighten Americans' awareness that the threat of climate change is here and now. As the U.S. Climate Change Science Program reported, "National parks that have special places in the American psyche will remain parks, but their look and feel may change dramatically" (Baron et al. 2008). With 80% of Americans living in metropolitan areas (U.S. Census Bureau 2000), the national parks offer rare opportunities for the public to experience firsthand the impacts of climate change on wild natural areas, whether through visibly retreating glaciers, lower lake and river water levels, declining native species of wildlife, or rising sea levels (Saunders et al. 2009). Studies indicate that people who experience the impacts of climate change are more likely to be concerned about the issue (Arctic Climate Impact Assessment 2004; Leiserowitz and Broad 2008).

Because of its position as one of the more esteemed federal agencies and an authoritative voice on the science occurring in the parks, the National Park Service may serve as a particularly trusted public source of information about climate change. One survey found that the Service was the third most trusted source of global warming information after scientists and local universities (Akerlof 2010). Four out of five Americans trust scientists on global warming (Leiserowitz et al. 2010b). Yet a plurality of the public—almost half—still believe there is a lack of scientific consensus that climate change is occurring. This may be partly because of media coverage that has portrayed the issue as scientifically controversial by giving equal weight to those who say climate change is occurring and those who do not, under the guise of balanced reporting (Boykoff and Boykoff 2004). Other authors have suggested it also may be caused by audiences who pay selective attention to the viewpoints of experts with whom they identify (Kahan et al. 2011). The disparity in levels of public trust in scientists, and in public understanding that more than 95% of climate experts believe that mean global temperatures have increased since before the 1800s and that human activity is a significant contributing factor (Doran and Zimmerman 2009), provides a potential messaging opportunity emphasizing the scientific consensus on climate change.

Conclusion

"There is nothing more American," former NPS Director Roger Kennedy said, "than to support America's national parks" (Wilkinson 2002). Understanding both the differences and commonalities in regard to Americans' beliefs about global warming is a first step in developing effective communication strategies on climate change. By serving as host to millions of Americans each year in many of the nation's iconic natural, cultural, and scenic areas, the National Park Service has a real opportunity to bridge these differences and speak to the science of climate change occurring in parks and the benefits of changing personal behaviors to lessen our carbon emissions and preserve these lands.

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NPS PHOTO

Communicating climate change at Pictured Rocks National Lakeshore

AS AN ACTIVE CLIMATE FRIENDLY PARK, Pictured Rocks National Lakeshore in Michigan has made considerable strides in reducing its carbon footprint and educating the public about climate change. The park has been recognized at the national level for its "Sustainable is Attainable" program (http://www.nps.gov/piro/parkmgmt/green.htm). Park staff has made progress on the park's Climate Friendly Action Plan with installation of two climate change interpretive wayside exhibits, summer interpretive programming, and a revision of all K–12 curricula to include climate change topics in the education outreach program.

The most recent climate change–related effort is part of the Environmental Protection Agency's Great Lakes Restoration Initiative. Both Apostle Islands and Pictured Rocks national lakeshores received an EPA grant for "Communicating Stewardship and Sustainable Values" in local communities. At Pictured Rocks the Alger Energy Savers outreach and carbon reduction program is in full swing, with an outreach park ranger to communicate climate change–related challenges facing national parks. Working with the Superior Watershed Partnership and Land Trust in Marquette, Michigan, Pictured Rocks is providing energy assessments and energy-saving devices to Alger County residents and tourism-related businesses. A total of 1,500 county households are targeted to receive compact fluorescent lightbulbs, faucet aerators, hot water pipe insulation, and a water heater insulating blanket. If fully implemented, energy savings over the life of these devices will be over 1.7 million kilowatt-hours of electricity and 16,500 metric tons (18,188 short tons) of CO_2.

The Superior Watershed Partnership, in collaboration with George Mason University's Center for Climate Change Communication, administered a survey of 765 Alger County residents to assess their knowledge and beliefs about climate change, and their percentage representation within the Six Americas. This study has guided the Alger Energy Savers and outreach activities in the park's gateway communities.

NPS PHOTO

Alger Energy Savers project director Natasha Koss (left) visits a local resident for her home energy audit and carbon savings retrofit. The audits are being done by T. J. Brown (second from right) of Michigan Energy Options. Gregg Bruff (right), chief of Heritage Education, Pictured Rocks National Lakeshore, oversees the project that will benefit Great Lakes parks.

The Alger Energy Savers project also includes application of social marketing research to frame the issue for local residents, and work with local resident beliefs and value systems. A contractor, ICF International, has developed targeted outreach materials for the project.

—Gregg Bruff

Citizen scientists in action: Providing baseline data for climate-sensitive species

By Tara Carolin, Jami Belt, and Melissa Sladek

Abstract
Since 2005 the Crown of the Continent Research Learning Center has been fostering a sense of stewardship in park visitors who are trained to monitor focal species of concern and contribute reliable data to Glacier National Park, Montana. In 2008 we initiated the High Country Citizen Science Program, which focuses on species of concern because of climate change, emphasizing mountain goats and pikas. Participants learn how to safely identify and observe the species, about their behavior and habitat, and why managers are concerned for their future under a changing climate. We have found that with proper study design, citizen scientists can collect reliable inventory data for management. Additionally, engaging the public and youth in data collection instills a strong sense of responsibility and a desire to promote resource conservation on behalf of the park.

Key words: citizen science, climate change communication, mountain goats, pikas

IN TIMES OF SHRINKING GLACIERS and funding opportunities, Glacier National Park (Montana) has had to seek creative new partnerships to meet management conservation goals. The park has developed a citizen science program both as a cost-effective means of gathering baseline data and as an outreach tool to educate visitors and foster resource appreciation and stewardship.

In 2005 the Crown of the Continent Research Learning Center (CCRLC), in collaboration with park resource managers, set out to determine whether some of Glacier National Park's numerous backcountry visitors would be willing to participate in a short training that would allow them to accurately collect data on common loons while hiking in the park. The answer was a resounding yes. The success of volunteer monitoring of loons led the park to formalize its citizen science efforts in 2008 by establishing the High Country Citizen Science Program for inventory of climate-sensitive species.

Climate-sensitive species

Over the past couple of decades, scientists have gathered excellent data documenting climatic changes in the Glacier National Park region. With data pointing toward warming climate trends, managers are increasingly concerned about how climate-sensitive species may be affected in the future. However, the park lacks sufficient staff to collect data on population distribution, abundance, and trends of species of concern.

For instance, although mountain goats have long been considered an icon of Glacier, staff knew little about their population status and distribution. Because of observed declines in goat populations at selected viewpoints and uncertainty about current and future effects of climate change, park managers sought more information on mountain goat abundance and distribution (fig. 1).

Managers are also concerned about population trends of temperature-sensitive species, such as the pika. Research has shown that temperature is a crucial factor in determining pika habitat and survival. Climate research in Glacier National Park shows that the mean annual temperature for the park and surrounding area has increased more than 1.3°C since 1900—almost twice the global average increase (NOROCK 2010)—making it critical to evaluate current pika distribution in order to inform future monitoring.

> *"Citizen science" is a term that describes scientific programs and projects in which volunteers, some with no prior scientific training, perform science-based inventory and monitoring or research-related tasks.*

NPS PHOTO

Figure 1. Following a yearlong study module on climate change, San Diego high school students survey for mountain goats near Hidden Lake in Glacier National Park.

Citizen science

To support data collection on these important species in the absence of NPS-staffed inventories, Glacier National Park turned to volunteer citizen scientists. "Citizen science" is a term that describes scientific programs and projects in which volunteers, some with no prior scientific training, perform science-based inventory and monitoring or research-related tasks. Citizen science programs offer a cost-effective method for monitoring wildlife over large geographic areas and for long periods of time. When working with species that are easy to identify and methodologies that do not require specialized experience or more than ordinary safety risks, citizen scientists can assist staff in data collection. By training volunteers on research methods and current science, the CCRLC's High Country Citizen Science Program not only increases understanding of particular species but also fosters a greater appreciation and awareness of the world we live in and the challenges we face in and around Glacier.

To help inventory mountain goats and pikas, we recruited citizen scientists through press releases, public presentations, flyers, partner groups, newspaper and magazine articles, radio spots, the park's Web page, and, more recently, social media. Eighty-six volunteers participated in the first year of the program. By 2010, the third year, that number rose to 143. Student interns are trained each year, and school groups from as far away as Houston, Minneapolis, and San Diego have participated in citizen science, generating enthusiasm for resource stewardship and science in youth.

Evaluating citizen science

Two studies have evaluated the efficacy of the High Country Citizen Science Program: first, a social science survey geared toward determining how well the program meets volunteer expectations, and second, a master's thesis that analyzes the reliability of mountain goat data collected by volunteers in comparison with data collected by biologists and aerial surveys.

In 2009, Rebecca Goe and Carly Phillips, sociology students at the University of Montana, surveyed participants in the program twice: once prior to the six-hour training session, and again at the end of the season. Most survey respondents indicated that the citizen science experience was "very fulfilling," and all had positive things to say about the program. Comments ranged from appreciation for the opportunity to learn more about park resources to finding satisfaction in giving something of value back to the park. As one respondent put it, "[This program] is another excuse to go into the park, sit down for an hour and just search with scope and binoculars, the greatest and most effective and cost-efficient therapy out there!" (Goe et al. 2010).

In 2010, program coordinator Jami Belt completed a master's thesis at the University of Montana evaluating the quality of citizen science data. She learned that biologists are often able to find more goats than do volunteers in a single survey, but volunteers were able to complete more frequent site visits than biologists (at least three times more often) and were more likely to capture the high minimum count on goats for a given survey site. In the final analysis, uncorrected density estimates from aerial survey counts (1.99 mountain goats/km^2 or 0.77/mi^2), volunteers (1.91 mountain goats/km^2 or 0.74/mi^2), and biologists (1.87 mountain goats/km^2 or 0.72/mi^2) were statistically similar. We also learned that utilizing professionally developed field methods and a statistically robust study design are key to program success. Belt's study concluded that with proper study design, citizen scientists can collect reliable inventory data on mountain goats (Belt 2010).

It is crucial … to know that citizen science contributions are valuable to the park and are more than a purely educational investment.

Conclusions

Belt's thesis results are great news for citizen science. While use of volunteers is a tremendous cost savings for resources management programs (in-kind value of volunteer hours in 2010 surpassed $95,000, or seven full-time GS-5 employees for five months), a considerable investment of effort is required to manage and administer the program. As such, it is crucial to us as managers (as well as to the volunteers) to know that citizen science contributions are valuable to the park and are more than a purely educational investment. Knowing this, we have confidence to continue program expansion with our next project—involving citizen scientists in collecting climate-sensitive aquatic insects. We are delighted to find that citizen scientists can assist us in gathering useful baseline inventory data for climate-sensitive species, while we develop a constituency of volunteers who are passionately concerned about the importance of stewardship, education, and conservation of national park resources.

Acknowledgments

We would like to thank all the citizen scientists and interns for their dedication and service, numerous park staff for their support, Sallie Hejl for her initial vision and establishment of the program, and Becca Goe and the late Carly Phillips (1984–2011) for the volunteer evaluation surveys. Funding for the High Country Citizen Science Program was provided by the Glacier National Park Fund.

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Using citizen science to study saguaros and climate change at Saguaro National Park

By Don E. Swann, Adam C. Springer, and Kara O'Brien

Abstract

The Saguaro Census is a long-term monitoring project in Saguaro National Park, Arizona, that features citizen scientist volunteers who learn about ecological change in the park while gathering data on saguaros. In 2010, more than 300 volunteers measured more than 20,000 saguaros. Results of the 2010 Saguaro Census suggest that, after years of decline in at least some areas of the park, the population of this slow-growing, long-lived southwestern cactus species has increased dramatically in recent decades, following the end of a long drought in the 1950s and a warming trend since the 1970s. Citizen science has the potential not only to help parks gather large amounts of data but also to promote greater understanding and communication of natural resources management and climate change science.

Key words: citizen science, climate change, long-term monitoring, saguaro, Saguaro National Park

IN 2009, SAGUARO NATIONAL PARK was declared one of America's 25 national parks most imperiled by climate change (Saunders et al. 2009). Climatologists have predicted hotter and drier conditions in the Southwest (Barnett et al. 2004; Seager and Vecchi 2010), increasing the urgency for the park not only to understand impacts of climate change on natural resources but also to better communicate them to the public. Volunteer citizen scientists regularly help resource managers at the park efficiently gather large amounts of field data. At a time when there is much confusion and misinformation about climate change, this type of hands-on participation also has educational value by helping demystify science. In 2010, volunteers played a major role in the Saguaro Census, a monitoring program designed to study long-term ecological change in the park.

Saguaros (*Carnegiea gigantea*) are large columnar cacti that can live more than 200 years. Beloved by Arizona residents and visitors, they are also well studied. One of the longest annual monitoring programs for any species in a national park occurs at Saguaro, where some plots have been monitored for 70 years (and currently by researchers Tom Orum and Nancy Ferguson).

Saguaro National Park was established as a national monument in 1933 to protect the magnificent stand of large saguaros, known as the "Cactus Forest," in the Rincon Mountains east of Tucson. The Tucson Mountain District, west of Tucson, was added in 1962, and after further expansion in 1994, the monument became a national park. Even in the 1930s many older giants were observed to be dying, and few young saguaros could be found. The decades-long decline of the Cactus Forest has been dramatically captured in repeat photographs compiled by saguaro researcher Ray Turner (fig. 1, next page). In 1962, researchers predicted that the species would disappear from the park by 2000.

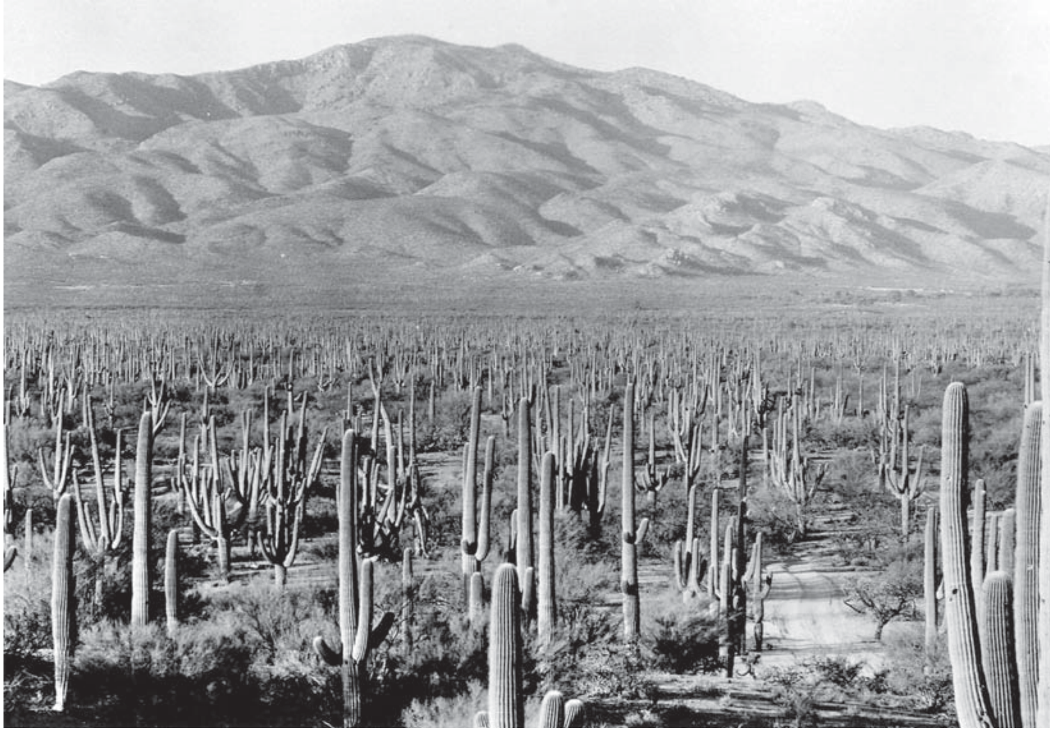
Although many factors influence saguaro recruitment, growth, and survival, research reveals that climate can be a major driver of population change. The saguaro is a subtropical plant that tolerates frost but not freezing, and severe freeze events in the 1970s are believed to have been the proximate cause of mortality of many older and very young individuals (Steenbergh and Lowe 1983). Though adults have a high tolerance for extreme heat and drought, young saguaros are very sensitive to these factors; thus recruitment appears to be episodic, coinciding with cooler, wetter periods (Drezner and Balling 2002). In addition, as a desert plant the saguaro is not fire-adapted, which may limit its distribution at higher elevations where flammable grasses are more abundant. Because minimum winter temperatures have become warmer in the Sonoran Desert during the past few decades (Weiss and Overpeck 2005), and climate models predict future decreased winter rainfall (Seager and Vecchi 2010), climate change may thus have a complex influence on saguaros—positive in response to warmer winters, but negative because of increased drought. A particular concern is that warmer winters are believed to promote an invasive African grass, buffelgrass (*Pennisetum ciliare*), that competes with saguaros and promotes fire in a desert ecosystem dominated by plants (like saguaros) that have not evolved with fire (Stevens and Falk 2009).

The Saguaro Census

Every 10 years since 1990, scientists have gathered at the park to seek a greater understanding of the long-term dynamics of the park's signature species in relation to its environment. Known as the Saguaro Census, the monitoring activities focus on individual saguaros, saguaro demographics, and associated Sonoran Desert plants

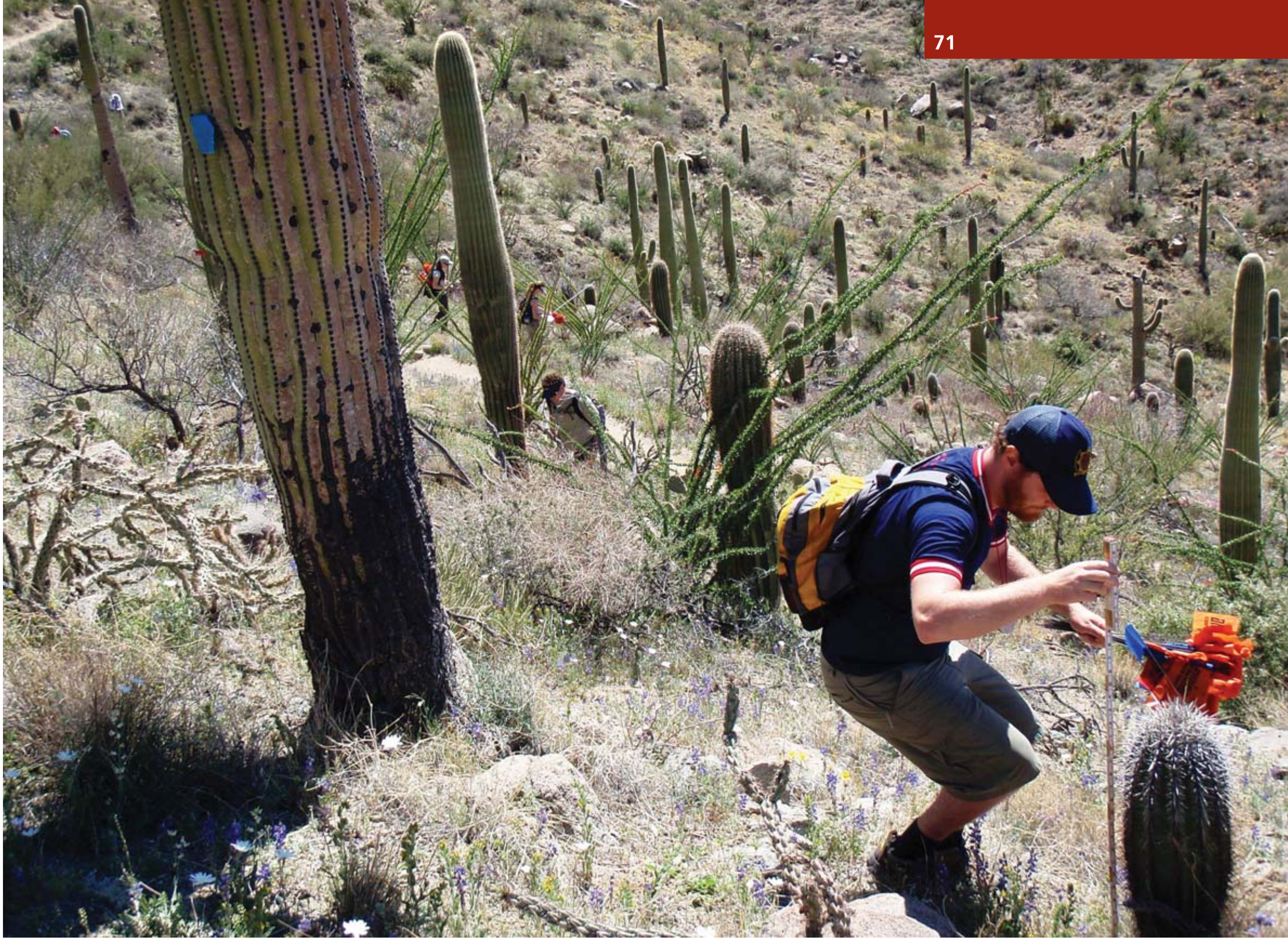
Although many factors influence saguaro recruitment, growth, and survival, research reveals that climate can be a major driver of population change.

1935 PHOTOGRAPHER UNKNOWN



1998 RAY TURNER

Figure 1. Repeat photos from 1935 (top) and 1998 (bottom) reveal dramatic changes in the saguaro population of the Cactus Forest area in the Rincon Mountain District of Saguaro National Park.



NPS/DON SWANN

Figure 2. Volunteer Matt Christensen measures a saguaro during the Saguaro Census.

on 45 randomly located, 4-hectare (9.9-acre) plots. The random distribution of study plots across a wide elevation gradient (680–1,231 m [2,231–4,039 ft]) provides an opportunity to detect changes in cactus distribution that may be related to climate or other landscape-level processes. Results of the Saguaro Census, such as estimates of the total saguaro population, have become an important part of the park's interpretive program. In 2000, when the census was first repeated, it also received significant publicity and volunteer support, and park staff saw its potential to build greater awareness of long-term ecological processes.

In 2010 the park made citizen science the core of the census. We hired an intern to coordinate volunteers, create educational products, and develop a process for leading volunteers, including methods for ensuring and evaluating data quality. From September 2009 through October 2010, more than 300 volunteers from local schools, hiking clubs, and businesses, directed by a core group of volunteers and park staff, counted and measured more than 20,000 saguaros (fig. 2). Previsit materials and an on-site orientation provided volunteers with background on ecological change at the park and why we conduct the census. Following a safety review in the field, volunteers were broken into small groups, each led by an experienced volunteer or biological technician. The group received training on how to use a clinometer to estimate cactus height, read metric rulers, identify bird cavities, and record data. Then they searched for, measured, and flagged all saguaros encountered along belt transects within the plot. After the first pass, the groups switched places and re-searched for any saguaros that could have been missed. Following their day in the field, the volunteers could visit the park's Web site to view photos and data graphs, and to compare their results with those of 1990 and 2000.

Results

Have changing climatic conditions already affected saguaro populations? Data from the Saguaro Census suggest so, but with a complexity that is characteristic of the natural world. The saguaro population in the park has surged since 1990, more than doubling on many plots—positive news for both volunteers and visitors (fig. 3, next page). We estimate the total saguaro population to be 1,896,030 (±228,163) in Saguaro National Park, an overall increase of nearly 66% since 1990. Although saguaro age cannot be directly measured, estimation of

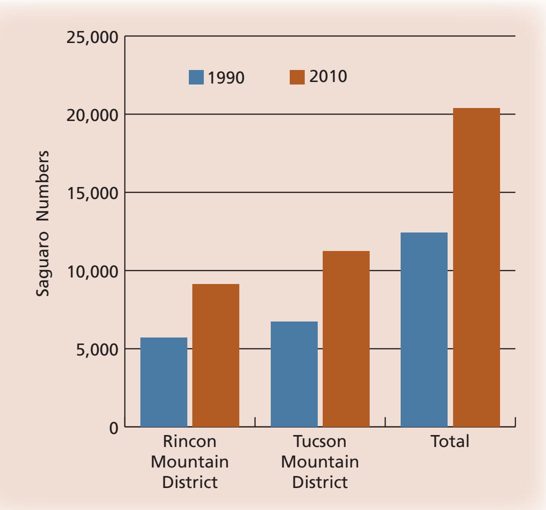


Figure 3. Number of saguaros greater than 10 cm (3.9 in.) in height detected on 45 Saguaro Census plots sampled during 1990 and 2010 in Saguaro National Park.

age based on mean local growth rates suggests recruitment began increasing in the 1960s following the severe drought of the 1950s, and accelerated in the 1980s after the end of the cold period a decade earlier. Alternative explanations for the increase are the elimination of cattle grazing and the regrowth of "nurse trees," such as the foothills palo verde (*Parkinsonia microphyllum*), that protect young saguaros from environmental extremes. The park and the NPS Sonoran Desert Network have been studying the effects of removing cattle from park lands. Based on a repeat survey conducted in 2007 of perennial plant species on treatment and control plots established in 1976, scientists with the network conclude that the effects of time outweigh the effects of grazing (Andy Hubbard, unpublished data). This suggests that climate may be more important than previously believed in controlling saguaro numbers. Conversely, the results of the 2010 Saguaro Census also suggest that, since the mid-1990s, recruitment of young saguaros has slowed. Because of the difficulty of detecting very small saguaros (a 10-year-old is approximately 4 cm [1.6 in.] in height), it is too soon to know the extent of this decline, which coincides with Tucson's hottest and driest decade on record (NOAA 2010). In addition, the park experienced an unusually cold period this past winter, in February 2011, which may have increased saguaro mortality.

Like many protected areas, Saguaro National Park faces extraordinary challenges in natural resource stewardship, especially during a time of climatic change. The saguaro's iconic role in southern Arizona makes it an ideal species to engage the public as true partners who can help us better understand these changes, respond to threats, and, most importantly, continue to learn as we move forward in the face of uncertainty. Hidden beneath the current landscape view of the park (see fig. 1) are not only many young saguaros growing slowly beneath nurse trees, but a complex story of ecological change occurring over years and decades. Citizen scientists who foray into the field to help us monitor saguaros have the opportunity to experience the process of doing science while learning about the complexity of managing natural resources in a rapidly changing world. In developing a deeper appreciation for the connection between science and the community, they may become some of our best advocates to communicate climate change issues.

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Cascades Climate Challenge: Taking home the lessons of glaciers

By Megan McGinty

Abstract

Communicating climate change and its effects is a complicated and politically challenging issue (Pew Research Center 2010). Recent research has shown that data alone are not sufficient to engage audiences on the topic of climate change (Center for Research on Environmental Decisions 2009). In addition, places where climate change is manifesting itself most dramatically, such as the glaciers of the North Cascades National Park Complex, Washington, are often perceived as irrelevant. In other cases, an informed perspective is needed to explain the significance of the data collected and the trends they indicate. North Cascades Institute and North Cascades National Park seek to address this disconnect between the scientific facts of climate change and lack of public awareness and response with the Cascades Climate Challenge. This program is cultivating the next generation of America's climate change leaders using experiential field science, study of climate change impacts, and community service. High school students from diverse communities across the Pacific Northwest spend three weeks in North Cascades National Park studying climate change with researchers in the field and developing their presentation skills. In the fall, the students return to their home communities and lead a service project based on teaching other youth in their area how climate change will affect them and what they can do to address it. Students leave the program more informed about climate science, with a better understanding of its impacts on the environment, communities, human health, and the economy, and prepared to engage their communities in strategies to alleviate the effects. By equipping emerging leaders with the skills to begin addressing climate change, we hope the people who will be most affected by it will also be better able to shape the future.

Key words: climate change, environmental education, North Cascades Institute, North Cascades National Park, partnership, service learning, youth

THE NORTH CASCADES NATIONAL Park Complex (Washington) is in the heart of the most heavily glaciated area in the contiguous United States. Iconic and defining features of the Pacific Northwest, these glaciers are places where physical evidence of climate change in North America is most easily seen and interpreted. However, given the difficulty of accessing the North Cascades backcountry, few of the people affected by the glaciers' recession ever see them, and of those, fewer still fully understand the effects of their disappearance.

A new outreach model is working to change that. The Cascades Climate Challenge (CCC) program brings youth from across the Pacific Northwest to the North Cascades, where they can witness firsthand the glaciers and their effects on surrounding ecosystems. After a three-week field experience, they are charged with taking the message back by way of a service project in their home communities, teaching others about climate change. The program was born in 2009 from a partnership among the National Park Foundation, the North Cascades National Park Complex, and North Cascades Institute, a private nonprofit educational organization. Today the program is run by North Cascades Institute, fulfilling the goal of creating teen ambassadors who can relay the message of climate change in effective and credible terms, especially to younger audiences. Each summer, 40 high school students participate in a field session based at North Cascades Institute's campus in the park, the North Cascades Environmental Learning Center. Half attend in July and the second half go in August. In exchange for the tuition-free trip, each participant agrees to reach 20 other people in his or her home community. "We try to recruit kids who are going to speak to audiences that we have difficulty reaching, whether it's a religious community, English-as-a-second-language populations, or just other teenagers," said CCC lead instructor Aneka Singlaub. "This way, not only do 40 students reach 800 other people, they reach 800 people who weren't likely to see [the park] in the first place."

Immersion

A central tenet of the program is that people value and take ownership of their public lands if they have had a chance to see and explore them on their own terms. The students spend three weeks camping in the park, immersed in the terrain they are learning about. At each turn they take advantage of their location, examining in detail different aspects of the mountain environment:

A hike up to the alpine meadows of Cascade Pass with Mignonne Bivin, NPS plant

Figure 1. NPS aquatic ecologist Ashley Rawhouser shows Cascades Climate Challenge participant Olivia Groethe and instructor Justin McWethy a fresh zooplankton sample from Ross Lake.

NPS/MICHAEL SILVERMAN

ecologist, who discusses alpine plants and their adaptations. An instructor then delivers a lesson on pikas, small alpine mammal residents who rely on the availability of specific plants in order to survive the winter. Later, students participate in a mock debate regarding whether the pika should be listed as an endangered species.

On Ross Lake they travel by canoe to meet NPS aquatic ecologist Ashley Rawhouser, who lays out the complexities of fish populations responding to changes in water temperature (fig. 1). Students conduct snorkel surveys of fish populations in the lake and discuss their findings.

During a hike along the edge of Mount Baker's Easton Glacier, NPS geologist Jon Riedel explains the patterns of glacial advance and recession over the past several thousand years, pointing out new moraines and ancient debris flows. Students ask questions about paleoecology and ice cores, trying to comprehend the role glaciers play in recording climate history.

Through these experiences the students come to see the North Cascades as an intricate, interrelated system, with small shifts precipitating a whole chain of effects. They begin to draw parallels to their local ecosystems, asking questions about the effects climate change will have on their communities.

The students are teachers too, each one presenting to the group on the topic of his or her home community. Throughout the program they create lessons based on interviews with park staff. They practice these lessons in front of the group, giving each other feedback and brainstorming the best ways to get a message across to their respective audiences.

As the students begin to explore adaptation to climate change, resource managers personify the leadership of the National Park Service. A firefighter explains the effects of hotter, drier summers and how NPS firefighting methods have changed in response. Presentations by staff implementing the Climate Friendly Parks program show the students examples of people and organizations currently working to anticipate and mitigate climate change.

Once the students are back home, they are eager to share stories of their trip and to tell others what they have learned. "We want to teach two fifth grade classrooms at a local elementary school about climate change and our own personal experiences," said Sierra Carey, a junior from Pendleton, Oregon. "It's important for people to be educated about climate change."

Support

The program would not be possible without the participation of many partners. The program costs $200,000 a year, but a significant portion of that is accounted for by in-kind support from the North Cascades National Park Complex, Mount Baker–Snoqualmie National Forest, and graduate residents at North Cascades Institute. The remainder of the cost is met through fundraising by North Cascades Institute. In 2010 and 2011, the Paul G. Allen Family Foundation was a primary funder.

The National Park Foundation was instrumental in the program's inception and continues to play an important role, funding the development of a national park–focused climate change curriculum in 2010 and a teacher training workshop in 2011. The North Cascades National Park Complex provides not only an exemplary classroom but also access to resource managers, interpreters, and maintenance staff, who make time in their busy schedules for the students, sharing their views and concerns with them. "It's rewarding and hopeful to see future leaders looking at solving these complicated issues," said Rawhouser.

North Cascades Institute runs the program, providing the administrative, logistical, and instructional service for the program, from recruiting the students to accompanying them through the field program to mentoring them afterward as they apply for college and jobs. The Mount Baker–Snoqualmie National Forest provides funds to help with campsites and encourages staff to accompany students on day hikes. Partner organizations in the students' hometowns help them line up their service projects and gain access to audiences.

Through these experiences the students come to see the North Cascades as an intricate, interrelated system, with small shifts precipitating a whole chain of effects. They begin to draw parallels to their local ecosystems, asking questions about the effects climate change will have on their communities.

Impact

Students from Astoria, Oregon, worked with their local national park to share what they learned in the North Cascades. Lewis and Clark National Historical Park (Oregon) staff helped recruit students from the area, kept in touch with them throughout the field experience, and accompanied them to their classroom presentations. After a recent presentation to elementary school students, "Kids gathered around [the CCC students] like they were rock stars and asked them question after question," said Cathy Peterson, education program coordinator at Lewis and Clark.

Cascades Climate Challenge students are invited back to the North Cascades Environmental Learning Center in the fall to attend the Youth Leadership Summit. During this three-day gathering, students learn about one another's progress in executing their projects, network with other youth, and collect information about future internships and jobs with federal agencies and partner organizations. While not every student aspires to be a ranger, all leave with a strong connection to the North Cascades and an understanding of the importance of public lands in addressing climate change.

For more information about the Cascades Climate Challenge, go to http://www.ncascades.org/programs/youth/climate_challenge/.

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