Implementing Climate Change Adaptation in Forested Regions of the United States

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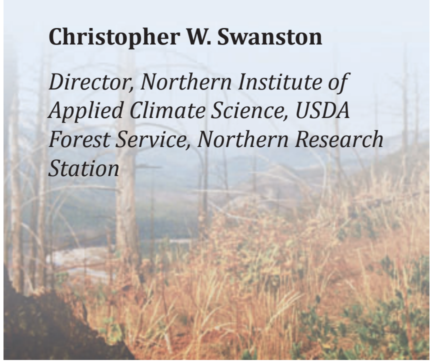

Abstract: *Natural resource managers need concrete ways to adapt to the effects of climate change. Science-management partnerships have proven to be an effective means of facilitating climate change adaptation for natural resource management agencies. Here we describe the process and results of several science-management partnerships in different forested regions of the United States (U.S.), including the Pacific Northwest, interior West, Pacific Southwest, and Upper Midwest and Northeast. Led by U.S. Forest Service scientists, these partnerships were developed to adapt resource management in National Forests, national parks, and land managed by other federal and state agencies to climate change and typically involved vulnerability assessments and science-management workshops to develop adaptation strategies and tactics. We discuss commonalities among these efforts, specific outcomes, and applicability to other regions and adaptation efforts.*

INTRODUCTION

Federal land management agencies in the United States are beginning to incorporate climate change into their management planning and operations. Department- and agency-level strategic plans and directives are increasingly recognizing the importance of incorporating climate change in agency activities. For example, Secretary of the Interior Order 3289, signed in 2009 and amended in 2010, suggests that potential climate change impacts necessitate changes in how the U.S. Department of the Interior (USDOI) manages natural resources and requires its agencies to incorporate climate change in planning, prioritization, and decision-making (USDOI 2009). Similarly, in the U.S. Department of Agriculture (USDA) strategic plan for fiscal years 2010–2015 (USDA 2010), one of four strategic goals is to ensure that National Forests and private working lands are conserved, restored, and made more resilient to climate change, and a 2011 Departmental Regulation (DR-1070-001) (USDA 2011), required the USDA and each agency within to prepare a climate change adaptation plan. More recently at the executive level, President Obama issued Executive Order 13653, “Preparing the United States for the Impacts of Climate Change” (Obama 2013). The Executive Order requires the heads of the Departments of Defense, the Interior, and Agriculture, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the Army Corps of Engineers, and other agencies to work with the Chair of CEQ and the Director of the Office of Management and Budget to, “complete an inventory and assessment of proposed and completed changes to their land- and water-related policies, programs, and regulations necessary to make the Nation’s watersheds, natural resources, and ecosystems, and the communities and economies that depend on them, more resilient in the face of a changing climate.” The assessments are required to include a timeline and plan for making changes to policies, programs, and regulations.

Agency directives have spurred a flurry of climate change-related activity in federal land management agencies over the last few years. From that activity, science-management partnerships have emerged as effective catalysts for development of vulnerability assessments and land management adaptation plans at both the strategic and tactical level (Cross and others 2013; Gaines and others 2012; Littell and others 2012; McCarthy 2012; Peterson and others 2011; Swanston and Janowiak 2012). Science-management partnerships typically involve iterative sharing of climate and climate effects information by scientists, and of local climate, ecological, and management information by managers. This iterative information exchange aids identification of vulnerabilities to climate change at the local scale and sets the stage for development of adaptation strategies and tactics, often developed through facilitated workshops.

The U.S. Forest Service (USDA FS) administers 78 million ha (193 million acres) of land in 155 National Forests and 20 national grasslands. The USDA FS is responsible for restoring, sustaining, and enhancing forests and grasslands while providing and sustaining benefits to the American people. Forest Service scientists and land managers are tasked with reducing the effects of climate change on ecosystem function and services (USDA FS 2008, 2011a). Partnerships among scientists in the Forest Service Research and Development branch, managers in the National Forest System, and other agencies and universities have played a major role in advancing climate change adaptation in the agency. Development of science-management partnerships is a performance measure in the USDA FS Climate Change Performance Scorecard (USDA FS 2011b), which rates National Forests on how well they are responding to climate change. Here, we describe the process and outcome of several recent science-management partnerships led by the USDA FS, identify key elements, and discuss future application to other regions.

ADAPTATION THROUGH SCIENCE–MANAGEMENT PARTNERSHIPS: STRUCTURE, PROCESS, AND OUTCOMES

Interior West

As a part of the WestWide Climate Initiative (Peterson and others 2011), a science-management partnership was initiated among a research scientist from the USDA FS Rocky Mountain Research Station office in Fort Collins, Colorado; the regional ecologist from the USDA National Forest System, Rocky Mountain Region’s office in Lakewood, Colorado; and the resource staff officer from the Shoshone National Forest supervisor’s office in Cody, Wyoming. The partnership was initiated to determine the potential effects of climate change on Shoshone National

Forest and develop tools to help national forest land managers adapt their management to climate change. Over time, involvement from the regional office and Shoshone National Forest expanded to include experts in wildlife, water, ecology, and planning. The scientists at Western Water Assessment at Cooperative Institute for Research in Environmental Sciences and the University of Colorado became important partners. In addition, scientists from the U.S. Geological Survey (USGS) and several universities participated in partnership activities. Periodic briefings were held at the Shoshone National Forest and in the regional office to keep interested staff updated on activities.

Initial discussions identified the need to synthesize the literature on climate change specific to the Shoshone National Forest and surrounding area. A report, "Climate Change on the Shoshone National Forest, Wyoming: A Synthesis of Past Climate, Climate Projections, and Ecosystem Implications" was jointly written by Rocky Mountain Research Station and National Forest staff to synthesize current scientific information about prehistoric, recent, and future climate and how future warming may affect natural resources on Shoshone National Forest (Rice and others 2012). A focused review of the potential impacts of climate change on quaking aspen (*Populus tremuloides* Michx.) was also conducted in cooperation with other scientists in the WestWide Climate Initiative, because aspen is a high priority for management across the western United States (Morelli and Carr 2011).

Staff on the Shoshone National Forest expressed a desire to interact with scientists on specific topics and to have sufficient time for discussion of each topic. Thus, the Natural Resource and Climate Change Workshop was held in Cody, Wyoming in 2011. The workshop was attended by over 50 participants from Shoshone National Forest, other federal and state agencies, and private sector organizations. Topics covered in the workshop, selected by Shoshone National Forest staff, included climate change, snow pack, and vegetation models. Seven local experts in the fields of climate and climate change effects, water resources, snow and glaciers, ecosystem modeling, Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*), and recreation and tourism offered information about climate and potential effects in the Shoshone area (USDA FS 2011c).

Both during the workshop and afterwards, discussions among scientists, and regional and Shoshone National Forest staff led to the identification of key resources for further consideration. These high-priority resources included water availability, Yellowstone cutthroat trout, and quaking aspen, and partnership scientists and managers conducted a vulnerability assessment for each resource. The vulnerability assessment for water availability was developed to provide information about the effects of climate change on water resources in the Shoshone National Forest region, an important source of water for human uses. For the Yellowstone cutthroat trout, a customized vulnerability assessment tool was developed using indicators for climate change exposure as well as inherent landscape, anthropogenic, and ecological factors of sensitivity and adaptive capacity (Rice and others, in review). This tool provides information to guide adaptation strategy development and conservation and monitoring planning (Rice and others, in review).

Aspen in Shoshone National Forest currently occupies a fraction of its potential habitat based on climate, topography, and soils, which suggest that its distribution is constrained by other factors. The question of where aspen may exist in the future could not be completely addressed in the assessment, although the assessment pointed to the potential for an expansion of aspen because of projected changes in climate (Rice and others, in preparation). The effects of other factors, such as conifer competition, fire regime, insects and pathogens, and wildlife browsing likely cause spatial and temporal variability of aspen distribution and abundance that may continue to be dynamic under climate change.

The results of the vulnerability assessments conducted through the partnership have informed conservation project planning for Yellowstone cutthroat trout, helped to inform the selection of hydrologic monitoring locations, and provide vulnerability information for the future management of water availability in grazing allotments. Rice and others (2012) was extensively used in the recent Shoshone National Forest planning process.

Pacific Northwest

In the first formal project to address climate change in a national forest, a science-management partnership was initiated by the USDA FS Pacific Northwest Research Station, Olympic National Forest, and Olympic National Park (Halofsky and others 2011b). Building on a long history of cooperation between a national forest and national park located on the Olympic Peninsula, this project engaged scientists and resource managers in a sequence of educational workshops, development of a vulnerability assessment, and compilation of adaptation options.

Early discussions among scientists and natural resource managers identified the need to increase awareness of climate change among federal natural resources managers on the Olympic Peninsula and assess the vulnerability of natural resources at Olympic National Forest and Olympic National Park. Four separate workshops were convened on the topics of hydrology and roads, fisheries, vegetation, and wildlife, with participants from different federal and state agencies, tribes, and other groups attending each workshop. At each workshop, scientists from the Forest Service and University of Washington provided state-of-science summaries on the effects of climate change on natural resources, and scientists and managers worked together to identify the most important impacts on the Olympic Peninsula. Smaller workshops were then convened with a core group of scientists and managers to review the vulnerability assessment and develop adaptation strategies and tactics for each of the four resource areas. All information was subsequently peer reviewed and published as documentation for management and decision making (Halofsky and others 2011b).

Building on knowledge gained from working with Olympic National Forest and Olympic National Park, the North Cascadia Adaptation Partnership (NCAP) was subsequently initiated in north-central Washington in 2011. The partnership covers 2.4 million ha (59 million acres) across the west and east sides of the Cascade Range and includes Mount Baker-Snoqualmie National Forest, Okanogan-Wenatchee National Forest, North Cascades National Park Complex, and Mount Rainier National Park (Raymond and others 2013; Raymond and others, in press). This diverse, mountainous region contains temperate rainforest, subalpine and alpine ecosystems, extensive dry forests subject to frequent fire, and shrub-steppe ecosystems. It also contains 17 000 km of roads and is adjacent to densely populated areas of western Washington.

The NCAP project started with one-day educational workshops at each of the four management units, which included resource managers, line officers, administrative personnel, and various stakeholders. Then, four two-day workshops were convened for all management units combined, with one workshop focused on each of the following topics: hydrology and access, fisheries, vegetation and ecological disturbance, and wildlife. The first day of each workshop focused on developing summaries of resource sensitivities as components of the vulnerability assessment, with scientists leading the discussion and managers contributing data and information on specific locations. The second day of the workshop focused on adaptation to sensitivities identified for each of the four resource areas, with managers providing both adaptation strategies useful for planning and adaptation tactics useful for on-the-ground applications. Information discussed and written at workshops was compiled in peer-reviewed documentation that will be used by the National Forests and national parks (Raymond and others 2013; Raymond and others, in press).

The NCAP project was premised on an "all lands" approach that considered public, private, and tribal lands other than Forest Service and National Park Service lands. Individuals from about 40 different federal and state agencies, tribes, and conservation groups participated in the workshops and assisted with identification of resource issues and adaptation options. The NCAP catalyzed an ongoing dialogue on climate change in the North Cascades region that has persisted beyond the formal phase of the project. For example, additional workshops have been convened on how climate change will affect extreme flood events that have the potential to damage roads on the west side of the Cascades. Workshops have also been convened to focus on how climate change will affect fisheries and estuarine systems in the Skagit River basin, a major watershed in the NCAP project area.

Pacific Southwest

In 2009, as a part of the WestWide Climate Initiative (Peterson and others 2011), a science-management partnership was established between research scientists at the USDA FS Pacific Southwest Research Station and managers at Inyo National Forest and Devils Postpile National Monument in the Sierra Nevada, California. This effort aimed to develop tools and information to help forest and park managers adapt their management and planning to climate change. At the start of the project, Inyo National Forest was beginning revision of its land management plan, and Devils Postpile National Monument was beginning development of a general management plan to identify long-term desired conditions for the monument and guide park managers as they decide how to best protect monument resources and manage visitation. After initial meetings to determine the direction of the partnership, the team determined that facilitated sharing of knowledge about climate change and its effects through targeted workshops and assessment reports (developed by scientists) would help managers integrate climate change into planning and management.

Inyo National Forest staff had several specific requests of scientists in the partnership: (1) compile a summary of climate trends and adaptation options relevant to the eastern Sierra Nevada, (2) develop a regional bibliography of information on climate change, (3) establish a technical advisory board that includes climate scientists conversant in eastern Sierra Nevada regional issues, (4) prepare a report and field survey for a potentially novel climate threat to quaking aspen in the eastern Sierra Nevada, (5) participate in the public engagement process before the land management plan revision process, and (6) conduct facilitated climate applications workshops. A desired outcome of the partnership was for Inyo National Forest to implement resource treatments developed by partnership discussions and products, and to incorporate climate considerations in the land management plan revision.

Priorities identified by staff at Devils Postpile National Monument, whose lands are surrounded by Inyo National Forest, included a need for high-resolution climate monitoring and information on the potential role of the monument as a cold-air pool that could serve as a climate refugium for some species. The latter led to a request for scientists to develop an analysis of cold-air pooling in the upper watershed of the monument. Partnership activities at the monument had a strong focus on science, including a combined field and classroom workshop, summary of ongoing research, and synopsis of research and monitoring efforts needed to guide future adaptation efforts. A scientific technical committee was also convened to consult on general management plan development and advise on implementation of adaptation treatments.

The science-management workshop conducted at Inyo National Forest, "Evaluating Change in the Eastern Sierra", was attended by a mix of federal, university, and other scientists, resource specialists, and concerned citizens. Scientists presented information on climate projections at the global, regional, and local scale, and discussed effects on other resources, such as vegetation (Morelli and others 2011). Implications for the Inyo National Forest were then discussed. For Devils Postpile National Monument, a science-management workshop was held with scientists from the USDA FS and USGS and managers from the National Park Service. The workshop included presentations on climate and hydrologic projections relevant to Devils Postpile National Monument as well as physical and ecological vulnerabilities and potential effects on visitors and infrastructure. Presentations were followed by a general discussion on implications for managing Devils Postpile National Monument as a refugium in an uncertain future.

In addition to education and training through facilitated workshops, outcomes of the science-management partnership in the eastern Sierra Nevada included several reports and tools. For Inyo National Forest, scientists developed a report reviewing aspen response to climate and describing an aspen screening tool (Morelli and Carr 2011). The Climate Project Screening Tool (Morelli and others 2012) was developed to provide a screening process to assess if climate change would affect resources involved in management projects in line for implementation. A report summarizing some of the latest data on climate change projections and effects relevant for eastern California was developed for use by land managers in the Sierra Nevada (Morelli and others 2011). In anticipation of the potential for Devils Postpile National Monument to serve as a climate change refugium, owing to its position at the bottom of a canyon with cold-air drainage, a network of temperature sensors in multiple-elevation transects and a climate monitoring station were recently installed to measure temperature patterns.

Upper Midwest and Northeast

The Forest Service in the Upper Midwest and Northeast created a structured approach to addressing the issue of climate change in forest management, led by the Northern Institute of Applied Climate Science. This approach, now called the Climate Change Response Framework (CCRF), needed to be responsive to the particularly diverse nature of the ownership patterns and forest practices within the region, in which National Forests and other federal lands comprise a small minority of all forested lands. The CCRF was designed to be a comprehensive program to support original science, literature synthesis, vulnerability assessment, education and outreach, adaptation planning, and adaptation implementation.

The goal was not to guide specific actions, but to instead foster climate-informed decisions in meeting a wide variety of management objectives. Meeting the needs of numerous land management organizations through an "all lands" approach required that the CCRF be flexible enough to be applied at multiple spatial and temporal scales, and address diverse management goals. Addressing the information and planning needs of the National Forests was thus a considered a core component of the CCRF, but providing information, tools, and outreach to the broader forestry community was equally critical. This was fully in keeping with the mission of the Forest Service and the explicit commitment of the Forest Service Eastern Region, Northeastern Area State and Private Forestry, and Northern Research Station to work together to support sound land stewardship across all lands (http://www.na.fs.fed.us/stewardship/pubs/conservation/land-scale_conservation.pdf).

The pilot for the CCRF was formally launched in northern Wisconsin in 2009, and the Chequamegon-Nicolet National Forest served as a "living laboratory" for the development of ideas, processes, and tools. The staff of the Chequamegon-Nicolet was absolutely essential to the evolution and success of the CCRF, providing valuable time, expertise, and often the hard voice of reality to the project. Likewise, their professional relationships in the broader forestry community helped the project grow in scope and experience. From the original pilot in northern Wisconsin, the CCRF is now being actively pursued in nine states in areas covering nearly 53 million hectares in the Northwoods (Michigan, Minnesota, and Wisconsin), Central Hardwoods (Illinois, Indiana, and Missouri), and Central Appalachians (Maryland, Ohio, and West Virginia). There are currently over 70 non-profit, private, county, state, tribal, and federal organizations partnering in the ecoregional CCRF projects.

A pilot forest ecosystem vulnerability assessment (Swanston and others 2011) and Forest Adaptation Resources book (Swanston and Janowiak, 2012) for northern Wisconsin have been published, and lessons learned from those efforts are being applied to five new vulnerability assessments (Brandt and others, in press; Handler and others, in press a/b) and an expansion of the Forest Adaptation Resources. The vulnerability assessments include chapters on 1) the contemporary landscape; 2) climate and climate modeling; 3) historic climate in the analysis area; 4) a range of projected, downscaled climates for the analysis area; 5) a literature synthesis of potential climate change impacts on forest ecosystems, and results of vegetation impact models from three different modeling platforms applied to the analysis area under a range of plausible climates ("bookends"); 6) an assessment of plausible regional climate shifts and corresponding ecosystem vulnerabilities; and 7) management implications of these shifts and vulnerabilities. A panel of ecologists, modelers, and land managers from numerous organizations were brought together through a structured expert elicitation process to produce the core of the actual assessment. They are led through a series of steps to identify and generate consensus on the vulnerability of key ecosystems being considered in the assessment, and then proceed to provide feedback on the subsequent vulnerability assessment chapters. The assessments do not make recommendations, but the Forest Adaptation Resources strategies menu and adaptation workbook can help managers choose the adaptation approaches most likely to meet their management goals.

Generating credible information about climate shifts and ecosystem vulnerability will inject critical information into the already enormous stream of information considered by land managers. However, generating clear examples of the application of that information in a realistic management context is necessary to operationalize climate-informed decision making. Creating these examples on a variety of land ownerships pursuing a wide range of management goals is thus a major objective of the CCRF. A community website (www.forestadaptation.org) serves as a common link between several sub-regional communities of practice, where these adaptation demonstrations can be briefly presented. Likewise, dozens of workshops, trainings, and conferences related to the CCRF have brought people together to discuss climate changes and forest and management responses. For those who are not interested in numerour seminars and want to get something done, the Forest Adaptation Planning and Practices training was designed to accommodate multiple organizations in a single training where participants bring real-world forest management projects and develop actionable adaptation steps using the Forest Adaptation Resources tools. Pre-work helps participants arrive ready to plan, and post-training follow-up aids organizations in their implementation processes.

The CCRF continues to grow, with new projects being planned in the Northeast and mid-Atlantic. Climate challenges can most effectively be addressed by a community, and the CCRF has successfully built a large-scale ecoregional network with widely diverse expertise, perspectives, and resources.

Keys to Successful Adaptation Partnerships

To date, all adaptation projects in National Forests and adjacent lands have used a number of common approaches and accomplished similar outcomes despite the fact that they were conducted in different geographic locations with varied natural resources issues and with different groups of managers (Peterson and others 2011). First, each project was developed on the foundation of a strong and enduring science-management partnership (Littell and others 2012) initiated by a Forest Service research station. Building these partnerships, which typically included other agencies (especially the National Park Service) and stakeholders (Table 1), required substantial time and energy to establish personal relationships and build trust. Having individuals to serve as liaisons between climate scientists and managers was critical, and the partnerships went well beyond simply providing climate data on a website or in a database for managers to access. The partnerships have persisted through time, even beyond the end of the original project, because of the effort that went into establishing relationships and providing information that can be directly applied to management.

Second, each project included an educational component in which natural resource personnel, line officers, and in some cases, administrative staff attended sessions in which they learned about the latest science on climate change and climate change effects, and shared their experiences with climate-related resource issues (Halofsky and others 2011a). This baseline of knowledge is critical for identifying key climate change vulnerabilities, developing adaptation plans, enhancing monitoring efforts, and generally incorporating climate change in planning and management.

Third, each project focused a great deal of effort on producing a peer-reviewed assessment of the vulnerability of natural resources to climate change (Table 1), in order to identify resources most at risk. These assessments, typically led by Forest Service scientists in collaboration with other agencies and universities, were state-of-the-science syntheses that focused on the topics considered by resource managers to be the most important (e.g., hydrology, fisheries, vegetation). Considerable effort was focused on downscaling and customizing information, often large scale and general in nature, to specific landscapes and resource management issues.

Table 1. Units involved, focus topics, and products for five science-management partnerships conducted with Forest Service Research and Development across the United States.

Partnership name	Geographic region	Primary partnering units	Focus topics	Published tools and reports
Inyo National Forest and Devils Postpile National Monument Case Study	Pacific Southwest	U.S. Forest Service Pacific Southwest Research Station, Inyo National Forest, and Devils Postpile National Monument	Quaking aspen, cold air pooling	Morelli and Carr 2011; Morelli and others 2011, 2012
North Cascadia Adaptation Partnership	Pacific Northwest	Forest Service Pacific Northwest Research Station, Mt. Baker-Snoqualmie National Forest, Okanogan-Wenatchee National Forest, North Cascades National Park Complex, and Mount Rainier National Park	Hydrology and access, fisheries, vegetation and ecological disturbance, and wildlife	Raymond and others 2013; Raymond and others, in press
Northwoods Climate Change Response Framework Project	Lake States	Forest Service Northern Institute of Applied Climate Science, Chequamegon-Nicolet National Forest	Forest ecosystems, carbon stocks	Swanston and others 2011; Swanston and Janowiak 2012
Olympic National Forest Case Study	Pacific Northwest	Forest Service Pacific Northwest Research Station, Olympic National Forest, Olympic National Park, University of Washington Climate Impacts Group	Hydrology and roads, fisheries, vegetation, wildlife	Halofsky and others 2011b
Shoshone National Forest Case Study	Interior West	Forest Service Rocky Mountain Research Station, Shoshone National Forest, National Forest System Rocky Mountain Region	Water availability, Yellowstone cutthroat trout, and quaking aspen	Morelli and Carr 2011; Rice and others 2012; Rice and others in review

Fourth, each project based the development of adaptation options directly on the vulnerability assessment and known principles of climate change adaptation (Joyce and others 2008, 2009; Peterson and others 2011). Scientists provided information on resource sensitivity to climate change for different scenarios, and resource managers responded with solutions for mitigating resource risk (Table 2). These responses typically included both an overarching adaptation strategy (conceptual, general) and a subset of adaptation tactics (specific, on the ground) for each strategy (Peterson and others 2011; Raymond and others 2013; Swanston and Janowiak 2012).

Commitment to regular, clear communication was a key to the success of all projects. Scientists spent many days on the ground in national forest landscapes and in offices where resource managers work. These conversations and experiences were critical for getting iterative feedback on the vulnerability assessment, management issues, and potential applications of climate change information. There is no substitute for scientists (typically with more discretionary time) working directly with resource managers (typically with minimal discretionary time) to ensure that the vulnerability assessment and adaptation options are relevant to local planning and management.

Picking up the Pace: A Challenge for the Future

Resource managers and leadership in National Forests and other lands where projects were conducted consistently cite the value of the projects in providing a new context for resource management and in enhancing "climate smart" thinking. However, implementation of information derived from climate change vulnerability assessments in national forest and national park resource assessments and monitoring is uncommon. Inclusion of climate change adaptation strategies and tactics in resource planning and project plans is just starting, even though current practices are often highly compatible with deliberate actions that enhance the ability of forests to adapt to climate change. More time may be needed for the climate change context of resource management to be incorporated as a standard component of agency operations.

At the national level, the federal agencies have a strong focus on advancing climate change issues. At the local scale, many management units would like to develop vulnerability assessments and adaptation plans. However, in the absence of a mandate to do so, the process of developing projects similar to those described above will continue to be slow. The USDA FS Climate Change Performance Scorecard requires development of climate change vulnerability assessments and adaptation plans, but the mandate is largely unfunded. Efforts to accelerate climate change implementation in National Forests come during a period of steep budget decreases, making it difficult to implement planned projects and initiate new projects. At the present time, relatively few National Forests have undertaken significant steps towards completing vulnerability assessments and adaptation plans, and the status of adaptation planning in other agency units is similar (Bierbaum and others 2013).

The slow pace of federal agencies in emulating the processes and applications described above (Peterson and others 2011) can be increased by mainstreaming (or operationalizing) climate change as a part of standard operations in the National Forest System and other federal lands. This transition has been enabled by various strategic documents in the Forest Service and other agencies. Concepts such as ecosystem-based management and ecological restoration that were originally plagued by skepticism and uncertainty evolved into operational paradigms. So too must climate change become incorporated in thought, actions, and management guidance; climate

Table 2. Examples of climate change sensitivities and related adaptation strategies and tactics. In science-management partnerships, sensitivities are typically communicated by scientists, and adaptation strategies and tactics are developed by land managers based on sensitivities.

Sensitivity	Adaptation strategy or tactic	
Increased opportunity for invasive species establishment	Implement early detection/rapid response for exotic species treatment	
Potential for mortality events and regeneration failures, particularly after large disturbances	Develop a gene conservation plan for ex situ collections for long-term storage Identify areas important for in situ gene conservation Maintain a tree seed inventory with-high quality seed for a range of species Increase production of native plant materials for post-flood and postfire plantings	
Increased forest drought stress and decreased forest productivity at lower elevations	Increase thinning activities Use prescribed burns and wildland fire to reduce stand densities and drought stress	
Increased winter and spring flooding	Implement more conservative design elements (more intensive treatments such as larger diameter culverts, closer spacing between ditch relief culverts and waterbars) Increase maintenance frequency of drainage features	

change needs to become a standard component in strategic planning, project planning, monitoring, and implementation. This will likely come with increased awareness of climate change, understanding of the potential effects of climate change, and the development and awareness of effective responses to decrease resource vulnerabilities.

Scientific knowledge about the effects of climatic variability and change on natural resources is for the most part not a limiting factor in moving forward with climate change activities in National Forests and other federal lands. However, effective transfer of climate-related knowledge from the scientific to the management community is lacking, and thus so is the application of the information in natural resource management. Future efforts can therefore focus on the synthesis of relevant scientific information for specific landscapes (vulnerability assessment), effective transfer of that information to the management community, and then development of responses that reduce negative effects on resources (adaptation planning). This can be expedited in agencies like the Forest Service and National Park Service by institutionalizing science-management partnerships to facilitate climate change adaptation and associated processes. An ideal partnership in the Forest Service includes scientists from research stations, resource managers in National Forests, and subject matter experts from regional offices, along with scientists and managers from other agencies, universities and organizations. National Oceanic and Atmospheric Administration Regional Integrated Sciences and Assessments (RISA) program scientists were involved in the adaptation partnership developed with Olympic National Forest and Olympic National Park (Halofsky and others 2011b), in the NCAP effort (Raymond and others 2013; Raymond and others, in press), and in the Shoshone National Forest effort, and scientists from RISA centers and USDOI Climate Science Centers could be key partners in future efforts. If participants in these partnerships work on multiple projects, they will accrue knowledge that will make each subsequent project more effective and efficient. In addition, vulnerability assessments and adaptation plans can be developed for clusters of National Forests and Parks (and, potentially, adjacent federal, tribal, and other lands) with similar biogeographic characteristics and management objectives, resulting in time and budgetary efficiencies. Different clusters of management units may be appropriate for different resources.

We are optimistic that climate change can be mainstreamed in the policies and management of the Forest Service and other federal agencies by the end of this decade. This can be expedited by considering climate change as one of many risks to which natural resources are subjected (Iverson and others 2012), and by considering adaptation as a form of risk management. This approach has been recently described for water resources, fire, carbon, forest vegetation, and wildlife (Peterson and others, in press; Vose and others 2012), and will be fully incorporated in future U.S. National Climate Assessments and assessments by the Intergovernmental Panel on Climate Change (Yohe and Leichenko 2010). We anticipate that evaluating climate change risks concurrently with other risks to resources will become standard practice over time.

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This paper received peer technical review. The content of the paper reflects the views of the authors, who are responsible for the facts and accuracy of the information herein.