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Adapting to the effects of climate change on natural resources in the Blue Mountains, USA

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ABSTRACT

National forests in the Blue Mountains (USA) region have developed adaptation options that address effects identified in a recent climate change vulnerability assessment. Adaptation strategies (general, overarching) and adaptation tactics (specific, on-the-ground) were elicited from resource specialists and stakeholders through a workshop process. For water supply and infrastructure, primary adaptation strategies restore hydrologic function of watersheds, connect floodplains, support groundwater-dependent ecosystems, maximize valley storage, and reduce fire hazard. For fisheries, strategies maintain or restore natural flow regimes and thermal conditions, improve water conservation, decrease fragmentation of stream networks, and develop geospatial data on stream temperature and geologic hazards. For upland vegetation, disturbance-focused strategies reduce severity and patch size of disturbances, protect refugia, increase resilience of native vegetation by reducing non-climate stressors, protect genotypic and phenotypic diversity, and focus on functional systems (not just species). For special habitats (riparian areas, wetlands, groundwater-dependent ecosystems), strategies restore or maintain natural flow regimes, maintain appropriate plant densities, improve soil health and streambank stability, and reduce non-climate stressors. Prominent interactions of resource effects makes coordination critical for implementation and effectiveness of adaptation tactics and restoration projects in the Blue Mountains.

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Practical Implications

Climate change adaptation is in its early stages in most of the western United States, including in the Blue Mountains (Oregon and Washington, USA) region. The U.S. Forest Service, which manages the majority of forested land in this region, has a major responsibility for ensuring sustainability of natural resources and ecosystem services. That task will become more difficult in a warmer climate, especially if extreme events (drought, wildfire, insect outbreaks) become more common.

Restoration of streams is already underway in national forests, but the expectation that climate change will have significant negative effects on water adds urgency to restoration programs. Maintaining functional hydrologic systems is an underlying adaptation strategy for many aspects of water management in the Blue Mountains. It will be especially important to reconnect floodplains and retain water within mountain landscapes. Adaptation tactics include adding wood to streams, encouraging American beaver populations, and reducing impacts from livestock grazing. In addition, it will be important to adapt existing roads and infrastructure by upgrading engineering standards (e.g., culvert size) and decommissioning roads that are particularly vulnerable to future flooding.

Most of these adaptation options are relevant for fisheries management, which also has ongoing restoration programs in the Blue Mountains. Maintaining cold water in streams and other water bodies is a primary objective for adaptation, especially in areas where it will be possible to retain cold water in future decades (coldwater refugia), typically at higher elevations. Sediment deposition from increased flooding and wildfires will also damage aquatic habitat, and proactive management that can reduce this stressor will be imperative for reproduction by bull trout and other species.

Increased frequency and extent of drought, wildfire, and insect outbreaks will be a major challenge for vegetation management in a warmer climate. Focusing on maintaining productive, functional forests and other ecosystems that are resilient to disturbance will

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be a central adaptation strategy. Ongoing stand density management and hazardous fuel reduction are climate-smart practices, but would need to be expanded to improve resilience across large landscapes. Special habitats (riparian areas, wetlands, groundwater-dependent ecosystems) are uncommon but critical for biodiversity. Controlling non-climate stressors such as non-native plant species and trampling by livestock is especially important in these habitats, which may see hydrologically mediated effects of climate change in the near future.

The number of potential climate change effects, as well as the number of potential adaptation strategies and tactics, make it imperative for resource managers in the Blue Mountains to coordinate efforts across disciplines and geographic locations. It will not be possible to address all issues everywhere. Using a ''climate change lens'' to establish priorities for adaptation, and more broadly for restoration, will increase the likelihood of success and ensure good investments across the landscape.

1. Introduction

This concluding article in a special issue of *Climate Services* focuses on climate change adaptation in the Blue Mountains region (Oregon and Washington, USA). Defined by the Intergovernmental Panel on Climate Change as an ''adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects'' (McCarthy et al., 2001), adaptation can help to reduce harm or transition organisms and systems to new conditions in a warmer climate. With 30 years of climate change science now available, federal land managers have sufficient information to start the adaptation process, and need to go beyond conceptual frameworks to develop concrete practices and implement timely actions on the ground.

Substantive planning and management for anticipated effects of climate change on U.S. public lands are still in the early stages. This slow response has been caused by real or perceived uncertainty of effects on biophysical conditions, lack of institutional capacity (budget and personnel) to address a major new topic, and until recently, absence of a mandate to incorporate climate change in agency operations. The U.S. federal government is now addressing climate change adaptation in earnest. Over the past decade, the U.S. Forest Service has established several science-management partnerships to address adaptation, providing strategic and on-the-ground approaches for adapting to climate change (Peterson et al., 2011; Swanston and Janowiak, 2012).

The Blue Mountains Adaptation Partnership (BMAP) is a science-management partnership focused on vulnerability assessment and adaptation planning for climate change in Malheur, Umatilla, and Wallowa-Whitman National Forests (2.1 million hectares) in Oregon and Washington. The BMAP assessed vulnerability of natural resources and infrastructure (water resources, fisheries, vegetation, special habitats) (see other articles in this special issue) as a foundation for developing options for adapting resources and management to a changing climate.

After identifying key vulnerabilities for each resource sector, a workshop was convened in La Grande, Oregon, in April 2014 to present and discuss the vulnerability assessment and to elicit potential adaptation options from resource managers. The workshop included an overview of adaptation principles (Peterson et al., 2011) and examples of efforts to adapt to climate change in the Pacific Northwest. For each resource sector, participants were assembled in workgroups to identify adaptation strategies (general approaches) and adaptation tactics (on-the-ground actions), as well as additional information on opportunities and barriers for implementing adaptation. Workshop participants were asked to identify adaptation options that were feasible in terms of effort, budget, and existing policies and laws. Facilitators captured information generated during the workshops with a set of spreadsheets adapted from Swanston and Janowiak (2012). Initial results from the workshops were augmented through continued dialogue with Forest Service resource specialists to ensure that all information was communicated accurately.

This article summarizes information elicited at the workshop described above: options for adapting water resources, fisheries, upland vegetation, and special habitats to a changing climate. Because adaptation options were developed by national forest resource managers in response to projected climate change effects, those who use these adaptation options can be assured that the strategies and tactics are grounded in practical knowledge of local landscapes.

2. Adapting water resources to climate change

2.1. Water use

Adaptation options were developed after considering climate change effects on lower summer streamflow, higher winter peak streamflow, earlier peak streamflow, lower groundwater recharge, and higher demand and competition for water by municipalities and agriculture (Table 1). Adaptation strategies included: (1) restore function of watersheds, (2) connect floodplains, (3) support groundwater-dependent ecosystems, (4) reduce drainage efficiency, (5) maximize valley storage, and (6) reduce fire hazard. The objective of most of these strategies is to retain water for a longer period of time at higher elevations and in riparian systems and groundwater of mountain landscapes. These strategies will help maintain water supplies, especially during summer, and reduce water loss when withdrawals are low.

The adaptation tactic of using a ''climate change lens'' generally reinforces practices that support sustainable resource management. Potential risk and uncertainty can be included in this process by considering a range of climate projections to frame decisions about responses to climate change. User awareness of vulnerability to shortages, reduced demand through education and negotiation, and collaboration among users can support adaptation.

Many adaptation tactics to protect water supply are considered ''best management practices (BMP),'' for water quality protection, and are required by the Forest Service in activities that may affect water quality, including road management and water developments. A related tactic is improving roads and drainage systems to maintain water within mountain watersheds. Although these tactics are expensive, they greatly benefit water retention and erosion control. Climate change may compel more frequent maintenance and repair.

Several adaptation tactics related to biological components of mountain landscapes can reduce the effects of climate change on water resources. Reducing stand density and surface fuels in low-elevation coniferous forest reduces the likelihood of fires that can damage soils, accelerate erosion, and degrade water quality. Vegetation treatments in high-snow areas may extend water yield into the summer for a few years following treatment.

Stream restoration techniques that improve floodplain hydrologic connectivity increase water storage capacity. Meadow and wetland restoration that removes encroaching conifers can improve hydrologic function and water storage capacity. Adding wood to streams improves channel stability and complexity, slows water movement, improves aquatic habitat, and increases resilience to both low and high flows. Increasing American beaver

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