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Assessing and adapting to climate change in the Blue Mountains, Oregon (USA): Overview, biogeography, and climate

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ABSTRACT

The Blue Mountains Adaptation Partnership (BMAP) was established to increase climate change awareness, assess vulnerability to climate change, and develop science-based adaptation strategies for national forest lands in the Blue Mountains region of northeast Oregon and southeast Washington (USA). The BMAP process included (1) development of a science-management partnership, (2) a vulnerability assessment of the effects of climate change on natural resources and infrastructure, (3) development of adaptation options that will help reduce negative effects of climate change and assist the transition of biological systems and management to a changing climate, and (4) ongoing dialogue and activities related to climate change in the Blue Mountains region. This special issue of *Climate Services* describes social context and climate change vulnerability assessments for water use and infrastructure, vegetation, and riparian ecosystems of the Blue Mountains region, as well as adaptation options for natural resource management. This manuscript introduces the special issue, describing the management, biogeographic, and climatic context for the Blue Mountains region; the climate change vulnerability assessment and adaptation process used in BMAP; and the potential applications of the information described in the special issue. Although the institutional focus of information in the special issue is U.S. Forest Service lands (Malheur, Umatilla, and Wallowa-Whitman National Forests), the broader social context and adaptation options should be applicable to other lands throughout this region and the Pacific Northwest.

Practical Implications

The vulnerability assessment described in this special issue of *Climate Services* is the first step in understanding how climate change may affect climate, natural resources, and ecosystem services in the Blue Mountains of northeast Oregon and southeast Washington (USA). Although uncertainty exists in the likelihood, magnitude, and timing of future changes in aquatic and terrestrial ecosystems, the information provided a basis for development of adaptation options that managers can choose from and utilize in the future.

Climate change effects in the semiarid Blue Mountains are a particular concern, because much of the landscape has already been greatly altered by land-use activities—timber harvesting, livestock grazing, water diversions—that have in many cases affected the functionality of systems and the distribution and abundance of species. These stressors provide an important context for considering how to adapt to climate change in the context of current land uses and policies. Infrequent, extreme events such as drought and wildfire will be a driving force for both ecological and social change, as they combine with existing stressors and interact with demands for ecosystem services (water, fish, timber, recreation, etc.).

Changes in hydrology and water availability will be major issues for the Blue Mountains region in a warmer climate. Lower snowpack and higher peak flows in winter will cause more damage to infrastructure. Upgrading engineering standards for roads and infrastructure (e.g., increasing culvert size) will likely help to minimize damage and repair costs. Lower stream flows in summer will reduce water supply for agriculture, municipal uses (drinking water), industrial uses,

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livestock grazing, and recreation. Competition among different users may become acute during future drought periods.

Disturbances such as drought, wildfire, and insect outbreaks will be a major challenge for vegetation management in a warmer climate. Thus, increasing vegetation resilience to disturbance is a focus of adaptation strategies for the Blue Mountains. Stand density management is a currently used tool that will likely be effective in mitigating effects of fire and drought in the future. Most people in the Blue Mountains region support active forest management (forest thinning, surface fuel reduction) and restoration to reduce the likelihood of high-intensity wildfires that would damage timber and threaten local communities.

Climate change will also be a challenge for the management of riparian areas and groundwater-dependent ecosystems, which have significant conservation value throughout western North America. Most riparian systems will be stressed to some degree in a warmer climate. Some changes may occur gradually and some may occur episodically (e.g., following wildfire). Maintaining hydrologic functionality and minimizing external damage from land use may be the most reasonable approach for building resilience in these systems.

Overall, this special issue of *Climate Services* provides a framework and key steps that can be used by resource management agencies and other entities to assess climate change vulnerabilities and develop feasible measures to reduce negative effects of climate change. A science-management partnership is a critical aspect of this approach. Although not all vulnerabilities and management options are relevant in all places, many of the principles and approaches can be applied elsewhere. Monitoring will be needed to both quantify current resource conditions and evaluate the effectiveness of climate-informed management. In addition, collaboration between federal agencies and a broad range of stakeholders will ensure that multiple perspectives are considered when building resilience in ecosystems and local communities facing a warmer climate.

1. Introduction

During the past decade, the U.S. Forest Service has begun the process of assessing the vulnerability of natural resources to climate change and developing appropriate adaptation options that can be implemented in planning and management (USFS, 2008; Peterson et al., 2011; Swanston et al., 2016). The Forest Service developed the National Roadmap for Responding to Climate Change (USFS, 2010a) and Performance Scorecard for Implementing the Forest Service Climate Change Strategy (USFS, 2010b) to provide guidance and accountability for including climate change in National Forest System operations.

The objective of the Forest Service climate change strategy is to "ensure our national forests and private working lands are conserved, restored, and made more resilient to climate change, while enhancing our water resources" (USFS, 2010b). The Scorecard addresses this strategy through 10 criteria grouped in four dimensions: (1) increasing organizational capacity, (2) partnerships, engagement, and education, (3) adaptation, and (4) mitigation and sustainable consumption. Each national forest annually reports its progress for the 10 criteria. All national forests in the Forest Service Pacific Northwest Region (Oregon and Washington) have also completed climate change action plans that describe how they will meet Scorecard requirements.

Previous efforts in the Pacific Northwest and beyond have demonstrated the success of science-management partnerships for increasing climate change awareness among federal land managers. Olympic National Forest, Olympic National Park (Halofsky et al., 2011) and Tahoe National Forest (Littell et al., 2012) conducted the first science-management partnerships that developed adaptation options for individual national forests. Similar to efforts on the Olympic Peninsula, the North Cascadia Adaptation Partnership assessed vulnerabilities and formulated adaptation options for two national forests and two national parks in Washington (Raymond et al., 2013, 2014). The Forest Service Rocky Mountain Research Station compiled future climate projections and potential effects of climate change on multiple ecosystems in Shoshone National Forest (Wyoming) (Rice et al. 2012). Finally, the Forest Service Northern Research Station collaborated with Chequamegon-Nicolet National Forest (Wisconsin) and other partners to develop a vulnerability assessment and adaptation options for natural resources in the forest (Swanston et al., 2011, 2016). A national-scale assessment focused on vulnerability of watersheds to climate change in 11 national forests throughout the United States, focused on climate change effects on water resource values, hydrologic function, watershed condition, and landscape sensitivity (Furniss et al., 2013).

We built on previous efforts to conduct a climate change vulnerability assessment and develop adaptation options for national forests in the Blue Mountains region of northeast Oregon and southeast Washington (USA). This special issue of *Climate Services* contains individual articles on social context (Hartter et al., 2018), and climate change vulnerability assessments for water resources (Clifton et al., 2018), upland vegetation (Kim et al., 2018 and Kerns et al., 2018), and riparian systems (Dwire and Mellmann-Brown, 2018) in the Blue Mountains. Each article on natural resources discusses climate change effects, specific sensitivities, and current conditions and management practices. A final article (Peterson and Halofsky, 2018) summarizes adaptation options for responding to the effects of climate change on natural resources.

In this introductory manuscript, we have three main objectives:

1) Provide a management, biogeographic and climatic context for the Blue Mountains region to set the stage and facilitate interpretation of information in other articles in the special issue.
2) Describe the development of the Blue Mountains science-management partnership and the vulnerability assessment and adaptation process that resulted in the information presented in this special issue.
3) Describe the potential applications of the information contained in this special issue in natural resource management in the Blue Mountains region.

Specific climate change vulnerability assessment methods and outcomes are described in the following papers in this special issue. Peterson and Halofsky (2018) has more detailed descriptions of the adaptation options and potential applications of vulnerability assessment information in resource management.

2. The Blue Mountains study region

2.1. National forest management

The Blue Mountains are comprised of several small mountain ranges, including the high-elevation Eagle Cap Mountains, and the smaller Elkhorn, Greenhorn, Strawberry, Wenaha, and Aldrich Mountains. Elevation ranges from 267 to 3000 m. Malheur National Forest covers 607,028 ha, including Monument Rock and Strawberry Mountain wilderness areas (35,742 ha) (Fig. 1). The Malheur River and North Fork Malheur River are protected as wild and scenic for their aesthetic value, fisheries, geology, and wildlife. Umatilla National Forest covers 566,560 ha (78% in Oregon, 22% in Washington), including Wenaha-Tucannon, North Fork Umatilla, and North Fork John Day wilderness areas (128,858 ha). Wild and scenic rivers (93 km) protect steelhead trout (*Oncorhynchus mykiss*), Chinook salmon (*O. tshawytscha*), and migratory bull trout (*Salvelinus confluentus*). Wallowa-