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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-

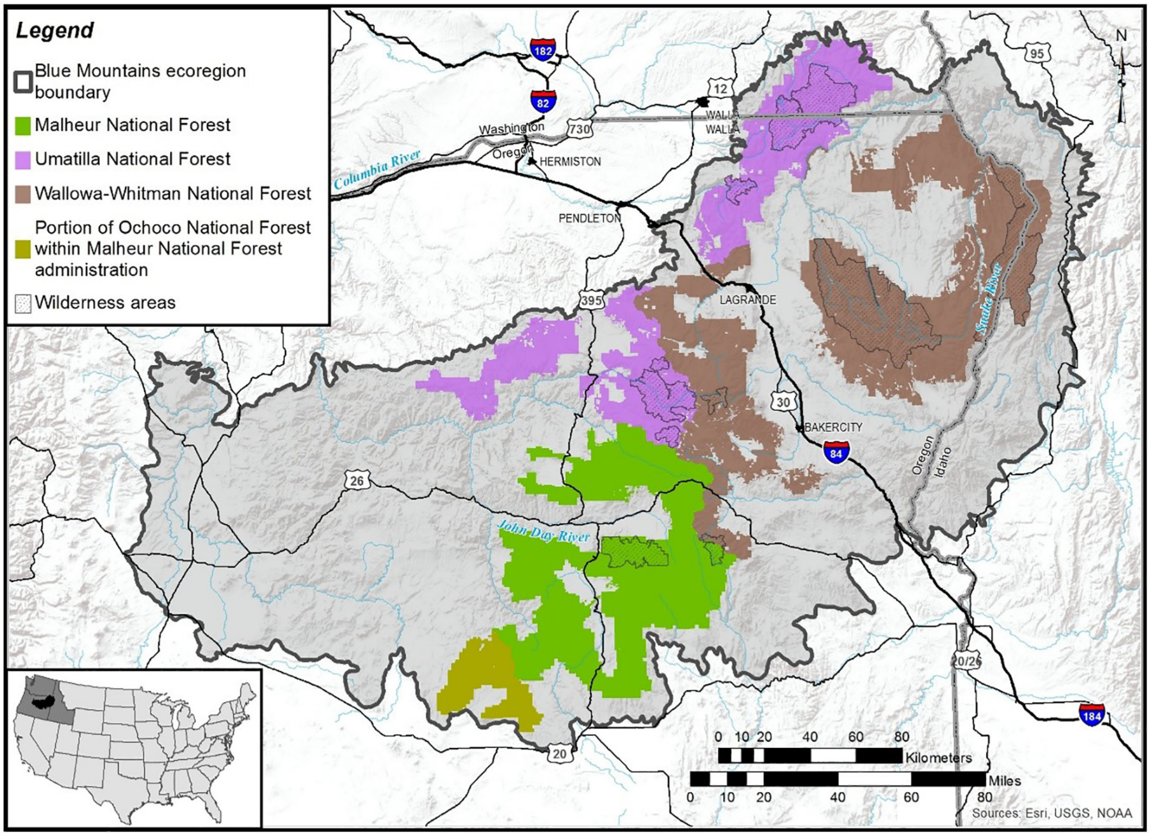

Fig. 1. The Blue Mountains ecoregion, including national forests.

Whitman National Forest covers 968,214 ha (a small portion in Idaho), including the Eagle Cap, Hells Canyon, North Fork John Day, and Monument Rock wilderness areas (237,024 ha). Ten wild and scenic rivers protect scenery, recreation, fisheries, wildlife, and historic and cultural resources.

The three national forests share a common administrative and management history. In 1908, the entire area was established as a forest reserve to protect water, timber, and rangeland (USFS, 1997). The Blue Mountains draft revised land management plan (USFS, 2014) guides all resource management activities.

National forests in the Blue Mountains are currently managed for a wide range of ecosystem services, including timber, water, fisheries, wildlife, livestock grazing, and recreation. Recreation and tourism have become increasingly important in terms of number of users and economic value. Current restoration efforts in the Blue Mountains focus on improving the vigor of low-elevation dry forests, reducing fire hazard, restoring functional fish passages, improving habitat for several animal species, and improving riparian and stream conditions (Potyondy and Geier, 2011).

2.2. Biogeographic and cultural context

Geological, biological, and cultural histories in the Blue Mountains region provide an important context for assessing the effects of climate change on natural resources. The complex geological history of the Blue Mountains—oceanic subduction, terrestrial sedimentation, and volcanic deposition (e.g., Brooks, 1979), followed more recently (20,000–14,000 BP) by glaciation (Johnson et al., 1994)—provides a foundation for ecological diversity. Variability in glacial deposition and volcanic ash contributes to spatial variation in soil productivity and vegetation (Johnson et al., 1994; Jaindl et al., 1996; Kelly et al., 2005; Simpson, 2007).

Native Americans, including the Nez Perce, Cayuse, Walla Walla, Shoshone, Bannock, Wasco, Burns Paiute, Umatilla, and Warm Springs Tribes, are the original inhabitants of the Blue Mountains region (Robbins and Wolf, 1994; Heyerdahl et al., 2001). Native Americans used local landscapes for hunting, fishing, and gathering of wild foods and plant materials (Robbins and Wolf, 1994; Richards and Alexander, 2006). Fire was often used to promote desired plant species and to improve habitat for preferred animals used for food (Johnson, 1994; Robbins and Wolf, 1994; Heyerdahl et al., 2001). The Blue Mountains are still an important location for hunting, fishing, gathering, and spiritual values for Native Americans.

Following Euro-American settlement, sheep and cattle grazing were common across most of the landscape, followed by extensive timber harvesting (Oliver et al., 1994; Wissmar et al., 1994). Outbreaks of mountain pine beetle (*Dendroctonus ponderosae*), western spruce budworm (*Choristoneura freemani*), and Douglas-fir tussock moth (*Orgyia pseudotsugata*) were widespread in the 1900s (Rainville et al., 2008). Insect outbreaks and wildfire are such prominent disturbances in the Blue Mountains that they are a major consideration in most aspects of resource management and restoration. Increasing concerns about water quality and fisheries after the mid-20th century have motivated increased effort on restoration of aquatic ecosystems.

Historically, low-severity wildfire regimes at low elevations promoted ponderosa pine (*Pinus ponderosa*) and dry mixed-conifer forest (Kerns et al., 2018), comprising 20–50% of the total landscape and 40–75% of all forests (Rainville et al., 2008). Western juniper (*Juniperus occidentalis*), Idaho fescue (*Festuca idahoensis*), bitterbrush (*Purshia tridentata*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), and curl-leaf mountain-mahogany *(Cercocarpus ledifolius* Nutt.) are also common at low elevation (Johnson et al., 1994; Jaindl et al., 1996). Mixed-severity fire regimes at mid elevations promote lodgepole pine (*Pinus contorta* var. *latifolia*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and western larch (*Larix occidentalis*). At high elevations, subalpine fir (*Abies lasiocarpa*) and whitebark pine (*Pinus* *albicaulis*) transition to alpine meadows (Johnson et al., 1994; Jaindl et al., 1996).

Decades of fire exclusion, livestock grazing, and timber harvest have heavily altered historical vegetation structure and fuel accumulations, creating conditions that can facilitate future insect outbreaks and intense wildfires (Lehmkuhl et al., 1994; Langston, 1995; Hessburg and Agee, 2003; Hessburg et al., 2005). Lower elevation ponderosa pine and mixed conifer forests have experienced the greatest changes (Harrod et al., 1999).

2.3. Historical and projected future climate

It is important to establish a baseline of climatic influences and historical climate in the Blue Mountains before considering future change. The Pacific Ocean and Cascade Range are dominant influences on climatic patterns in the Pacific Northwest. Diurnal temperature range is generally higher east of the Cascade crest, further inland from the Pacific Ocean. More precipitation falls west of the Cascade crest, and a strong rain shadow greatly reduces precipitation east of the crest. The southern portion of the Blue Mountains, including the Strawberry subrange, is in the rain shadow of the Cascade Range and is predominantly influenced by Great Basin climatic patterns, resulting in warmer and drier conditions. In the northern Blue Mountains, maritime air flows through the Columbia River Gorge, causing slightly higher precipitation and moderate temperature variations (Western Regional Climate Center, http://www.wrcc.dri.edu). Regional annual average precipitation is 44 cm, with more precipitation in higher elevation areas. Temperatures in the Blue Mountains are cooler than those of the entire Pacific Northwest, with historical mean annual temperature of about 7.5 °C (and colder temperatures at higher elevations).

In northeast Oregon, mean annual temperature increased 0.06 °C per decade between 1895 and 2013 (NOAA National Centers for Environmental Information, https://www.ncei.noaa.gov) (Fig. 2). Only three years have been below the 20th century annual average temperature of 7.5 °C since 1990. Annual precipitation in the Pacific Northwest has high interannual variability, and is influenced by the El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (Mote et al. 2013). The northeast Oregon region has exhibited no significant precipitation trend, although the last 30 years were generally drier than the 20th century average, with some very wet years in the mid-late 1990s (Fig. 3).

For the Pacific Northwest, Mote et al. (2013) summarized climate projections from 41 global climate models under Representative Concentration Pathways 4.5 and 8.5 (van Vuuren et al., 2011) from the fifth phase of the Coupled Model Intercomparison Project, used in the Intergovernmental Panel on Climate Change Fifth Assessment Report (Stocker et al., 2013). Projections for future climate in the Pacific Northwest suggest continued warming in the future in the Blue Mountains region (Mote et al., 2013). Global climate model output for 2041–2070 projects warming of 1.1–4.7 °C compared to historical (1970–1999) temperatures, with the degree of warming dependent on emissions scenario, particularly after about 2050 (Fig. 4). All GCMs agree that each season will be warmer in the future, with the greatest warming in summer (Table 1). Projections for future annual precipitation are highly variable, ranging from wetter to drier, with any trends being small compared to historical interannual variability. The average of all model outputs for annual precipitation is essentially no change from historical, with a broad range of projections. However, the majority of models agree that summers will be slightly drier in the future (Mote et al., 2013) (Table 1).

3. The Blue Mountains adaptation partnership process

In 2013, several organizations developed a science-management partnership focused on an assessment of climate change effects in the Blue Mountains. Termed the Blue Mountains Adaptation Partnership (BMAP), participants included Malheur, Umatilla, and Wallowa-Whitman National Forests; U.S. Forest Service (USFS) Pacific Northwest Research Station; USFS Pacific Northwest Region; University of Washington; and Oregon State University Climate Impacts Research Consortium. The BMAP goals were to increase climate change awareness, assess vulnerability to climate change, and develop science-based adaptation strategies to reduce adverse effects of climate change and ease the transition to new climate states and conditions (see http://adaptationpartners.org/bmap).

The BMAP built on several initiatives in ecological restoration in the Blue Mountains region. In 2013, the Blue Mountains Restoration Strategy interdisciplinary team was convened to coordinate restoration

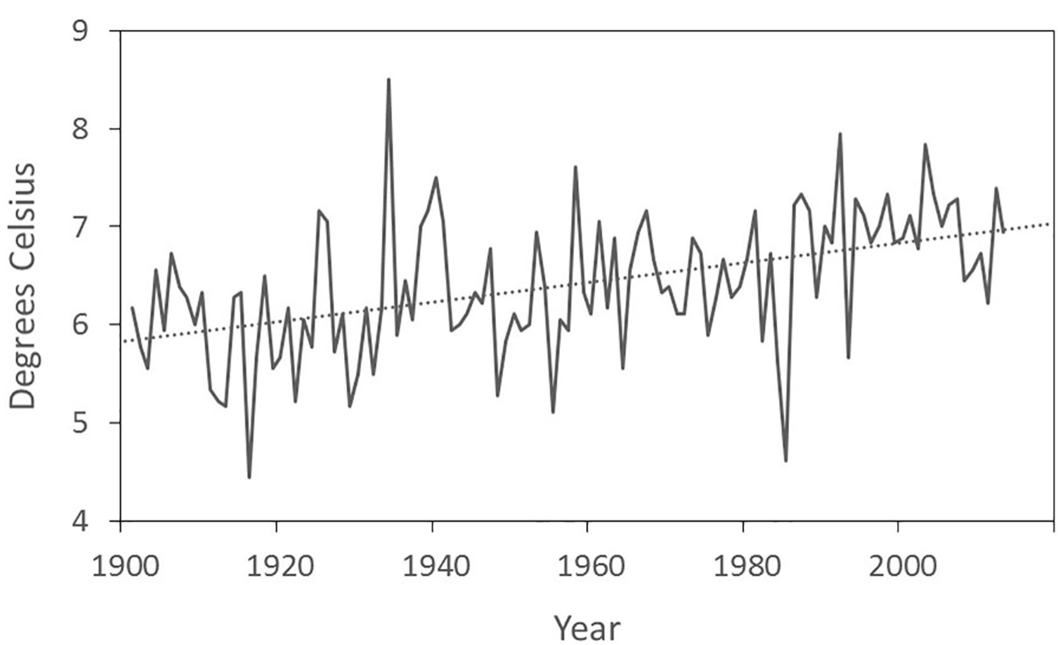

Fig. 2. Annual historical temperature for Oregon Climate Division 8. Data are from NOAA National Centers for Environmental Information (http://www.ncdc.noaa.gov/cag/time-series/us).

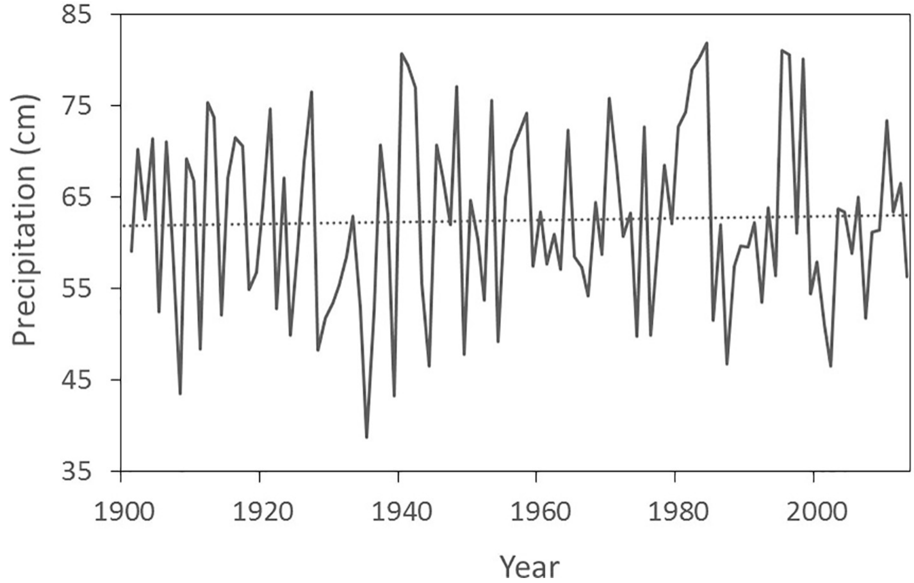

Fig. 3. Annual historical precipitation for Oregon Climate Division 8. Data are from NOAA National Centers for Environmental Information (http://www.ncdc.noaa.gov/cag/time-series/us).

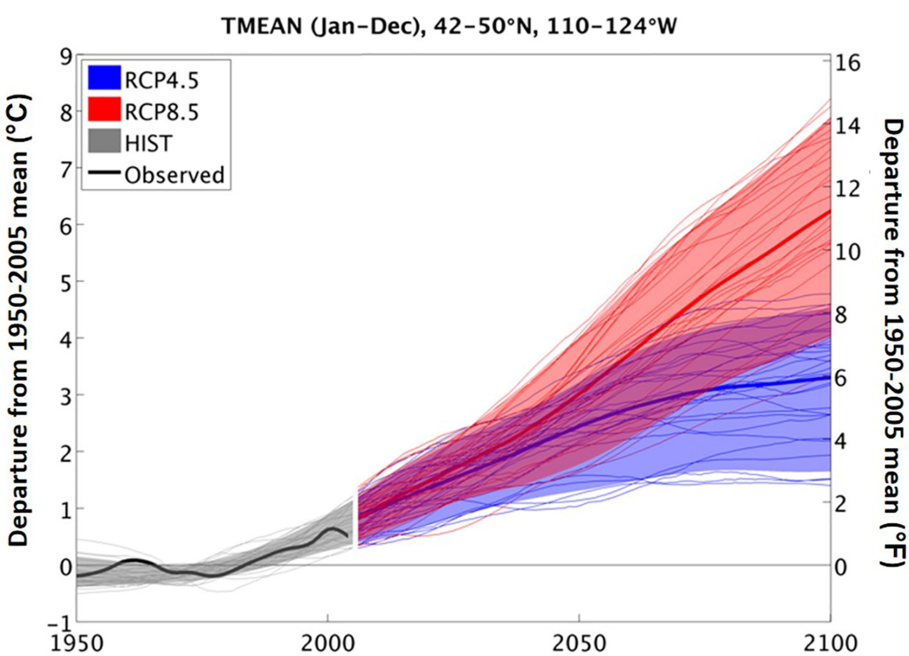

Fig. 4. Observed (1950–2011) and simulated (1950–2100) regional mean temperature for the Pacific Northwest. The gray (historical), red (RCP 8.5), and blue (RCP 4.5) envelopes represent the range of model projections. Narrow lines represent individual model projections, bold lines are means of the model projections. Data are from 41 global climate models used in the fifth phase of the Coupled Model Intercomparison Project, analyzed and described for the Pacific Northwest by Mote et al. (2013).

Table 1
Summary of global climate model temperature and precipitation projections for the Representative Concentration Pathway (RCP) 4.5 and RCP8.5 (van Vuuren et al., 2011) for the Pacific Northwest between the historical period (1950–1999) and mid-21st century (2041–2070)[a]. Data are from 41 global climate models used in the fifth phase of the Coupled Model Intercomparison Project, analyzed and described for the Pacific Northwest by Mote et al. (2013).

	Annual		Winter[b]		Spring		Summer		Autumn	
RCP Temperature (°C)	4.5	8.5	4.5	8.5	4.5	8.5	4.5	8.5	4.5	8.5
Maximum	3.7	4.7	4.0	5.1	4.1	4.6	4.1	5.2	3.2	4.6
Mean	2.4	3.2	2.5	3.2	2.4	3.0	2.6	3.6	2.2	3.1
Minimum	1.1	1.7	0.9	1.3	0.5	1.0	1.3	1.9	0.8	1.6
Precipitation (%)										
Maximum	10.1	13.4	16.3	19.8	18.8	26.6	18.0	12.4	13.1	12.3
Mean	2.8	3.2	5.4	7.2	4.3	6.5	−5.6	−7.5	3.2	1.5
Minimum	−4.3	−4.7	−5.6	−10.6	−6.8	−10.6	−33.6	−27.8	−8.5	−11.0

[a] Values are for the maximum model projection, multi-model mean, and minimum model projection.
[b] Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Autumn = September, October, November.

among the three Blue Mountains national forests, coordinating with five non-federal collaborative groups in the area. Management priorities for the team are dry forest restoration and strategic fuel treatments, which are ecological priorities described in Hessburg et al. (2005). These efforts are aimed at restoring fire-adapted forests and reducing wildfire severity in the Blue Mountains for the benefit of forest ecosystems and local communities (USFS, 2013; Hartter et al., 2018). Other restoration activities are prioritized by individual national forests (e.g., within river basins for aquatic restoration).

In addition, national forests in the Blue Mountains are in the process of jointly revising their land management plan (USFS, 2014), which is the guiding document for all resource management and planning activities in national forests. Previous versions of the plan were developed before climate change was a prominent physical, biological, and social concern for natural resource conditions. The climate change assessment developed by the BMAP will inform forest plan revisions as a component of risk assessment (effects) and risk management (actions). Links among the assessment, forest plan, and restoration provide a new framework for coordinated and consistent management of natural resources in national forests (Halofsky and Peterson, 2017).

The BMAP focused on climate change vulnerability assessment and adaptation planning across 2.14 million ha of mostly forested land in Oregon and Washington within the Blue Mountains ecoregion (Fig. 1). Building on the framework described in Peterson et al. (2011) and Swanston et al. (2016), 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 (Fig. 5). The BMAP focused on the social context for addressing climate change (Hartter et al., 2018), water resources (Clifton et al., 2018), fisheries (Isaak et al., 2017), upland vegetation (Kim et al., 2018 and Kerns et al., 2018) and riparian systems (Dwire and Mellmann-Brown, 2018), based on priorities set by national forest leadership and resource specialists.

Vulnerability assessments typically consider the interaction of exposure, sensitivity, and adaptive capacity (Parry et al., 2007), where exposure is the degree to which the system is exposed to changes in climate, sensitivity is an inherent quality of the system that indicates the degree to which it could be affected by climate change, and adaptive capacity is the ability of a system to respond and adjust to the exogenous influence of climate. For the BMAP, scientific literature, modeling, and expert knowledge were used to assess exposure, sensitivity, and adaptive capacity and to identify key vulnerabilities for water use and infrastructure (Clifton et al., 2018), fisheries (Isaak et al., 2017), vegetation (Kim et al., 2018 and Kerns et al., 2018), and riparian systems (Dwire and Mellmann-Brown, 2018). Assessments included both quantitative and qualitative evaluation of sensitivity and adaptive capacity, and the scale of assessment varied from the species to community level.

The assessment process took place over six months, involving numerous phone meetings and in-person meetings for each resource-specific science-management assessment team. Each assessment team refined key questions that the assessment needed to address, selected specific topics, and determined which climate change effects models best informed the assessment. In some cases, assessment teams conducted spatial analyses or ran and interpreted models, selected criteria by which to evaluate model output, and developed maps of model output and resource sensitivities. Teams focused on effects and model projections specific to the Blue Mountains region and used projections at the finest spatial scale considered valid (Littell et al., 2011).

A principal goal of the BMAP was to go beyond general concepts to identify adaptation options that can be implemented into projects and plans (Peterson et al., 2011; Swanston et al., 2016; Raymond et al., 2013, 2014; Halofsky and Peterson, 2017). After key vulnerabilities were developed for each resource sector in the draft assessment, a workshop was convened to present and discuss the vulnerability assessment and to elicit potential adaptation options from resource managers. Participants (mostly resource managers and stakeholders and a few research scientists) identified strategies (general approaches) and tactics (on-the-ground actions) for adapting resources and management practices to climate change for each resource sector. Participants also identified opportunities and barriers for implementing adaptation options into current projects, management plans, partnerships, regulations, and policies. Adaptation options are described in Peterson and Halofsky (2018).

Participants generally focused on adaptation options that can be implemented given our current scientific understanding of climate change effects, but they also identified research and monitoring that would benefit future efforts to assess vulnerability and adapt management practices (Peterson and Halofsky, 2018). Initial results from the workshops were augmented with continuous dialogue with Forest Service resource specialists to confirm the final content of the assessment and adaptation options.

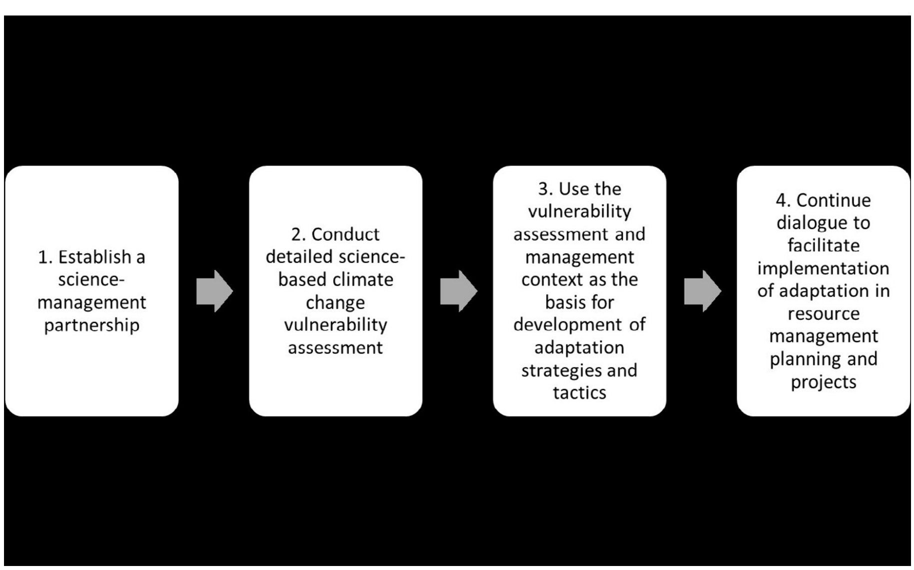

Fig. 5. The steps in the process used in the Blue Mountains Adaptation Partnership.

4. Application of the vulnerability assessment and adaptation options in the Blue Mountains

The information in this special issue has several uses. First, the assessments provide a state-of-science reference on the projected condition of aquatic and terrestrial ecosystems in a warmer climate. Second, resource managers can reference the assessments in planning documents (e.g., land management plans) that address desired future conditions. Third, adaptation options can be used to fine-tune and prioritize implementation of on-the-ground projects. Finally, information on social factors, human values, and natural resource issues provides decision makers (e.g., forest supervisors, government officials) with an important new context for regional to local policies. We anticipate that the urgency of climate change will motivate disparate organizations and the public to collaborate with federal land managers to identify and implement adaptation options that maintain the integrity of ecosystems and ensure continuity of issues.

Integration of the information in this assessment in everyday work is critical. Flooding, wildfire, and insect outbreaks may all be exacerbated by climate change, thus increasing hazards faced by federal employees and the public. Resource management can help minimize these hazards through activities such as reducing fuels, and restoring hydrologic function. These activities are already common, illustrating that much of current resource management is already climate smart. This assessment can improve current management practice by helping to prioritize and accelerate implementation of specific options and locations for adaptation.

Adaptation planning for climate change is an ongoing, iterative process, not a one-time solution. Considerations of adaptation can occur at regular intervals (e.g., as part of land management plan revisions), or after some extreme event (e.g., drought, wildfire) provides the motivation and opportunity to implement new practices and policies. In this special issue, we focus mostly on issues and options for national forests in the Blue Mountains, but the information should also be useful for other land management agencies in the region. In addition, the BMAP process discussed here, involving establishment of a science-management partnership, conducting science-based vulnerability assessments, and developing place-based adaptation strategies and tactics (Fig. 5), can be emulated by other national forests, national parks, and other organizations, thus spreading climate-smart management in the Pacific Northwest and beyond.

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