Chapter 1: Introduction

Jessica E. Halofsky[1]

Project Description and Objectives

The Pacific Southwest Region of the U.S. Department of Agriculture, Forest Service (USFS), in collaboration with the USFS Pacific Northwest and Pacific Southwest Research Stations and the Office of Sustainability and Climate, formed a science-management partnership and conducted a climate change vulnerability assessment for infrastructure and recreation in Sierra Nevada national forests. The vulnerability assessment set the stage for developing adaptation options in a series of science-management workshops. The outcomes of the effort, called the Sierra Nevada Infrastructure and Recreation Vulnerability Assessment and Adaptation Partnership, are described in this report. Specific objectives of the effort were to:

- Synthesize the best available science to assess climate change vulnerabilities and develop adaptation options for recreation and infrastructure resources on national forests in the Sierra Nevada.
- Develop a framework and tools for managers to incorporate the best available science, including other complementary assessments, into USFS recreation and engineering program assessments.
- Define priority regional- and forest-level climate change vulnerabilities for integration in the land management planning process.
- Identify priority areas for cross-boundary partnerships and third-party investments to best leverage agency appropriations and to maximize opportunities for shared stewardship.

Climate change is an agencywide priority for the USFS. In 2008, the USFS released a Strategic Framework for Responding to Climate Change (USDA FS 2008). In 2010, the USFS provided specific direction to the National Forest System in the form of the National Roadmap for Responding to Climate Change (USDA FS 2010a) and the Climate Change Performance Scorecard (USDA FS 2010b). These directions were followed by the 2012 Planning Rule (USDA FS 2012), which requires national forests and grasslands to address climate change in the land management plan (forest plan) revision process. Requirements of the Roadmap, Scorecard, and the 2012 Planning Rule are mutually supportive and provide a framework for responding to changing conditions over time.

[1] **Jessica E. Halofsky** is the director, Western Wildland Environmental Threat Assessment Center and Northwest Climate Hub, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512.

National Forest System units in the Sierra Nevada have initiated or will likely initiate the land management plan revision process in the next several years. In preparation for plan revision in the region, and to ensure the use of the best available science in the revision process, the USFS Pacific Southwest Research Station developed a synthesis of relevant science for the Sierra Nevada (Long et al. 2014). The Pacific Southwest Region then used information in the science synthesis to frame a bioregional assessment, which provides context on resource management issues that cross boundaries in the Sierra Nevada region (USDA FS 2014).

The assessment described in this report builds upon the Sierra Nevada science synthesis and bioregional assessment, along with other past climate change assessments conducted in the Sierra Nevada region. For example, EcoAdapt and partners conducted a climate adaptation project for the Sierra Nevada that involved assessing vulnerabilities for key wildlife species, ecosystems, and ecosystem services (Kershner 2014). To support this effort, the Geos Institute developed a report on projected climatic and hydrological changes in the region (Geos Institute 2013).

The assessment described in this report also builds on climate change vulnerability assessments conducted for national forests across the United States, including assessments in the Pacific Northwest (Halofsky et al. 2011, 2017, 2019; Raymond et al. 2014), Northern Rockies (Halofsky et al. 2018a), the Intermountain West (Halofsky et al. 2018b), and Eastern United States (Butler et al. 2015; Swanston et al. 2011, 2016). The processes, products, and techniques used for climate change efforts on national forests are described in a guidebook for developing adaptation options for national forests (Peterson et al. 2011). The Sierra Nevada effort followed the principles and practices in the guidebook.

Approach

Vulnerability assessments typically incorporate three features: exposure, sensitivity, and adaptive capacity (Parry et al. 2007). 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. Adaptive capacity is the ability of a system to respond and adjust to the exogenous influence of climate. We used scientific literature, model output, and expert knowledge to assess exposure, sensitivity, and adaptive capacity and identify key vulnerabilities for infrastructure and recreation in the Sierra Nevada.

The vulnerability assessment was conducted through a science-management partnership. Science-management partnerships have emerged as effective catalysts for developing vulnerability assessments and land management adaptation at both the strategic and tactical level (Cross et al. 2013, Littell et al. 2012, McCarthy 2012,

Peterson et al. 2011, Swanston et al. 2016). Partnerships among scientists in the USFS 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 (Halofsky et al. 2016). 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 (Peterson et al. 2011). This iterative information exchange aids identification of vulnerabilities to climate change at the local scale and sets the stage for developing adaptation options (Halofsky et al. 2016).

The vulnerability assessment process was initiated with an in-person expert elicitation workshop in July 2018. Attendees included infrastructure and recreation representatives from most of the national forest units, along with science teams, other USFS leaders, and partners. Project objectives and general approaches to the vulnerability assessment were introduced. Science team leads then reviewed the vulnerability assessment outline, potential sources of information, and preliminary results. This was followed by group discussion about potential sources of information for the assessment, and unit-specific drivers, stressors, and issues affecting recreation and infrastructure in the Sierra Nevada.

Following the expert elicitation workshop, science teams for recreation and infrastructure developed the vulnerability assessment, consulting with regional and unit-level land managers as needed. Each assessment team refined key questions that the assessment needed to address, selected values to assess, 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 for which to evaluate model outputs, and developed maps of model output and resource sensitivities. To the greatest extent possible, teams focused on effects and projections specific to the region and used the finest scale projections that are scientifically valid.

After identifying key vulnerabilities for infrastructure and recreation, scientists, land managers, and stakeholders convened at three 1-day workshops in June of 2019 in the north, central, and southern Sierra Nevada. The workshops focused on presentation and discussion of the vulnerability assessment, and elicitation of adaptation options from resource managers. During these workshops, scientists and resource specialists presented information on climate change effects and current management practices for infrastructure and recreation. Facilitated dialogue was used to identify key sensitivities and adaptation options.

Participants identified strategies (general approaches) and tactics (on-the-ground actions) for adapting resources and management practices to climate

change, as well as opportunities for implementing these adaptation actions in projects, management plans, partnerships, and policies. 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 guide management practices. Facilitators captured information generated during the workshops with worksheets adapted from Swanston et al. (2016). Initial results from the workshops were augmented by continued dialogue with USFS resource specialists.

Study Region Description

This report focuses on 10 National Forest System units in the Sierra Nevada: Eldorado National Forest (NF), Inyo NF, Lake Tahoe Basin Management Unit, Lassen NF, Modoc NF, Plumas NF, Sequoia NF, Sierra NF, Stanislaus NF, and Tahoe NF (fig. 1.1). These national forests provide a variety of ecosystem services, including fresh water, hydropower, diverse plant and animal assemblages, and recreation and economic opportunities. The national forest units in the Sierra Nevada provide about 16 percent of the water supply in California (Brown et al. 2016), providing for both municipal and agricultural uses. The Sierra Nevada national forest units are home to eight wild and scenic rivers, totaling 643 mi, providing natural, cultural, and recreational river-related values (USDA FS 2014). Sierra Nevada rivers generate half of all hydropower in California and 15 percent of all power generated in the state (Dettinger et al. 2018).

Most of the forests and high-elevation landscapes in California are located in the Sierra Nevada, and over 40 percent of the Sierra Nevada region is managed by federal agencies, including the USFS and U.S. Department of the Interior Bureau of Land Management and National Park Service (Minnich and Padgett 2003). The southern half of the region has many specially designated areas, including three national parks, two national monuments, and extensive wilderness areas. Wilderness areas are concentrated along the crest of the Sierra Nevada and on both sides from Lake Tahoe south on the Stanislaus, Sierra, Sequoia, and Inyo NFs (USDA FS 2014). Large inventoried roadless areas border the wilderness.

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The Sierra Nevada region supports large recreation and tourism industries. The 10 national forest units have over 17 million visitors annually. Outdoor recreation is integral to many local communities, and demand for recreation opportunities has increased in recent decades (USDA FS 2014). The population of California is expected to grow 37 percent between 2010 and 2050, and for counties partially or entirely within the Sierra Nevada region, total population is projected to increase by 69 percent by 2050 (California Department of Finance 2012). Higher

Figure 1.1—Ten National Forest System units in the Sierra Nevada.
Lake Tahoe Basin = Lake Tahoe Management Unit.

population will likely increase demand for recreation and increase demand for water resources. Population growth may also lead to increased development in the wildland-urban interface, resulting in challenges in managing wildland fires and protecting infrastructure.

American Indians have been part of Sierra Nevada landscapes for thousands of years (Anderson and Moratto 1996), managing the land by burning, irrigating, pruning, harvesting, sowing, and weeding (USFS 2014). American Indians continue to participate in traditional activities on national forests, including hunting, fishing, trapping, and gathering berries, thus sustaining family and tribal traditions, providing sustenance for families, and continuing a spiritual connection to the land (McAvoy et al. 2005).

Harvesting nontimber forest products is also an important cultural activity for nontribal communities (Richards 1996). Nontimber forest products gathered from national forest in the Sierra Nevada include wild food plants, medicinal plants, floral greens, seeds and cones, posts, poles, firewood, transplants, and Christmas trees (USDA FS 2014).

There is a long history of timber harvest in the Sierra Nevada region. However, timber harvest from national forests has decreased since the 1990s (Charnley and Long 2014). Similarly, grazing on forest lands has decreased in recent years because of market conditions and environmental concerns (USDA FS 2014). Although these activities have recently decreased, past timber harvest and grazing practices, along with fire suppression over several decades, have increased tree densities, shade-tolerant species, and surface fuel loading in forests that were historically characterized by frequent fire (e.g., ponderosa pine [*Pinus ponderosa* Lawson and C. Lawson], Jeffrey pine [*P. Jeffreyi* Balf.], and mixed-conifer forests in the Sierra Nevada) (Collins and Skinner 2014).

These changes in forests have increased their vulnerability to uncharacteristic fire severity and extent (Stephens and Collins 2004, van Wagtendonk 1985, van Wagtendonk and Fites-Kaufman 2006), and fire severity has increased in some forest types in recent decades (Mallek et al. 2013, Miller et al. 2009, Steel et al. 2018). Increased forest density has also increased risk of drought-induced insect outbreaks and tree mortality events, such as the mortality event that occurred in the central and southern Sierra Nevada during the 2012–17 drought (Fettig et al. 2019). With the occurrence of large wildfire and mortality events in the Sierra Nevada, there has been greater focus on increasing the pace and scale of restoration to increase ecological and community resilience to disturbance (Long et al. 2014, USDA FS 2014).

Assessment Overview

This publication contains information on expected climatological and biophysical changes in the Sierra Nevada (chapter 2), projected changes to hydrologic processes and water resources (chapter 3), infrastructure vulnerabilities to climate change (chapter 4), recreation vulnerabilities to climate change (chapter 5), adaptation options that were compiled at the workshops (chapter 6), and conclusions and discussion on potential applications of the vulnerability assessment and adaptation options (chapter 7). Interactions between different resource areas are described throughout, and issues are summarized for the three different Sierra Nevada zones identified by the Pacific Southwest Region (North, Central, and South Zones) where this geographic specificity is relevant.

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