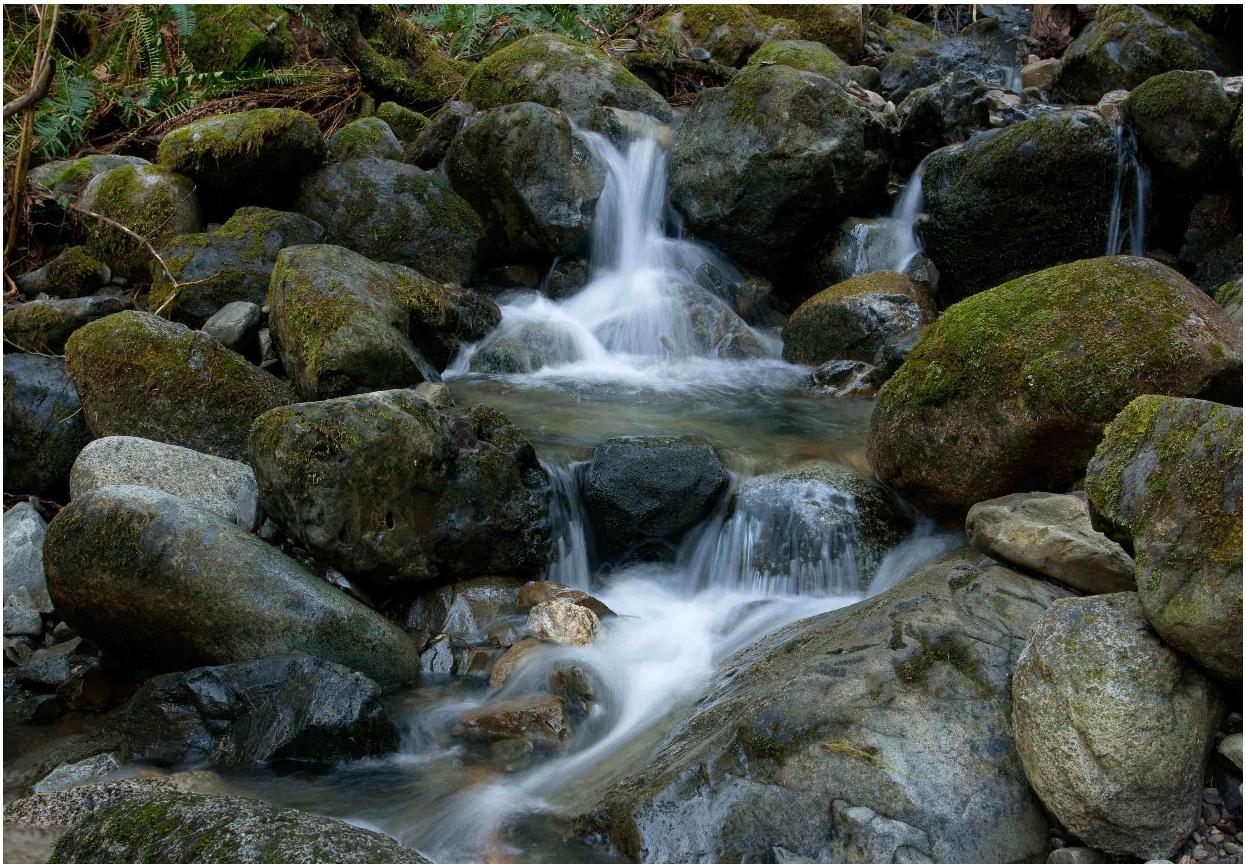
Climate Change Adaptation Strategies for Focal Resources of the Sierra Nevada



A report to the California Landscape Conservation Cooperative
and U.S. Forest Service Region 5

EcoAdapt

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Executive Summary

EcoAdapt, in collaboration with the U.S. Forest Service and California Landscape Conservation Cooperative (CA LCC) hosted the *Adaptation Planning Workshop for the Sierra Nevada* June 4-5, 2013 in Sacramento, California. The goal of the workshop was to identify management strategies that will help regionally important ecosystems and species adapt to changing climate conditions and to lay the groundwork for adaptation action. Thirty-two attendees representing 21 public agencies (including national forests), non-governmental organizations, and others participated in the workshop.

The objectives of the workshop were to:

1. Collaboratively identify management and conservation goals and objectives for focal resources.
2. Present outcomes of spatial analysis and mapping to facilitate adaptation planning.
3. Develop adaptation strategies to reduce the identified vulnerabilities of resources (from an associated vulnerability assessment workshop) and increase positive long-term outcomes for regional management goals.
4. Create a list of implementation needs to facilitate incorporation of adaptation strategies into regional planning and management activities.
5. Provide climate change adaptation training, resources, support, and tools to participants to extend this process to similar efforts in their own work.

Over two days of presentations, discussion and small working groups, managers, scientists, and conservation practitioners identified adaptation strategies for six focal resources: alpine/subalpine systems, Sierra Nevada and southern mountain yellow-legged frogs, yellow pine/mixed conifer systems, red fir systems, wet meadows and fens, and oak woodlands.

Key outcomes of the workshop were:

1. Refined management goals and objectives for focal resources.
2. Evaluation of management objective feasibility given climate and non-climate stressors.
3. A suite of adaptation approaches and actions for each focal resource that can be implemented to help achieve management objectives in the face of climate change.
4. A prioritized list of adaptation actions for resources across the Sierra Nevada.
5. Group-developed implementation plans for prioritized actions.

Participants identified a suite of adaptation actions for each of the focal resources and developed draft implementation plans for priority actions. Example adaptation actions for each focal resource considered are described below. Details of these and other workshop-derived adaptation actions are presented in Sections 3-7.

Adaptation Actions for Alpine and Subalpine Systems

- Implement large-scale, coordinated monitoring program (including "citizen science" groups) designed to improve our ability to identify, detect, and predict future insect and disease outbreaks
- Thinning in targeted, non-wilderness areas projected to have a significant change in climatic water deficit, which will help reduce a number of stressors on trees so they are better able to resist insects and drought stress
- Greater use of managed wildfire to restore stand structure, promote diversity of seral classes, and reengage key ecosystem processes, especially in wilderness areas
- In targeted, non-wilderness areas consider:
    - Restoring structure through silvicultural treatments (lowering the density, removing undesirable species, etc.) to reduce the susceptibility of forests to insects and disease that may be exacerbated by climate change
    - Creating and planting genetically modified species to reduce the susceptibility of forests to insects and disease that may be exacerbated by climate change
    - Minimizing the spread of invasive species (e.g., cheatgrass) at higher elevations using early detection and rapid response approach
- Complete gene-screening for white pine blister rust and, where feasible, identify and plant disease-resistant strains of white pine species (e.g., in stands already impacted by blister rust and areas that we are already losing individuals) to reduce susceptibility of forests to disease that may be exacerbated by or exacerbate climate impacts

Adaptation Actions for Mountain Yellow-Legged Frogs

- Remove non-native fish populations through electroshocking and/or gill netting in order to reduce overall stress on frogs, increasing their ability to respond to climate change
- Engage recreational anglers to prevent fish stocking in fishless areas, preventing the establishment of invasive species that can exacerbate climate impacts on native amphibians
- Protect existing mountain yellow-legged frog populations by monitoring for disease outbreaks and treating frogs when infected, as climate changes may increase spread of disease and/or interact with disease to further impact species (e.g., through decreased recruitment or survival)
- Prevent the establishment of predators and/or competitors that are better able to expand ranges due to climate change by maintaining and improving fish barriers to prevent invasion into fishless systems
- Focus mountain yellow-legged frog reintroductions in restored areas where frogs have been extirpated and are likely to still be viable frog habitat in the future
- Focus conservation activities in areas identified as climate refugia and/or areas likely to be suitable future habitat

Adaptation Actions for Yellow Pine/Mixed Conifer Systems

- Restore forest structure, function and composition through targeted thinning of fire-intolerant species, prescribed burning, actively managing natural fires, assisted translocation of species to suitable future habitats, planting and promoting climate

appropriate tree genotypes and species (e.g., drought tolerant species), and planting disease-resistant species to improve overall ecosystem resilience under changing climate conditions
- Identify key metrics (i.e., indicator species, structure attributes, important functions) to evaluate climate and non-climate impacts and management action effectiveness, and set up realistic, long-term monitoring programs to track each
- Increase public education and outreach to improve the public's connection to the environment, understanding of interconnections, and short-term versus long-term risks in light of climate change
- Promote climate-smart policies society wide such as valuing ecosystem services or creating a biomass energy market

Adaptation Actions for Red Fir Systems and Marten

- Develop an ecosystem management strategy specific to Sierra Nevada red fir forests with a focus on a summary of current science information from an interdisciplinary perspective (e.g., forest ecology, wildlife ecology, silviculture), climate change considerations, and research gaps (similar to North et al. 2009 and North 2012)
- Develop large-scale, coordinated monitoring program (including "citizen science" groups) designed to improve our ability to detect and predict future changes in red fir forests
- Apply an adaptive management experiment, which includes testing a combination of different levels of thinning (i.e., no thinning, targeted species thinning, gap thinning) and the use of fire (i.e., no use of fire, use of fire through prescribed burning and/or managed wildfire), to improve understanding of fundamental ecological functions and processes of red fir (e.g., tree recruitment and growth) and how they might change in the future, and promoting those actions or combinations of actions that enhance tree recruitment and overall ecosystem resilience under climate change
- Develop and maintain core current and projected marten habitat areas and corridors by maintaining red fir ecosystems closer to their natural range of variability (using findings of adaptive management experiment described above) to continue to provide habitat for marten under changing climate conditions, prioritizing key habitat and corridors for protection and/or management action, and avoiding the creation of uncharacteristically large gap openings and fragmentation of red fir forests in key habitat and corridors

Adaptation Actions for Wet Meadows and Fens

- Restore floodplain function by establishing setbacks, stabilizing banks and headcuts, and employing plug-and-pond techniques to support current and future hydrology
- Re-examine grazing intensity, animal densities, and timing of use in light of predicted climate change impacts to minimize synergistic effects of grazing and climate-driven changes (e.g., reduced soil moisture, precipitation changes) on vegetation recruitment and growth as well as floodplain structure and soils
- Reduce fuel loading through fire reintroduction, mechanical treatments at the landscape and watershed levels, and ecological restoration at the landscape level to

decrease the potential for high severity fires and improve the overall resilience of the system
- Reduce the negative impacts of recreation, roads and trails to help wet meadows better cope with potential climate change impacts

Adaptation Actions for Oak Woodlands

- Restore structure, function, and composition of oak woodlands to limit high severity fires and moisture stress by reducing non-native grasses and forbs, utilizing fire management practices (e.g., prescribed burning), and planting native bunch grasses within woodlands
- Reduce herbivory and grazing pressure on mature trees, seedlings, and acorns by fencing priority oak areas or individual plants as needed to exclude browsers in order to minimize synergistic effects of grazing and climate-driven changes (e.g., decreased soil moisture) on recruitment and survival
- Identify and protect oak climate refugia, which could include identifying areas with less predicted climatic water deficit, protecting priority areas from high severity fire and browsing/herbivory pressure, and controlling and/or removing non-native grasses and forbs. Where oak climate refugia have been identified, establish extra protection for priority areas using management designations and planning to exclude humans and browsers
- Facilitate oak translocation by planting climate-smart seedlings in suitable future habitats including favoring existing genotypes that are better adapted to future conditions; using seeds from across a greater geographic range or from drier, warmer climates; and maintaining current genetic diversity across its range
- Engage the public in the stewardship of oaks and oak woodlands by increasing education about the intrinsic value and ecosystem services of oak woodlands and how they might be affected by climate change, encouraging climate-smart restoration activities and volunteer work days, and enhancing oak stewardship on private lands

Government agencies and other groups that could lead the implementation of priority adaptation actions identified above, help with needed resources, and address possible barriers to implementation included the U.S. Forest Service (USFS), National Park Service (NPS), Bureau of Land Management (BLM), Army Corps, Natural Resources Conservation Service (NRCS), Bureau of Reclamation (BOR), U.S. Fish and Wildlife Service (USFWS), California Department of Fish & Wildlife (CDFW), California Department of Parks and Recreation (Cal Parks), private landowners, county/local governments, tribal lands, public utilities, and timber companies.

The common barriers to implementation that were identified included air quality, liability, and safety issues associated with prescribed and natural fires; social issues such as human use of resources (e.g., grazing, recreational fishing, reduced access); limited access to areas for implementing actions (e.g., remote locations); other technical barriers associated with gathering necessary data and information to help prioritize actions and locations; and funding (e.g., funding is often earmarked for specific tasks that do not address climate adaptation).

The *Adaptation Planning Workshop for the Sierra* Nevada was the second in a series of two workshops organized by EcoAdapt and was part of a larger effort led by EcoAdapt and funded by the CA LCC with the goals of conducting a large-scale vulnerability assessment and developing associated adaptation strategies for focal resources of the Sierra Nevada. Its three principal components include: (1) a vulnerability assessment workshop, (2) spatial analysis and comparative mapping to inform the vulnerability assessment and facilitate adaptation planning, and (3) an adaptation planning workshop. Partners included the U.S. Forest Service, Geos Institute, and Conservation Biology Institute.

Outputs from the overall project include:

- A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada (includes outputs from the first workshop)
- Climate Change Adaptation Strategies for Focal Resources of the Sierra Nevada (this report)
- Spatial datasets and maps (climate and non-climate) relevant for focal resources of the Sierra Nevada[1]

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[1] Datasets and maps can be found on the Data Basin group page titled *EcoAdapt-CA LCC: Climate Adaptation Project for the Sierra Nevada* (http://databasin.org/groups/e6cfbd4218f54b32b695fad7af8cce31).

1. Introduction

EcoAdapt, in collaboration with the U.S. Forest Service and California Landscape Conservation Cooperative (CA LCC), convened a 1.5-day workshop entitled *Adaptation Planning Workshop for the Sierra Nevada* on June 4-5, 2013 at Modoc Hall on the California State University Sacramento campus in Sacramento, California (see the workshop support page for the agenda: http://ecoadapt.org/workshops/sierra-nevada-adaptation-workshop). A total of 32 participants representing 21 federal and state agencies, non-governmental organizations, and others participated (see individual adaptation sections for organizations and agencies).

This report focuses on output from this Adaptation Planning Workshop, which was second in a series of two workshops on climate change vulnerability assessment and adaptation planning for the Sierra Nevada. These workshops were part of a larger project led by EcoAdapt and funded by the CA LCC and including partners from Geos Institute, Conservation Biology Institute, and the U.S. Forest Service. The objectives of the larger project were to: (1) assess the vulnerabilities of a suite of Sierra Nevada focal resources to climate change; (2) use spatial analysis to inform the vulnerability assessment and facilitate adaptation planning; (3) identify priority management strategies for the Sierra Nevada; and (4) provide training, resources, and support for managers, planners, and others to conduct similar processes in their work. To achieve these objectives, the project was comprised of three principal components: (1) a vulnerability assessment workshop, (2) spatial analysis and comparative mapping, and (3) an adaptation planning workshop.

The first workshop (*A Vulnerability Assessment Workshop for Focal Resources of the Sierra Nevada),* held March 5-7, 2013 in Sacramento, CA, included a review of climate trends for the Sierra Nevada region; vulnerability assessment training following the process described in Glick et al. (2011); vulnerability assessment application for a suite of species, habitats, and ecosystem services chosen prior to the workshop; and identification of spatial analysis and mapping needs to support the vulnerability assessment and adaptation planning.[2]

The vulnerabilities of 27 resources were evaluated during the Vulnerability Assessment Workshop and included eight ecosystems (alpine/subalpine, yellow pine/mixed conifer, red fir, wet meadows and fens, oak woodlands, chaparral, sagebrush, and aquatic), fifteen species [fisher (*Pekania [Martes] pennanti*), marten (*Martes americana*), bighorn sheep (*Ovis canadensis sierra*), wood rat (*Neotoma fuscipes, Neotoma macrotis*), willow flycatcher (*Empidonax traillii*), mountain quail (*Oreortyx pictus*), sage grouse (*Centrocercus urophasianus*), Sierra Nevada yellow-legged frog (*Rana sierra*), mountain yellow-legged frog (*Rana muscosa*), red fir (*Abies magnifca*), blue oak (*Quercus douglasii*), black oak (*Quercus kelloggii*), whitebark pine (*Pinus albicaulis*), bristlecone pine (*Pinus longaeva*), and aspen (*Populus tremuloides*)], and four ecosystem services (timber and wood products, carbon, fire, and recreation). Results of

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[2] Information from the workshop such as the agenda, presentations, handouts, readings, and other resources can be found at: http://ecoadapt.org/workshops/sierra-nevada-va-workshop.

the focal resource vulnerability assessments including vulnerability technical syntheses (comprised of information from participant evaluations, peer-reviewed resources, and expert review), vulnerability assessment methodologies, and climate information from Geos Institute (2013) is included in the report titled *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada* (EcoAdapt 2013). In addition, vulnerability briefings (short documents summarizing key vulnerability findings) were created for each focal resource. The report, briefings, and other project related information is available online through the California Climate Commons (http://climate.calcommons.org/) and EcoAdapt (http://ecoadapt.org/) websites.

Participants also applied the *Yale Framework* to specific resource goals (e.g., enhance and restore oak woodlands within their current distributions) as part of the focal resource vulnerability assessment process in this workshop. The *Yale Framework* (http://yale.databasin.org/) is an online tool that assists conservation planners in selecting the assessment scale, spatial analysis, and modeling strategies most relevant to support their specific climate change adaptation planning. The *Yale Framework* Matrix, an integral part of the tool, specifically links general adaptation approaches (e.g., identifying and protecting climate refugia) to the various types of mapping and modeling tools available that practitioners can apply in an assessment to help identify where on the landscape to implement an approach. Workshop participants were asked to use the *Yale Framework* Matrix to identify assessment approaches that would be most helpful or desirable in achieving selected resource goals. The Conservation Biology Institute, in partnership with EcoAdapt, then used the information from this exercise as well as the vulnerability assessment results to assemble key climate and non-climate spatial datasets on Data Basin.[3] The assemblage of datasets on Data Basin provide an online resource of spatial information that help inform vulnerability assessments and facilitate adaptation planning for focal resources of the Sierra Nevada.[4] For example, stakeholders can use the spatial information and maps to help prioritize conservation areas and/or actions.

The second workshop (*Adaptation Planning Workshop for the Sierra Nevada*) is the focus in this report.[5] Five ecosystems (alpine/subalpine, yellow pine/mixed conifer, red fir, wet meadows and fens, and oak woodlands) and three species (marten, Sierra Nevada and mountain yellow-legged frogs) were considered in this workshop. These ecosystems and species were selected based on participant knowledge and expertise.

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[3] Data Basin is a science-based mapping and analysis platform created by the Conservation Biology Institute that supports learning, research, and environmental stewardship (http://databasin.org).

[4] Datasets and maps can be found on the Data Basin group page titled *EcoAdapt-CA LCC: Climate Adaptation Project for the Sierra Nevada* (http://databasin.org/groups/e6cfbd4218f54b32b695fad7af8cce31).

[5] Information from the workshop such as the agenda, presentations, handouts, readings, and other resources can be found at: http://ecoadapt.org/workshops/sierra-nevada-adaptation-workshop.

Adaptation Planning Workshop Goal and Objectives

The main goals of the Adaptation Planning Workshop were to develop a portfolio of adaptation actions for focal resources and lay the groundwork for implementation of actions. Objectives included:

1. Collaboratively identify management and conservation goals and objectives for focal resources.
2. Present outcomes of spatial analysis and mapping to facilitate adaptation planning.
3. Develop adaptation strategies to reduce the identified vulnerabilities of resources (from vulnerability assessment workshop) and increase positive long-term outcomes for regional management goals.
4. Develop implementation plans to facilitate incorporation of adaptation strategies into regional planning and management activities.
5. Provide climate change adaptation training, resources, support, and tools to participants to extend this process to similar efforts in their own work.

Adaptation Workshop Outcomes

Over the course of 1.5 days, participants worked through an interactive process to identify adaptation strategies and actions for focal resources. Workshop outcomes included:

1. Refined management objectives for focal resources.
2. Evaluation of management objective feasibility given climate and non-climate stressors.
3. A suite of adaptation approaches and actions for each focal resource that can be implemented to help achieve management objectives in the face of climate change.
4. A prioritized list of adaptation actions for resources and across the Sierra Nevada.
5. Group-developed implementation plans for prioritized actions.

2. Workshop Methodology: Presentations and Activities

There were two phases in the workshop. Participants were first prepared through presentations of background information and adaptation planning theory and process. They then worked in small groups to undertake activities with structured guidance and facilitation where needed. Activities included defining management goals and objectives, evaluating potential vulnerabilities and opportunities given climate and non-climate stressors, identifying adaptation actions, and brainstorming resources needed and timeframe for implementation for a smaller suite of adaptation actions. This section presents a summary of the workshop presentations and activities. Sections 3-7 present summaries and findings from small group activities.

Background Information and Presentations for Developing Adaptation Strategies and Actions

Adaptation Planning Cycle

The workshop began with an overview of a general adaptation planning cycle (Figure 1) as well as the goals, objectives, and desired outcomes for the workshop (described above in the Introduction). The adaptation planning cycle used is summarized here (modified from Swanston et al. 2012 and NWF 2013).

> **Step 1. DEFINE management goals and objectives, area of interest, and time frames.** This includes clarifying existing management goals and objectives and determining relevant geographic scope and time horizons.
>
> **Step 2. ASSESS climate impacts and vulnerabilities.** Understanding climate vulnerabilities is key to designing effective adaptation approaches and actions. Assessing the specific components of vulnerability – sensitivity, adaptive capacity, and exposure – can provide a useful framework for linking relevant climate and non-climate stressors with actions to address impacts from those stressors.
>
> **Step 3. EVALUATE management objectives given vulnerabilities and revise, if necessary.** This includes identifying the management challenges and opportunities associated with climate impacts and vulnerabilities as well as evaluating the feasibility of achieving management objectives under current management options. This information can be used to review management goals and objectives and revise, if necessary, to better account for anticipated climate change impacts.
>
> **Step 4. IDENTIFY adaptation approaches and actions; evaluate and prioritize actions.** A broad array of adaptation approaches and actions that reduce key vulnerabilities or take advantage of emerging opportunities should be identified. Approaches and actions should focus on both existing management options that may be easier to implement in the short-term as well as more creative and innovative approaches to consider for the future. The array of possible actions can be evaluated and prioritized to determine

which are likely to be most ecologically effective and socially, technically, and financially feasible.

Step 5. IMPLEMENT priority actions. Implementation requires institutional commitment and resources and depends on identifying and engaging key partners early on, identifying and pursuing key resource needs, and developing a specific timeline with associated tasks. Clearly defining the activities and resources needed to implement actions is an important first step.

Step 6. MONITOR and evaluate effectiveness. Monitoring provides context for understanding what changes are occurring as a result of climate change as well as management action effectiveness. Monitoring approaches should be designed to not only identify when and how ecological conditions are changing due to climate change but also whether management goals are achieved in the future and whether the recommended actions were effective.

For the purposes of the Adaptation Planning Workshop, breakout groups focused on completing Steps 1, 3, 4, and part of 5 of the adaptation cycle (described in more detail below under Activities); Step 2 was addressed at the previous vulnerability assessment workshop and the results informed Step 3 discussions.

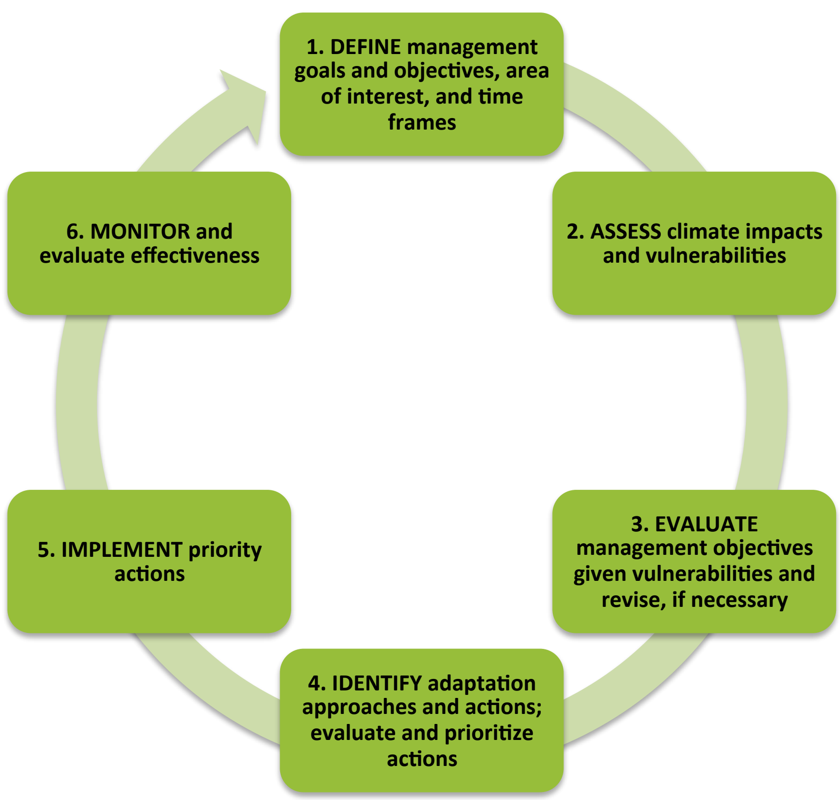

Figure 1. General adaptation planning cycle that can be used to incorporate climate change considerations into management decision-making. Modified from Swanston et al. (2012) and National Wildlife Federation (2013).

Introduction to Adaptation Planning

The workshop continued with two adaptation presentations: an introduction to adaptation strategy development (Eric Mielbrecht, EcoAdapt), and an adaptation portfolio approach to managing climate risk (Greg Aplet and John Gallo, The Wilderness Society).[6]

Key points from the Introduction to *Adaptation Strategy Development* presentation include:

- Adaptation refers to: efforts to reduce the negative effects of or respond to or prepare for climate change
- Developing adaptation strategies can be approached in multiple ways:
    1) Adaptation (I): Addressing vulnerabilities of resources by reducing exposure, decreasing sensitivity, or increasing adaptive capacity.
    2) Adaptation (II): Developing Resistance, Resilience, or Response strategies. (a) Resistance: defending high-risk, high-value resources against disturbance to maintain relatively unchanged conditions; (b) Resilience: accommodating some change but encouraging a return to prior conditions after a disturbance, either naturally or through management; and (c) Response: intentionally accommodate or support change and enable or assist ecosystems and resources to respond to changing and new conditions.
    3) Adaptation (III): Applying EcoAdapt's Five Tenets of Adaptation. (a) Protect adequately and appropriately for a changing world (plan spatially, think temporally); (b) Reduce non-climate stresses; (c) Manage for uncertainty; (d) Reduce local and regional climate change; and (e) Reduce greenhouse gas emissions (Hansen and Hoffman 2011).
    4) Adaptation (IV): Adopting common types of adaptation strategies in capacity building; policy; natural resource management and conservation; and infrastructure, planning, and development.
- General adaptation approaches and developing more specific actions for each approach:
    - *Approach:* an adaptation response for a single ecosystem or resource (e.g., alter forest structure or composition to reduce risk or severity of fire).
    - *Action:* a prescriptive tactic for individual site conditions or management objective (e.g., plant fire-resistant species, such as hardwoods, between more flammable conifers to reduce vulnerability to wildfires).

Key points from the *Adaptation Portfolio Approach to Managing Climate Risk* presentation include:

- To appropriately manage climate risk, we need to: identify the risk, adopt a framework for considering change, spread the risk with a portfolio of strategies, and make the approach spatial.

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[6] Slides from both presentations as well as supporting materials can be viewed or downloaded at: http://ecoadapt.org/workshops/sierra-nevada-adaptation-workshop.

- We now have three choices in the face of climate change: (1) accept change – observation only; (2) resist change – restoration; and (3) guide change – innovation and experimentation.
- A portfolio of approaches, including short-term and long-term strategies as well as adaptation and mitigation measures, can diminish risks associated with climate change.
- An experimental landscape approach can be implemented where *observation*, *restoration, and innovation* are integrated across the landscape in a cohesive experiment.
- More information about this approach can be found in Aplet and Gallo (2012).
- The Wilderness Society is in the process of pulling together climate and ecological datasets into a multi-criteria and multi-objective decision analysis tool to improve decision-making under climate change.

Spatial Analysis and Mapping

The remaining two presentations of the workshop focused on spatial analysis and mapping for the Sierra Nevada (Jessi Kershner, EcoAdapt). The first presentation, described in more detail below, discussed the results of the vulnerability assessment workshop, how they informed spatial analysis and mapping, and how products could be used in adaptation planning and management decision-making.[7] The second presentation introduced participants to the data layers and maps available on Data Basin to support climate-smart planning for the Sierra Nevada.[8] Table 1 summarizes the datasets and maps included.

Table 1. Datasets available for viewing and download on the Data Basin project group page (EcoAdapt-CA LCC: Climate Adaptation Project for the Sierra Nevada).

Variable	Datasets
Climate	Precipitation and Seasonal Precipitation: • Historical (1961-1990) • PCM A2 and B1: 2010-2029, 2030-2049, 2060-2079, 2080-2099 • GFDL A2 and B1: 2010-2029, 2030-2049, 2060-2079, 2080-2099 Temperature and Seasonal Temperature: • Historical (1961-1990) • PCM A2 and B1: 2010-2029, 2030-2049, 2060-2079, 2080-2099 • GFDL A2 and B1: 2010-2029, 2030-2049, 2060-2079, 2080-2099
Fire	• Historic area burned 1980-2004 • California time-enabled fire history (1950-2007) • California wildfire damage to soil (1999-2006) • Simulated carbon consumed during historical period (1961-1990)

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[7] Slides from this presentation can be viewed or downloaded at: http://ecoadapt.org/workshops/sierra-nevada-adaptation-workshop.

[8] Maps and data layers on Data Basin can be accessed by joining the EcoAdapt-CA LCC: Climate Adaptation Project for the Sierra Nevada group on Data Basin here: http://databasin.org/groups/e6cfbd4218f54b32b695fad7af8cce31.

	• Forecast carbon consumed under PCM B1 and A2 scenarios (2010-2029, 2030-2049, 2060-2079, 2080-2099) • Forecast carbon consumed under GFDL B1 and A2 scenarios (2010-2029, 2030-2049, 2060-2079, 2080-2099)
Hydrology	Streamflow • Simulated historical streamflow (1961-1990) • Forecast streamflow under PCM A2 scenarios (2010-2029, 2030-2049, 2060-2079, 2080-2099) Climatic Water Deficit • Historic (1971-2000) • PCM A2: 2010-2039, 2040-2069, 2070-2099 • GFDL A2: 2010-2039, 2040-2069, 2070-2099 Climatic Water Deficit Change: • GFDL A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) • PCM A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) Recharge • Historic (1971-2000) • PCM A2: 2010-2039, 2040-2069, 2070-2099 • GFDL A2: 2010-2039, 2040-2069, 2070-2099 Recharge Change: • GFDL A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) • PCM A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) Runoff • Historic (1971-2000) • PCM A2: 2010-2039, 2040-2069, 2070-2099 • GFDL A2: 2010-2039, 2040-2069, 2070-2099 Runoff Change: • GFDL A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) • PCM A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) Snowpack (Spring and Winter) • Historic (1971-2000) • PCM A2: 2010-2039, 2040-2069, 2070-2099 • GFDL A2: 2010-2039, 2040-2069, 2070-2099 • Simulated snowpack during historical period (1961-1990) • Forecast snowpack under PCM A2, GFDL A2, and GFDL B1 (2010-2029, 2030-2049, 2060-2079, 2080-2099) Snowpack Change: • GFDL A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099) • PCM A2 change from early (2010-2039), mid- (2040-2069), and late century (2070-2099)

	National Hydrography Dataset: Lakes, Streams and Rivers
Vegetation	Current and Projected Vegetation Types: • MC1 simulated vegetation type during historical period (1961-1990) • MC1 forecast vegetation type under PCM B1 and A2 scenarios (2010-2029, 2030-2049, 2060-2079, 2080-2099) • MC1 forecast vegetation type under GFDL B1 and A2 scenarios (2010-2029, 2030-2049, 2060-2079, 2080-2099) • TNC Sierra Nevada vegetation forecasts Existing Vegetation Distributions from California Wildlife Habitat Relationships (CWHR) database: • Hardwood • Mixed conifer • Montane chaparral • Oak woodlands • Red fir • Sagebrush • Subalpine • Yellow pine Existing Vegetation Distributions: • Meadows from Fryjoff-Hung and Viers 2012
Wildlife	Species Current Distribution (from CWHR database): • Big-eared wood rat • Bighorn sheep • Mountain quail • Sierra Nevada and mountain yellow-legged frogs • Sage grouse • Willow flycatcher • Blue oak • Black oak • Red fir • Aspen • Bristlecone pine • Whitebark pine • Fisher • Marten Species Historic and Projected Occurrence (4km and 800m, seasonal and year-round, CSIRO and MIROC): • Fisher (1986-2005, 2046-2065, 2076-2095) • Marten (1986-2005, 2046-2065, 2076-2095) California fish distribution datasets
Other	• Endemic mammal richness 2007 • Road density • Watersheds with dams • Natural landscape blocks • Cal Fire Land Cover (CDF-FRAP) • California Natural Resource Project Inventory

	• Livestock grazing allotments and resource use areas • California urban growth scenarios 2020, 2050

Key points from the *Spatial Analysis and Mapping* presentation include:

- Adaptation strategies are often developed without specifying where they should be implemented (e.g., increasing connectivity). However, there is a large amount of spatial information available – both climate and non-climate – that can help identify where best to implement adaptation actions.
- The results of the vulnerability assessment workshop were used to identify key climate and non-climate elements to map for each focal resource. For example, precipitation, climatic water deficit, wildfire, runoff, grazing, and urbanization were all identified as elements influencing components of vulnerability for oak woodlands. Maps for each of these elements were gathered from existing sources or created for the Sierra Nevada and posted on Data Basin for participants to access and manipulate (e.g., create comparative overlays).
- The results of the *Yale Framework* exercise (from the vulnerability assessment workshop) were also used to tie map products to adaptation strategies for each resource.
    - The *Yale Framework* is an online tool that links general adaptation approaches to the kinds of mapping and modeling that help identify where on the landscape to implement the approach. The online tool provides examples of different maps, modeling and mapping approaches and tools, and case studies.
    - While consensus was mixed regarding the Yale Framework, subsequent brainstorming produced a list of potential analyses and GIS needs for focal resources that could help identify where on the landscape to implement different adaptation strategies.
- EcoAdapt and Conservation Biology Institute used the results of the *Yale Framework* Matrix exercise to gather spatial data layers and create new maps housed by Data Basin.
    - For example, data layers for projected snowpack, climatic water deficit, runoff, and recharge were gathered and analyzed for Sierra Nevada meadows. Other data layers such as current meadow location and grazing allotments were also collected so that users could overlay different data to identify, for example, areas of potential refugia.

Workshop Breakout Group Activities

Workshop participants were organized into one of five resource breakout groups: alpine/subalpine, yellow pine/mixed conifer, red fir, wet meadows and fens, or oak woodlands based on participant knowledge and expertise. Discussions in breakout groups centered on the ecosystems themselves as well as species within those systems.

ACTIVITY 1: DEFINING MANAGEMENT GOALS AND OBJECTIVES FOR RESOURCES

Step 1 of the Adaptation Planning Cycle

Breakout group participants were asked to list the management goals and objectives for their resources (i.e., what is your mandate or goal with respect to the resource?). Management goals were defined as "broad, general statements that express a desired state or process to be achieved" whereas management objectives were defined as "concise statements of measurable planned results that correspond to pre-established goals in achieving a desired outcome" (Society of American Foresters 2011). Participants were encouraged to use existing management goals or objectives for resources; if new objectives were developed, participants were asked to make those objectives as SMART (i.e., specific, measurable, attainable, relevant, and time-based) as possible. The purpose of identifying management goals and objectives was to provide a foundation for evaluating whether and how climate change might compromise objectives and participants' ability to achieve them, whether objectives need to be revised, and for developing adaptation strategies and actions for reducing climate impacts. Participants were also asked to identify and describe the area of interest (e.g., Sierra-Nevada wide or region-specific, geographic area such as a management unit, or a more specific feature such as a forest stand) and approximate time frame for implementing management actions.

ACTIVITY 2: EVALUATING MANAGEMENT OBJECTIVES GIVEN VULNERABILITIES TO CLIMATE AND NON-CLIMATE STRESSORS

Step 3 of the Adaptation Planning Cycle

Using information gathered from the vulnerability assessment workshop (Step 2 of the Adaptation Planning Cycle), literature review, and expert review, participants were provided with synthesized vulnerability assessment results for each resource[9]. This information included bullet points summarizing key climate exposure elements, key sensitivities to climate and non-climate elements, and key adaptive capacity elements, as well as more detailed paragraphs summarizing overall vulnerability, sensitivity, exposure, and adaptive capacity. The purpose of providing this information was to help participants identify management challenges and opportunities associated with climate impacts and vulnerabilities, and to evaluate the feasibility of achieving management objectives given vulnerabilities and current management options.

For each management objective, participants were asked to use the summarized vulnerability assessment results to:

- Identify ways in which climate impacts and associated vulnerabilities might make it more difficult to achieve the objective (CHALLENGES);
- Identify ways in which climate impacts and associated vulnerabilities might make it easier to achieve the objective (OPPORTUNITIES);
- Evaluate the feasibility of using current management strategies and actions (i.e., are existing management options sufficient to overcoming challenges to meeting objectives under climate change or are additional resources or enhanced efforts necessary?) to achieve the objective given challenges and opportunities identified (High: existing management options can be used to overcome challenges; Moderate: existing

[9] Available at http://climate.calcommons.org/ and http://ecoadapt.org.

management options can be used in most cases, but additional resources or approaches may be necessary; and Low: existing management options are insufficient);

- Identify other considerations that might influence the decision to pursue management objectives with low feasibility; and
- Assess whether management objectives need to be revised to better account for anticipated climate or non-climate impacts.

ACTIVITY 3: IDENTIFYING ADAPTATION APPROACHES AND ACTIONS

Step 4 of the Adaptation Planning Cycle

To overcome challenges and achieve management objectives for each resource, participants were asked to brainstorm general adaptation approaches (e.g., alter forest structure or composition to reduce risk or severity of fire) as well as more specific actions to take to implement adaptation approaches (e.g., use prescribed burning to minimize fuel loading or plant fire-resistant species between more flammable species). Benefits, drawbacks, barriers, and practicability were assessed for each specific action. Participants identified actions as having high, moderate, or low practicability, and documented rationale as follows. High practicability: the action is both effective (meets desired intent) and feasible (capable of being implemented), Moderate: there are drawbacks or barriers that could reduce effectiveness or feasibility, and Low: the action is unlikely to be effective or feasible.

This brainstorming session was intended to generate a diverse range of potential approaches and actions that could be considered. The resulting lists are not exhaustive of all adaptation approaches and actions available. Participants were provided with example adaptation approaches and actions from Swanston et al. (2012) and management option reports generated by the Template for Assessing Climate Change Impacts and Management Options (TACCIMO).[10]

Breakout groups shared adaptation approaches and actions for each management objective, as well as action practicability, with the larger group. Commonalities among approaches and barriers to implementation, as well as possible incompatibilities among different approaches were discussed and highlighted. These are described in more detail in Section 8. Each participant was invited to rank five actions as their highest priority following all group presentations.

ACTIVITY 4: DEVELOPING IMPLEMENTATION PLANS FOR PRIORITY ACTIONS

Beginning of Step 5 of the Adaptation Planning Cycle

Each group selected 1-3 actions and developed general implementation plans that included identifying: (1) agencies, organizations, or other groups that could implement the action; (2) resources needed for implementation (e.g., funding, permits, data); (3) key partners to involve that can help address resource needs or implementation; (4) the timeframe for implementation; and (5) where on the landscape actions could be implemented. Groups were encouraged to use the datasets and maps available on Data Basin to help identify where actions

[10] http://www.sgcp.ncsu.edu:8090/

could be prioritized for implementation on the landscape. The purpose of this activity was to lay out the general activities and resources needed to begin implementation of a specific action.

Breakout groups shared implementation plans with the larger group. Commonalities among key partners and resource needs were identified and are described in Section 8.

3. Adaptation Strategy Development: Alpine and Subalpine Ecosystems and Mountain Yellow-Legged Frog Species

Participants: California Department of Fish and Wildlife: Chris Stermer
California Department of Fish and Wildlife: Laura Patterson
California Tahoe Conservancy: Bryan Hofmann
Sierra Nevada Alliance: Anna Olson
Sierra Club: Bruce Hamilton
U.S. Forest Service Lake Tahoe Basin Management Unit: Shana Gross

Distribution and General Overview

The alpine/subalpine ecological zone of the Sierra Nevada forms a wide band across the top of the mountain range in the southern Sierras but narrows progressively north through Tahoe National Forest, after which it becomes discontinuous islands (Bioregional Assessment 2013). The subalpine zone of the Sierra Nevada includes both forested and non-forested vegetation, although non-forested vegetation may dominate the landscape in higher elevation sections of the range. Subalpine forests in the Sierra Nevada often include mountain hemlock, western white pine, whitebark pine, foxtail pine, lodgepole pine, and limber pine. East of the Sierra crest, species composition differs from slopes west of the crest including, for example, absent or restricted red fir (Fites-Kaufman et al. 2007) and the presence of limber pine. Bristlecone pine, although not in the Sierra Nevada, is included in the bioregion (i.e., White and Inyo Mountains). Subalpine forests are thought to be within the natural range of variability (Meyer 2013a), although there have been some shifts in structure due to climate warming and 19th century logging. Additionally, some species have migrated upward into alpine zones (e.g., bristlecone pine), likely due to increased temperatures. Alpine and subalpine ecosystems are considered vulnerable to climate change (Bioregional Assessment 2013).

The mountain yellow-legged frog species consists of two species. The southern mountain yellow-legged frog (*R. muscosa*) is endemic to the southern Sierra Nevada, while the Sierra Nevada mountain yellow-legged frog (*R. sierrae*) is endemic to the northern and central Sierra Nevada (referred to collectively as "mountain yellow-legged frogs"). Existing mountain yellow-legged frog populations occur mostly on national park and national forest lands and are generally restricted to mid- to high-elevation aquatic habitat. Prior to the 1970s, the mountain yellow-legged frog was abundant in aquatic ecosystems of the Sierra Nevada, however significant declines have led to the disappearance of frogs from between 70-90% of their historic localities. A number of factors are thought to have contributed to their decline including introductions of non-native fishes, pesticides, pollutions, pathogens, livestock grazing, and recreational activities (CDFW: http://www.dfg.ca.gov/regions/6/Conservation/Amphibians/Mountain_Yellow-legged_Frog.html). Climate changes including increased temperatures, changes in precipitation timing and amounts, and altered hydrologic regimes, among others, are likely to negatively impact the species.

Management Goals and Objectives

The group's task was to identify at least one management goal and one objective for the alpine/subalpine system in the Sierra Nevada. The purpose of identifying management goals and objectives was to provide a foundation for evaluating whether and how climate change might compromise participants' shared conservation objectives for alpine/subalpine systems and species and for developing adaptation strategies for reducing climate impacts. The group chose to create a new management goal and objectives for the system rather than using existing ones.

The group agreed to the following management goal and objectives for the alpine/subalpine system, which were largely focused on public lands throughout the Sierra Nevada[11]:

Goal: *Maintain and restore healthy and sustainable wildlife, fish, and plant communities in alpine and subalpine ecosystems.*

- Objectives for plant communities:
  - *Guard against wide-scale die-offs and species loss by conducting a complete gene screening for disease and climate change resistant seedlings of foxtail pine, whitebark pine, limber pine, and bristlecone pine within ten years.*
  - *Reduce the loss of subalpine forest habitat by X[12] amount and restore current stand structure and key ecological processes in bristlecone pine, foxtail pine, western white pine, and limber pine forests, within the natural range of variability by 2100.*
  - *Facilitate subalpine species transitions using assisted migration techniques.*
- Objective for amphibians:
  - *Protect and restore native amphibians, such as the mountain yellow-legged frogs, to X[13]% of current numbers and distribution within 30 years.*

Climate Change Impacts Assessment, Adaptation Actions and Implementation

After creating management goals and objectives, the group reviewed the findings from the alpine/subalpine ecosystem and mountain yellow-legged frogs vulnerability assessments to identify potential challenges and vulnerabilities as well as potential opportunities for achieving objectives given climate impacts and associated vulnerabilities.[14]

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[11] Two other objectives were identified by the group, although they did not have time to explore them further: (1) Prevent disease transmission for bighorn sheep in critical habitat by installing livestock exclusion fencing in known bighorn sheep watering areas within five years; and (2) Maintain and archive diversity by developing a seed bank for focal conifers, cushion plants, and other rare plant species within ten years.

[12] The group was unable to identify exactly what amount would be appropriate and thought that other subalpine system experts should be consulted to select an amount.

[13] The group was unable to identify exactly what percentage of current numbers would be appropriate to include and thought that other amphibian experts should be consulted to select a percentage.

[14] Full findings from the vulnerability assessment are available online through the California Climate Commons (http://climate.calcommons.org/) and EcoAdapt (http://ecoadapt.org/) websites.

The group brainstormed strategic climate adaptation actions that might help alpine and subalpine ecosystems and mountain yellow-legged frogs survive in the Sierra Nevada given potential vulnerabilities and challenges. This brainstorming session was intended to generate a diverse range of potential adaptation approaches and strategic actions that could be considered. The resulting tables are not comprehensive, nor do they necessarily represent participants' consensus on what actions should be implemented; rather, it is an initial list of strategic actions that might be considered. Tables 2 and 4 present these strategic adaptation actions, as well as additional actions for consideration from the peer-review literature for alpine/subalpine systems and mountain yellow-legged frogs, respectively.

In general, the group identified strategies that involve conventional approaches to ecological protection and restoration, including targeted thinning and prescribed burning, non-native fish removal, and monitoring and treating for disease, among others. As part of this exercise, participants also highlighted some potential benefits and barriers associated with adaptation actions. For example, a potential benefit related to maintaining and improving fish barriers is that a taller barrier structure or new structure could increase water storage capacity upstream. By contrast, when using fire as a management or restoration tool there are serious air quality concerns and, while not as critical currently in high elevation protected areas, there are also potentially lower risks due to the lower density of humans and structures in these areas. One of the biggest concerns in using fire as a management tool at high elevations is the risk of burning entire stands. Some of these forests have very long fire-return intervals (e.g., 500 years) and will take considerable time to reestablish. Other forest types (e.g., dry lodgepole pine stands) have relatively shorter fire-return intervals and are well-suited to the reintroduction of wildland fire.

After analyzing the climate vulnerabilities and brainstorming strategic adaptation actions, participants were asked to select one to two strategic actions and expand on the resources needed and timeframe for implementation. The group was also asked to begin thinking about areas in the Sierra Nevada that may be appropriate for implementation. These findings are detailed in Tables 3 and 5 below.

Alpine/Subalpine Ecosystems: Vulnerabilities, Adaptation Actions and Implementation

Alpine/Subalpine System: Climate Change Vulnerabilities and Opportunities

Potential Challenges and Vulnerabilities:

- Increased drought could lead to more mountain pine beetle outbreaks and higher tree mortality.
- Increased temperatures will lengthen the growing season for bark beetles and could lead to increased opportunities to reproduce during one year, leading to more outbreaks and increased tree mortality.
- Increased large and severe fires could replace entire stands at high elevations.

- Increased frequency of wildfires likely to impact denser subalpine stands at lower elevations.
- Climatic changes could impact tree dispersal agents such as small mammals and birds.
- Alpine and subalpine areas have limited room to vertically migrate.
- It is unclear whether whitebark pine has sufficient adaptive genetic diversity to tolerate projected increases in temperature and associated climatic water deficit.

Potential Opportunities and Adaptive Capacity:

- Climatic changes could allow subalpine habitat to shift upslope creating some limited opportunities (e.g., in non-wilderness areas) for tree translocation (Note: current vegetation models for the Sierra Nevada show subalpine habitat decreasing throughout its current range).
- Warmer temperatures could lead to increased growth rates and productivity of high-elevation trees, especially at the upper elevation margins; for example, high winter precipitation and warm summers associated with maximum growth for foxtail, lodgepole, and western white pines near treeline.
- Subalpine and alpine areas are more continuous in the southern Sierras and may have greater potential to persist or “move up” in elevation than more fragmented and limited upper elevation habitats in the northern Sierra Nevada.
- Areas with north and northeast aspect slopes, narrow or deep canyons, or along riparian areas may provide cool, wet refuge habitats for these ecosystems.
- Limber pine, lodgepole pine, foxtail pine, bristlecone pine, western white pine, and whitebark pine are likely less sensitive to drought stress in less dense and short-statured stands.
- Southern Sierra Nevada populations of whitebark pine and western white pine are located at the southern edge of the distribution, indicating that these populations are better adapted to drier conditions and could be targeted as a potential genetic source for assisted migration efforts in the future.

Alpine/Subalpine Ecosystem: Adaptation Actions

Table 2. Adaptation approaches and actions for Alpine/Subalpine Systems. Note: The group had insufficient time to describe the rationale for strategic actions or to evaluate action effectiveness or feasibility.

Adaptation Approach	*Strategic Actions*

Maintain or improve the ability of forests to resist insects and disease (i.e., mountain pine beetle, blister rust) and invasive species now and in the future	*Actions identified by participants:*
	▪ Actions in wilderness areas:
	    ○ Implement large-scale, coordinated monitoring program (including "citizen science" groups) designed to improve our ability to identify, detect, and predict future insect and disease outbreaks
	▪ Actions in targeted, non-wilderness areas:
	    ○ Thinning in targeted, non-wilderness areas projected to have a significant change in climatic water deficit, which will help reduce a number of stressors on trees so they are better able to resist insects and drought stress
	    ○ Promote diversity of age classes to improve overall ecosystem resistance and resilience to non-climate and climate stressors
	    ○ Implement large-scale, coordinated monitoring program (including "citizen science" groups) designed to improve our ability to identify, detect, and predict future insect and disease outbreaks
	
	Additional actions for consideration from the literature in targeted, non-wilderness areas:
	▪ Restore structure through silvicultural treatments (lowering the density, removing undesirable species, etc.) to reduce the susceptibility of forests to insects and disease that may be exacerbated by climate change
	▪ Create and plant genetically modified species to reduce the susceptibility of forests to insects and disease that may be exacerbated by climate change
	▪ Minimize spread of invasive species (e.g., cheatgrass) at higher elevations using early detection and rapid response approach
	
	Relevant references: Peters and Darling 1985, Beatley 1991, Burton et al. 1992, Bartlein et al. 1997, Halpin 1997, Shafer 1999, Rogers and McCarty 2000, McCarty 2001, Noss 2001, Schwartz et al. 2001, Honnay et al. 2002, Morecroft et al. 2002, Spittlehouse and Stewart 2003, Chambers et al. 2005, Hulme 2005, Maciver and Wheaton 2005, Pearson and Dawson 2005, Williams et al. 2005, Harris et al. 2006, de Dios et al. 2007, Millar et al. 2007, Ogden and Innes 2008, and Keane et al. 2012

Adaptation Approach	*Strategic Actions*
Restore fire to fire-adapted ecosystems to minimize fuel loading and reduce the potential for high severity fires, which are predicted to increase in the future as a result of climate change	*Actions identified by participants:* ▪ Greater use of managed wildfire to restore stand structure, promote diversity of seral classes, and reengage key ecosystem processes, especially in wilderness areas ▪ Reduce stand densities with available management tools to minimize likelihood of catastrophic fires ▪ Maintain refugia to provide suitable habitat for populations of species under changing climate conditions ▪ Use of prescribed burning in lower elevation subalpine forests (non-wilderness areas) to minimize fuel loading and reduce severity of potential fires ▪ Take advantage of natural fire occurrences by controlling fire path and severity *Additional actions for consideration from the literature*: ▪ Apply fire in a mosaic of micro-prescribed burns to lessen the smoke and risk potential ▪ Promote active experimentation in management approaches focused on reducing water stress or wildfire risk under changing climate conditions. For example, use targeted ground cover management (mulching) under trees to reduce soil evaporative water loss and moisture stress, although it is important to note that this could increase the risk of high-severity fire in the long term <u>Relevant references:</u> Spittlehouse and Stewart 2003, Millar et al. 2007, Ogden and Innes 2008, Halofsky et al. 2011, Swanston et al. 2012, and Grant et al. 2013
Increase diversity of nursery stock and maintain seeds of desired species for use after severe disturbances and to protect species from insect and disease outbreaks now and in the future	*Actions identified by participants:* ▪ Complete gene-screening for blister rust and, where feasible, identify and plant disease-resistant strains of white pine species (e.g., in stands already impacted by blister rust and areas that we are already losing individuals) to reduce susceptibility of forests to disease that may be exacerbated by or exacerbate climate impacts *Additional actions for consideration from the literature*: ▪ When appropriate, consider including more drought or heat-tolerant species (e.g., Jeffrey pine, limber pine) in plantings to facilitate novel or new climate-adapted subalpine forests ▪ Model, assess, and prioritize climate refugia areas to provide suitable habitat for populations of species under changing climate conditions ▪ Encourage restoration activities and volunteer work days and/or engage community service organizations to help plant disease-resistant species to improve overall forest resilience to climate

Adaptation Approach	*Strategic Actions*
	and non-climate stressors <u>Relevant references:</u> Burton et al. 1992, Staple and Wall 1999, McCarty 2001, Rice and Emery 2003, Maciver and Wheaton 2005, Harris et al. 2006, de Dios et al. 2007, Millar et al. 2007, and Keane et al. 2012

Alpine/Subalpine System: Implementation Needs for Adaptation Actions

Table 3. Adaptation action implementation needs for Alpine/Subalpine Systems.

Goal:	Maintain and restore healthy and sustainable wildlife, fish, and plant communities in alpine and subalpine ecosystems.
Strategic action:	When appropriate, use wildland fires to achieve resource benefits, including the reduction of fuel loading associated with catastrophic wildfires.
Resources needed:	Updated fire management plans Communications plans (including public outreach) Fuel inventories Firefighting resources and staff on call
Potential partners:	Air Resources Board USFS EPA NPS Interagency Southern Sierra Fire Science Working Group The Nature Conservancy Fire Learning Network California Fire Science Consortium (CFSC) Southern Sierra Prescribed Fire Council
Agencies that could implement action:	Land management agencies/owners (both public and private)
Timeframe:	2 – 5 years to develop and update fire management plans Less than 2 years for outreach and education
Where to implement:	Appropriate sites (taking into account): > Fuel loading > Cultural resources > Roads > Topography (slope) > Development > Priority stands > Available water sources

Mountain Yellow-Legged Frogs: Vulnerabilities, Adaptation Actions and Implementation

Mountain Yellow-Legged Frogs: Climate Change Vulnerabilities and Opportunities

Potential Challenges and Vulnerabilities:

- Variability in snowpack and precipitation will impose serious challenges to the process of prioritizing lakes for fish removal because it will be a moving target.
- Increased runoff and/or flooding may overwhelm and possibly remove natural fish barriers allowing fish to move further and invade additional, historically fish-free habitat.
- Increased temperatures may raise water temperatures allowing lakes to support fish species previously unable to survive in cold-water conditions.
- Increased temperatures may contribute to an increase in diseases, such as Chytridiomycosis (amphibian chytrid fungus disease).
- Changes in frequency, intensity, and timing of stream flows and decreased snowpack likely to influence water supply, which is necessary for reproduction, metamorphosis, and dispersal.
- Sensitivity to changing climate conditions is compounded by non-climatic stressors including natural system modifications, high-elevation logging, grazing, fish stocking, fungal infections, and pesticides.
- Require specialized, vulnerable high-elevation habitats including lakes, seeps and springs, and slow-moving streams.

Potential Opportunities and Adaptive Capacity:

- Climatic impacts such as warming temperatures and changes in precipitation, snowpack, and runoff, may make it easier to remove fish populations by helping change the habitat conditions that fish require for survival.
- Increased temperatures and decreased snowpack may increase population viability by reducing overwintering mortality and/or allowing juvenile frogs to forage and transition earlier to larger age classes.

Mountain Yellow-Legged Frogs: Adaptation Actions

Table 4. Adaptation approaches and actions for Mountain Yellow-Legged Frogs. Boxes highlighted in green indicate actions identified by participants as having high effectiveness (action meets desired intent) and feasibility (action capable of being implemented); yellow boxes indicate actions with moderate effectiveness and feasibility.

Adaptation approach	**Strategic actions identified by participants**	**Rationale for action**
Remove non-native fish populations that exacerbate climate impacts on native amphibians	Electroshock and/or gill netting of aquatic invasive species to reduce overall stress on frogs and help increase their ability to respond to climate change	Electroshock is recommended for easy-to-access lakes. Gill netting is recommended for remote, high elevation lakes, as electroshock equipment is difficult to transport into these areas. These actions are already in place and successful at removing non-native fish populations.
	Public outreach to prevent the establishment of invasive species that can exacerbate climate impacts on native amphibians	*Not able to address in time allotted.*
	Additional actions for consideration from the literature: ▪ Pheromone-based trapping and/or hoop netting to remove invasive species that exacerbate climate impacts <u>Relevant references:</u> Young et al. 2003, Lamansky et al. 2009, and Coggins and Yard 2010	
Prevent establishment of predators/competitors that could amplify climate impacts on native amphibians	Maintain and improve fish barriers in fishless systems to prevent invasion and establishment of species better able to expand ranges due to climate change and that could amplify climate impacts on native amphibians	This action is already in place and is currently effective in some areas but requires maintenance.
	Public outreach to prevent stocking in fishless areas to prevent invasion and establishment of species that could amplify climate impacts	This action can be highly effective when done adequately; however, agency resources often limit the effectiveness of outreach activities and the angling community may be difficult to sway. Non-governmental organizations may be important to engage with to support implementation of this action.

<table>
<tr><th>Adaptation approach</th><th>Strategic actions identified by participants</th><th>Rationale for action</th></tr>
<tr><td></td><td colspan="2">Additional actions for consideration from the literature:
▪ Conduct additional monitoring to emphasize early detection of and rapid response to invasive species
▪ Develop dispersal models of key fish and prioritize potential invasion sites for action

<u>Relevant references:</u> Peters and Darling 1985, Mulholland et al. 1997, Guo 2000, Knapp et al. 2001, Chornesky et al. 2005, Guisan and Thuiller 2005, Ferrier and Guisan 2006, Rounsevell et al. 2006, and Viers and Rheinheimer 2011</td></tr>
<tr><td rowspan="2">Protect existing populations from climate and non-climate stressors</td><td>Monitor populations for disease outbreaks and treat animals when infected (in field or captivity), as climate changes may increase spread of disease and/or interact with disease to further impact species (e.g., through decreased recruitment or survival)</td><td>Because disease can wipe out entire populations, it is desirable to intervene early.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Prioritize protection sites based on size, integrity and potential impact from both climate and non-climate stressors and their interactions

<u>Relevant references:</u> Dyer 1994, Alongi 2002, Erasmus et al. 2002, Chambers et al. 2005, and Crozier and Zabel 2006</td></tr>
<tr><td rowspan="2">Reintroduce animals to areas where they have been extirpated and are still likely to be viable frog habitat in the future</td><td>Focus reintroductions to areas that have been restored to help re-establish and sustain these species at least in the short term</td><td>Based on current distribution, this action will likely be necessary to re-establish self-sustaining populations within hydro-basins.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Reintroduce species where their future climate space might be

<u>Relevant references:</u> Morecroft et al. 2002, Pearson and Dawson 2005, Millar and Brubaker 2006, and Millar et al. 2007</td></tr>
<tr><td>Focus activities in areas identified as climate refugia</td><td>Identify and protect climate refugia (Note: no specific refugia characteristics were identified by the group) to help buffer</td><td>There is currently a general lack of information as to what constitutes an appropriate climate space for the species. However, when the climate space is defined and ground-truthed, this</td></tr>
</table>

<table>
<tr><th>Adaptation approach</th><th>Strategic actions identified by participants</th><th>Rationale for action</th></tr>
<tr><td rowspan="3"></td><td>species populations against climate change and short-term disturbances</td><td>information could greatly aid in prioritizing locations for actions and efficiently using limited funding.</td></tr>
<tr><td>Prioritize locations for actions (Note: no specific prioritization characteristics were identified by the group); for example, protecting existing populations on unique sites, protecting future suitable habitat, removing non-native species from suitable current habitat, etc.</td><td>Using available data can help with prioritization.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Monitor and protect key areas from other stressors that could amplify climate impacts
<u>Relevant references:</u> Bush 1996, Eeley et al. 1999, Noss 2001, Scott et al. 2002, and Chambers et al. 2005</td></tr>
</table>

Mountain Yellow-Legged Frogs: Implementation Needs for Adaptation Actions

Table 5. Adaptation action implementation needs for Mountain Yellow-Legged Frogs.

Goal:	Maintain and restore healthy and sustainable wildlife, fish, and plant communities in alpine and subalpine ecosystems.
Strategic action:	Electroshock and gill netting to remove non-native fish that could spread as a result of climate change and/or exacerbate climate impacts on native amphibians.
Resources needed:	Funding (~$25,000 per year for 5 small lakes) Float tubes for gill netting Volunteers Permits Maps of existing and potential frog range Current frog population maps and condition Map lakes with fish populations Maps of existing and potential barriers
Potential partners:	Landowners and land management agencies USFWS (Section 6 funding potential) NGOs for funding volunteers National fish and wildlife (funding)
Agencies that could implement action:	NPS USFS CDFW Universities Cal Parks
Timeframe:	*Next 2 years:* Prioritization; Continue existing projects *2 – 10 years:* Implement in additional priority areas; Monitor for results *10 – 20 years:* Complete in remaining high priority areas and reintroduce species as needed
Where to implement:	High mountain lakes (CDFW has data) Implement in climate refugia areas Low human use sites

4. Adaptation Strategy Development: Yellow Pine and Mixed Conifer

Participants: Defenders of Wildlife: Aimee Delach
Kings Canyon and Sequoia National Parks: Koren Nydick
National Forest Foundation: Vance Russell
Sierra Forest Legacy: Craig Thomas
U.S. Forest Service Plumas National Forest: Terri Simon-Jackson
U.S. Forest Service Pacific Southwest Regional Office: Sarah Sawyer

Distribution and General Overview

The mixed conifer forest is the most widely distributed forest type, covering an estimated 10% of vegetated area in the Sierra Nevada (Ansley 1998). Mixed conifer forests are found between 4,000-8,000 feet elevation and includes tree species such as black oak, ponderosa pine, incense cedar, sugar pine, giant sequoia, white fir, Jeffrey pine, and red fir. Species abundances vary across the Sierra Nevada. The condition of eastside yellow pine and mixed conifer forests is comparable to westside montane pine and mixed conifer forests including denser trees, more uniform forests, fire regimes outside the natural range of variability, and larger, higher intensity fires (Safford 2013; Bioregional Assessment 2013). Although plant composition has changed, most species are still present. Significant stressors for yellow pine and mixed conifer systems include fire suppression and climate changes. Fire suppression practices have resulted in species that are less drought and fire tolerant, which can result in more severe fires. Climate changes including decreased soil moisture and increased frequency and severity of wildfire are likely to negatively impact the system.

Management Goals and Objectives

The group's task was to identify at least one management goal and one objective for the yellow pine/mixed conifer system of the Sierra Nevada. The purpose of identifying management goals and objectives was to provide a foundation for evaluating whether and how climate change might compromise participants' shared conservation objectives for yellow pine/mixed conifer systems and species and for developing adaptation strategies for reducing climate impacts. The group chose to create new management goals and objectives for the system rather than using existing ones.

The group agreed to the following management goal and objectives for the yellow pine/mixed conifer system, which were largely focused on public lands throughout the Sierra Nevada[15]:

[15] Two other objectives were identified by the group, although they did not have time to explore them further: (1) Sustain key wildlife, such as the fisher, by protecting habitat structure over the entire range and facilitating range expansion over the next 30 years; and (2) Protect individual trees of special interest, such as Giant Sequoia, from damage from fire and other stressors in the next two years.

Goal: *Restore and maintain species composition, structure, and function within natural range of variability to promote resilience to fire, insects, drought, etc.*

- Objectives:
  - *Reduce risk of stand-replacing fire and landscape scale die-off events by increasing the percentage of fire tolerant pines (to a target) and decreasing the percentage of shade tolerant firs (to a target) over the entire range in the next 10 to 30 years.*[16] Note: Targets vary by site-specific topography (e.g., dry, moist, etc.) and spatial extent and should focus on high priority areas. Additionally, composition targets should be based on restoring short-term resilience, not manipulating long-term composition.
  - *Reduce basal area to a target range by increasing the spatial heterogeneity across the entire range over the next 30 years.* Note: Spatial heterogeneity can be defined as gaps, patches, and coarse woody debris (North et al. 2009[17]).
  - *Restore the natural fire regime by increasing the use of fire by 40% across the Sierra Nevada within the next 30 years.*

There is currently disagreement among federal and state agencies about the importance of vegetation species composition as an objective. In general, composition targets are meant to restore forests to a more fire-resilient state so that stressors, such as climate change, have less of an overall effect. This can be successful on short and medium-term timeframes, but not likely over the long-term (i.e., end of the century). *Thus participants thought the original objective should be modified to incorporate the appropriate timeframes associated with composition targets. For example, the objective should identify that composition is based on restoring short-term resilience, not manipulating composition in the long-term.*

Climate Change Impacts Assessment, Adaptation Actions and Implementation

After creating management goals and objectives, the group reviewed the findings from the yellow pine/mixed conifer ecosystem vulnerability assessment to identify potential challenges and vulnerabilities as well as potential opportunities for achieving objectives given climate impacts and associated vulnerabilities.[18]

The group brainstormed strategic climate adaptation actions that might help yellow pine/mixed conifer ecosystems survive in the Sierra Nevada given potential vulnerabilities and challenges.

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[16] The group did not identify target numbers and thought that other yellow pine/mixed conifer system experts should be consulted to select targets.

[17] North et al. (2009) refers to USFS General Technical Report (GTR) 220, which describes an ecosystem management strategy for Sierran mixed-conifer forests, specifically focusing on ecological restoration that produces different stand structures and densities across the landscape using topographic variables (e.g., slope shape, aspect, position) as a guide for varying treatments.

[18] Full findings from the vulnerability assessment are available online through the California Climate Commons (http://climate.calcommons.org/) and EcoAdapt (http://ecoadapt.org/) websites.

This brainstorming session was intended to generate a diverse range of potential adaptation approaches and strategic actions that could be considered. The resulting tables are not comprehensive, nor do they necessarily represent participants' consensus on what actions should be implemented; rather, it is an initial list of strategic actions that might be considered. Table 6 presents these strategic adaptation actions, as well as additional actions for consideration from the peer-review literature for yellow pine/mixed conifer systems.

In general, the group identified strategies that involve conventional approaches to restoring and maintaining species composition, structure, and function including targeted thinning and prescribed burning, planting disease resistant species, establishing long-term monitoring programs, and increasing education and outreach, among others. As part of this exercise, participants also highlighted some potential benefits and barriers associated with adaptation actions. For example, the most well-known barrier is associated with using fire as a management or restoration tool. There are serious budget, air quality and smoke concerns, and considerable risk to humans and structures. Additionally, because of the somewhat degraded condition of mixed conifer ecosystems (i.e., relatively high fuel loads and thus high flammability), it was therefore suggested that we may be beyond our ability to fully restore natural or historic fire regimes. However, if this action is implemented it was suggested that a phased approach should be used for prescribed fire. In addition, the timing and intensity of prescribed fires should be coordinated with targeted thinning operations and managed natural fires. Furthermore, it was highlighted that better collaboration across all landowners will be needed to burn larger "fire-sheds" instead of small fragmented areas. Although these barriers are important when using fire as a tool, the potential benefits, such as improving ecosystem health and habitat condition, were recognized as significant.

Other barriers identified included market demand, lack of funding, and social/political support. For example, the U.S. Forest Service has existing management options to focus thinning on species such as cedar, but market demand will influence the price and feasibility of such targeted thinning operations. Other land management agencies and private landowners will also be affected by the dynamic between market demand and thinning objectives. However, the small-diameter market is improving especially in the southern Sierra Nevada.

After analyzing the climate vulnerabilities and brainstorming strategic adaptation actions, participants were asked to select one to two strategic actions and expand on the resources needed and timeframe for implementation. The group was also asked to begin thinking about areas in the Sierra Nevada that may be appropriate for implementation. These findings are detailed in Table 7.

Yellow Pine/Mixed Conifer Ecosystems: Climate Impacts, Adaptation Actions and Implementation

Yellow Pine/Mixed Conifer System: Climate Change Vulnerabilities and Opportunities

Potential Challenges and Vulnerabilities:

- Increased susceptibility to disease and insects for pines.
  - For example, new diseases moving in such as the pine pitch canker, bark beetle, mountain pine beetle, sudden oak death, white pine blister rust, etc.
- Post-fire species and forest conversion could change species composition to more shrub/grassland systems and could allow for increased invasion of exotic species.
  - For example, fire and other major disturbances have the potential to affect entire landscapes.
- Fire exclusion has already affected composition greatly and increased risk of high severity fire.
- Increased coarse woody debris could increase the likelihood of more intense fires and could increase the mortality of trees.
- The "natural" fire regime for this ecosystem is not precisely known.
- The fire season is lengthening due to climate change.
- The risk of very large and severe fires is also increasing due to climate change.
- This increased risk of large and severe fires and longer fire seasons is reducing the window for implementing managed (i.e., prescribed) fire.
- Due to fire risks and concerns, prescribed fires are occurring in seasons when they were not historically active (i.e., outside of the natural fire regime).

Potential Opportunities and Adaptive Capacity:

- Increased fire frequency reduces shade tolerant firs, but will likely not cause total system conversion in areas that have seen fire in the last century.
- Increased fire frequency, especially large and severe fires, can bring the issue of fire to the attention of more people. It could result in more public support and funding or at a minimum bring a higher tolerance of smoke from prescribed fire activities.
- Private landowners are becoming more pro-active with their fuel reduction activities.
- More frequent fires will increase fires on the landscape, however, whether we can "manage" it is currently debated.

Yellow Pine/Mixed Conifer Ecosystems: Adaptation Actions

Table 6. Adaptation approaches and actions for Yellow Pine/Mixed Conifer Ecosystems. Boxes highlighted in green indicate actions identified by participants as having high effectiveness (action meets desired intent) and feasibility (action capable of being implemented); yellow boxes indicate actions with moderate effectiveness and feasibility.

Adaptation approach	Strategic actions identified by participants	Rationale for action
Restore structure, function, and composition of yellow pine/mixed conifer systems to enhance and preserve ecosystem integrity and processes now and in the future	Targeted thinning of fire-intolerant species to minimize fuel loading and reduce the severity of potential fires, as well as reduce the risk of insect and disease outbreaks which may increase with longer and drier growing seasons and lead to increased fire risk	Moderate to highly feasible for technological concerns because agencies can usually achieve desired composition. However, it was also identified that if disease outbreaks and/or insect infestations occur, then those infected trees would also have to be thinned, thus making it more difficult to achieve the composition objective. Financial feasibility is low due to limited market demand for small diameter trees. Social-political feasibility is likely moderate (but not applicable in wilderness areas).
	Use prescribed burning to restore ecosystem functioning, minimize fuel loading and reduce the severity of potential fires, as well as reduce the risk of insect and disease outbreaks which may increase with longer and drier growing seasons and lead to increased fire risk	Prescribed fire has successfully been used in the past to control ecosystem structure and species composition; however, air quality and fire risk are major concerns among the public.
	Actively manage natural fires by controlling path and severity to meet management objectives and reduce risk of catastrophic fires, which may increase due to longer and drier growing seasons	*Not able to address in time allotted.*
	Assisted translocation of species to suitable habitat in the future to help maintain overall ecosystem function	The USFS and to some extent the NPS have had success with planting seedlings from low elevations at higher elevations. There is likely high feasibility in implementing assisted translocation by planting genotypes from either (1) low elevations at high elevations, or (2) from more southern locations to more northern locations.
	Plant and promote climate appropriate	*See rationale above for Assisted translocation of species.*

Adaptation approach	Strategic actions identified by participants	Rationale for action
	genotypes and species (e.g., drought tolerant species) through management activities	
	Plant genetically resistant species (e.g., resistant to white pine blister rust) to prevent potential for increased spread of disease and/or vulnerability under climate change	Highly feasible to plant genetically resistant species, such as sugar pine species that are genetically-resistant to white pine blister rust, in priority areas.
	Additional actions for consideration from the literature: ▪ Identify key functions that are important for these ecosystems (e.g., fire, nutrient cycling, hydrology, etc.) and implement management actions aimed at maintaining the integrity of ecosystems and sustaining fundamental functions to improve overall ecosystem resilience to climate change impacts ▪ Apply fire in a mosaic of micro-prescribed burns to lessen the smoke and risk potential and reduce the potential for high severity fires that may increase as a result of climate change ▪ Restore structure through silvicultural treatments (lowering the density, removing undesirable species, etc.) to reduce the susceptibility of forests to disturbances that may increase as a result of climate change (e.g., risk of fire, insect and pathogen outbreaks) ▪ Use seeds from across a greater geographic range or from drier, warmer climates for restoration and plantings to help ensure species and ecosystem persistence under changing conditions <u>Relevant references:</u> Peters and Darling 1985, Beatley 1991, Burton et al. 1992, Bartlein et al. 1997, Halpin 1997, Shafer 1999, Staple and Wall 1999, Rogers and McCarty 2000, McCarty 2001, Noss 2001, Schwartz et al. 2001, Honnay et al. 2002, Morecroft et al. 2002, Rice and Emery 2003, Spittlehouse and Stewart 2003, Chambers et al. 2005, Hulme 2005, Maciver and Wheaton 2005, Pearson and Dawson 2005, Williams et al. 2005, Harris et al. 2006, de Dios et al. 2007, Millar et al. 2007, and Ogden and Innes 2008	
Monitor success to evaluate whether adaptation actions are working and/or need to be revised	Identify key metrics (i.e., indicator species, structure attributes, important functions) to evaluate climate and non-climate impacts and management action effectiveness and set up realistic, long-term monitoring programs to track each	Monitoring by all agencies and landowners was seen as moderately feasible because most have experience doing it but it is not a top priority.
	Additional actions for consideration from the literature:	

<table>
<tr><th>Adaptation approach</th><th>Strategic actions identified by participants</th><th>Rationale for action</th></tr>
<tr><td></td><td colspan="2">▪ Monitor progress of management actions using a standard plot methodology, such as the Forest Service's permanent plots (Forest Inventory and Analysis - FIA) to track effectiveness of implemented adaptation actions

<u>Relevant references:</u> Peters and Darling 1985, Mulholland et al. 1997, Noss 2001, Opdam and Wascher 2004, Chambers et al. 2005, Hulme 2005, Welch 2005, Root and Schneider 2006, and Underwood and Fisher 2006</td></tr>
<tr><td rowspan="2">Increase education to improve understanding of ecosystem value, how future climate changes may impact the system and its services, and potential management actions to reduce impacts</td><td>Increase people's connection to the environment and understanding of the interconnections and the short-term versus long-term risks, particularly around fire frequency and severity which are predicted to increase under climate change</td><td>Not able to address in time allotted.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Focus education on the ecosystem services of mixed conifer ecosystems to improve understanding about potential climate impacts on services people depend upon
▪ Encourage restoration activities and volunteer work days and/or engage community service organizations to improve understanding about climate impacts to forest resources and enhance overall forest resilience to climate and non-climate stressors

<u>Relevant references:</u> Ramakrishnan 1998, Eeley et al. 1999, Desanker and Justice 2001, Opdam and Wascher 2004, Tompkins and Adger 2004, Lovejoy 2005, Chapin et al. 2006, and McClanahan et al. 2008</td></tr>
<tr><td rowspan="3">Promote climate-smart policies to improve social and ecological resilience to climate change</td><td>Promote ecosystem services for payment (e.g., water users could pay for water coming from forested lands)</td><td>Not able to address in time allotted.</td></tr>
<tr><td>Create a biomass energy market by promoting biomass energy generation, which could help reduce the risk of high severity fires predicted to increase from climate change</td><td>Not able to address in time allotted.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Consider leaving some slash on the site after thinning to improve fertilization/nutrient cycling, although large amounts of slash may be a fire risk
▪ Plant climate-appropriate species and genotypes that are better adapted to future conditions (e.g., pest or disease resistance or broad tolerances for environmental conditions)
▪ Control pest and disease outbreaks before they turn into significant problems and have the potential to exacerbate climate impacts</td></tr>
</table>

Adaptation approach	Strategic actions identified by participants	Rationale for action
	Relevant references: Peters and Darling 1985, Franklin et al. 1992, Peterson et al. 1997, Eeley et al. 1999, Guo 2000, Scott et al. 2002, Opdam and Wascher 2004, Lovejoy 2005, Welch 2005, Ferrier and Guisan 2006, Millar and Brubaker 2006, and Halofsky et al. 2011	

Yellow Pine/Mixed Conifer Systems: Implementation Needs for Adaptation Actions

Table 7. Adaptation action implementation needs for Yellow Pine/Mixed Conifer Systems.

Goal:	Restore and maintain species composition, structure, and function within natural range of variability to promote resilience to fire, insects, drought, etc.	
Strategic action:	Restore ecosystem structure, function, and composition by using prescribed burning, actively managing natural fires, and through targeted thinning of fire-intolerant species to help reduce the risk of high severity fires and insect and pathogen outbreak, both of which are predicted to increase as a result of climate change.	
Resources needed:	Information on liability responsibility in terms of fire Completed National Environmental Policy Act (NEPA) that includes climate change Additional fire staffing for implementation Funding Added capacity to help with project planning and facilitation Information on social perception Stakeholder engagement and prioritization (i.e., balancing values and risk) Compliance – air permits Training – interest-based negotiations	
Potential partners:	Landowners Cal Fire Tribes Recreation interests Businesses Academia	National Forest Foundation (to build capacity) Environmental and community NGOs Local and regional communities Air Resources Board Youth
Agencies that could implement action:	USFS BLM NGOs Private landowners	NPS State of California County or local governments Tribal lands
Timeframe:	Treat 30% of each of five pilot projects within 20 years	

Where to implement:	Where fire-sheds cross land ownerships Where strong collaborations already exist Take into account modeled fire risk results (FRID, FLAMM)

5. Adaptation Strategy Development: Red Fir

Participants: California Tahoe Conservancy: Tricia York
The Wilderness Society: Greg Aplet
U.S. Forest Service Eldorado National Forest: Tony Valdes
U.S. Forest Service Pacific Southwest Research Station: Angela White
U.S. Forest Service Sierra Nevada National Forest: Greg Schroer

Distribution and General Overview

In the Sierra Nevada, red fir forests extend near the northern California border southward to Kern County in the southern Sierras. Red fir dominates large high elevation areas, preferring cool and moist climates with more precipitation (especially in the form of snow) and soil moisture. Red fir forests are currently both in and outside their natural range of variability, as the structure of red fir forests has shifted with homogenization including increases in small and medium trees and decreases in large trees (Meyer 2013b). Significant stressors for the red fir system include insects and pathogens, fire suppression practices that have increased interspecific competition, and moisture stress leading to increased mortality (Bioregional Assessment 2013). In particular, red fir systems appear vulnerable to altered hydrology including changes in snowpack, precipitation, and soil moisture.

Management Goals and Objectives

The group's task was to identify at least one management goal and one objective for the red fir ecosystem of the Sierra Nevada. The purpose of identifying management goals and objectives was to provide a foundation for evaluating whether and how climate change might compromise participants' shared conservation objectives for red fir systems and species and for developing adaptation strategies for reducing climate impacts. The group chose to create new management goals and objectives for the system rather than using existing ones.

The group agreed to the following management goal and objectives for the red fir system, which were largely focused on public lands throughout the Sierra Nevada:

Goal: *Develop and maintain healthy and resilient red fir ecosystems.*

- Objectives:
    - *Promote and maintain adequate canopy and ground cover in red fir stands to enhance sustained soil fertility and nutrient cycling necessary for sustaining red fir forests in the Sierra Nevada.*
    - *Ensure habitat connectivity for marten in red fir forests in the Sierra Nevada by maintaining the abundance and distribution of forest and non-forest cover within the natural range of variability, and that also sustains marten populations.*

- *Maintain and improve tree recruitment of red fir in existing stands over the next ten years.*

Climate Change Impacts Assessment, Adaptation Actions and Implementation

After creating management goals and objectives, the group reviewed the findings from the red fir ecosystem vulnerability assessment to identify potential challenges and vulnerabilities as well as potential opportunities for achieving objectives given climate impacts and associated vulnerabilities.[19]

The group brainstormed strategic climate adaptation actions that might help red fir ecosystems survive in the Sierra Nevada given potential vulnerabilities and challenges. This brainstorming session was intended to generate a diverse range of potential adaptation approaches and strategic actions that could be considered. The resulting tables are not comprehensive, nor do they necessarily represent participants' consensus on what actions should be implemented; rather, it is an initial list of strategic actions that might be considered. Table 8 presents these strategic adaptation actions, as well as additional actions for consideration from the peer-review literature for red fir systems.

In general, the group focused on strategies that involve current management approaches to developing and maintaining red fir stands including targeted thinning and prescribed burning, allowing natural fire to enter stands, and minimizing soil compaction from mechanized activities. To enhance the success of any or all of these activities, participants highlighted the need for better collaboration across all landowners. Also as part of this exercise, participants identified some potential benefits and barriers associated with adaptation actions. For example, the most well-known barrier is associated with using fire as a management or restoration tool. There are serious budget, air quality and smoke concerns, considerable risk to humans and structures, and significant institutional and logistic barriers. However, given that fire will likely burn red fir stands at some point in the future, it may be beneficial to implement proactive strategies that limit catastrophic impacts as well as improve overall ecosystem health and resiliency. Other potential barriers identified include noise disturbance to marten from mechanized activities, slash buildup that creates a potential fire hazard, lack of accessibility to some red fir stands (particularly if fuel prices continue to rise and the market for small diameter logs remains low), and lack of funding for management activities.

In addition to identifying possible adaptation actions, this group also designed an adaptive management experiment using current management strategies (i.e., fire and thinning). The experiment is intended to test different hypotheses about strategy effectiveness, including identifying what actions actually enhance tree recruitment, and improve knowledge about the red fir system that can be applied in future management actions. The experiment, designed to be implemented at a landscape level, includes replication of treatments within each of the

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[19] Full findings from the vulnerability assessment are available online through the California Climate Commons (http://climate.calcommons.org/) and EcoAdapt (http://ecoadapt.org/) websites.

three Sierra Nevada sub-regions. Figure 2 describes the red fir ecosystem adaptive management experiment.

After analyzing the climate vulnerabilities and brainstorming strategic adaptation actions, participants were asked to select one to two strategic actions and expand on the resources needed and timeframe for implementation. The group was also asked to begin thinking about areas in the Sierra Nevada that may be appropriate for implementation. Participants in the red fir group chose to focus on resources needed for implementation of their adaptive management experiment (Table 9).

Red Fir Ecosystems: Climate Impacts, Adaptation Actions and Implementation

Red Fir System: Climate Change Vulnerabilities and Opportunities

Potential Challenges and Vulnerabilities:

- Warmer temperatures have resulted in substantial declines in annual snowpack (Safford et al. 2010), which leads to less available water and decreased soil moisture during the summer dry period and this trend is expected to continue (Geos Institute 2013).
- Red fir is relatively more sensitive to changes in climatic water deficit than other species (e.g., Jeffrey pine, white fir, and sugar pine).
- There has been a trend of increasing fire severity in red fir forests in the Sierra Nevada (e.g., increase in total area of stand-replacing fires), although current regional rates of burning in red fir are still far below their pre-settlement rates for all severity classes (Mallek et al. 2013).
- Key core habitat areas for marten, which are currently a priority for connectivity, may be negatively impacted by changing climate conditions (i.e., red fir forests could decrease) thus reducing potential for re-establishing marten in the future.
- The current and future projected loss of snowpack and freezing temperatures are a major obstacle even though the current strategies to maintain habitat connectivity are fairly good.
- Loss of snowpack and freezing temperatures that support red fir forests may be inevitable.

Potential Opportunities and Adaptive Capacity:

- Increased public awareness of climate change may create new opportunities and funding for the charismatic marten.

Red Fir Ecosystems: Adaptation Actions and Adaptive Management Experiment

Table 8. Adaptation approaches and actions for Red Fir Ecosystems. Boxes highlighted in yellow indicate actions identified by participants as having moderate effectiveness (action helps meet desired goal) and feasibility (action capable of being implemented).

Adaptation approach	Strategic actions identified by participants	Rationale for action
Understand fundamental ecological functions and processes of red fir recruitment and growth, such as maintaining soil moisture content, and how they might change in the future, then promote these to sustain healthy red fir stands	Decrease soil moisture deficit by reducing stem density (while maintain canopy cover) to the natural range of variability	Can provide greater resilience to climate and non-climate stressors
	Experiment with silvicultural techniques to see which ones achieve the desired structure and composition now and in the future	Can help bring system closer to natural range of variability
	Develop an ecosystem management strategy specific to Sierra Nevada red fir forests with focus on a summary of current science information from an interdisciplinary perspective (e.g., forest ecology, fire ecology, wildlife ecology, silviculture), climate change considerations, and research gaps (similar to North et al. 2009 and North 2012)	Can provide direction on ecological restoration and other management strategies needed to address immediate forest health issues (e.g., drought stress, increased incidence of pathogens) and long-term climate adaptation questions.
	Develop large-scale, coordinated monitoring program (including "citizen science" groups) designed to improve our ability to detect and predict future changes in red fir forests	Can help understand how red fir forests respond to changing climate at a bioregional scale.
	Thin red fir stands sequentially and, when possible, use prescribed fire so that when natural fires occur they are less severe	Single-tree and other thinning techniques can help increase stand complexity, bringing the system closer to the natural range of variability and providing greater resilience to current and projected stressors
	Manage natural fire in red fir stands to restore natural fire regime and reduce risk	*Not able to assess in time allotted.*

<table>
<tr><th>Adaptation approach</th><th>Strategic actions identified by participants</th><th>Rationale for action</th></tr>
<tr><td rowspan="4"></td><td>of high severity fires that are predicted to increase in frequency as a result of climate change</td><td></td></tr>
<tr><td>Maintain adequate canopy cover and ground cover (e.g., litter, hummus) to maintain and/or improve soil quality and/or nutrient cycling that will help sustain ecosystem integrity and fundamental ecological functions under changing climate conditions</td><td>Not able to assess in time allotted.</td></tr>
<tr><td>Minimize soil compaction from mechanized activities, such as forest thinning with heavy equipment, to maintain and/or improve soil quality that will help sustain ecosystem integrity and fundamental ecological functions under changing climate conditions</td><td>Not able to assess in time allotted.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Apply fire in a mosaic of prescribed burns to lessen the smoke and risk potential and reduce the potential for high severity fires that may increase as a result of climate change
▪ Apply silvicultural treatments to restore red fir forest structure to more closely resemble the natural range of variability (i.e., by lowering the density, removing undesirable species, etc.) and to minimize fuel loading and reduce the severity of potential fires, as well as reduce the risk of insect and disease outbreaks which may increase with longer and drier growing seasons and lead to increased fire risk
▪ Actively plant and protect red fir seedlings in high priority areas (current and future suitable habitat) to provide suitable habitat for populations under changing climate conditions

<u>Relevant references:</u> Peters and Darling 1985, Franklin et al. 1992, Dyer 1994, Bartlein et al. 1997, Halpin 1997, Dixon et al. 1999, Shafer 1999, Thomas et al. 1999, Williams 2000, Buckland et al. 2001, Noss 2001, Soto 2001, Morecroft et al. 2002, Chambers et al. 2005, Chornesky et al. 2005, Hulme 2005, Williams et al. 2005, and Crozier and Zabel 2006</td></tr>
</table>

Adaptation approach	Strategic actions identified by participants	Rationale for action
Develop and maintain core current and projected marten habitat areas and corridors	Avoid the creation of large gap openings as well as fragmentation of red fir forests in key current and projected marten habitat areas and corridors	*Not able to assess in time allotted.*
	Prioritize areas for key habitat and corridors, focusing on the most suitable corridors that connect habitat areas likely to be resilient/resistant to climate changes	It may be difficult to maintain connectivity across the entire landscape thus it may be beneficial to prioritize smaller geographical areas for implementation.
	Maintain red fir ecosystems closer to their natural range of variability using management techniques identified above in *Understand fundamental ecological processes and functions* to improve overall ecosystem resilience and to continue to provide habitat for martens under changing climate conditions	*N/A*

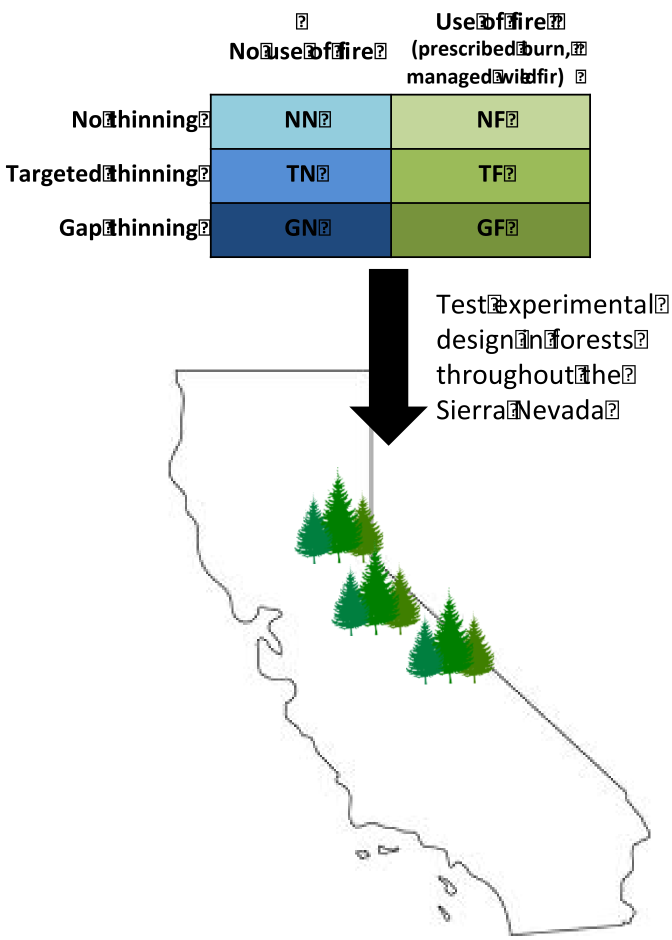

Figure 2. Adaptive management experiment for red fir ecosystems designed to test implementation of different management options/combinations that will improve overall knowledge about the system and enhance tree recruitment. The experiment includes three thinning treatments: (1) no thinning (N), (2) targeted species thinning (T), and (3) gap thinning (G), and two fire treatments: (1) no use of fire (N) and (2) use of fire (e.g., through prescribed burning or managed wildfire; (F)). The experiment is designed to be implemented at a landscape level, including replication of treatments within each of the three Sierra Nevada sub-regions, and could improve understanding about which treatments and/or combinations of treatments achieve the desired structure and composition now and in the future. Those combinations of actions thought to be most likely to be implemented include: no use of fire or thinning, targeted species thinning combined with fire, and gap thinning combined with fire.

Red Fir Systems: Implementation Needs for Adaptation Actions

Table 9. Implementation needs for Red Fir Ecosystem adaptive management experiment.

Goal:	Develop and maintain healthy and resilient red fir ecosystems.	
Strategic action:	Apply the adaptive management experiment described in Figure 2, which includes testing a combination of thinning, prescribed burning, and/or managed wildfire to improve understanding of fundamental ecological functions and processes of red fir recruitment and growth and how they might change or be impacted in the future, and promoting those actions or combinations of actions that enhance tree recruitment and overall ecosystem resilience under climate change.	
Resources needed:	Funding Research/Science practitioners Biomass market resources Red fir stand information Resource specialists including silviculturists, fuels planners, and wildlife biologists Additional fire staffing for implementation Compliance – air quality permits	
Potential partners:	Air Resources Board EPA NGOs Academia Tribes Landowners Southern Sierra Prescribed Fire Council	Forest industry and local contractors California Fire Science Consortium (CFSC) Environmental and community Local and regional communities Interagency Southern Sierra Fire Science Working Group The Nature Conservancy Fire Learning Network
Agencies that could implement action:	NPS Sierra Pacific Industries County/Local governments Contractors	USFS NGOs State Parks
Timeframe:	Short-term: 2-10 years for thinning Short-term: 2-10 years for prescribed fire Intermediate: 2-30 years for unmanaged fire	
Where to implement:	USFS lands for thinning and fire NPS lands for prescribed fire and managed wildfire Overall strategy for implementation:	

	▪ Replicate each action described in experiment six times within the three Sierra Nevada sub-regions ▪ Use monitoring information to inform future treatments and management ▪ Bracket the conditions to replicate the experiment across those three sub-regions o Prioritize areas where: (1) prescribed fire can be used as the primary tool, (2) areas where fire can be combined with thinning, and (3) control areas with no fire or thinning treatments

6. Adaptation Strategy Development: Wet Meadows and Fens

Participants: Earth Justice: Emily Brown
Point Blue Conservation Science (formerly PRBO): Ryan Burnett
Sierra Nevada Alliance: Gavin Feiger
The Nature Conservancy: Ed Smith
U.S. Forest Service Pacific Southwest Regional Office: Bruce Goines
U.S. Forest Service Sequoia National Forest: Nina Hemphill

Distribution and General Overview

Wet meadows are well distributed across the Sierra Nevada at different elevations (Whitney 1979), but account for only one percent of total area (Viers et al. 2013). The southern Sierra, with its steeper topography and drier climate, has less meadow area than the northern Sierra. Sierra Nevada wet meadows are largely defined by their hydrology (Weixelman et al. 2011); for example, meadows in mid- to high-elevations usually receive water supply from snowmelt (Viers et al. 2013). Other water sources for meadows include overland flow, surface flow and/or groundwater entering via stream and spring networks, and direct precipitation (Lord et al. 2011). Wet meadows are important ecosystems, providing key habitat for numerous species as well as a variety of ecosystem services including water filtration, attenuating floods, aesthetic value, and water storage, among others. Unfortunately, meadows have been identified as one of the most altered and impacted landscapes in the Sierra Nevada (Loheide et al. 2009). Livestock grazing, recreation, roads and culverts, and water diversion and storage represent some of the most common threats to wet meadow persistence.

Management Goals and Objectives

The group's task was to identify at least one management goal and one objective for the wet meadows and fens system in the Sierra Nevada. The purpose of identifying management goals and objectives was to provide a foundation for evaluating whether and how climate change might compromise participants' shared conservation objectives for wet meadow systems and species and for developing adaptation strategies for reducing climate impacts. The group chose to create new management goals and objectives for the system rather than using existing ones.

The group agreed to the following management goal and objectives for the wet meadows and fens system, which were largely focused on public lands throughout the Sierra Nevada[20,21]:

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[20] One other objective was identified for the goal described above, although they did not have time to further develop adaptation actions. Objective: By 2015, prioritize meadows across the Sierra Nevada region for conservation and restoration. Sub-objectives or tasks: (1) Up-to-date inventory of the Sierra Nevada meadows by sub-region and (2) Evaluate ecological condition of Sierra Nevada meadows.

[21] Two other goals and associated objectives were identified by the group, although they did not have time to explore them further. (1) Goal: Increase water retention in high elevation meadows and fens; counteract earlier snowmelt, dampen predicted runoff from increased high flows. Objective: Increase floodplain lateral connectivity

Goal: *Restore and maintain meadow and fen ecosystem functions and processes across the Sierra Nevada.*

- Objectives:
  - *By 2025, triple the number of acres of meadows with functional floodplains.*
  - *By 2032, double the acres over baseline of the Sierra Nevada meadows with high biological diversity as measured by indices for taxonomic groups (birds, fish, macroinvertebrates, amphibians, and plants and/or rare plants) and based on National Fish and Wildlife Foundation (NFWF) funded evaluations of appropriate/important/useful indices.*

Climate Change Impacts Assessment, Adaptation Actions and Implementation

After creating management goals and objectives, the group reviewed the findings from the wet meadows and fens vulnerability assessment to identify potential challenges and vulnerabilities as well as potential opportunities for achieving objectives given climate impacts and associated vulnerabilities.[22]

The group brainstormed strategic climate adaptation actions that might help wet meadows and fens survive in the Sierra Nevada given potential vulnerabilities and challenges. This brainstorming session was intended to generate a diverse range of potential adaptation approaches and strategic actions that could be considered. The resulting tables are not comprehensive, nor do they necessarily represent participants' consensus on what actions should be implemented; rather, it is an initial list of strategic actions that might be considered. Table 10 presents these strategic adaptation actions, as well as additional actions for consideration from the peer-review literature for wet meadow and fen systems.

In general, the group identified strategies that involve conventional approaches to restoration of meadow ecosystems, including plug-and-ponding; bank and headcut stabilization; restoring soils, structure, and meanders; grazing exclosures and maintaining fencing; mechanical fuels reduction and prescribed burning to manage wildfires; and reassessment and revision of roads and trails, among others. Overall, participants determined that there are management systems in place (including those for data collection and monitoring) to achieve the identified goal for wet meadows and fens, but strategies and standards need to be changed to better address meadow systems. As part of this exercise, participants also highlighted some potential benefits and barriers associated with adaptation actions. For example, potential benefits related to restoring and maintaining wet meadows include increased water storage, sustained base flows,

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to restore floodplain function in Sierra Nevada high elevation meadows. Areas of Interest: Sierra Nevada by sub-region = north of Tahoe, south of Tahoe, southern Sierra. Timeframe: 2025. (2) Goal: Reduce sedimentation resulting from increased flows predicted from climate change. Objective: Preserve meadow soils, prevent or restore head- and down-cutting processes. Areas of Interest: Sierra Nevada by sub-region = north of Tahoe, south of Tahoe, southern Sierra. Timeframe: 2025.

[22] Full findings from the vulnerability assessment are available online through the California Climate Commons (http://climate.calcommons.org/) and EcoAdapt (http://ecoadapt.org/) websites.

and increased biodiversity, among others. Potential barriers associated with adaptation actions include financial (lack of funding resources), institutional (e.g., closing grazing allotments), technical (e.g., lack of consistent and detailed data for informing meadow prioritization), and social and political barriers such as interest in maintaining a current way of life and the need to raise awareness of meadow importance and social value. Lack of resources may be the biggest hurdle, but could be overcome with public, private, and public-private partnership (PPP) investments (e.g. Coca-Cola, utilities, public goods charge, DWR). Fire reintroduction also includes potential barriers such as air quality concerns, liability, urban expansion, carbon cycling, and carbon accounting (AB 32[23]) – loss of carbon in fire with a carbon mandate.

After analyzing the climate vulnerabilities and brainstorming strategic adaptation actions, participants were asked to select one or more strategic actions and expand on the resources needed and timeframe for implementation. The group was also asked to begin thinking about areas in the Sierra Nevada that may be appropriate for implementation. These findings are detailed in Tables 10-13 below.

Wet Meadow and Fen Ecosystems: Climate Impacts, Adaptation Actions and Implementation

Wet Meadow and Fen Systems: Climate Change Vulnerabilities and Opportunities

Potential Challenges and Vulnerabilities:

- Climate envelope of many meadow species may move to higher elevations where topography limits the number of large meadow systems.
- Frequency and intensity of extreme runoff events may increase.
- Frequency of stand-replacing fires in a large percentage of watersheds above meadows and fens may increase, resulting in increased erosion and sedimentation into the meadow systems, as well as reduce the thermal cooling from riparian vegetation.
- Increased climatic water deficit may increase conifer encroachment.
- Increased demand on Sierra meadows for grazing due to changing seasonality of high quality rangeland.
- Increased sedimentation and runoff due to compaction of roadways and trails due to increased use during winter from lack of snow.
- Loss of snowpack and decreased groundwater recharge.
- Increased construction of poorly engineered roads and/or culverts around meadows leads to a change in hydrologic connectivity (e.g., channelization of streams due to under-engineered culverts) and narrows flows, causing erosion and deepening of the channel.

[23] Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006, set the 2020 greenhouse gas emissions reduction goal of California into law in 2006. AB 32 directed the California Air Resources Board to begin developing discrete early actions to reduce greenhouse gases while also creating a plan to identify how to reach the 2020 limit (http://www.arb.ca.gov/cc/ab32/ab32.htm).

- Political opposition to projects seen as sequestering water from downstream user groups.
- Thermal range of individual species may shift species composition of both plants and wildlife.
- Extrinsic factors beyond habitat quality (e.g., Chytrid fungus) that are limiting rare species populations.
- Indices have not yet been developed for important or indicator taxonomic groups.
- Long-term, large scale monitoring of a diverse set of taxa is expensive and political will may not exist to conduct this effectiveness monitoring.
- Increased demand on Sierra water both within and outside of the Sierra Nevada.

Potential Opportunities and Adaptive Capacity:

- Increased erosion from increased fire and runoff (see above) could provide sediment to fill in gullied channels.
- More rain over a longer period may make up for loss of snowpack, which currently regulates flow.
- Increased primary productivity due to longer growing season may increase functionality through bank stabilization or allow for more successful restoration.
- Increased fire frequency and severity may counteract conifer encroachment.

Wet Meadows and Fens: Adaptation Actions

Table 10. Adaptation approaches and actions for Wet Meadows and Fens. Boxes highlighted in green indicate actions identified by participants as having high effectiveness (action meets desired intent) and feasibility (action capable of being implemented); yellow boxes indicate actions with moderate effectiveness and feasibility.

Adaptation approach	Strategic actions identified by participants	Rationale for action
Restore floodplain function to enhance ecosystem integrity and resilience under climate change, in particular, limiting impacts from projected changes including increased drought, reduced soil moisture, increased flooding, runoff and/or sedimentation, and decreased snowpack and groundwater recharge	▪ Plug and pond (redirects flow from incised channel to stable channel with broad floodplain) ▪ Establish setbacks ▪ Bank stabilization ▪ Headcut stabilization (to stabilize upslope soils) ▪ Restore soils and structure ▪ Restore meanders ▪ In-stream restoration ▪ Promote beavers where appropriate to keep water in the system	Knowledge, infrastructure and funding exist to continue to restore meadows in the next 10 years. However, the current pace and scale of restoration activities is insufficient. New approaches, additional funding, and greater stakeholder buy-in (e.g., Central Valley water users) are needed.
	Additional actions for consideration from the literature: ▪ Restore historical hydrology and channel migration ▪ Minimize engineering techniques (e.g., rip-rap or other inflexible materials) ▪ Remove barriers and dams to restore sediment and hydrological flow ▪ Manage and reduce invasive species to limit synergistic impacts <u>Relevant references:</u> Eeley et al. 1999, Lovejoy 2005, Halofsky et al. 2011, and Raymond et al. 2013	
Reduce the negative impacts of grazing on achieving ecosystem objectives, as these impacts have the potential to amplify the effects of climate change	Grazing exclosures to minimize synergistic effects of grazing and climate impacts (e.g., decreased soil moisture, precipitation changes) on vegetation recruitment and growth as well as floodplain structure and soils	Cheap and beneficial.
	Increase monitoring to include indices that address biological diversity to evaluate	Development of indices is underway, and is essential to protect wildlife and rare plants

Adaptation approach	Strategic actions identified by participants	Rationale for action
	climate and non-climate impacts and management action effectiveness for key biological parameters	
	Re-examine grazing intensity and livestock densities in light of predictions of climate change (e.g., considering changes in precipitation and soil moisture and subsequent effects on vegetation recruitment and growth) to better manage grazing now and in the future	High benefits and regulatory structure in place however, some drawbacks present. Data may be lacking to evaluate this thoroughly (e.g., what will the palatability thresholds be for cows in foothills and how resilient will drier meadows be to the same grazing pressure?). Need to demonstrate impacts to meadows first, but is likely a high priority action.
	Re-address timing and season of grazing use to address predicted change (e.g., considering changes in temperature and precipitation and subsequent effects on vegetation growth) to better manage grazing now and in the future	See comments above. Need to reassess intent and practices of current management including standards, measures, and priorities (e.g., ensure grazing standards meet wildlife needs). Need more incentives to complement regulations.
	Manage to reduce impacts of grazing including maintaining fencing and providing off-channel water and minerals to prevent exacerbation of climate impacts	Beneficial and well-funded.
	Close allotments with highest biological value with species sensitive to grazing (such as T&E species; 2001-2004 changes in framework) to help sustain these species on-site and enhance their ability to cope with climate impacts	If limited to T&E species (i.e., without considering other species important for meadow ecosystems), it would not necessarily meet overall Sierra-wide objective. However, it may be one way to be most efficient and work toward objective by creating reserves where resources are already in place. This may only require closing grazing with no active restoration to increase populations.
	More active cattle management (e.g., rotation) to limit negative effects on ecosystem structure and function and enhance ecosystem ability to cope with	*Not able to address in time allotted.*

Adaptation approach	Strategic actions identified by participants	Rationale for action
	climate impacts	
	Additional actions for consideration from the literature: ▪ Establish extra protection for high priority areas using management designations, management action plans, and extra levels of protection by excluding livestock, motorized vehicles, and other human disturbances so that they are better able to respond to and cope with climate impacts ▪ Increase education on the intrinsic value and ecosystem services of meadows now and in the future, including how climate may affect the ability of meadows to continue to provide key services ▪ Create accessible forms of information (web-based, factsheets, etc.) on the value and vulnerability of meadows (i.e., ecosystem services) now and in the future ▪ Encourage restoration activities and volunteer work days to improve understanding about climate impacts to wet meadows and enhance overall ecosystem resilience to climate and non-climate stressors <u>Relevant references:</u> Bohn and Buckhouse 1986, Ramakrishnan 1998, Eeley et al. 1999, Williams 2000, Desanker and Justice 2001, Bellows 2003, Opdam and Wascher 2004, Tompkins and Adger 2004, Lovejoy 2005, Welch 2005, Chapin et al. 2006, and McClanahan et al. 2008	
Increase the role of fire in shaping the ecosystem to limit high severity fires, insect and disease outbreaks, and moisture stress, all of which are predicted to increase in the future	Restore natural fire regime to minimize fuel loading and reduce the potential for high severity fires, which may increase to due to longer and drier growing seasons ▪ Wildland fire use in every National Forest LRMP[24] ▪ Increased use of prescribed fire ▪ Fire reintroduction	Benefits outweigh some of the drawbacks, but air quality concerns and liability may hamper efforts. Broadly need to restore wildland fire to the landscape to increase pace and scale of fuels reduction.
	Fuels reduction to minimize fuel loading and decrease the potential for high severity fires, and limit insect and disease outbreaks (which could lead to increased fire risk if not managed properly) ▪ Holistic watershed or landscape level management of fuels reduction (i.e.,	Likely moderate-high across the landscape; moderate on forest/district/private levels; with additional funding could be elevated to high across all levels. Not enough funding to meet pace and scale required to make a significant difference. Need to focus on holistic watershed scale restoration – currently focused on towns/wildland-urban interface (WUI) and uplands only. Need to tailor and prioritize meadow and stream health when planning

[24] Land and resource management plan

Adaptation approach	Strategic actions identified by participants	Rationale for action
	mechanical techniques) with emphasis on meadows	fuels reduction programs in watershed, especially to include NEPA and CEQA documentation.
	Message "watershed health" and make Sierra Nevada meadows an example of climate-smart conservation in California as these ecosystems can help ensure continued and adequate water supply	Currently difficult to make meadows a priority in existing management programs and techniques, which makes it important to message them as part of "watershed health" and use them as a key indicator. Social value needs to be communicated to the general public.
	Implement North et al. (2009)/North (2012)[25], which clearly lay out the need for landscape level ecological restoration that focuses on utilizing topographic features to identify appropriate species and management actions for continued ecosystem function and persistence under climate change	*Not able to address in time allotted.*
	Focus on high priority meadows (current and future) to use in setting priorities for adaptation activities	*Not able to address in time allotted.*
	Additional actions for consideration from the literature: ▪ Actively manage natural fires by controlling path and severity to meet management objectives and reduce the risk of high severity fires that may increase as a result of climate change ▪ Allow fires to burn through meadow areas, using meadows as natural fire breaks <u>as this may help reduce conifer encroachment now and in the future</u> <u>Relevant references:</u> Peters and Darling 1985, Franklin et al. 1992, Halpin 1997, Peterson et al. 1997, Eeley et al. 1999, Shafer 1999, Guo 2000, Noss 2001, Scott et al. 2002, Opdam and Wascher 2004, Lovejoy 2005, Welch 2005,	

[25] North et al. (2009), also known as USFS General Technical Report (GTR) 220, describes an ecosystem management strategy for Sierran mixed-conifer forests, specifically focusing on ecological restoration that produces different stand structures and densities across the landscape using topographic variables (e.g., slope shape, aspect, position) as a guide for varying treatments. North (2012), also known as USFS GTR 237, is a follow-up report to North et al. (2009) that clarifies some of the concepts presented in that report, and presents information and applications relevant to implementation for this forest management approach.

Adaptation approach	Strategic actions identified by participants	Rationale for action
	Ferrier and Guisan 2006, Millar and Brubaker 2006, and Halofsky et al. 2011	
Reduce negative impacts of recreation, roads, and trails to help wet meadows better cope with the effects of climate change	▪ Assess and consider removing roads in sensitive meadow areas in light of projected climate impacts ▪ Enhance route designation plans in light of projected climate impacts	Need to change standards and consider changing amount of roads around meadows and timing of use.
	Additional actions for consideration from the literature: ▪ Identify and prioritize high risk areas in light of projected climate change impacts and restrict use ▪ Reroute roads out of meadow floodplains in light of projected climate impacts <u>Relevant references:</u> Halofsky et al. 2011 and Raymond et al. 2013	
Provide suitable habitat for species by providing key components missing from the ecosystem that are viable now and in the future to improve ability to cope with potential climate impacts	Increase use of plants with high value to wildlife, and that are likely to be viable now and in the future, in restoration projects (e.g., fruiting species)	*Not able to address in time allotted.*
	Additional actions for consideration from the literature: ▪ Identify and restore key functions that are important for these ecosystems (e.g., fire, nutrient cycling, hydrology, etc.) that will improve ability of the system and species to cope with potential effects of climate change ▪ Identify and restore beneficial plant species that are viable now and in the future <u>Relevant references:</u> Millar et al. 2007, Lawler et al. 2009, and Peterson et al. 2011	

Wet Meadows and Fens Systems: Implementation Needs for Adaptation Actions

Table 11. Adaptation action implementation needs for Wet Meadows and Fens - Restoration.

Goal:	Restore and maintain meadow and fen ecosystem functions and processes across the Sierra Nevada now and in the future.
Strategic action:	Restore floodplain function to enhance ecosystem integrity and resilience under climate change, including: plug and ponding; establishing setbacks; bank stabilization; headcut stabilization; restoring soils and structure; restoring meanders; in-stream restoration; and promoting beavers where appropriate.

Resources needed:	NEPA, CEQA ESA consultation ACE nationwide permit (27) State water quality board approval 100% design for hydrology, soils, engineering Funding In-kind services Volunteers
Potential partners:	Army Corps of Engineers Potential funders: National Fish & Wildlife Foundation (NFWF), Coca-Cola, National Forest Foundation Volunteer organizations CDFW USFWS NGOs DWR UC Davis Integrated Regional Water Management (IRWM) groups Private property owners Local governments
Agencies that could implement action:	IRWM groups USFWS NPS USFS ACE NRCS Private Public utilities BLM Water agencies BOR State of California Timber companies
Timeframe:	Short-term: 2-10 years Ongoing as past land use has disturbed these areas already
Where to implement:	Identify places to implement using: • State water resources report • UC Davis/NFWF/FS • Morelli data • UC Merced, UC Berkeley • Viers et al. data

	• Purdy et al. data • Species ranges for willow flycatcher, Yosemite toad, great grey owl, fish, amphibian, bird critical habitat, and habitat for state aquatic species of concern (e.g., western pond turtle)

Table 12. Adaptation action implementation needs for Wet Meadows and Fens - Grazing.

Goal:	Restore and maintain meadow and fen ecosystem functions and processes across the Sierra Nevada now and in the future.
Strategic action:	Manage to reduce the negative impacts of grazing by maintaining fencing and providing off channel water and minerals to prevent exacerbation of climate impacts.
Resources needed:	NEPA, CEQA ESA, CESA Funding Hydrological expertise
Potential partners:	National Resources Conservation Service (NRCS) – funding Cattlemen's Association Land trusts Watershed councils IRWM groups NGOs
Agencies that could implement action:	IRWM groups USFWS NPS USFS Private land owners BLM Timber companies
Timeframe:	Immediate (<2 years) and on-going Especially 10-year permits/Environmental Assessments
Where to implement:	Develop range-wide best management practices for broad implementation Time-bound closures for restored meadows Look for willing partners for voluntary measures Especially sensitive or degraded meadows/fens

Table 13. Adaptation action implementation needs for Wet Meadows and Fens - Recreation and Roads.

Goal:	Restore and maintain meadow and fen ecosystem functions and processes across the Sierra Nevada now and in

	the future.
Strategic action:	Reduce negative impacts of recreation, roads, and trails to help wet meadows better cope with the effects of climate change.
Resources needed:	NEPA Special use permits Civil engineers
Potential partners:	Volunteers NGOs Counties Private landowners Outdoor recreation groups (motorized and non-motorized)
Agencies that could implement action:	NPS USFS Timber companies BLM Public utilities Counties Private landowners State Parks
Timeframe:	Immediate (<2 years) and short-term (2-10 years) Ongoing
Where to implement:	Areas with high biological value Degraded waterways Degraded or unused roads or trails (each land unit has evaluated status of roads and trails)

7. Adaptation Strategy Development: Oak Woodlands

Participants: California Department of Fish & Wildlife: Cassidee Shinn
The Wilderness Society: John Gallo
U.S. Forest Service Pacific Southwest Research Station: Rick Bottoms
Yosemite National Park: Bill Kuhn

Distribution and General Overview

Oak woodlands exist largely (>80%) on private lands of the Sierra Nevada foothills. Distribution of remaining oak woodlands occurs on public lands at higher elevations (400-6000 ft) with low fragmentation (Kueppers et al. 2005). Canopy species including blue oak, valley oak, canyon live oak, and California black oak, as well as other species present in smaller amounts, occur in oak woodlands. Oak woodlands support over 330 species of birds, mammals, reptiles, and amphibians – the highest animal biodiversity of all habitats in California. Significant stressors for oak woodlands include land conversion to agriculture and urban/suburban development; overbrowsing and predation by cattle, deer and rodents; and climate change. Land use conversion has already significantly reduced the extent of oak woodlands throughout California, and is likely to continue to be a problem (Kuhn and Cummings 2013). Future climate changes including reduced soil moisture, drought, and altered fire regimes may further impact oak woodlands.

Management Goals and Objectives

The group's task was to identify at least one management goal and one objective for the oak woodlands ecosystem in the Sierra Nevada. The purpose of identifying management goals and objectives was to provide a foundation for evaluating whether and how climate change might compromise participants' shared conservation objectives for oak woodlands and for developing adaptation strategies for reducing climate impacts. The group chose to create new management goals and objectives for the system rather than using existing ones.

The group agreed to the following management goal and objectives for the wet meadows and fens system, which were largely focused on public lands throughout the Sierra Nevada[26]:

Goal: *Protect and enhance oak woodlands and ecosystems that support oaks now and in the future.*

- Recruitment Objective:
  - *Create healthy and sustainable stand/population demographic structure for all oak species across the Sierra Nevada by 2100 via enhanced recruitment.* Note: Enhanced recruitment refers to a broader definition that includes

[26] One other objective was identified for the goal described above, although the group did not have time to further develop adaptation actions. Objective: Better inform oak and oak ecosystem management plans by improving scientific understanding of current ecosystem conditions in the near-term (1-3 years) across the Sierra Nevada.

methods such as planting and protecting, using fire, reducing herbivore densities, etc. Additionally, management strategies to achieve this objective may need to be different for different oak species and for different regions of the Sierra Nevada (e.g., due to differing sensitivities).

        - For example, by 2050 there should be 1,000 young blue oak of Baja California genetic stock that are established and protected from herbivory growing throughout the Sierra Nevada.
        - After re-examining the projected impacts of climate change, the group thought the original objective should be modified to incorporate future oak species' distributions. This added information could help in prioritizing areas to enhance recruitment and increase restoration success (i.e., by decreasing mortality).

- Monitoring Objective:
    - *Restore and protect oak woodlands by implementing a monitoring and caretaking program in key locations to evaluate climate and non-climate impacts and management action effectiveness.*
        - For example, establish an ongoing program that utilizes crowdsourcing and citizen stewards to increase stewardship, engagement outreach, and political pressure.
- Protect Refugia Objective:
    - *Identify and protect oak climate refugia for conservation and restoration prioritization of actions to be taken in the near-term (1-3 years) across the Sierra Nevada for benefit in the long-term.*
        - For example, enhance oak recruitment and seedling survival (by using climate resilient seedlings) in locations most likely to undergo the least amount of climatic change in the future.

Climate Change Impacts Assessment, Adaptation Actions and Implementation

After creating management goals and objectives, the group reviewed the findings from the oak woodlands vulnerability assessment to identify potential challenges and vulnerabilities as well as potential opportunities for achieving objectives given climate impacts and associated vulnerabilities.[27]

The group brainstormed strategic climate adaptation actions that might help oak woodlands survive in the Sierra Nevada given potential vulnerabilities and challenges. This brainstorming session was intended to generate a diverse range of potential adaptation approaches and strategic actions that could be considered. The resulting tables are not comprehensive, nor do they necessarily represent participants' consensus on what actions should be implemented; rather, it is an initial list of strategic actions that might be considered. Table 14 presents these

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[27] Full findings from the vulnerability assessment are available online through the California Climate Commons (http://climate.calcommons.org/) and EcoAdapt (http://ecoadapt.org/) websites.

strategic adaptation actions, as well as additional actions for consideration from the peer-review literature for oak woodland systems.

In general, the group identified a number of strategies that involve conventional approaches to protection and enhancement of oak woodland ecosystems, including planting and protecting seedlings and acorns from browsers, using prescribed burning to remove non-native grasses, and increasing public education and outreach, among others. The group also recognized that many of these current management strategies are successful at a small scale, but may not be as successful at the large scale. Therefore, it was recommended that pilot case studies could be implemented to help clarify whether these strategies are effective at larger scales. In addition to conventional approaches, the group also identified a number of new climate-smart strategies including identifying and protecting oak woodlands in areas that may be climate refugia, using seeds from across a greater geographic range and/or from drier, warmer climates for restoration and plantings, and prioritizing areas for restoration that are expected to experience the least amount of projected change to ensure long-term success. In addition, the group thought that future climate change projections could be helpful in selecting key locations for a monitoring and caretaking program. This program could focus on monitoring areas projected to experience the most climate change, and have potential management options in place for if and when those changes occur.

As part of this exercise, participants also highlighted some potential benefits and barriers associated with adaptation actions. For example, protecting oak climate refugia has the potential benefit of long-term, stronger protection and increased likelihood of species conservation. However, increasing protected space can be cost intensive, requires significant political will, and could reduce human access. Similarly, when planting and protecting seedlings from browsing pressure there may be some substantial drawbacks, such as intensive labor and cost requirements and a high level of required maintenance. However, browse exclosures can not only provide protection for oaks but also many of the associated oak ecosystem plants. Other potential barriers associated with adaptation actions include air quality concerns and risk to humans and structures when using prescribed fire as a tool, the current gap of a Sierra Nevada-based non-profit organization to shepherd a public education and outreach program around the benefits of oak woodlands, and lack of funding and staff support to implement a large-scale recruitment and/or restoration program. However, participants thought that the high cultural and intrinsic values of oaks and oak-dominated ecosystems could increase overall public support for this objective and help to re-prioritize current management and funding.

After analyzing the climate vulnerabilities and brainstorming strategic adaptation actions, participants were asked to select one or more strategic actions and expand on the resources needed and timeframe for implementation. The group was also asked to begin thinking about areas in the Sierra Nevada that may be appropriate for implementation. These findings are detailed in Tables 14-17 below.

Oak Woodland Ecosystems: Climate Impacts, Adaptation Actions and Implementation

Oak Woodland Systems: Climate Change Vulnerabilities and Opportunities

Potential Challenges and Vulnerabilities:

- Changing climate may lead to a different expected or actual population structure – these systems may represent a moving target and therefore it is difficult to define a “healthy or sustainable” structure.
- Increased fire frequency and severity could negatively affect restoration efforts by increasing seedling mortality.
- Continued grazing and browsing of planted seedlings will decrease survival and make it more difficult to restore sites and enhance recruitment.
- Increased water deficit will lower seedling survival and reduce restoration success.
- Disturbances such as increased fire frequency and severity may adversely affect top predators, which would increase deer and rodent populations and increase acorn and seedling predation and herbivory.
- Thermal range of individual species may shift species composition of both plants and wildlife.
- Blue oaks are primarily on private land and therefore access and management could be more difficult.
- Accessibility to the sites that need stewardship could be more difficult.

Potential Opportunities and Adaptive Capacity:

- Increased fire frequency will reduce conifer competition for oaks and may enhance natural seedling recruitment and survival.
- Blue oaks are primarily on private land and therefore access and management could be easier as there would be less bureaucracy to deal with.

Oak Woodlands: Adaptation Actions

Table 14. Adaptation approaches and actions for Oak Woodlands. Boxes highlighted in green indicate actions identified by participants as having high effectiveness (action meets desired intent) and feasibility (action capable of being implemented); yellow boxes indicate actions with moderate effectiveness and feasibility; red boxes indicate actions with low feasibility and effectiveness.

Adaptation approach	Strategic actions identified by participants	Rationale for action
Restore structure, function, and composition of oak woodlands to limit high severity fires and moisture stress, both of which are predicted to increase in the future	Use prescribed burning to remove non-native grasses from the understory of oak woodlands to reduce competition for declining water resources between seedlings and invasive species	On a large scale it is likely not feasible but on smaller scales it may be more feasible.
	Plant native bunch grasses within oak woodlands to reduce spread of invasive species, which are predicted to increase as a result of climate change and compete more effectively with oak seedlings for water	On a large scale likely less feasible. Potentially more difficult on private lands. However, on smaller scales (e.g., areas of climate refugia) and on public lands likely more feasible.
	Plant and adequately protect acorns and seedlings from browsing, as losses to predation may be magnified by climate-driven reductions in recruitment (e.g., through reduced soil moisture)	Feasible on a small scale and in individual priority areas (e.g., small climate refugia areas) however, on a large scale likely less feasible due to high setup and maintenance costs.
	Fence priority oak areas or individual plants as needed to exclude browsers (i.e., deer, rodents, cattle) to minimize synergistic effects of grazing and climate-driven changes (e.g., decreased soil moisture) on recruitment and survival	*See rationale above for Plant and protect acorns and seedlings.*
	Additional actions for consideration from the literature: ▪ Create fuel-breaks to limit hazard of undesirable fires, as fire frequency and intensity is predicted to increase under climate change ▪ Take advantage of natural fire occurrences by controlling fire path and severity, and to limit the potential for	

<table>
<tr><th>Adaptation approach</th><th>Strategic actions identified by participants</th><th>Rationale for action</th></tr>
<tr><td></td><td colspan="2">catastrophic wildfires predicted to increase in the future
▪ Use other ground cover management (mowing, spraying) to reduce non-native grasses that may increase risk of catastrophic wildfire and/or more effectively compete for declining soil moisture under changing climate conditions
<u>Relevant references:</u> Spittlehouse and Stewart 2003, Ogden and Innes 2008, Halofsky et al. 2011, and Swanston et al. 2012</td></tr>
<tr><td rowspan="5">Identify and protect oak climate refugia to use as priority areas for conservation and restoration</td><td>Protect priority areas from high severity fires, which are projected to increase under climate change</td><td>Not able to address in time allotted.</td></tr>
<tr><td>Control and/or remove non-native grasses and forbs in identified refugia to reduce competition for declining water resources in the future</td><td>Not able to address in time allotted.</td></tr>
<tr><td>Identify and prioritize areas for conservation and/or restoration where water deficit is expected to experience the least amount of decrease</td><td>Not able to address in time allotted.</td></tr>
<tr><td>Establish extra protection for priority refugia areas using management designations, management action plans, and extra levels of protection by excluding humans and browsers</td><td>Highly feasible on public lands; less feasible on private lands because it may be difficult to get landowner cooperation.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Conduct further bioclimatic and mechanistic modeling of key oaks and oak ecosystems to identify important climate drivers
▪ Map these important drivers across the landscape to help prioritize current and potential refugia areas
▪ Monitor and evaluate the stands that successfully regenerate, and promote these stands to serve as future refugia
<u>Relevant references:</u> Bush 1996, Eeley et al. 1999, Noss 2001, Scott et al. 2002, Chambers et al. 2005, Millar et al. 2007, Halofsky et al. 2011, and Swanston et al. 2012</td></tr>
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<table>
<tr><th>Adaptation approach</th><th>Strategic actions identified by participants</th><th>Rationale for action</th></tr>
<tr><td rowspan="4">Facilitate oak translocation by planting “climate-smart” seedlings in areas that are deemed to be climatically suitable in the future</td><td>Favor existing genotypes that are better adapted to future conditions for restoration and plantings</td><td>Not able to address in time allotted.</td></tr>
<tr><td>Use seeds from across a greater geographic range or from drier, warmer climates for restoration and plantings</td><td>Not able to address in time allotted.</td></tr>
<tr><td>Maintain the current genetic diversity across its range to facilitate the ability of the ecosystem to cope with potential climate changes and impacts</td><td>Not able to address in time allotted.</td></tr>
<tr><td colspan="2">Additional actions for consideration from the literature:
▪ Test seedling survival in pilot areas before out-planting on a large scale. <u>Note</u>: although many environmental factors may match seedlings to geographic area, cold tolerance or other limitations may remain
<u>Relevant references:</u> Burton et al. 1992, Bush 1996, Eeley et al. 1999, Shafer 1999, Staple and Wall 1999, Thomas et al. 1999, McCarty 2001, Noss 2001, Rice and Emery 2003, Maciver and Wheaton 2005, Pyke et al. 2005, Pyke and Fischer 2005, Harris et al. 2006, de Dios et al. 2007, and Millar et al. 2007</td></tr>
<tr><td>Engage the public in stewardship of oaks and oak woodlands to improve understanding about ecosystem value and potential climate impacts</td><td>▪ Increase education on the intrinsic value and ecosystem services of oaks and oak woodlands and how they may change in light of climate change impacts
▪ Encourage climate-smart restoration activities and volunteer work days to improve understanding about potential climate impacts and enhance the ability of oaks to cope with the effects of climate change
▪ Engage community service organizations to improve understanding about climate impacts to oak woodlands and the services people depend on</td><td>High feasibility and effectiveness possible but will require an agency and/or NGO to lead it. There are some examples of active stewards at fine-scales in California including small habitat restoration clubs, watershed groups, Native American tribes, and landowners. These examples need to be scaled-up to increase effectiveness; it may also be beneficial to utilize new approaches such as social media and mobile technology to encourage engagement.</td></tr>
</table>

Adaptation approach	Strategic actions identified by participants	Rationale for action
	▪ Enhance oak stewardship on private lands to improve the ability of oaks to cope with changing climate conditions	
	Additional actions for consideration from the literature: ▪ Hold town-halls and invite community leaders to improve understanding about climate impacts to oak woodlands and the services people depend on ▪ Create accessible forms of information (web-based, factsheets, etc.) on the values of oaks and oak woodlands (i.e., ecosystem services) now and in the future Relevant references: Ramakrishnan 1998, Eeley et al. 1999, Williams 2000, Desanker and Justice 2001, Opdam and Wascher 2004, Tompkins and Adger 2004, Lovejoy 2005, Welch 2005, Chapin et al. 2006, McCool 2007, and McClanahan et al. 2008	
Maintain and enhance landscape habitat function and connectivity to support top predators, which will help reduce herbivore numbers thus limiting synergistic impacts of grazing and climate changes (e.g., decreased soil moisture) on oak recruitment and survival now and in the future	*Not able to address in time allotted.*	*Not able to address in time allotted.*
	Additional actions for consideration from the literature: ▪ Identify and prioritize top predators for re-introduction/re-establishment and evaluate habitat needs ▪ Implement habitat mapping to locate priority areas now and in the future ▪ Use connectivity modeling (e.g. Circuitscape, www.circuitscape.org/) to identify important pinch points for protection ▪ Prioritize climate-informed protection or restoration of these important areas Relevant references: Beatley 1991, Franklin et al. 1992, Halpin 1997, Dixon et al. 1999, Eeley et al. 1999, Shafer 1999, Collingham and Huntley 2000, Guo 2000, Rogers and McCarty 2000, Williams 2000, Noss 2001, Schwartz et al. 2001, Morecroft et al. 2002, Scott et al. 2002, Opdam and Wascher 2004, Chambers et al. 2005, Da Fonseca et al. 2005, Hulme 2005, Lovejoy 2005, Welch 2005, Wilby and Perry 2006, de Dios et al. 2007, and Millar et al. 2007	

Oak Woodland Ecosystems: Implementation Needs for Adaptation Actions

Table 15. Adaptation action implementation needs for Oak Woodlands - Establish Extra Protection by Excluding and/or Reducing Browse Pressure.

Goal:	Protect and enhance oak woodlands and ecosystems that support oaks now and in the future.

Strategic action:	Establish extra protection for priority climate refugia areas by excluding and/or reducing herbivory pressure from browsers such as deer, cattle and/or rodents in order to minimize synergistic effects of grazing and climate-driven changes (e.g., decreased soil moisture) on oak recruitment and survival.	
Resources needed:	Research and review of scientific literature regarding limitations of approach Fencing materials Population data on top predators and deer Staff and volunteer time Funding Resources for controlled culling of deer	
Potential partners:	Ranchers Conservation groups Government representatives Tribes	Public lands Private foundations Research institutions Private landowners
Agencies that could implement action:	NPS Private landowners BLM State of California	USFS Tribal lands County/Local governments NGOs
Timeframe:	Implement short-term actions periodically over multiple decades	
Where to implement:	Where cattle are currently grazing in oak woodlands (e.g., State and County Parks) Identified high priority areas Climate refugia within current oak woodland distributions Conservation/protection refugia A mix of the above (and/or other areas) so action is well-represented across the entire distribution of oak woodlands.	

Table 16. Adaptation action implementation needs for Oak Woodlands – Planting and Protecting Seedlings.

Goal:	Protect and enhance oak woodlands and ecosystems that support oaks now and in the future.
Strategic action:	Plant and adequately protect acorns and seedlings from browsing in current and future high priority areas as losses to predation may be magnified by climate-driven reductions in recruitment (e.g., through reduced soil moisture).

Resources needed:	Accurate maps of current distribution of oaks and oak woodlands Acorn collection and nursery growth Fencing materials Staff and volunteer labor Necessary permits Mapped information on within-species genetic diversity Modeled refugia and suitable climate areas
Potential partners:	Tribes Conservation groups Public lands "Friends" groups Private foundations Government representatives Universities and/or graduate students
Agencies that could implement action:	NPS USFS Private landowners Tribal lands BLM County/Local governments State of California NGOs
Timeframe:	Implement short-term actions periodically over multiple decades
Where to implement:	High priority areas that are well-represented across the entire region and distribution of oaks High priority areas also include climate refugia within current distribution and conservation/protection refugia Areas identified as high priority for conservation for all oak species

Table 17. Adaptation action implementation needs for Oak Woodlands – Prescribed Burning.

Goal:	Protect and enhance oak woodlands and ecosystems that support oaks now and in the future.
Strategic action:	Use prescribed burning to remove non-native grasses from the understory of oak woodlands to reduce competition for declining water resources between seedlings and invasive species now and in the future.
Resources needed:	Permits to burn Modeled priority areas of climate or conservation refugia Fire crews (CA, government agencies) Funding Air quality regulations Fuel loading data at sites

	Water deficit conditions at sites
Potential partners:	Fire management agencies Private landowners Local political support California Air Resources Board Fire protection
Agencies that could implement action:	NPS USFS Tribal lands BLM State of California County/Local governments Private landowners NGOs
Timeframe:	Short term to very long term (2-50 years)
Where to implement:	Areas that are outside of "natural" fire frequency Areas where human risk is low for life and property Areas identified as high priority for conservation of many/all species

8. Emerging Commonalities Among Resource Adaptation Actions and Plans

A number of possible adaptation approaches and actions identified by participants were common across resources; during a brief exercise those actions in *italics* were selected as priorities (Table 18).

Multiple groups identified a number of adaptation actions as both highly feasible and effective including: assisted species translocation, habitat restoration for sustained ecosystem function under future conditions, and increased diversity of nursery stock to withstand future conditions. Assisted species translocation included more specific actions such as planting climate-smart seedlings (e.g., genotypes better adapted to future conditions or drier, warmer climates) in areas projected to be future suitable habitat, planting seedlings from lower elevations to higher elevations or from southern locations to northern locations in the yellow pine/mixed conifer forest, and reintroducing mountain yellow-legged frogs to suitable current and/or future habitat. Habitat restoration activities, particularly those focused on restoring floodplain function to enhance wet meadow ecosystem integrity and resilience under climate change, were highlighted as a priority adaptation action by all workshop participants. Increasing the diversity of nursery stock and maintaining seeds of desired species, specifically those exhibiting disease resistance, were identified as effective actions for yellow pine/mixed conifer and alpine/subalpine ecosystems as these seeds will be important to plant following severe disturbance and may prevent or limit future outbreaks.

Two priority actions, targeted thinning and promoting the use of fire (through prescribed burning or managed natural fires), were the most commonly identified adaptation actions by participants. These actions can help return ecosystems to within their natural range of variability, restore ecosystem functioning, and/or enhance resilience to current and projected stressors, which could help limit the impacts of stand-replacing fires that are projected to occur with increased frequency under climate change. For example, stand-replacing fires in watershed areas above wet meadows can result in increased erosion and sedimentation into the meadow system, as well as decrease thermal cooling from riparian vegetation. Reducing stand densities through thinning or prescribed burning in these upland areas can minimize the likelihood or extent of catastrophic, stand-replacing fire, thus preventing or limiting significant erosion impacts in wet meadows. Further, participants advocated for the implementation of these actions at scales larger than which they are currently applied (e.g., watershed or landscape level) to improve overall ecosystem resilience across a broader geographic area.

Table 18. Common adaptation actions identified during the workshop and the corresponding system or species in which the action was proposed. Those actions identified as priorities for implementation appear in *italics*. Boxes highlighted in green are those actions identified by participants as being highly effective and feasible; boxes highlighted in yellow are those actions identified as moderately effective and feasible.

Adaptation Actions Identified During Workshop	**Systems and/or Species**
Targeted thinning to reduce: • Stand densities, • Fire-intolerant species, • Risk of catastrophic wildfires, and/or • Risk of insects and disease spreading. Targeted thinning can minimize fuel loading and reduce the potential for high severity, stand-replacing fires, as well as reduce the risk of insect and disease outbreaks, both of which are predicted to increase as a result of climate change.	Yellow Pine/Mixed Conifer Alpine/Subalpine Wet Meadows Red Fir (including marten)
Promoting the use of fire including: • Using prescribed burning (to provide ecosystem function now and in the future; to remove non-native grasses that compete with native species for declining water) • Allowing natural fires to burn/actively managing natural fires to meet management objectives and reduce the risk of catastrophic wildfires These activities can help limit high severity fires, insect and disease outbreaks, and moisture stress, all of which are predicted to increase in the future due to climate change.	Yellow Pine/Mixed Conifer Alpine/Subalpine Oak Woodlands Wet Meadows Red Fir (including marten)
Assisted species translocation and/or reintroduction to suitable current or future habitat	Yellow Pine/Mixed Conifer Oak Woodlands Mountain Yellow-Legged Frogs
Reduce grazing pressure: • Plant and protect acorns and seedlings from browsing, as losses to predation may be magnified by climate-driven reductions in recruitment (e.g., through reduced soil moisture) • Fence priority areas or individual plants and/or close allotments to minimize synergistic impacts of grazing and climate change (e.g., reduced soil moisture, changes in precipitation) on vegetation recruitment, growth, and survival • Re-examine grazing intensities, animal densities, and timing of use in light of predictions climate change impacts (e.g., reduced soil moisture and subsequent effects on vegetation recruitment and survival) to better manage grazing now and in the future • Increase monitoring to include indices that address biological diversity to evaluate climate and non-climate impacts and management action effectiveness in light of climate change	Oak Woodlands Wet Meadows

Adaptation Actions Identified During Workshop	**Systems and/or Species**
Identify and protect climate refugia to help buffer ecosystems and species populations against climate change and disturbances, for example: • Protect priority areas from high severity fires, which are projected to increase under climate change • Prioritize areas for conservation/restoration where climatic water deficit is likely to change less • Focus management activities in priority refugia areas (e.g., protect current and future suitable habitat, remove non-native species or limit impacts of other non-climate stressors in refugia areas) • Use management designations, action plans, etc. to protect priority refugia areas from non-climate stressors • Prioritize areas for key habitat and corridors, focusing on the most suitable corridors that connect habitat areas likely to be resilient/resistant to climate changes	Oak Woodlands Mountain Yellow-Legged Frogs Marten
Restoration of habitat to enhance and preserve ecosystem structure, function, and composition now and in the future by: • Planting native species to improve the ability of the ecosystem or species to cope with potential climate impacts • *Restore floodplain function (e.g., plug and pond, establish setbacks, bank stabilization) to limit impacts from projected climate changes and enhance overall ecosystem resilience*	Oak Woodlands Wet Meadows
Increasing diversity of nursery stock and maintaining seeds of desired species for use after disturbances; for example: • Plant genetically resistant species (e.g., disease-resistant species) • Complete gene-screening for diseases and identify and plant resistant strains to reduce susceptibility of forests to disease that may be exacerbated by or exacerbate climate impacts • Use seeds from across a greater geographic or climatic range and/or those genotypes that are better adapted to future conditions	Yellow Pine/Mixed Conifer Alpine/Subalpine Oak Woodlands
Increase education and outreach to improve people's connection to the environment and understanding of ecosystem value and how climate changes may affect services people depend upon; for example, by: • Engaging community service organizations to improve understanding about potential climate impacts • Enhancing stewardship on private lands and/or encouraging climate-smart restoration activities and volunteer work days to improve the ability of ecosystems and species to cope with changing climate conditions • Engaging recreational anglers to prevent re-stocking of invasive species that exacerbate climate impacts on native amphibians	Yellow Pine/Mixed Conifer Oak Woodlands Mountain Yellow-Legged Frogs

Adaptation Actions Identified During Workshop	**Systems and/or Species**
Control and/or remove non-native species that exacerbate or will be exacerbated by climate impacts; for example: • *Electroshocking and gill netting to remove non-native fish species that amplify climate impacts and increase stress on native amphibians* • Planting native grasses to improve the ability of the ecosystem or species to cope with potential climate impacts and/or limit the spread of invasive species that exacerbate climate impacts	Oak Woodlands Mountain Yellow-Legged Frogs
Develop large-scale, coordinated monitoring program (including "citizen science" groups) designed to improve our ability to detect and predict future changes	Alpine/Subalpine (including whitebark pine) Red Fir
Minimize spread of invasive species (e.g., cheatgrass) at higher elevations using early detection and rapid response approach	Alpine/Subalpine (including whitebark pine) Red Fir

As part of the adaptation action implementation plan exercise, facilitators and participants identified a number of common agencies, organizations, and others that could implement priority actions. These included: USFS, NPS, BLM, Army Corps, NRCS, BOR, USFWS, CDFW, Cal Parks, private landowners, county/local governments, tribal lands, public utilities, and timber companies.

A number of common barriers to implementation also emerged during discussions including air quality, liability, and safety issues associated with prescribed and natural fires; social issues such as human use of resources (e.g., grazing, anglers, reduced access); challenges with cooperation and collaboration across jurisdictional boundaries; limited access to areas to implement actions (e.g., remote locations); other technical barriers associated with gathering necessary data and information to help prioritize resources or locations; and funding. Participants also discussed the challenge of earmarked funds from sources such as paid ecosystem services, which can only be spent on specific actions that may not be high priorities.

Finally, participants discussed possible incompatibilities between resource adaptation actions. One incompatibility that arose was competition for funding resources. For example, limited funding could lead to competition among groups for adaptation funds and it could lead to competition among groups for conflicting strategies (e.g., fighting fires versus prescribed burns). One participant suggested the need to better communicate and collaborate to align values at risk so they are mutual rather than mutually exclusive, which could include leveraging existing projects to better use existing resources. Another incompatibility that arose was thinning intensity. For example, heavy commercial thinning practices that involve things like road development could have unintended consequences for the system itself, neighboring systems, or wildlife. Collaboration and consideration of a larger geographic area when planning treatments may help to avoid unintended consequences to resources.

9. Conclusions and Next Steps

The *Adaptation Planning Workshop for the Sierra Nevada* made important progress on the response of resource managers and planners to climate change, provided a synthesis of potential vulnerabilities of and opportunities for focal resources of the region, contributed potential management options to address vulnerabilities and take advantage of opportunities, and catalyzed a collaboration of stakeholders seeking to address climate change across the Sierra Nevada.

The adaptation options in this report, as well as the process used to develop them, enabled the national forests involved to achieve several components of the USFS Climate Change Performance Scorecard and inform the forest plan revision process. The vulnerability assessment and adaptation workshops contributed to the ability of participating forests to respond with "yes" to scorecard questions for external partnerships and adaptation activities. Additionally, adaptation actions can inform the development of draft forest plan components such as desired conditions, objectives, and management strategies. The adaptation options in this report as well as the collaborative process used to develop them are also relevant for other land management agencies and stakeholders in the region. Many of the adaptation actions identified are applicable throughout the Sierra Nevada and can be implemented by a variety of stakeholders.

Although this was a collaborative process that involved local and regional stakeholders from throughout the Sierra Nevada, more work is needed to achieve a Sierra Nevada-wide approach to adaptation. Expanding this effort beyond its current scope will improve the likelihood that many of the adaptation actions recommended (e.g., thinning, managed fire, habitat restoration) will be implemented at scales necessary to improve the resilience of ecosystems across the Sierra Nevada. Further, the adaptation actions generated in this report are not comprehensive, nor do they necessarily represent consensus on what actions should be implemented. There were a number of general adaptation strategies that were not adequately explored during the workshop, such as expanding the boundaries of reserves to increase diversity, maintaining and creating habitat corridors and connectivity, establishing and expanding reserves to link habitats, and increasing or fostering diversity of different ecosystem elements (e.g., diversity in component species, functional groups, structure, conditions, etc.). This workshop represents the beginning rather than the end of a long-term process for understanding and responding to the challenge of climate adaptation for species and ecosystems of the Sierra Nevada.

Over the next year (2014), the information in this report will be refined, revised, and/or expanded upon through discussions with agency partners as well as the Vulnerability Assessment/Adaptation Strategy (VA/AS) Collaborative Working Group (described in the companion report: *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada*, EcoAdapt 2013). This will be accomplished through directed outreach activities with key agency partners (USFS, NPS, CDFW, USFWS), which will include intensive 1-day trainings with key agency partners (USFS, NPS, CDFW, USFWS) and customized product development to improve delivery of project information to partners so they can incorporate climate considerations into land management plan revisions and other conservation decisions. Intensive trainings will explore the results of the vulnerability assessment and adaptation planning efforts and discuss how the findings can be integrated into participants' decision-making processes. Specifically, we will work with agency partners to refine existing and/or develop new adaptation options for their management goals. Further, we will consult with agency partners to develop customized products from trainings and current project findings. For example, this could include technical briefings for agency staff that explain resource vulnerabilities, identify possible adaptation options, and discuss how the information can be used in forest planning. Outcomes from these engagements, such as the generation of new adaptation actions or refinement of existing actions, will be included in future versions of this report.

In the following sections, we discuss how land managers and other stakeholders in the Sierra Nevada region can apply the adaptation strategies in this report.

Adopting a Toolbox Approach, Part I: Land Managers

No single adaptation strategy or individual management approach will be appropriate to all situations or in all places (Millar et al. 2007). As with all management actions, adaptation strategies need to be tailored to particular resource locations and management contexts. Resource managers are encouraged to mix and/or combine adaptation strategies (those detailed in this report as well as others) to best meet their individual context (Table 19). For example, managing the impacts of grazing in wet meadows by employing grazing exclosures and re-examining grazing intensities, animal densities, and timing of use in light of climate change to revise grazing rotation. Although it may be tempting to only implement strategies that require little investment in capacity building (i.e., "easier" adaptation actions), these strategies alone are unlikely to conserve key resources or ecosystem functioning in the face of climate change. Moderate or more difficult strategies, though requiring more substantial investment (technical, financial, institutional), improve the likelihood of success over the long term. Accordingly, managers are encouraged to implement what is feasible now (i.e., "low hanging fruit") while simultaneously planning and building the capacity necessary to implement those actions that improve overall ecosystem resilience and likelihood of resource persistence.

Table 19. Resistance, resilience, and response adaptation strategies for the Sierra Nevada region. *Easier* strategies may be more feasible to implement (e.g., social, institutional, or financial capacity exists or is relatively easy to obtain), already in use, and/or require little investment in scientific research to support implementation. *Moderate* strategies may be feasible to implement, but require some capacity building (e.g., technical, financial, social, institutional). *More difficult* adaptation strategies are those that have critical elements that must be addressed prior to implementation. These strategies likely require significant capacity building efforts on social, financial, or technical fronts. For example, significant effort (technical, financial) may need to be invested in first identifying habitat cores and corridors, followed by prioritizing those for protection and implementing protective measures.

	Easier	Moderate	More Difficult
Resistance (short-term strategies)	▪ Grazing exclosures to minimize synergistic impacts of grazing and climate change on vegetation growth, recruitment, and survival ▪ Removing non-native species to reduce overall stress on native species and improve species' ability to cope with climate impacts ▪ Maintaining and improving fish barriers to prevent invasion and establishment of species better able to expand ranges due to climate change and that could amplify climate impacts on native species ▪ Monitoring for disease outbreaks and treating when infected, as climate changes may increase the spread of disease and/or interact with disease to further impact species (e.g., through decreased recruitment or survival)	▪ Prescribed burning to remove non-native grasses that compete with native species (e.g., for declining water) ▪ Preventing stocking/re-stocking fishless areas through public outreach to prevent the establishment of invasive species that exacerbate climate impacts on native species ▪ Planting disease-resistant species to reduce overall stress on ecosystem	
Resilience (medium to long-term strategies)	▪ Restoring habitat (to natural range of variability (NRV) to improve overall resilience to climate change impacts ▪ Targeted thinning to minimize fuel loading, reduce severity of potential fires, and/or reduce risk of insect and	▪ Prescribed burns on small scales to minimize fuel loading and limit insect and disease outbreaks now and in the future ▪ Stocking seed banks with seeds from across a greater geographic range or	▪ Implementing mechanical fuels treatment at watershed or landscape-levels to minimize fuel loading and decrease potential for high severity fires, which are

	Easier	Moderate	More Difficult
	disease outbreaks now and in the future ▪ Planting vegetation with high wildlife value in restoration projects that are likely to be viable now and in the future ▪ Planting native grasses to prevent spread of invasive species and reduce competition for declining water resources in the future ▪ Maintaining adequate canopy and ground cover to help sustain ecosystem integrity and functions under changing climate conditions ▪ Assessing roads and trails and revising route plans based on potential climate impacts	warmer, drier climates for future plantings ▪ Re-examine grazing intensities, livestock densities, and timing of use in light of predictions of climate change impacts on vegetation recruitment and growth to better manage grazing now and in the future	predicted to increase in the future ▪ Actively managing natural fires by controlling path and severity to reduce risk of catastrophic fires now and in the future ▪ Prescribed burns on large scales to minimize fuel loading and reduce the potential for high severity fires, which may increase in the future to due to longer and drier growing seasons ▪ Maintaining current genetic diversity across range to facilitate ecosystem ability to cope with potential climate changes and impacts
Response (long-term strategies)	▪ Identifying key monitoring metrics (species, structure attributes, functions) to evaluate climate and non-climate impacts and management action effectiveness, and to inform future actions ▪ Planting genotypes better adapted to future conditions	▪ Experimenting with silvicultural techniques to see which achieve desired conditions now and in the future ▪ Establishing realistic, long-term monitoring programs that trigger responses and track management action effectiveness in light of climate impacts ▪ Restoring habitat for future conditions (e.g., planting vegetation likely to be viable in the future) ▪ Assisted translocation of species to suitable future habitat	▪ Prioritizing and protecting key current and future habitat areas and corridors ▪ Identifying and protecting climate refugia

Managers are also persuaded to implement actions that address different time scales. For example, implementing those actions that are appropriate to the short-term (e.g., resistance strategies) as well as those actions that may be effective for the long-term (e.g., response strategies) may better position managers for an uncertain future (Table 19). In one area this could include removing non-native grasses (resistance), planting with native seeds from across a greater geographic range (resilience), and planting with native genotypes that are better adapted to potential future conditions (response). Finally, adaptation strategies implemented in spatial isolation (e.g., without considering neighboring landowners) run the risk of failure. For example, removing non-native grasses on one parcel while the neighboring parcel continues to serve as a seed source. Spatial considerations are especially important to explore for those adaptation strategies focused on protecting habitat cores and corridors.

Adopting a Toolbox Approach, Part II: All Sierra Nevada Stakeholders

The resistance, resilience, and response adaptation approaches discussed above represent possible actions that can be employed to decrease vulnerability or increase resilience of Sierra Nevada natural resource management and conservation in the face of climate change. However, holistic climate change adaptation planning is not just about developing actions specific to natural resource management and conservation. Rather, climate-smart natural resource management and conservation can be thought of as one type of adaptation activity important to implement. Other types of activities include capacity building; policy; and infrastructure, planning, and development (Table 20; Gregg et al. 2012).

Table 20. Types of climate adaptation strategies important to consider implementing across the Sierra Nevada. *Easier* strategies may be more feasible to implement, particularly on short time scales. *Moderate* and *more difficult* strategies will likely take longer implementation time frames and may require significant financial, institutional, social, or technical investment. Those strategies in bold appear as adaptation actions in this report.

	Easier	Moderate	More Difficult
Natural Resource Management & Conservation	▪ **Reduce local climate or related change** ▪ **Reduce non-climate stressors**	▪ **Incorporate climate-smart guidelines into restoration**	▪ **Enhance connectivity and areas under protection**
Capacity Building	▪ Conduct training & planning exercises ▪ **Increase/improve public awareness & education**	▪ **Conduct research, studies, & assessments** ▪ Create/enhance tools and resources	▪ Design or reform institutions ▪ **Monitor climate change impacts** and adaptation efficacy
Policy	▪ Develop adaptation plans	▪ Implement adaptation plans ▪ **Create new or enhance existing policies or regulations**	▪ **Develop/implement adaptive management strategies**
Infrastructure,	▪ Develop disaster	▪ Make infrastructure	▪ Retrofit existing

	Easier	Moderate	More Difficult
Planning, & Development	preparedness plans	resistant or resilient to climate change ▪ Community planning	infrastructure to withstand climate change ▪ Managed retreat (e.g., due to landslides, flooding) of infrastructure

Building capacity of agencies, organizations, and the public can improve the ability to plan, develop, and implement adaptation actions as well as increase likelihood of success. This activity includes strategies such as conducting research, studies, and assessments, increasing public awareness, education, and outreach efforts, and monitoring climate change impacts and adaptation efficacy, among others (Gregg et al. 2012). In particular, these strategies can enhance the ability of natural resource managers to develop and implement many of the adaptation actions highlighted above for focal resources. For example, improving public awareness about the potential for catastrophic and stand-replacing fires as a result of climate change could increase the likelihood of public support for managed fire if the necessary link is made between this adaptation strategy and its ability to prevent or limit wildfire impacts. Similarly, habitat assessments and targeted research studies on wildlife corridors are an important first step toward prioritizing and protecting key wildlife habitat areas. Monitoring both climate change impacts as well as adaptation efficacy can also help practitioners track changes and identify needed modifications in applied management strategies (Gregg et al. 2012). To date, there is an overall lack of adaptation efficacy monitoring, likely to due to the absence of guidance necessary to conduct an evaluation. EcoAdapt is currently working on developing this guidance.

The development and implementation of policies related to climate change is also critical to adaptation efforts, and is a key part of this effort. Central strategies for this activity include developing adaptive management approaches and creating new or enhancing existing policies (Gregg et al. 2012). Adaptive management approaches play an important role in overcoming the uncertainty associated with climate change by allowing practitioners to test hypotheses and adjust decisions and actions based on outcomes. Experimenting with different silvicultural techniques, for example, can improve understanding of what techniques work best for achieving desired conditions under changing climate conditions. Implementing adaptive management approaches can help spread risks so that failure in one area does not mean failure in all. Incorporating future climatic changes and impacts into new or existing policies involves considering how desired outcomes or management goals may be affected as the climate changes (Gregg et al. 2012). The findings from this project are meant to inform the creation of desired conditions, objectives, and management strategies for revised USFS land management plans as well as those efforts of other land management agencies in the region. Integrating potential climate impacts to and adaptation options for natural resources, communities, and social/economic values into Sierra Nevada policies, plans, and practices increases the likelihood of meeting long-term goals.

Though not discussed here in great detail, adaptation strategies related to infrastructure, planning, and development are also important to implement as they have the potential to significantly impact natural resource management and conservation. These types of activities include improving existing or designing new infrastructure to withstand the effects of climate change, incorporating climate change into community planning, and developing disaster preparedness plans and policies. Planners and managers need to identify and assess vulnerabilities and develop adaptive responses to protect infrastructure and public health and safety, ensure continuation of ecosystem services (e.g., water supply, water quality), and limit environmental impacts (Gregg et al. 2012).

Regional stakeholders (i.e., land managers, conservation planners, scientists, community organizations, etc.) are encouraged to participate in and contribute to the different types of adaptation activities discussed above as each plays a role in the ability to meet long-term goals for focal resources of the Sierra Nevada. Table 20 also provides a useful framework for stakeholders to assess whether adaptation activities are occurring throughout all four categories and may be a useful starting point for evaluating whether those activities are sufficient to meet social and ecological goals for the Sierra Nevada.

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EcoAdapt, founded by a team of some of the earliest adaptation thinkers and practitioners in the field, has one goal - creating a robust future in the face of climate change. We bring together diverse players to reshape planning and management in response to rapid climate change.

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