Southern California Conifer and Subalpine Habitats

Climate Change Adaptation Synthesis

Introduction

The following section presents climate change adaptation planning results for conifer and subalpine habitats. The results summarize discussions and activities completed by participants during a two-day adaptation workshop as well as peer-review comments and revisions and relevant examples from the literature or other similar efforts.[1] We first present current management **goals** identified by participants. The purpose of identifying management goals is to provide a foundation for evaluating whether and how climate change might affect the ability to achieve a given goal, and to develop options for reducing vulnerabilities through revised management activities. For each management goal, participants identified potential climate change vulnerabilities. This activity was followed by the evaluation of current management actions, including whether, in their current form, they can help to reduce identified vulnerabilities and/or how they can be modified to better address climate challenges. Following the evaluation of potential vulnerabilities of current management goals and actions, participants explored potential future management goals and adaptation **strategies** and identified more specific adaptation **actions** designed to reduce vulnerabilities or increase resilience of conifer and subalpine habitats. For each adaptation action, participants then evaluated where, when, and how to implement those actions as well as collaboration and capacity needs. Lastly, we present a table summarizing all adaptation actions developed by participants as well as additional actions for consideration from the literature and from other similar efforts. Adaptation actions are grouped according to whether they (1) enhance resistance, (2) promote resilience, (3) facilitate transition, (4) increase knowledge, or (5) engage coordination in terms of responding to climate change.

Defining Terms

Goal: A desired result for a given resource.

Adaptation strategy: General statements of how to reduce vulnerabilities or increase resilience of current management goals.

Adaptation actions: Specific activities that facilitate progress towards achieving an adaptation strategy.

Current Management Goals and Potential Vulnerabilities

Workshop participants identified five key current management goals for conifer and subalpine habitats:

(1) Prevent large-scale, catastrophic wildfire and re-introduce fire to the landscape where fire has been suppressed; this includes mitigating fire hazards, protecting trees,

[1] Workshop participants included: Alison Anderson, USFWS; Jan Beyers, USFS; Jen Hooper, USFS; Megan Jennings, San Diego State University; Sarah Sawyer, USFS; Gloria Silva, USFS; and Neil Sugihara, USFS

increasing survival, restoring natural and sustainable fire return intervals, protecting old growth, preventing a decrease in sensitive species distribution, and improving forest health,

(2) Facilitate regeneration/restoration of montane conifer,
(3) Facilitate regeneration and protection of black oaks,
(4) Maintain the diversity of subalpine species of southern California Sky Islands, especially species that are rare or particularly sensitive to climate change, and
(5) Maintain healthy stand conditions in subalpine forest (limber pine, lodgepole pine, other upper elevation conifers).

As part of the workshop activities, participants identified potential climate and non-climate vulnerabilities to current management goals and actions for conifer and subalpine habitats. Potential vulnerabilities identified included:

- Altered temperature and precipitation regimes could shift plant and pollinator composition
- Enhanced moisture stress and drought
    - Earlier snowmelt and decreased snowpack may lead to earlier drying and extended fire season
    - Decreased snowpack will likely further decrease water availability in summer
    - Warming could further increase drought stress at lowest elevations
    - Reduced seedling recruitment under drought conditions; plantings are likely to have very low survival rates (particularly true for oaks, which are also threatened by beetle infestations/attacks)
    - Drought stress may predispose trees to beetle attack
- Increased extent and frequency of stand-replacing fire
    - Actions are currently not aggressive enough to restore stands to historical fire return intervals or to reduce stand densification across large areas
    - Fire may result in landscape-scale shifts in vegetation that are beyond agency capacity to replant with standard procedures (e.g., grid planting)
    - Increased cumulative impacts of fire suppression activities, particularly the loss of native vegetation and an increase in non-native plants along ridge lines where bulldozers often construct fire lines/breaks
    - Prescribed fire under future conditions may burn hotter and create a greater threat to oak seedlings
    - Increased conifer regeneration increases need for fire protection
- Lack of diversity in stand age and structure
- Elevational limits restrict species' ability to migrate as climate conditions change
- Increased introduction of non-native species
- Increased insect outbreaks
- Increased threats from encroaching human development:
    - Increasing wildland-urban interface
    - High levels of human activity and use of the forested environment

  - High risk from reintroduced fire in an urbanized forest – must consider liability issues and need to protect life and property
  - Increased population around subalpine areas increases need for fire suppression
  - Increased recreation could increase number of fire ignitions
  - Recreation management must be compatible with natural resource management goals
  - Habitat loss and fragmentation
- Silvicultural practices developed in mesic environments do not account for threats and vulnerabilities in a xeric environment
- Regulatory requirements for the protection of threatened and endangered species limits management actions

In response to these vulnerabilities, participants then evaluated whether or not existing management actions may be effective in reducing vulnerability; identified what, if any, climate and non-climate vulnerabilities the action helps reduce; and evaluated the feasibility of action implementation. Given action effectiveness and feasibility, participants then evaluated whether or not to continue implementation of the action. For those actions recommended for continued implementation, participants then identified both how and where to implement.

Terminology

Action effectiveness: Identify the effectiveness of the action in reducing vulnerability.
High: action is very likely to reduce vulnerability and may benefit additional goals or habitats; *Moderate*: action has moderate potential to reduce vulnerability, with some limits to effectiveness; or *Low*: action is unlikely to reduce vulnerability.

Action feasibility: Identify feasibility of implementing the action.
High: there are no obvious barriers and it has a high likelihood of being implemented; *Moderate*: it may be possible to implement the action, although there may be challenges or barriers; or *Low*: there are obvious and/or significant barriers to implementation that may be difficult to overcome.

How to implement: Identify how to apply this action given vulnerabilities.
For example, consider planting native species that can cope with a range of future conditions or those best adapted to projected future conditions.

Where to implement: Identify the management, ecological, or site conditions where the action could be most appropriately implemented.
For example, is it best to implement in areas with high soil moisture holding capacity, areas projected to lose the most water supply, post-fire areas, highly roaded areas, etc.?

Table 1 below explores current management goals and actions, potential vulnerabilities, and ways to revise current actions to reduce vulnerabilities for conifer and subalpine habitats. The table is structured to provide:

1. A current management goal;

2. Potential climate and non-climate vulnerabilities that affect the success of achieving the management goal;
3. Multiple current management actions;
4. An evaluation of action effectiveness, feasibility, and potential vulnerabilities that the may be reduced by action implementation; and
5. A description of where and how to implement the action given climate vulnerabilities and whether or not implementation of the action may have indirect effects on other resources, either positive or negative.

Revised Management Actions

The following list describes trends and commonalities amongst the climate-informed current management actions discussed by participants in Table 1.

- The management actions identified by workshop participants primarily dealt with wildfire, forest regeneration and succession, and reducing non-climate stressors, which included insect outbreaks and recreational impacts. Specific actions fell into the following categories, with the majority of actions falling within the first two:
    - *Enhance resistance* to climate change by protecting oak seedlings, preventing wildfire, monitoring insect outbreaks, and reducing impacts from public use;
    - *Promote resilience* to climate change by replanting after wildfire events, allowing natural regeneration of forest, utilizing prescribed fire, reducing the impacts of both wildfire and prescribed fire, and educating the public about the impact of off-highway vehicles (OHVs) and other recreational uses;
    - *Facilitate transition* under changing climate conditions by developing seed collections that include lower-elevation bands and increase genetic diversity; and
    - *Increase knowledge* of subalpine vegetation and species shifts that may occur under changing climate conditions.
- Workshop participants identified wildlife and species diversity as the additional resources most likely to benefit from these management actions. Potential sources of conflict included increased risk of stand-replacing fire among protected oaks, increased resource competition among wildlife because of seed collection, soil loss after site preparation, decreased access, and recreational users.
- Participants recommended that the implementation of these actions focus on areas that are heavily used and/or most susceptible to disturbances such as fire, drought, and insect outbreaks. Participants also recommended that seed collection occurs across an elevational gradient, and plantings focus on higher-elevation sites.

Table 1. Current management goals, potential vulnerabilities, and current management actions for conifer and subalpine habitats. For each current management action participants evaluated its effectiveness (likely to reduce climate vulnerability) and feasibility (likelihood of implementation), and identified climatic and non-climatic stressors the action could help to ameliorate the effects of. Given action effectiveness and feasibility, participants then evaluated whether or not the action should continue to be implemented. If the action was recommended for continued implementation, participants detailed any changes regarding where and how to implement given climate vulnerabilities. Lastly, participants evaluated whether there were potential conflicts with or benefits to other resources from action implementation.

Current Management Goal: Prevent large-scale, catastrophic wildfire and re-introduce fire to the landscape where fire has been suppressed; this includes fire hazard mitigation, tree protection, increasing survival, restoring natural and sustainable fire return intervals, protecting old growth, preventing a decrease in sensitive species distribution, and improving forest health

Potential vulnerabilities:

- Actions are currently not aggressive enough to restore stands to historical fire return intervals or to reduce stand densification across large areas
- Increased insect outbreaks
- Increased threats from encroaching human development include an increasing wildland-urban interface, high levels of human activity and use of the forested environment, and an increased need for fire suppression in subalpine areas
- Silvicultural practices developed in mesic environments do not account for threats and vulnerabilities in a xeric environment
- Regulatory requirements for the protection of threatened and endangered species limits management actions

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Thin	Effective	High	Yes – reduces fuel loading, competition, risk of disease outbreak and spread, and risk of stand-replacing crown fire	Yes	**Where**: Prioritize areas that have had no fuel treatment and no fire to naturally thin stands; focus on overly dense stands and those that are mostly single-species and uniform age **How**: Continue thinning, consider implementing prescribed fire that would make stands most resilient	**Other resources action benefits**: Makes stands more resilient and enhances our ability to protect or even improve habitat that other species rely on. **Other resources with potential conflicts**: Thinning is not always compatible with management of threatened and endangered species; the impact of thinning on other natural resources must be taken into account

Pile and burn	Effective	High	Yes – crowning fire mitigated when piled far away	No	**Where**: N/A **How**: Scatter instead	**Other resources action benefits**: N/A **Other resources with potential conflicts**: N/A

Current Management Goal: Facilitate regeneration/restoration of montane conifer

Potential vulnerabilities:

- Enhanced moisture stress and drought
- Increased extent and frequency of stand-replacing fire
  - Fire may result in landscape-scale shifts in vegetation that are beyond agency capacity to replant with standard procedures (e.g., grid planting)
- Lack of diversity in stand age and structure

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Implement post-fire low-grid planting	Moderate – if prescription responsive to climate change as noted	Moderate	Moderate – High – addresses post-fire deforestation; increases species diversity; makes seedlings less vulnerable to pests (though more vulnerable to being eaten by gophers, deer, etc.)	Yes	**Where**: Ensure appropriate site (e.g., do not plant conifers on non-montane site); may prioritize mature trees desired for recreation or aesthetics **How**: Plant using diverse species and elevation band stock; consider climate change in species selection; take advantage of rain events (El Niño); thin to reduce moisture stress. If cannot fund grid planting, try founder stands where seeds can disperse	**Other resources action benefits**: Wildlife/habitat diversity, recreation/visuals **Other resources with potential conflicts**: Soil impacts from site prep (e.g., grapple out large shrubs); heritage resources (and other sensitive resources); stand age and structure. Some public opposed to post-fire planting; must remove nitrogen-fixing Ceanothus in order to plant trees.

Release natural regeneration	Moderate	High	High – natural regeneration adapted to specific site; release from competition enhances moisture availability for residual seedlings, especially if scalp and mulch, and leads to more robust growth	Yes	**Where**: Areas where stand density is too low or where disturbance (e.g., fire or disease) has resulted in a loss of canopy cover **How**: Release natural regeneration from competition; can scalp/mulch residual; can use various methods such as manual, or mechanical; use nurse plants to facilitate regeneration; determine which factors drive regeneration in southern California	**Other resources action benefits**: Wildlife, increased likelihood of tree survival, recreation/aesthetics **Other resources with potential conflicts**: Shrubs that would be cleared are also habitat and there could be negative effects from altering the natural successional process.
Create a seed collection to improve genetic diversity	Moderate	Moderate	Yes – higher species diversity and more elevation bands	Yes	**Where**: Focus on lower elevations, but distinguish between use of lower elevation seed where species occurs (e.g., Jeffrey Pine from 6000' compared to 5500' elevation) vs. conifers planted toward subalpine **How**: Consider climate change and future needs when collecting seeds; stock seed from lower elevational bands, including Coulter pine if possible; southern California habitat differs from typical commercial seed stock – consider pinyon, low elevations	**Other resources action benefits**: No answer provided by participants **Other resources with potential conflicts**: Takes cones from wildlife

Current Management Goal: Facilitate regeneration and protection of black oaks

Potential vulnerabilities:

- Reduced seedling recruitment under drought conditions; plantings are likely to have very low survival rates (particularly true for oaks, which are also threatened by beetle infestations/attacks)
- Increased stand-replacing fire
- Prescribed fire under future conditions may burn hotter and create a greater threat to oak seedlings

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Protect seedlings during prescribed fire activities	Moderate	High	Yes – helps maintain species diversity and bi-layered canopy; increases future resilience to insects and diseases	Yes	**Where**: Areas with ongoing oak mortality caused by drought and pests, especially areas with low to no regeneration **How**: Consider revising burn plans to adjust prescriptions in areas of oak regeneration; can avoid altogether if burn conditions may be too hot	**Other resources action benefits**: Large impact for wildlife species that will eventually depend on mature oaks because of food resources and refugia oaks provide **Other resources with potential conflicts**: Protecting areas of oak regeneration from prescribed fire could make the areas more vulnerable to stand-replacing wildfire
Plant acorns	Moderate	High	Yes – helps maintain species diversity and bi-layered canopy; increases future resilience to insects and diseases	Yes	**Where**: Areas with ongoing oak mortality caused by drought and pests, especially areas with low to no regeneration **How**: Identify potential options for source material of varied genetic stocks; investigate longer-term banking/storage options and rotating planting schedule	**Other resources action benefits**: Large impact for wildlife species that will eventually depend on mature oaks because of food resources and refugia oaks provide **Other resources with potential conflicts**: Acorn collection could increase competition for acorn resources by wildlife under stress from changing climate conditions

Current Management Goal: Maintain the diversity of rare subalpine species of southern California Sky Islands

Potential vulnerabilities:

- Altered temperature and precipitation regimes could shift plant and pollinator composition
- Enhance moisture stress and drought
  - Earlier snowmelt and decreased snowpack may lead to earlier drying and extended fire season
- Increased extent and frequency of fire
  - Increased cumulative impacts of fire suppression activities, particularly the loss of native vegetation and an increase in non-native plants along ridge lines where bulldozers often construct fire lines/breaks
  - Increased conifer regeneration increases need for fire protection
- Increased population around subalpine areas increases need for fire suppression
- Change in pollinator conditions – hill topping

Current Management Action[1]	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Insert protective measures (via resource advisors) to minimize impacts from bulldozers and retardants, when safety allows, during wildfire/prescribed fire	Moderate – first responders do not have controls, but long term this action will reduce fire impacts	High – can be implemented for prescribed fire and wildfire contingency planning	Yes – reduces impacts within subalpine habitats; keeps bulldozers and retardant lines out of subalpine zones by going on existing roads/trails	Yes	**Where**: High elevation sites – Mt. Pinos, Sawmill, Cerro Noroeste **How**: Increase awareness of the need to avoid bulldozers/retardants during fires; educate resource advisors/firefighters/line officers; learn more about fire return intervals in subalpine habitat, what the effects of suppression are, and whether it is needed	**Other resources action benefits**: High elevation wildlife species (associated with fell-field); reduced potential for invasive plant spread along disturbed bulldozer lines **Other resources with potential conflicts**: No answer provided by participants

Current Management Goal: Maintain sensitive plants and sky islands habitat

Potential vulnerabilities:

- Altered temperature and precipitation regimes could shift plant and pollinator composition
- Increased fire frequencies may lead to increased fire suppression impacts

[1] Off-highway vehicle control was identified as an additional current management action by workshop participants but was not evaluated further, so is not included in this table.

Current Management Action[2]	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Remove and/or rehabilitate roads and trails to minimize OHV impacts	Moderate – only minimizes impacts, does not address declines in species' ranges	High – currently implemented	Yes – limits impacts from recreation and OHVs	Yes	**Where**: No answer provided by participants **How**: No answer provided by participants	**Other resources action benefits**: Minimizing OHV impacts and ground disturbance could also benefit many wildlife species (i.e., minimize crushing and disturbance) **Other resources with potential conflicts**: Decreased access for fire suppression, vegetation management, and other beneficial actions (non-native removals, species reintroductions)
Utilize fencing, signs, and public education to minimize recreation impacts	Moderate	High – currently implemented	Limits impacts to recreation and OHV; limited effectiveness in addressing declines in species' ranges	Yes	**Where**: No answer provided by participants **How**: No answer provided by participants	**Other resources action benefits**: Minimizing recreational impacts could also benefit many wildlife species **Other resources with potential conflicts**: May create conflicts with recreationalists
Current Management Goal: Maintain healthy stand conditions in subalpine forest (limber pine, lodgepole pine, and other upper elevation conifers)						
Potential vulnerabilities: • Warming could lead to drought stress at lowest elevations • Decreased snowpack will likely further decrease water availability in summer						

[2] Additional current management actions recommended by workshop participants were: 1) Monitor for species declines and increase protection as appropriate, 2) Use monitoring results to identify most threatened populations and ensure connectivity and genetic diversity, and 3) Develop seed and botanical collections. These actions were not evaluated further, so are not included in this table.

- Elevational limits restrict species' ability to migrate as climate conditions change
- Increased recreation could increase number of fire ignitions
- Drought may predispose trees to beetle attack

Current Management Action	Current Effectiveness	Current Feasibility	Does Action Ameliorate Effects of Any Vulnerabilities?	Continue to Implement Action Given Climate Vulnerabilities?	Where/How to Implement Given Climate Vulnerabilities	Other Resource Considerations
Implement fire suppression and prevention	Moderate – High – have kept fire regime at ~200 years; fate of high-elevation forests is tied to fuel management effectiveness in mixed conifer	High – currently implemented	Yes – limits area burned due to anthropogenic fire starts, keeps fire regime within natural range of variability	Yes	**Where**: Limited area of forest; focus protection on smallest stands (most susceptible to loss due to high severity fire) **How**: Target fuel management at ecotone between mixed conifer and high elevation forest; manage lightning fires for resource benefit if feasible; if high severity fire occurs, replant with lowest elevation seed stock (collect seeds beforehand)	**Other resources action benefits**: Actually need more fire in lower elevation forests if feasible **Other resources with potential conflicts**: No answer provided by participants.
Manage recreation	High – if use increases, permit systems can limit impacts	High	Yes – managing recreation can reduce risk of fire escape (from campfires)	Yes	**Where**: Most heavily used areas (Mt. Pinos) **How**: Institute fire permit restrictions during very dry summers	**Other resources action benefits**: Managing recreation levels will benefit subalpine shrub and herb habitats **Other resources with potential conflicts**: No answer provided by participants.
Monitor insect outbreaks	Low – Moderate	Moderate – no roads to remove trees in some	No – not sure we could do anything if a beetle outbreak	Yes	**Where**: No answer provided by participants **How**: Increased diligence to detect insipient insect	**Other resources action benefits**: Beetle-attacked trees are woodpecker habitat **Other resources with potential**

		areas	was detected		outbreaks	**conflicts**: Beetle-killed trees are a hazard for recreation if near trails and camping areas

Future Management Goals and Adaptation Actions

Workshop participants identified the following possible future management goals and adaptation actions for conifer and subalpine habitats:

Management Goal/Adaptation Strategy: Maintain bigcone Douglas-fir as component of chaparral, mixed evergreen, and conifer forest communities in southern California.

Adaptation action: Thin/underburn bigcone Douglas-fir and canyon live oak stands to reduce crown fire likelihood and protect habitats (especially for California spotted owl).

Management Goal/Adaptation Strategy: Review wilderness paradigm to allow fuels modification prior to wildfires.

Adaptation action: Facilitate options for fuels reduction in mixed conifer wilderness so that there is less need to manage intense wilderness mixed conifer fires near urban areas.

Management Goal/Adaptation Strategy: Reduce crown fire risk in conifer forest by directing thinning activities to areas with high likelihood of fire coming up from below; get chaparral fire to drop to the ground at forest interface to protect conifer forest from crown fire.

Adaptation action: Based on likely increase in fire activity due to climate change, focus thinning of mixed conifer in areas where fire is most likely to carry up from chaparral or oak woodland vegetation.

Management Goal/Adaptation Strategy: Maintain biodiversity of shifting communities and species.

Adaptation action: Facilitate migration of co-adapted species.

Management Goal/Adaptation Strategy: Restore the resilience of forest to fire by maintaining fuel structure in mixed conifer forest and big-cone/canyon live oak stands.

Adaptation action: Develop desired resilient forest structure through thinning and other treatments.

Management Goal/Adaptation Strategy: Ensure survival of restoration/reforestation efforts.

Adaptation action: Create barriers between restoration areas, individual seedlings, and human fire ignition sources.

Management Goal/Adaptation Strategy: Improve stand resilience.

Adaptation action: Track and manage groundwater extraction both on and off the forest to prevent drawdown and to promote forest resilience in the face of drought and higher temperatures.

Management Goal/Adaptation Strategy: Protect species most vulnerable/least resilient to climate change within montane conifer areas (mountain yellow-legged frog [*Rana muscosa*],

Laguna Mountains skipper [*Pyrgus ruralis lagunae*]) from wildfire impacts (e.g., post-fire impacts such as mudslides, direct impacts).

Adaptation action: Manage vegetation around habitat occupied by narrow endemics.

Management Goal/Adaptation Strategy: Allow natural return to historical fire return intervals in coniferous forest to promote forest health and resilience.[4]

Adaptation action: Stop suppressing fire, particularly in the wilderness (e.g., in eastern San Gabriel Mountains).

Adaptation action: Develop a nighttime prescribed fire program.

Management Goal/Adaptation Strategy: Promote resilience in the ecosystem such that it reduces vulnerability to climate change for a range of species.[4]

Adaptation action: Prioritize research efforts to identify refugia (areas that are buffered to some degree from the effects of climate change), and compare these refugia ecologically to the rest of the habitat.

Adaptation action: Coordinate management actions across land management designations for cross-border goals.

Management Goal/Adaptation Strategy: Safeguard the most vulnerable/sensitive species from the effects of climate change and develop options for rescue/reintroduction if necessary.[4]

Adaptation action: Collect seeds from and monitor species with the highest vulnerability to climate change.

Management Goal/Adaptation Strategy: Improve stand resilience and resistance to climate stressors to protect ecosystem structure and function.[4]

Adaptation action: Plant resilient species intermixed with current species (monocultures are more susceptible to long-distance outbreaks), and consider planting in other places besides just post-burn areas.

Management Goal/Adaptation Strategy: Track the effects of a changing climate and engage local communities in their forests.[4]

Adaptation action: Develop a citizen science program for monitoring and engagement.

After identifying possible future management goals and actions for conifer and subalpine habitats, participants were asked to evaluate action effectiveness and feasibility; identify the timeframe for action implementation; describe where and how to implement the action; and identify collaboration and capacity needs. Timeframe, collaboration and capacity needs are defined below.

- **Implementation timeframe:** Identify when the action could feasibly be implemented.
  - *Near*: <5 years; *Mid*: 5-15 years; or *Long*: >15 years.

[4] The following adaptation goals and actions were discussed at the workshop activity, but no additional information was collected and they are not listed in Table 2.

- **Collaboration:** Identify any other agencies, organizations, or people – both internal and external – needed to collaborate with in order to implement this tactic.
- **Capacity needed**: Identify capacity needed for implementation such as data, staff time and resources, funding, or policy changes, among others.

Table 2 below explores the future management goals/adaptation strategies, actions, and implementation recommendations developed by workshop participants for conifer and subalpine habitats. The table is structured to provide:

1. A future management goal/adaptation strategy;
2. Adaptation actions for each goal/strategy;
3. An evaluation of action effectiveness, feasibility, and implementation timeframe; and
4. A description of where and how to implement and collaboration and capacity needed to move forward with implementation.

This workshop activity was intended to generate a range of recommended adaptation actions that could be implemented both now and in the future. The resulting actions are not comprehensive, and users of this report are encouraged to explore additional adaptation actions that may help reduce vulnerabilities, increase resilience, or capitalize on opportunities presented by climate change for conifer and subalpine habitats.

Future Management Actions

The following list describes trends and commonalities amongst the future management actions discussed by participants in Table 2.

- Several workshop participants included thinning and other fuels reduction activities among their future management actions. Facilitated migration and the placement of barriers around restored and sensitive sites were also mentioned multiple times. Most actions are centered on addressing species range shifts and wildfire.
- Management actions fell into a range of categories, with most actions designed to either *enhance resistance* or *promote resilience*:
    - *Enhance resistance* by decreasing water extraction to prevent groundwater drawdown, targeting thinning in areas where fire may spread from nearby chaparral or oak woodlands, developing a nighttime prescribed fire program, placing barriers between people and restoration areas, thinning bigcone Douglas-fir and canyon live oak stands to reduce crown fires, and managing habitat around endemic species;
    - *Promote resilience* by collecting seed from vulnerable species, planting resilient species to increase biodiversity, and planting in locations other than just post-burn areas;
    - *Facilitate transition* by assisting conifer migration among co-adapted species;
    - *Increase knowledge* by researching refugia and comparing them to the rest of the habitat, and monitoring climate change assumptions on local scales before taking large management actions; and
    - *Engage coordination* by coordinating actions across land management designations and developing citizen science projects.

- Workshop participants recommended that management actions focus first on transition zones (especially in the conifer-chaparral ecotone), in very large or particularly dense areas of mixed conifer forest, in areas around likely fire ignition sources, and in areas occupied by protected species such as the Laguna Mountains skipper and the mountain yellow-legged frog.
- Given the large-scale efforts needed to undertake the management actions identified, participants noted that good collaborative relationships were important for success. These could include both internal and external collaborations with the U.S. Forest Service, USGS, U.S. Fish and Wildlife, and the Bureau of Land Management, as well as state and local government agencies, NGOs, scientists and researchers, policymakers, and the general public. Workshop participants also identified the need for additional funding, staffing, access to data, and monitoring programs.

Table 2. Potential future management goals, adaptation actions, and action implementation details including where and how to implement and collaboration and capacity needs for conifer and subalpine habitats. Action effectiveness (likelihood of reducing vulnerability), feasibility (likelihood of implementation), and timeframe (near: <5 years; mid: 5-15 years; long: >15 years) were also evaluated for each adaptation action.

Management Goal: Maintain bigcone Douglas-fir as component of chaparral, mixed evergreen, and conifer forest communities in southern California					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Thin/underburn bigcone Douglas-fir and canyon live oak stands to reduce crown fire likelihood (protect habitats, especially for California spotted owl)	Moderate	Moderate	Long	**Where**: Areas with large stands of big-cone Douglas fir and canyon live oak; probably on fairly steep north-facing slopes between chaparral and conifer **How**: Hand-thin, pile, burn-piles; underburn stand to create opportunity for bigcone Douglas-fir seedling recruitment (needs shade)	**External collaboration**: Air Quality Management District for burning, crew/contractor for thinning **Internal collaboration**: Fire crew, wildlife biologist since this is likely CA spotted owl habitat **Capacity needed**: Funding for analysis, fire crew, contractor; need to enlist monitoring (researcher) to help document effects on spotted owl habitat/usage, so will need good control stands to compare to; may need to pay for research
Management Goal: Review wilderness paradigm to allow fuels modification prior to wildfires					
Adaptation Action[5]	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Facilitate options for fuels reduction in mixed conifer so that there is less need to manage intense wilderness mixed conifer fires near urban areas	High	Moderate – Low; depends on perceived wilderness values and what is considered natural	Long	**Where**: Immense areas of mixed conifer on forests, particularly the Los Padres National Forest, which is 45% wilderness; San Rafael, Dick Smith, Sespe, etc.; Silver Peak wilderness – Santa Lucia fir **How**: Pick a wilderness area mixed conifer stand in need of fuels modification and apply minimum resource decision guide to facilitate discussion of wilderness values	**External collaboration**: Cal Fire, Wilderness Coalition, Center for Biological Diversity, Wilderness Society **Internal collaboration**: Forest and regional fuels, ecology, and wilderness staff **Capacity needed**: Staff time and focus, workshop time, collaboration meetings, policy review, land management plan modification

[5] Test and/or monitor climate change assumptions on a local scale before making changes was also identified as a current management action for this goal, but was not evaluated, so is not listed in this table.

Management Goal: Reduce crown fire risk in conifer forest by directing thinning activities to areas with high likelihood of fire coming up from below; get chaparral fire to drop to the ground at forest interface to protect conifer forest from crown fire.					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Based on likely increase in fire activity due to climate change, focus mixed conifer thinning actions in areas where fire is most likely to carry up from chaparral or oak woodland vegetation	Moderate – High	Moderate – access, cost; no policy change is needed, as this is just directed implement-ation of existing activity	Mid (ideal)	**Where**: Apply to dense mixed conifer stands (or pinyon pine/Jeffrey pine monoculture) closest to chaparral ecotone – access could be a problem **How**: Identify areas where fire is most likely to burn up from below (need fire modeling exercise to find these areas); schedule thinning projects (difficulty may be in access, as these areas are often steep slopes, not a lot of road access; helicopter logging may be an option)	**External collaboration**: Public (need acceptance of tree thinning); private in-holders; timber contractor/ stewardship contractor to do work; if pile and burn, coordinate with Air Quality Management District **Internal collaboration**: Botany and wildlife on any rare species issues (e.g., could be spotted owl habitat); need fire crew to do pile burning **Capacity needed**: Substantial funding may be needed as "harvest" unlikely to be economical; funds for fire crew to do pile and burn; over time, need to thin entire border (lots of expenses)
Management Goal: Maintain biodiversity of shifting communities and species					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Facilitate migration of co-adapted species	High	Moderate – limited by need to identify range (or habitat) shifts first	Mid	**Where**: Vegetation transition zones – at lower and upper elevational limits **How**: Identify species associations where one of several co-adapted species is limiting the migration rate of all, and move the limiting species (e.g., Cleveland NF – bring/reintroduce pinyon from escarpment up to top of Mt. Laguna)	**External collaboration**: Any stakeholders, scientists, researchers, ecologists, entomologists, and ornithologists (experts on associations); state and county parks, California Dept. of Fish and Wildlife, U.S. Fish and Wildlife, Bureau of Land Management, other land managers **Internal collaboration**: GIS, consulting biologists involved in planning (habitat conservation plans), etc. **Capacity needed**: Monitoring for movement (GIS models); funding for studies, surveys, and analyses; niche analysis and risk analysis (pay local experts to identify likely assemblages and impacts on other species and assemblages,

					other vegetation/communities); identify/use surrogate species to indicate habitat shift
Management Goal: Restore forest resilience to fire by maintaining fuel structure in mixed conifer forest and big-cone/canyon live oak stands					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Implement thinning and other treatments to develop desired resilient forest structure	High – reduces fire severity and improves water availability for each tree	High – must establish this as a priority; large-scale, expansive process	Long	**Where**: Throughout mixed conifer and bigcone Douglas-fir belt (if it is to be maintained) **How**: Mechanical and fire treatments can be used in a restoration phase; maintenance is essential	**External collaboration**: No answer provided by participants **Internal collaboration**: No answer provided by participants **Capacity needed**: Staff to maintain desired structure for stands, funding
Management Goal: Ensure survival of restoration/reforestation efforts					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Create barriers between restoration areas, individual seedlings, and human fire ignition sources	High – allows seed-bearing age to be reached	Moderate	Mid (seedlings) and Long (everything else)	**Where**: Areas most likely to be impacted by human ignition **How**: Talk to experts about fire resistant tree tubes/barriers; place seedling barriers (tubes – fire resistant) and K-rails (Adopt-a-K-rail program where local artists paint K-rails for visual appeal) at key ignition points	**External collaboration**: Caltrans, public, San Dimas Technology and Development Center **Internal collaboration**: Vegetation management **Capacity needed**: Fire-resistant tree tubes, develop visual policy

Management Goal: Improve stand resilience					
Adaptation Action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Track and manage groundwater extraction both on and off the forest to prevent drawdown and promote forest resilience in the face of drought and higher temperatures	Moderate – High	Low	Long	**Where**: Watersheds in and adjacent to coniferous forest; focus on transition zones first and more mesic sites with highest chance of improving condition **How**: Identify status of water rights; engage with landowners; monitor groundwater levels to quantify change; target acquisitions in areas where protecting groundwater is a priority	**External collaboration**: State Water Resources Control Board, state, legislators, NGOs, Office of General Counsel **Internal collaboration**: Hydrologists, silviculturists, lawyers **Capacity needed**: Data, political and public will, legal/policy change, funding
Management Goal: Protect species most vulnerable/least resilient to climate change impacts within montane conifer areas (mountain yellow-legged frog, Laguna Mountains skipper) from wildfire impacts (e.g., post-fire impacts such as mudslides, direct impacts)					
Adaptation action	**Effectiveness**	**Feasibility**	**Timeframe**	**Implementation (where/how)**	**Collaboration & Capacity**
Implement vegetation management around occupied habitat for narrow endemics	Moderate	Moderate	Near	**Where**: Areas near Laguna Mountains skipper and mountain yellow-legged frog-occupied habitat and potential reestablishment areas **How**: Design such that impacts due to treatment itself are effectively avoided or minimized	**External collaboration**: U.S. Fish & Wildlife Service, U.S. Geological Survey and consultants (post-project monitoring), NGOs **Internal collaboration**: Wildlife, fire **Capacity needed**: Funding, collaboration, prioritization

Additional Adaptation Actions for Consideration

Table 3 summarizes all of the adaptation actions generated by workshop participants for conifer and subalpine habitats and includes additional actions for consideration; additional actions comprise those from the literature as well as those identified by land and resource managers during other workshops. These strategies and actions are grouped according to one of five categories:

1. **Enhance Resistance**. Implementation of these strategies can help to prevent the effects of climate change from reaching or affecting a resource. One common type of resistance actions are those designed to reduce non-climate stressors.
2. **Promote Resilience**. These strategies can help a resource weather the impacts of climate change by avoiding the effects of or recovering from changes.
3. **Facilitate Transition (or Response)**. Transition or response strategies intentionally accommodate change and enable resources to adaptively respond to changing and new conditions.
4. **Increase Knowledge**. These strategies are aimed at gathering more information about climate changes, impacts, and/or the effectiveness of management actions in addressing the challenges of climate change.
5. **Engage Coordination**. Coordination strategies may help align budgets and priorities for program of work across lands or establish or expand collaborative monitoring efforts or projects, among others.

Table 3. Summary of adaptation goals and actions for conifer and subalpine habitats grouped by category (enhance resistance, promote resilience, facilitate transition, increase knowledge, and engage coordination). Adaptation goals and actions include those generated by workshop participants for conifer and subalpine habitats, as well as additional actions identified from the literature and by land and resource managers during other workshops.

CONIFER AND SUBALPINE HABITATS		
Category	**Adaptation Goal**	**Adaptation Action**
Enhance resistance	Prevent stand-replacing wildfire	• Focus thinning activities in areas where fire is most likely to carry up from neighboring habitats (e.g., chaparral or oak woodland) • Increase fire permit restrictions for recreation users during dry summers • Review wilderness paradigm to allow fuel modification in mixed conifer wilderness • Implement prescribed burns to prevent severe wildfires
	Ensure survival of seedlings after habitat restoration efforts	• Create barriers (e.g., tree tubes, K-rails) between habitat restoration areas and key human ignition points • Create an Adopt-a-K-rail program, in which local artists paint K-rails to increase visibility before they are placed near possible fire ignition sources
	Protect vulnerable plant and wildlife species in conifer and subalpine habitats	• Increase awareness of the need to incorporate bulldozer/retardant avoidance around rare subalpine species during fires • Protect the area around rare, vulnerable, and/or endemic wildlife species wildfire and post-fire impacts (e.g. landslides)
	Minimize the impacts of recreation on conifer and subalpine habitats	• Increase signage and public education to minimize the impacts of recreation • Modify and/or remove roads and trails to minimize the impacts of off-highway vehicles (OHVs)
Promote resilience	Maintain bigcone Douglas-fir as a component of conifer and mixed conifer forests	• Thin/underburn bigcone Douglas-fir and canyon live oak stands to reduce the likelihood of crown fires and create opportunities for seedling recruitment • Focus big-cone Douglas fir management and protection in identified climate refugia
	Allow natural return to historical fire return intervals in coniferous forest to promote forest health and resilience	• Stop fire suppression, particularly in wilderness areas • Develop a nighttime prescribed fire program • Use resource advisors to avoid or minimize the impacts of bulldozers and fire retardants

Promote resilience (con't)		• Apply a minimum resource decision guide to a stand in need of fuel modification to facilitate discussion of wilderness value
	Facilitate regeneration of montane conifer forest	• Thin overly dense stands and/or those that are mostly single-species and uniform in age, in order to reduce competition • Use nurse plants to facilitate regeneration of conifer species
	Carry out post-fire restoration activities	• Use grid planting to re-vegetate slopes with native species that have genotypes better adapted to future conditions • Plant founder stands for seed dispersal
	Protect and facilitate regeneration of black oaks	• Avoid prescribed burns in areas of oak regeneration if burn conditions would be too hot for seedling survival • Plant acorns from varied genetic stocks • Investigate longer-term banking or storage options for acorns and use rotating planting schedule
	Improve stand resilience to improve ecosystem structure and function	• Plant resilient species intermixed with current species to reduce outbreaks associated with monocultures and consider planting outside of post-burn areas
Facilitate transition	Develop seed collections to increase genetic diversity	• Collect seed from trees in lower-elevation bands • Increase species and genetic diversity within seed collections • Collect seeds from and monitor species with are highly vulnerable to climate change
	Maintain biodiversity of shifting plant communities	• Facilitate migration of co-adapted species, focusing on species where one species within an association is limiting the migration of all • Use monitoring results to identify threatened populations and aid efforts to increase connectivity and genetic diversity
	Identify and protect refugia	• Prioritize research efforts to identify refugia and compare their ecological value to the rest of the habitat • Map fire refugia, identify the processes and conditions that create fire refugia, and protect fire refugia areas [6,7]

[6] Mackey, B., S. Berry, S. Hugh, S. Ferrier, T. D. Harwood, and K. J. Williams. 2012. Ecosystem greenspots: Identifying potential drought, fire, and climate-change micro-refuges. Ecological Applications **22**:1852–64.

Increase knowledge	Monitor groundwater extraction both inside and outside the forest	• Determine the status of water rights • Monitor groundwater extraction to quantify changes to the water table, focusing on transition zones and mesic areas where the greatest opportunities for improvement exist
	Protect rare and sensitive plants in the southern California Sky Islands	• Monitor for species declines or an increase in invasive species • Learn more about fire return intervals in subalpine habitat and the effects and possible necessity of fire suppression
	Monitor forest to detect impacts of additional non-climate stressors	• Monitor forests for beetle outbreaks
Engage coordination	Work across jurisdictions	• Coordinate management actions across land management designations to meet mutual goals • Communicate about projects and coordinate on-the-ground activities[8]
	Track the effects of climate change and monitor forest conditions by engaging multiple entities, as well as local communities	• Implement a large-scale monitoring program designed to increase the identification, detection, and prediction of insect and disease outbreaks • Develop a citizen science program to engage communities in monitoring their local forest

[7] Kolden, C. A., J. A. Lutz, C. H. Key, J. T. Kane, and J. W. van Wagtendonk. 2012. Mapped versus actual burned area within wildfire perimeters: characterizing the unburned. Forest Ecology and Management **286**:38–47.

[8] Actions were sourced from the Climate Adaptation Project for the Sierra Nevada and/or the Northern Rockies Adaptation Partnership.