Southern California Conifer Habitats

Climate Change Vulnerability Assessment Summary

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for conifer habitats based on expert input and existing information. Specifically, the information presented below comprises habitat expert vulnerability assessment survey results and comments, peer-review comments and revisions, and relevant references from the literature. The aim of this document is to expand understanding of habitat vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.*

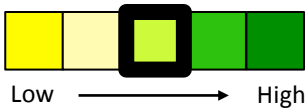

Photo by USFS Region 5 (CC by 2.0)

Habitat Description

In southern California, conifer habitats occur across a wide elevational gradient, ranging from closed-cone pine and cypress stands on coastal bluffs to pine stands on high-elevation mountaintops. The spatial arrangement of conifer habitats is dynamic, and strongly influenced by climatic gradients, topography, latitude, distance from the coast and/or desert, disturbances, and understory composition.[1-3] These habitats are dominated by coniferous species, although hardwoods may also be present in some habitat types. For the purposes of this section, the following California Wildlife Habitat Relationships System (CWHRS) groupings were considered: montane hardwood-conifer (includes bigcone Douglas-fir),[4] closed-cone pine-cypress,[5] and ponderosa pine.[6]

Habitat Vulnerability

Moderate Vulnerability



The relative vulnerability of conifer habitats in southern California was evaluated to be moderate by habitat experts due to moderate sensitivity to climate and non-climate stressors, moderate-high exposure to future climate changes, and moderate adaptive capacity. Conifer and mixed conifer habitats are sensitive to decreases in water availability, and moisture-stressed trees are more vulnerable to additional stressors, including insect outbreaks, disease, and pollution. Dead or dying trees can exacerbate wildfire by providing additional fuel, and wildfire may accelerate shifts in species composition by extirpating local populations, promoting fire-tolerant species or habitat types, and creating conditions suitable for invasive species. Conifer habitats are also sensitive to non-climate stressors (e.g., air pollution) that can exacerbate the impacts of climate change. Southern California conifer habitat types vary in extent and continuity, including stands comprised of endemic species with very limited extent (e.g., Torrey pine [*Pinus torreyana*]) and large tracts of forest made up of species that can be found throughout the western U.S. (e.g., ponderosa pine [*P. ponderosa*]). Range shifts in montane forests are limited by elevation and the lack of connectivity between mountaintops, while lower-elevation forests and coastal stands are primarily limited by habitat fragmentation and human activity. The ability of conifer habitats to resist stressors and recover from

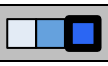
disturbance varies depending on specific species requirements; however, recovery is often dependent on the rate of forest regeneration, which is generally slow (~40-60 years). Conifer habitats provide food and shelter for many wildlife species, and are highly valued for aesthetic and recreational purposes, as well as for the many ecosystem services that they provide (e.g., carbon sequestration, water supply, air quality, and flood/erosion protection).

Sensitivity

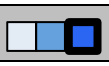
Moderate Sensitivity

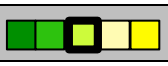
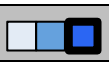
Conifer habitats are sensitive to multiple climate drivers, with key factors including drought, precipitation, snowpack depth, and soil moisture; additional factors may include air temperature, extreme heat events, timing of snowmelt/runoff, and low stream flows. Sensitivity is driven primarily by moisture availability, as water is the limiting factor in all but the highest-elevation sites.[2,7] Conifer habitats are often affected by complex interactions among biotic and abiotic stressors, and changes in climate and non-climate stressors may further magnify the impact of these interactions.[1]

Habitat sensitivity factors and impacts*

CLIMATIC DRIVERS	Moderate Sensitivity  High Confidence 
Precipitation, soil moisture, & drought	Precipitation amounts in southern California fall on a rough west to east gradient; coastal forests receive more precipitation, as well as benefits from cloud shading and fog condensation.[8,9] Shifts in the timing and amount of precipitation and increased drought may result in: • Decreased growth and seedling survival[8,10] • Increased competition for water resources, especially in dense stands[3,11,12] • Reduced forest extent and/or shifts in species composition[1,8,9] • Widespread mortality of conifers, especially when other stressors are present (e.g., drought, pollution)[1–3,9]
Air temperature & extreme heat events	At higher elevations, conifer forests are limited by energy (e.g., light and warmth) rather than by soil moisture,[7] although factors such as season, slope, aspect, and microsite conditions can alter the influence of temperature on conifer habitats.[13] Shifts in air temperature may cause: • Longer growing seasons and changes in phenology[10] • Increased evapotranspiration rates, resulting in lower soil moisture[15] • Increased growth in high-elevation sites typically limited by temperature[14] • Increases in heat-tolerant species such as ponderosa and Jeffrey pines[3]
Low stream flows	Streamflow is strongly influenced by evapotranspiration rates, and less precipitation runs off the forest floor into streams when conditions are warmer and/or drier.[2,15] Lower stream flows are associated with: • Reduced soil moisture and increased summer water deficit[15]

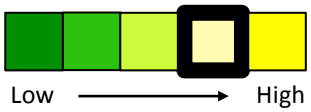
* Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found in the Conifer Habitats Climate Change Vulnerability Assessment Synthesis.

	• Increased drying of middle stream reaches, with some perennial streams becoming ephemeral[16]
Snowpack depth & timing of snowmelt/ runoff	Snowmelt contributes to soil moisture availability,[17] and the timing of snowmelt is tied to the beginning of yearly conifer growth.[10] Reduced snowpack and earlier snowmelt may lead to: • Increased dependency on spring precipitation events[12,15] • Reduced soil moisture, resulting in longer summer drought periods[12,15] • Earlier start to the growing season where snowmelt typically limits the season length[10,12] • Increased flooding and erosion during peak runoff events[18]
DISTURBANCE REGIMES Moderate-High Sensitivity  High Confidence 	
Wildfire	Wildfire is one of the primary drivers of natural succession in conifer habitats, and all habitat types are adapted to some level of fire. However, fire regimes vary widely among habitats, as do individual species' sensitivity to fire.[2,19] Warming temperatures, drought, and earlier snowmelt may be among the factors that contribute to altered fire regimes.[20–22] Impacts of shifting wildfire regimes could include: • Increased stand density where fires are less frequent[20] • Shift in species composition, with changes in the abundance of fire-adapted species (e.g., oaks) and fire-sensitive, shade-adapted species (e.g., incense cedar)[23,24] • Stand extirpation where increased fire severity and/or frequency does not allow regeneration, or where fire regime requirements are not [25] • Reduced forest extent and possible type conversion
Insects	Insect population success is linked to seasonal temperature, and warming can alter insect developmental stages, synchronicity, and mortality.[26] Insect outbreaks can cause: • Widespread mortality, especially where additional factors increase vulnerability to attack (e.g., drought, pollution)[3,26,28] • Increased susceptibility to other stressors during the recovery period[27] • Increased availability of dead wood as fuel[1,27]
Wind	Autumn Santa Ana winds are often associated with increased wildfire size, rate of spread, and intensity,[2,29] while coastal winds help to capture condensed fog, and may push fog and stratus clouds inland.[9] Possible impacts include: • Fire ignitions due to downed power lines during wind events • Increased desiccation in high-elevation sites and on granite outcrops[2,9] • Inland transport of nitrogen and ozone from developed coastal areas[8]

NON-CLIMATE STRESSORS	Moderate Sensitivity & Exposure  High Confidence 
Fire suppression practices	Anthropogenic activity altered historical fire regimes beginning in the 1800s, and fire suppression practices were adopted in the early 1900s.[24] While not all researchers agree on the effect of anthropogenic activity on fire regimes,[30] many studies conclude that fire exclusion has affected fire size and intensity, species composition, stand density, and available fuel loads.[1,2,11,16,19]
Land-use conversion	Many high-elevation conifer habitats are relatively protected by their lack of accessibility and/or by inclusion within state parks and national forests. However, lower-elevation habitats can be heavily impacted by increasing urban development and agriculture, as well as the infrastructure associated with these activities (e.g., roads and highways, water delivery systems).[16]

Exposure†

Moderate-High Exposure



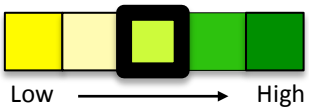
Under future climate conditions, conifer habitats will likely be exposed to changes in precipitation, decreased soil moisture, increased drought, increased wildfire, earlier snowmelt and runoff, and increased extreme heat events. In both wetter and drier climate scenarios, future climatic water deficit is expected to increase, leading to more arid conditions.[31] Conifer habitats are expected to shift towards higher elevations, with an overall loss of habitat in the southwestern U.S.[33,34] Refugia may exist on north- and east-facing slopes, near seeps and springs, in swales and canyons, and on rocky slopes where fuels are limited.[2,34]

Projected climate and climate-driven changes for Southern California

CLIMATIC DRIVERS	PROJECTED CHANGE
Precipitation & soil moisture	Variable annual precipitation volume and timing; decreased soil moisture
Drought	Longer, more severe droughts with drought years twice as likely to occur
Wildfire	Increased fire size, frequency, and severity
Timing of snowmelt/runoff	Snowmelt will likely occur 1-3 weeks earlier
Extreme heat events	Heat waves, particularly humid nighttime heat events, will occur more frequently, last longer, and feature hotter temperatures

Adaptive Capacity‡

Moderate Adaptive Capacity

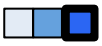
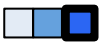
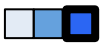
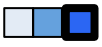


† Relevant references for regional climate projections can be found in the Southern California Climate Overview (http://ecoadapt.org/programs/adaptation-consultations/socal).

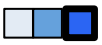
‡ Please note that the color scheme for adaptive capacity has been inverted, as those factors receiving a rank of "High" enhance adaptive capacity while those factors receiving a rank of "Low" undermine adaptive capacity.

Conifer habitats occur across multiple ecosystems in southern California (e.g., coastal, inland, montane). Their ability to resist and recover from stressors varies by habitat type and location, with some areas faring much better than others. As a whole, southern California conifer habitats are diverse and include many endemic tree species (e.g., Cuyamaca cypress).[16]

Habitat adaptive capacity factors and characteristics[§]

FACTORS	HABITAT CHARACTERISTICS
Habitat extent, integrity, & continuity Low-Moderate  High Confidence 	+ Conifer habitats are widespread throughout much of southern California, and span a broad elevational gradient[2] - Some habitat types are limited by site requirements (e.g., bigcone Douglas-fir forests rely on steep, eroded slopes to facilitate establishment)[2] - Several habitat types are severely limited in extent due to changing conditions and development pressure (e.g., Torrey pine)[35]
Landscape permeability Moderate  High Confidence 	- Habitat shifts are limited by elevation and the lack of connectivity between mountaintops in montane forests[32,33] - Species at the southern edge of their range are more likely to experience range contraction[32] - Lower-elevation and coastal forests are more likely to be limited by land-use change, grazing, and transportation infrastructure[16]
Resistance & recovery Low-Moderate  High Confidence 	+ Phenotypic plasticity may be maintained by variable climate conditions (e.g., inconsistent drought stress), especially in long-lived species[3] +/- Recovery is largely dependent on the rate of forest regeneration, which depends on seed availability, germination rate, and growing conditions (full recovery takes 40-60 years in most habitats)[2,11,23] - In dense stands, seedling survival may be severely limited by competition for resources[11] - It is likely that widespread tree mortality has lowered genetic variability, decreasing the ability of species to adapt to future change[3]
Habitat diversity Moderate-High  High Confidence 	+ Conifer habitats are diverse and variable, supporting many plant and wildlife species[4-6] + Conifer habitats have developed inter-species associations between trees/shrubs and underground fungal and bacterial communities, which may aid in drought tolerance and post-fire recovery[36,37] - Some rare endemic species have low genetic diversity that may

§ Characteristics with a green plus sign contribute positively to habitat adaptive capacity, while characteristics with a red minus sign contribute negatively to adaptive capacity.

FACTORS	HABITAT CHARACTERISTICS
	threaten survival of individual stands and/or the whole species[35]
Management potential Moderate  High Confidence 	+ Conifer habitats have high societal value, in part because they are relatively rare and easily recognizable; they are valued primarily for recreation, water, and grazing opportunities + Conifer habitats provide many ecosystem services, including carbon sequestration, flood and erosion protection, biodiversity, water supply/quality/sediment transport, recreation, grazing, air quality, nitrogen retention, public health, timber, fire regime controls, and quality of life

Recommended Citation

Hilberg, L. E., W. A. Reynier, and J. M. Kershner. 2017. Southern California Conifer Habitats: Climate Change Vulnerability Assessment Summary. Version 1.0. EcoAdapt, Bainbridge Island, WA.

This document is available online at the EcoAdapt website (http://ecoadapt.org/programs/adaptation-consultations/socal).

Literature Cited

[1] McKenzie, D., Peterson, D. L., & Littell, J. J. (2009). Global warming and stress complexes in forests of western North America. *Developments in Environmental Science*, *8*, 319–337.

[2] Minnich, R. A. (2007). Southern California conifer forests. In M. G. Barbour, T. Keeler-Wolf, & A. A. Schoenherr (Eds.), *Terrestrial Vegetation of California* (pp. 502–538). Berkeley, CA: University of California Press.

[3] Grulke, N. E. (2010). Plasticity in physiological traits in conifers: Implications for response to climate change in the western U.S. *Environmental Pollution*, *158*(6), 2032–2042.

[4] Anderson, R. (1988). Montane hardwood-conifer. In K. E. Mayer & J. Laudenslayer (Eds.), *A Guide to Wildlife Habitats of California*. Sacramento, CA: Resources Agency, California Department of Fish and Game.

[5] Jensen, D. B. (1988). Closed-cone pine-cypress vegetation. In K. E. Mayer & J. Laudenslayer (Eds.), *A Guide to Wildlife Habitats of California*. Sacramento, CA: Resources Agency, California Department of Fish and Game.

[6] Fitzhugh, E. L. (1988). Ponderosa pine. In K. E. Mayer & J. Laudenslayer (Eds.), *A Guide to Wildlife Habitats of California*. Sacramento, CA: Resources Agency, California Department of Fish and Game. Retrieved from http://www.dfg.ca.gov/biogeodata/cwhr/wildlife_habitats.asp

[7] Adams, H. D., & Kolb, T. E. (2005). Tree growth response to drought and temperature in a mountain landscape in northern Arizona, USA. *Journal of Biogeography*, *32*(9), 1629–1640.

[8] Peterson, D. L., Silsbee, D. G., Poth, M. A., Arbaugh, M. J., & Biles, F. E. (1995). Growth response of bigcone Douglas fir (Pseudotsuga macrocarpa) to long-term ozone exposure in southern California. *Journal of the Air & Waste Management Association*, *45*(1), 36–45.

[9] Fischer, D. T., Still, C. J., & Williams, A. P. (2008). Significance of summer fog and overcast for drought stress and ecological functioning of coastal California endemic plant species. *Journal of Biogeography*, *36*(4), 783–799.

[10] Chmura, D. J., Anderson, P. D., Howe, G. T., Harrington, C. A., Halofsky, J. E., Peterson, D. L., … St. Clair, J. B. (2011). Forest responses to climate change in the northwestern United States: Ecophysiological foundations for adaptive management. *Forest Ecology and Management*, *261*(7), 1121–1142.

[11] Bailey, J. D., & Covington, W. W. (2002). Evaluating ponderosa pine regeneration rates following ecological restoration treatments in northern Arizona, USA. *Forest Ecology and Management*, *155*(1-3), 271–278.

[12] Royce, E. B., & Barbour, M. G. (2001). Mediterranean climate effects. II. Conifer growth phenology across a Sierra Nevada ecotone. *American Journal of Botany*, *88*(5), 919–932.

[13] Fritts, H. C. (1974). Relationships of ring widths in arid-site conifers to variations in monthly temperature and precipitation. *Ecological Monographs*, *44*(4), 411–440.

[14] McKenzie, D., Hessl, A. E., & Peterson, D. L. (2001). Recent growth of conifer species of western North America: Assessing spatial patterns of radial growth trends. *Canadian Journal of Forest Research*, *31*, 526–538.

[15] Franco-Vizcaino, E., Escoto-Rodriguez, M., Sosa-Ramirez, J., & Minnich, R. A. (2002). Water balance at the southern limit of the Californian mixed-conifer forest and implications for extreme-deficit watersheds. *Arid Land Research and Management*, *16*, 133–147.

[16] Stephenson, J. R., & Calcarone, G. M. (1999). *Southern California mountains and foothills assessment: Habitat and species conservation issues* (p. 402). Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

[17] Sheffield, J., Goteti, G., Wen, F., & Wood, E. F. (2004). A simulated soil moisture based drought analysis for the United States. *Journal of Geophysical Research*, *109*, D24108.

[18] Stewart, I. T., Cayan, D. R., Dettinger, M. D., Jolla, L., Survey, U. S. G., Jolla, L., … Jolla, L. (2005). Changes toward earlier streamflow timing across western North America. *Journal of Climate*, *18*(8), 1136–1155.

[19] Steel, Z. L., Safford, H. D., & Viers, J. H. (2015). The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere*, *6*(1), 8.

[20] Goforth, B. R. (2009). *Effects of extreme drought and megafires on sky island conifer forests of the Peninsular Ranges, southern California*. Retrieved from http://escholarship.org/uc/item/3r83g614

[21] Keeley, J. E., & Syphard, A. D. (2015). Different fire–climate relationships on forested and non-forested landscapes in the Sierra Nevada ecoregion. *International Journal of Wildland Fire*, *24*, 27–36.

[22] Westerling, A. L., Bryant, B. P., Preisler, H. K., Holmes, T. P., Hidalgo, H. G., Das, T., & Shrestha, S. R. (2011). Climate change and growth scenarios for California wildfire. *Climatic Change*, *109*(S1), 445–463.

[23] Franklin, J., Spears-Lebrun, L. A., Deutschman, D. H., & Marsden, K. (2006). Impact of a high-intensity fire on mixed evergreen and mixed conifer forests in the Peninsular Ranges of southern California, USA. *Forest Ecology and Management*, *235*, 18–29.

[24] Weatherspoon, C. P., Husari, S. J., & van Wagtendonk, J. W. (1992). Fire and fuels management in relation to owl habitat in forests of the Sierra Nevada and southern California Sierran mixed-conifer. In J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutierrez, G. I. J. Gould, & T. W. Beck (Eds.), *The California spotted owl: A technical assessment of its current status* (pp. 247–260). Albany, CA: Gen. Tech. Rep. PSW-GTR-133. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

[25] Enright, N. J., Fontaine, J. B., Bowman, D. M. J. S., Bradstock, R. A., & Williams, R. J. (2015). Interval squeeze: Altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes. *Frontiers in Ecology and the Environment*, *13*(5), 265–272.

[26] Bentz, B. J., Regniere, J., Fettig, C. J., Hansen, E. M., Hayes, J. L., Hicke, J. A., … Seybold, S. J. (2010). Climate change and bark beetles of the western United States and Canada: Direct and indirect effects. *BioScience*, *60*(8), 602–613.

[27] Briggs, J. S., Hawbaker, T. J., & Vandendriesche, D. (2015). Resilience of ponderosa and lodgepole pine forests to mountain pine beetle disturbance and limited regeneration. *Forest Science*, *61*(4), 689–702.

[28] van Mantgem, P. J., & Stephenson, N. L. (2007). Apparent climatically induced increase of tree mortality rates in a temperate forest. *Ecology Letters*, *10*, 909–916.

[29] Keeley, J. E. (2004). Impact of antecedent climate on fire regimes in coastal California. *International Journal of Wildland Fire*, *13*, 173–182.

[30] Keeley, J. E., & Zedler, P. H. (2009). Large, high-intensity fire events in southern California shrublands: Debunking the fine-grain age patch model. *Ecological Applications*, *19*(1), 69–94.

[31] Thorne, J. H., Boynton, R. M., Flint, L. E., & Flint, A. L. (2015). The magnitude and spatial patterns of historical and future hydrologic change in California' s watersheds. *Ecosphere*, *6*(2), 1–30.

[32] Kelly, A. E., & Goulden, M. L. (2008). Rapid shifts in plant distribution with recent climate change. *Proceedings of the National Academy of Sciences*, *105*(33), 11823–11826.

[33] Friggens, M. M., Warwell, M. V., Chambers, J. C., & Kitchen, S. G. (2012). Modeling and predicting vegetation response of western USA grasslands, shrublands, and deserts to climate change. In *Climate change in grasslands, shrublands, and deserts of the interior American West: A review and needs assessment* (pp. 1–20). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[34] Flint, L. E., Flint, A. L., Thorne, J. H., & Boynton, R. (2013). Fine-scale hydrologic modeling for regional landscape applications: The California Basin Characterization Model development and performance. *Ecological Processes*, *2*, 25.

[35] Ledig, F. T., & Conkle, M. T. (1983). Gene diversity and genetic structure in a narrow endemic, Torrey pine (Pinus torreyana Parry ex Carr.). *Evolution*, *37*(1), 79–85.

[36] Claridge, A. W., Trappe, J. M., & Hansen, K. (2009). Do fungi have a role as soil stabilizers and remediators after forest fire? *Forest Ecology and Management*, *257*(3), 1063–1069.

[37] Mohan, J. E., Cowden, C. C., Baas, P., Dawadi, A., Frankson, P. T., Helmick, K., … Witt, C. A. (2014). Mycorrhizal fungi mediation of terrestrial ecosystem responses to global change: Mini-review. *Fungal Ecology*, *10*(1), 3–19.