Coastal Redwood Forest

Climate Change Vulnerability Assessment for the Santa Cruz Mountains Climate Adaptation Project

This document represents an initial evaluation of mid-century climate change vulnerability for coastal redwood forest in the Santa Cruz Mountains region based on expert input during an October 2019 vulnerability assessment workshop as well as information in the scientific literature.

Habitat Description

Coastal redwood forests in the Santa Cruz Mountains region are near the southern edge of their distribution, which extends northward into southern Oregon and inland to the edge of the coastal fog zone[1,2]. For the purposes of this assessment, coastal redwood forests are defined as areas where at least 30% of the relative canopy cover is comprised of coast redwood (*Sequoia sempervirens*)[3]. Douglas-fir (*Pseudotsuga menziesii*) and tanoak (*Notholithocarpus densiflorus)* are the most common associates in the region, but a variety of other conifers and hardwoods can also occur[4,5]. Understory vegetation is comprised of species adapted to cool, moist microclimates and low light[1,5,6]. Forest structure and composition in second-growth stands varies depending on site conditions, logging practices, and time since disturbance, but these forests are generally denser and skewed towards younger age classes[2].

Vulnerability Ranking

Moderate Vulnerability

Mod Confidence

Coastal redwood forests are sensitive to climate stressors that increase water stress, which affects plant growth and survival. Altered fire regimes may additionally drive shifts in species composition and forest structure, particularly within the understory and sub-canopy. Non-climate stressors may exacerbate the impacts of changes in climate factors and disturbance regimes; for instance, fire exclusion and suppression can increase forest vulnerability to large, intense wildfires.

Because coastal redwood forests within the study area are located on a peninsula that restricts gradual shifts in distribution, they are more likely to contract than to shift under changing climate conditions. Redwood forests are able to recover rapidly from disturbance, and redwood, in particular, has a competitive advantage over other species due to its greater fire resistance, prolific sprouting, and rapid growth. However, long-lived species such as redwoods are also slow to adapt to environmental changes. Management actions such as conserving existing old-growth coastal redwood forests as well as biologically-significant second-growth forests that connect existing intact forest patches and restoring degraded second-growth forests (e.g., through thinning for fuel reduction or release from competition) may help increase resilience of this habitat to future climate changes.

As part of this project, Pepperwood Preserve modeled how major vegetation types in five landscape units of the Santa Cruz Mountains region are projected to shift in response to climate change.[1] They found that redwood forests are likely to decline in the three landscape units where they most commonly occur.

Vegetation Type	San Francisco	Santa Clara Valley	Santa Cruz Mtns. North	Santa Cruz	Sierra Azul
Redwood forest	—	—	▽	▽	▽

Table 1. Projected trends in vegetation distribution (increase, relatively stable, moderate decline, or dramatic decline) by mid-century within five landscape units of the Santa Cruz Mountains region.

Sensitivity and Exposure

Moderate Impact

Mod Confidence

Sensitivity is a measure of whether and how a habitat is likely to be affected by a given change in climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors. **Exposure** is a measure of how much change in these factors a resource is likely to experience.

Sensitivity and future exposure to climate and climate-driven factors

Coastal redwood forests are sensitive to climate stressors that increase water stress, which affects plant growth and survival.

Climate Stressor	Trend Direction	Projected Future Changes
Precipitation	▲▼	• Shorter winters and longer, drier summers likely, with higher interannual variability[7,8]
Coastal fog	▼	• Possible 12–20% decline in the frequency of days with coastal fog and low clouds[9]
Soil moisture	▼	• Reduced soil moisture likely due to increased evaporative demand[7,10]
Drought	▲	• Increased frequency of drought years, including periods of prolonged and/or severe drought[7,11]
Air temperature	▲	• 1.5–3.1°C (2.7–5.6°F) increase in annual mean temperature[12,13]

[1] Information about the methods used to generate these projections can be found on the project page (http://ecoadapt.org/programs/awareness-to-action/santa-cruz-mountains).

- **Changes in patterns of precipitation and coastal fog, reduced soil moisture, and increases in the severity and length of future droughts** are likely to enhance moisture stress[14–16], reducing redwood growth and seedling recruitment[1,17,18] and potentially driving range contractions over time[16,19,20]. This is particularly likely for redwood forests in the Santa Cruz Mountains region, which already experience higher moisture stress and lower growth and productivity compared to more northern sites[1,5,18]. Because understory plant communities are comprised of species that are highly dependent on fog to provide growing season moisture, changes in the frequency of foggy days have the potential to alter understory species composition[14].

  Forests that have experienced historical timber harvest may also be more vulnerable to climate-driven changes in moisture regimes, as the removal of large redwoods alters the hydrological balance and forest microclimate, reducing the ability of the ecosystem to capture fog water and creating more xeric site conditions[6,14].

- **Warmer air temperatures** are likely to increase evaporative demand within coastal redwood forests, enhancing water stress[19]. Redwood growth has been negatively correlated with high spring or summer maximum temperatures in the drier southern portion of their range[18,21], and these patterns suggest possible growth reductions may occur under future climate conditions.

Sensitivity and future exposure to climate-driven changes in disturbance regimes

Wildfire is the key disturbance regime in coastal redwood forests within the Santa Cruz Mountains region, where altered fire regimes may drive shifts in species composition and forest structure.

Disturbance Regimes	Trend Direction	Projected Future Changes
Wildfire	▲	• Slight to moderate increase in wildfire risk, particularly in areas of higher rainfall[12,13]

- Because mature redwoods have thick bark that protects them from injury or mortality during all but the most intense fires[17,22,23], climate-driven changes in **wildfire regimes** are primarily likely to alter forest composition and structure within the sub-canopy and understory layers[22]. The risk of uncharacteristically severe fires is enhanced in young second-growth stands, where shrubs and small-diameter trees increase the availability and continuity of fuel[24]. Young stands also have more litter on the ground and a drier microclimate compared to older forests[1,24]. These conditions may interact with climate stressors to modify future fire regimes; for instance, drier conditions could also enhance the risk of intense crown fires, resulting in uncharacteristically severe fires that may be capable of injuring or killing larger redwoods[24]. Additionally, the presence of sudden oak death within a stand appears to increase post-fire mortality in both redwood and tanoak, especially in the middle stages of disease progression[25].

Sensitivity and current exposure to non-climate stressors

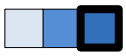
Fire exclusion and suppression are the primary non-climate stressors for coastal redwood forests within the Santa Cruz Mountains region, though a number of others may also impact the habitat to a lesser degree (e.g., land-use conversion to development or agriculture, invasive species, timber harvest, roads).

- **Fire exclusion and suppression** has altered historical disturbance regimes in coastal redwood forests, significantly increasing fire return intervals within the Santa Cruz Mountains region over

the past 150 years[26–28]. These changes have contributed to shifts in fuel structure and increased fuel loading, increasing the risk of more intense fires in the future[17]. Second-growth forests are particularly vulnerable to intense fires due to increased tree and understory density[2,17].

Adaptive Capacity

Moderate Adaptive Capacity



High Confidence

Adaptive capacity is the ability of a habitat to accommodate or cope with climate change impacts with minimal disruption.

Habitat extent, integrity, continuity, and barriers to dispersal

Timber harvesting has significantly reduced the extent of old-growth forest areas and altered the composition and structure in logged areas[29–32]. Within the Santa Cruz Mountains region, less than 10,000 acres of old-growth forest remains, and significant declines in connectivity have occurred among remaining old-growth patches[33]. Second-growth forests are more continuous and cover over 30,000 acres within the region, but the majority of these are young or intermediately-aged forests with low integrity and spatial complexity[2,29,31].

Because coastal redwood forests within the study area are located on a peninsula that restricts gradual shifts in distribution, they are more likely to contract than to shift under changing climate conditions[34]. Other barriers to habitat continuity and dispersal include roads and land-use conversion to agriculture and development. Within the Santa Cruz Mountains region, refugia may occur in wet areas, riparian corridors, and north-facing slopes[34].

Habitat diversity

Coast redwood is the keystone species within this forest type, dominating the canopy due to its great height and longevity[1,5,17,35] and creating microclimates that support understory species adapted to the cool, moist conditions maintained under closed canopies[6]. Compared to many other northern California forest types, coastal redwood forests host relatively low species richness[36] and a significant portion of the species diversity in this forest type is harbored within the forest canopy[6]. Old-growth forests support high spatial and structural complexity in tree stems and crowns[5,37], which is created by small-scale disturbances that damage trees and stimulate trunk iterations[32]. Redwood forests, and in particular old-growth forests, are likely vital to the persistence of many species dependent on specific characteristics (e.g., snags, downed logs, complex crown structure) and/or specialized habitat niches[6,36].

Resistance and recovery

Redwood forests are able to recover rapidly from disturbance because both redwood and tanoak can resprout following injury or topkill[17,22,23]. Redwood, in particular, has a competitive advantage over other species due to its greater fire resistance, prolific sprouting, and rapid growth[22,30,31]. These factors have contributed to the persistence of this forest type under relatively stable conditions for millennia, suggesting that coastal redwood forests may respond more slowly to climate changes than many other forest types[17,20,31]. However, long-lived species such as redwoods are also slow to adapt to

environmental changes, and the low rates of sexual reproduction in this species further reduce opportunities for species migration and/or genetic shifts towards more adaptive traits[20,31].

Management potential

Support for management of coastal redwood forests is high due to their significant public and societal value, which is recognized worldwide[2,38]. Coast redwoods are considered an iconic species of California, although they receive no formal federal or state protections[2,6]. However, coastal redwood forests have received significant attention from the public, scientists, conservationists, and the forest industry[6,38]. Additionally, the work of the Sempervirens Fund and the Save the Redwoods League have focused conservation efforts, and many old-growth forests are now protected within parks, experimental forests, and private reserves[2,6].

Management of late-seral coastal redwood forests in the Santa Cruz Mountains region is challenging, largely because it tends to be costly and difficult to scale up to the level that would be necessary to reduce climate impacts[34]. However, conserving existing old-growth coastal redwood forests is vital because old-growth forests are more resistant to changing climate conditions and disturbance regimes, including fire, drought, insects, and disease[6,31]. Protecting forests in areas where projected climate conditions are expected to remain within or close to the suitable range for coast redwood would provide refugia and increase connectivity for many rare and/or endemic species threatened by climate change[39]. Protection efforts could also consider biologically-significant second-growth forests that represent the natural range of variability within this habitat type, particularly those that connect existing intact forest patches[40]. In degraded second-growth forests, the scientific literature supports several management strategies that may enhance or restore ecosystem functioning, accelerate the development of old-growth forest characteristics, and increase resilience to future climate changes[39,41]. These include variable-density thinning[30,42], strategic crown injury to increase structural complexity[32], and reintroduction of low- to moderate-intensity fire through prescribed burns[4,41].

Recommended Citation

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Further information on the Santa Cruz Mountains Climate Adaptation Project is available on the project page (http://ecoadapt.org/programs/awareness-to-action/santa-cruz-mountains).

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