Southern California Chaparral Habitats

Climate Change Vulnerability Assessment Synthesis

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for chaparral 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.*


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Executive Summary

Chaparral ecosystems in southern California occur in coastal, inland, and montane areas, harbor high floristic diversity, and provide critical habitat for a variety of wildlife species (Stephenson and Calcarone 1999; USDA Forest Service 2009). Dominant chaparral species can be categorized by mode of regeneration following fire: seedling recruitment, resprouting, or a combination of both strategies, termed facultative seeding. Obligate seeders accumulate seed stores that require fire for germination. Obligate resprouters recruit from seed during fire-free intervals, but seeds are killed by fire, requiring these plants to resprout from underground root structures or burls following burns (Keeley 1991; Keeley et al. 2005a; Ramirez et al. 2012). Facultative seeders utilize both vegetative resprouting and seed germination following fire-induced topkill; although their seeds largely germinate after fire, they have been documented to germinate in the absence of fire as well (Keeley 1991; Ramirez et al. 2012).

The relative vulnerability of chaparral habitats in southern California was evaluated to be low-moderate[1,2] by habitat experts due to low-moderate sensitivity to climate and non-climate stressors, low-moderate exposure to projected future climate changes, and moderate adaptive capacity.

Sensitivity and Exposure	<u>Climate sensitivities</u>: Drought <u>Disturbance regimes</u>: Wildfire <u>Non-climate sensitivities</u>: Invasive & problematic species, land-use conversion

Drought is the key climate driver affecting chaparral habitats. Chaparral species are adapted to seasonal drought, but prolonged and/or more frequent drought or shifts in the onset of seasonal drought may contribute to plant dieback, shrub mortality, and/or altered community

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[1] Confidence: High

[2] Vulnerability assessments are designed to be living documents, and as more information becomes available, this and other vulnerability rankings may change. This score reflects the opinions of habitat experts at the time of document publication, although literary evidence suggests that the overall vulnerability of chaparral habitats in southern California may be higher.

composition, including increased dead fine fuel load that may increase large fire events in the future by increasing the frequency of firebrands and spot fires. Many chaparral species are fire-adapted, but more frequent fires driven by increased human ignitions and drought can inhibit chaparral regeneration and facilitate conversion to non-native grasslands or degraded shrublands with reduced biodiversity. Invasive and problematic species perpetuate shifting fire regimes and compete with native vegetation for limited resources, while land-use conversion contributes to habitat fragmentation and altered ecological processes (e.g., fire, invasive species spread).

Adaptive Capacity

Habitat extent, integrity, and continuity: Moderate-high geographic extent, low-moderate integrity (partially degraded in localized areas), moderate-high continuity
Resistance and recovery: Low-moderate resistance, moderate recovery potential
Habitat diversity: Moderate-high overall diversity
Management potential: Moderate societal value and management potential

Chaparral habitats have experienced significant fragmentation. Current and future habitat continuity and extent are threatened by development, land-use conversion, and a variety of other landscape barriers such as transportation corridors, agriculture, grazing, and fuel clearance/vegetation treatments. Interacting climate and non-climate stressors may reduce the inherent resiliency of chaparral habitats, but moderate diversity may bolster habitat adaptive capacity in the face of climate change. Chaparral habitats provide a variety of ecosystem services (e.g., biodiversity, recreation, water supply/quality, sediment transport, carbon sequestration). Potential management options identified by habitat experts largely deal with mitigating non-climate stressors (e.g., invasive species, development).

Sensitivity

The overall sensitivity of chaparral habitats to climate and non-climate stressors was evaluated to be low-moderate by habitat experts.[3]

Sensitivity to climate and climate-driven changes

Habitat experts evaluated chaparral habitats to have low-moderate sensitivity to climate and climate-driven changes,[4] including: drought.[5] Habitat experts also identified that soil moisture, precipitation, and extreme temperature events (high and low temperatures) may affect this habitat, but to a lesser degree than drought.

Drought

Chaparral ecosystems typically experience hot, dry summers with extended rainless periods (May through September; Minnich 2007) and mild, wet winters (Keeley and Davis 2007). Consequently, chaparral systems feature semi-arid shrub-dominated assemblages of

[3] Confidence: High
[4] Confidence: High
[5] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

sclerophyllous (i.e. hard-leaved) plants with adaptations to counter seasonal drought, such as waxed leaf coatings, thick cell layers, and recessed stomata to reduce evaporative moisture loss (Keeley and Davis 2007). Some species (e.g., chamise, *Adenostoma fasciculatum*) also alter leaf production, maintenance, and structure in response to changing moisture conditions (Narog 1993, 2008). Chaparral species typically go through a transition period between wet and dry seasons, making changes such as hardening xylem in order to survive dry seasonal conditions (Jacobsen et al. 2014).

Chaparral species exhibit different mechanisms and capacity to deal with moisture stress (Jacobsen et al. 2007; Pratt et al. 2007, 2008; Ramirez et al. 2012). Obligate seeders are typically associated with drier areas and have higher cavitation resistance (i.e. resistance of xylem to collapse), enabling survival during high levels of water stress (Jacobsen et al. 2014, 2007). Obligate resprouters are associated with more mesic areas (Ramirez et al. 2012) and typically have deeper root systems, allowing enhanced access to water during drought periods (Burk 1978; Meentemeyer and Moody 2002; Thomas and Davis 1989).

Although chaparral is a drought-adapted community, severe and/or prolonged drought can lead to significant chaparral dieback and mortality (Paddock et al. 2013). Cavitation resistance does not necessarily confer plant resistance to severe or extended drought; several studies have documented higher mortality and dieback of obligate-seeding species compared to obligate-resprouting species in response to severe drought conditions (Jacobsen et al. 2007; Paddock et al. 2013). For example, in a study conducted in a chaparral-desert ecotone in Riverside County, an extended five-year drought period followed by a severe drought in 2002-03 led to significant mortality and dieback of several mature obligate-seeding chaparral species, as well as amongst mature shallow-rooted sprouting species (Paddock et al. 2013). Early-season drought and drought occurring in areas that are typically more mesic may be particularly threatening for chaparral communities (Jacobsen et al. 2014). In a study conducted in the Santa Ana and San Gabriel Mountains, Jacobsen et al. (2014) found that in relatively mesic areas within the study area (e.g., San Gabriel Mountains), as well as in most chaparral communities at the tail-end of the wet season, cavitation resistance is typically lower, making chaparral species vulnerable to hydraulic failure when exposed to moisture stress.

Severe drought, such as is currently occurring in southern California, can also drive shifts in community composition (Paddock et al. 2013; Pratt et al. 2014; Ramirez et al. 2012). Recent research in the Santa Monica Mountains indicates that hot soil conditions (>70°C), thought to be linked with drought-induced canopy dieback and mature plant mortality, have stimulated germination of three different seeding *Ceanothus* spp., which were previously known to germinate only after experiencing heat cues associated with fire. Depending on seedling survival rates (likely correlated with rooting depth) this novel seed germination could either reduce seedbanks via seedling establishment failure or offset drought-induced losses of adult vegetation (Burns 2014).

Drought conditions can also increase fire risk (Keeley and Zedler 2009) and impair chaparral recovery post-fire (Keeley et al. 2012; Pratt et al. 2014). Contrary to previous studies of post-fire chaparral recovery, Pratt et al. (2014) found that drought caused significant mortality of shrubs that had re-sprouted post-fire in a study site in Los Angeles County. Mortality was linked with highly embolized resprout stems and minimal hydraulic conductivity during the drought period, as well as with depleted starch in lignotubers. Compared to the higher drought sensitivity of mature plants, obligate-seeder seedlings (particularly those species that are highly tolerant of water stress) may fare better than resprouting species in post-fire environments plagued by drought (Pratt et al. 2014).

<u>Temperature, precipitation, and soil moisture</u>

Community composition of chaparral types is strongly determined by latitude, elevation, winter temperatures, soil moisture, and precipitation (Keeley and Davis 2007; Ramirez et al. 2012). For example, soil moisture is a strong determinant of community composition, and chaparral can become established across a range of conditions, from arid locations such as ridges and south-facing slopes to mesic locations on north-facing aspects (Keeley and Davis 2007). In general, increasing precipitation contributes to higher chaparral species richness and facilitates chaparral regeneration (Keeley et al. 1981), and obligate seeders may be able to respond most quickly to increasing precipitation (Burk 1978). However, increased precipitation and resultant non-native herbaceous growth may also increase fire risk in subsequent years (Keeley and Syphard 2015).

In general, chaparral-dominated habitats experience average January temperatures that range between 5-15°C (Keeley and Davis 2007), but winter freeze events are a strong selective force for chaparral community assemblages, making minimum winter temperature an important climatic characteristic for chaparral species (Davis et al. 2007; Keeley and Davis 2007). Inland chaparral species are generally more tolerant of cold temperatures, as significant temperature gradients exist from coastal to inland locations and from mountaintops to valley bottoms (i.e. thermal inversions; Davis et al. 2007). Notably, freeze events co-occurring with drought can cause persistent xylem embolisms, leading to freezing injury and/or plant dieback (Davis et al. 2007; Ewers et al. 2003).

Sensitivity to disturbance regimes

Habitat experts evaluated chaparral systems to have low sensitivity to disturbance regimes,[6] including: wildfire.[7]

<u>Wildfire</u>

Fire is a dominant driver of vegetation dynamics in chaparral ecosystems, resetting succession and increasing biodiversity (Keeley et al. 2005a). Chaparral species feature diverse regeneration mechanisms (e.g., obligate seeding, obligate resprouting, facultative seeding) that allow them to survive burns and/or recover post-fire (Keeley et al. 2005a; Ramirez et al. 2012). Recovery after fire is typically rapid; obligate-seeding species, which depend on fire for germination,

[6] Confidence: High

[7] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

quickly reestablish across the burned landscape (Keeley and Davis 2007; Pratt et al. 2014, 2008) along with annual herbaceous species (Keeley et al. 2005b), followed by slower recruitment of obligate resprouters (Keeley et al. 2005a). However, post-fire recovery is also influenced by soil moisture, topography, and other factors (Lippitt et al. 2013; Narog 2008), contributing to variable recovery rates in different geographic locations (e.g., inland, coastal, montane areas; Vulnerability Assessment Reviewers, pers. comm., 2015).

Fires occurring in chaparral are almost always active crown fires, with intensity and spread influenced by wind, weather, living and dead canopy mass, past burn patterns, and topography (Keeley and Fotheringham 2001; Lombardo et al. 2009; Narog et al. 1994; Syphard and Keeley 2015). Fire spread is frequently exacerbated by Santa Ana wind events, which typically coincide with the end of seasonal drought periods in southern California chaparral systems (Keeley 1995; Keeley and Fotheringham 2001; Lombardo et al. 2009). Historical fire return intervals and burn patterns for chaparral are difficult to determine due to the stand-replacing nature of fire events in this ecological system, but estimates range from 30-130+ years (Keeley and Fotheringham 2001; Keeley et al. 2005a; Lombardo et al. 2009; Van de Water and Safford 2011) depending on location (e.g., coastal, inland, montane; Van de Water and Safford 2011).

Fire return intervals in chaparral systems have become shorter largely due to increased anthropogenic ignitions, as well as enhanced drought conditions (Keeley and Davis 2007; Keeley and Fotheringham 2001; Keeley et al. 1999; Keeley and Zedler 2009; Safford and Van de Water 2014; Syphard and Keeley 2015). More frequent fires typically undermine the ecological health of chaparral communities and inhibit regeneration, facilitating shifts in community structure and composition (Haidinger and Keeley 1993; Keeley 1995; Keeley and Brennan 2012; Keeley et al. 2011; Lippitt et al. 2013). For example, dominant obligate-seeding chaparral species such as *Ceanothus* spp. and *Arctostaphylos* spp. have been extirpated in some areas and are at risk for extirpation in other areas due to shortened fire intervals (<10 and <20 years, respectively), which limit their ability to accumulate an adequate seed bank for post-fire regeneration (Keeley and Davis 2007; see also Haidinger and Keeley 1993, Jacobsen et al. 2004, Keeley and Brennan 2012). After successive fires in 1979 and 1980 burned the same stand of chaparral on Otay Mountain near San Diego, researchers found that in areas where the burn sites overlapped, the previously dominant seeding shrub hairy ceanothus (*Ceanothus oliganthus*) was virtually eliminated and densities of the facultative-seeding chamise were reduced by up to 97% (Zedler et al. 1983). Similarly, obligate resprouters are also vulnerable to increasing fire frequency (Zedler et al. 1983; Haidinger and Keeley 1993). These species recruit during fire-free intervals (Pratt et al. 2008); increased fire frequency can kill recent resprouts (Haidinger and Keeley 1993), leading to reduced species abundance and diversity and altered community composition (Haidinger and Keeley 1993; Keeley and Brennan 2012).

Too frequent fire may also contribute to conversion to exotic grassland or degraded shrubland (Haidinger and Keeley 1993; Keeley 1995; Keeley and Brennan 2012; Keeley et al. 2011; Lippitt et al. 2013). Lippitt et al. (2013) found that short fire intervals of 5-10 years may result in chaparral conversion to degraded shrubland, and fire intervals of less than five years may lead to non-native forbs and grasses becoming the dominant vegetation type (see also Haidinger and Keeley 1993; Jacobsen et al. 2004; Keeley and Brennan 2012; Keeley et al. 2011). Exotic and invasive grasses and forbs often make up a significant portion of the post-fire vegetation assemblage, especially in areas with reduced post-fire establishment of native woody plants (Keeley and Davis 2007); these species are favored by, and perpetuate, more frequent fire return intervals, creating a positive feedback loop that increases likelihood of type conversions (Haidinger and Keeley 1993; Jacobsen et al. 2004; Keeley and Davis 2007; Keeley and Brennan 2012; Keeley et al. 2011; Syphard et al. 2007).

Unlike many other habitat types in southern California, effective fire suppression activities may benefit chaparral systems by preventing very short fire return intervals (Keeley et al. 1999). At the very least, fire suppression activities have not exacerbated shifting fire regimes in chaparral systems (Keeley et al. 1999, 2005a; Keeley and Zedler 2009; Mensing et al. 1999).

Sensitivity and current exposure to non-climate stressors

Habitat experts evaluated chaparral systems to have moderate sensitivity to non-climate stressors,[8] with an overall moderate-high exposure to these stressors within the study region.[9] The key non-climate stressor identified by habitat experts for chaparral systems was invasive and problematic species.[10] Habitat experts also identified land-use conversion as a critical non-climate stressor for chaparral habitats.[11] Habitat experts evaluated exposure to invasive species and land-use conversion to be fairly consistent across the study region.

<u>Invasive and problematic species</u>

The closed-canopy structure of chaparral habitats generally confers resistance to invasion, but shifts in disturbance regimes, particularly fire, can alter invasive species establishment and dominance (Keeley et al. 2011). The presence of invasive species can also exacerbate shifting fire regimes in chaparral habitats, and create competition for resources (Keeley and Brennan 2012; Keeley and Davis 2007; Keeley et al. 2011). Invasive species are often introduced to chaparral areas via transportation corridors (Vulnerability Assessment Reviewers, pers. comm., 2015), and nitrogen deposition may exacerbate invasive species establishment following disturbance that opens the chaparral canopy (Keeley et al. 2011, 2009). Annual species, including *Bromus* spp. and *Centaurea* spp., are common invaders (Keeley and Brennan 2012; Keeley et al. 2011), although the invasive perennial grass *Ehrharta calycina* is also affecting shrublands along the southern California coast (Roye 2004 cited in Keeley et al. 2011).

<u>Land-use conversion</u>

Shrublands in the California Floristic Province of southern California have sustained habitat loss and fragmentation to such an extent that they have been labeled as a global hotspot of concern (Wilson 1992 cited in Syphard et al. 2007). Substantial human population growth in the region has impacted shrubland ecosystems directly through habitat loss and fragmentation, limiting

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[8] Confidence: High

[9] Confidence: High

[10] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

[11] Not all habitat experts agreed on this non-climate stressor.

chaparral migration and dispersal in response to climate change, particularly since the vast majority of chaparral species have limited dispersal capability (Beltrán et al. 2014). Expanding low-density rural populations have also significantly altered ecological drivers (Beltrán et al. 2014; Keeley et al. 1999; Keeley and Zedler 2009; Syphard et al. 2007, 2009), increasing fire ignitions (Keeley and Fotheringham 2001; Keeley and Syphard 2015; Keeley and Zedler 2009; Lombardo et al. 2009; Syphard et al. 2007, 2009; Syphard and Keeley 2015) and human- and fire-mediated invasive species establishment (Keeley et al. 1999; Syphard et al. 2007). For example, intermediate levels of human population activity and development may be one of the greatest drivers of increased wildfire frequency and area burned in shrubland cover types (Syphard et al. 2007, 2009). Future development, particularly development that extends into previously isolated chaparral stands and that expands the wildland-urban interface, could have significant ecological impacts (Syphard et al. 2007, 2009, 2013). Future population growth and urban development are likely to interact with climate drivers to create spatially variable vulnerability amongst chaparral habitats and species (Bonebrake et al. 2014; Keeley and Syphard 2015; Syphard and Keeley 2015; Syphard et al. 2013).

Future Climate Exposure

Habitat experts evaluated chaparral systems to have low-moderate exposure to future climate and climate-driven changes[12], and key climate variables to consider include: precipitation changes, increased wildfire, and increased drought (Table 1).[13] For a detailed overview of how these factors are projected to change in the future, please see the Southern California Climate Overview (http://ecoadapt.org/programs/adaptation-consultations/socal). Potential chaparral refugia areas from changing climate conditions may include canyons, north-facing slopes, more mesic areas, heterogeneously complex areas, areas with deeper soils, and/or areas isolated from human ignitions and exotic species (Vulnerability Assessment Reviewers, pers. comm., 2015).

Table 1. Anticipated chaparral responses to climate and climate-driven changes.

Climate and climate-driven changes	Anticipated chaparral habitat response
Air temperature and precipitation *+2.5 to +9°C by 2100; variable annual precipitation volume and timing, with wetter winters and drier summers; increased climatic water deficit*	• Shifts in community composition • Altered phenological timing • Potential shifts in chaparral range; declines in overall habitat area likely • Years with higher precipitation: increased species richness, regeneration, and non-native herbaceous growth (which may increase fire risk in subsequent years)

[12] Confidence: High

[13] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

Climate and climate-driven changes	Anticipated chaparral habitat response
Drought *Longer, more severe droughts with drought years twice as likely to occur*	• Increased shrub mortality and dieback; mature obligate-seeding species and shallow-rooted sprouting species may be particularly vulnerable • Shifts in community composition and potential novel germination patterns via canopy dieback • Potential range shifts • Elevated fire risk by expanding length of peak ignition season • Increased mortality of re-sprouting individuals post-fire
Wildfire *Increased fire size, frequency, and severity*	• Reduced species diversity • Shifts in community composition due to inhibited recruitment (e.g., obligate seeders unable to accumulate seedbank; obligate resprouters experience high resprout mortality) • Potential conversion to degraded shrubland and/or non-native grassland and herbaceous plant communities, resulting in chaparral habitat fragmentation and loss • Increased invasive species establishment

Air temperature and precipitation

Shifts in temperature and precipitation may affect chaparral phenology (Willis et al. 2013) and/or chaparral distribution (Beltrán et al. 2014; Lenihan et al. 2008), although sensitivity likely varies by species (Beltrán et al. 2014; Syphard et al. 2013) and not all range shifts can be attributed to temperature and precipitation drivers (Schwilk and Keeley 2012). Shifting precipitation regimes are also likely to affect future fire activity by influencing relative abundance of non-native herbaceous vegetation (Keeley and Syphard 2015).

Increased monsoonal activity in the study region could result in different chaparral responses than identified in this assessment. However, predictions of monsoon activity in North America are highly uncertain, as the models driving these predictions are not well developed (e.g., El Niño; Bukovsky et al. 2015), and temperature differentials between the ocean and land may alter seasonal precipitation patterns (Torres-Alavez et al. 2014).

Drought

Increasing drought frequency and severity could lead to chaparral range shifts and/or altered community composition, including reduced abundance and/or elimination of shallow-rooting and seeding chaparral species, particularly in drier ecotones (Paddock et al. 2013). Shifts in drought onset to earlier in the season may also further expand the seasonality of frequent ignitions (Syphard et al. 2013; Pratt et al. 2014), and persistent drought conditions in post-fire landscapes may contribute to the post-fire mortality of resprouting shrubs (Pratt et al. 2014). In addition, drought combined with urban encroachment may lower water tables enough to impact chaparral species even in identified refugia (e.g., north-facing slopes; Vulnerability Assessment Reviewers, pers. comm., 2015).

Wildfire
Chaparral ecosystems are sensitive to shortened fire return intervals, and it is likely that fire will continue to occur at short intervals in southern California as a result of increasingly dry conditions and increased anthropogenic ignitions from expanding population centers and rural communities (Lippitt et al. 2013). The interaction of fire frequency, land-use changes, and population growth may impact chaparral communities at various spatial scales (Bonebrake et al. 2014; Syphard et al. 2007, 2013; Syphard and Keeley 2015), as well as interact with shifts in Santa Ana wind patterns to create variable fire risk (Miller and Schlegel 2006; Sawyer et al. 2014). Shifting fire regimes may contribute to a higher rate of chaparral conversion to degraded shrubland or grass-dominated vegetation types, increasing chaparral fragmentation and reducing habitat extent (Lenihan et al. 2008; Lippitt et al. 2013).

Habitat and species distribution
Lenihan et al. (2008) estimate that shrublands will experience range contractions in southern California by the end of the century under all future climate scenarios, largely due to grassland expansion. Beltrán et al. (2014) also project declining habitat area for several chaparral species by late century (2080) as a result of warmer and drier conditions, as well as significant shifts in core habitat location (10 km or more). Beltrán et al. (2014) project that obligate-seeding species, particularly those that currently have small ranges, will experience larger contractions in climatically suitable habitat than obligate-resprouting species by late century (2080) as a result of climate change.

Species distribution modeling by Principe et al. (2013), which utilized 11 downscaled A2 emissions scenario climate projections, indicates that the majority of modeled species associated with chaparral habitats (e.g., *Ceanothus* spp., *Arctostaphylos* spp., scrub oak [*Quercus berberidifolia*]) will maintain 50% or more of their current distribution by mid-century (2045-2065) in southern California. The exception to this trend is chamise, which Principe et al. (2013) project to experience an 82% reduction in suitable habitat area relative to current distribution during the same time period.

Adaptive Capacity

The overall adaptive capacity of chaparral systems was evaluated to be moderate by habitat experts.[14]

Habitat extent, integrity, continuity and landscape permeability
Habitat experts evaluated chaparral habitats to have a moderate-high geographic extent (i.e., habitat occurs across state[s]),[15] low-moderate integrity (i.e., habitat is partially degraded),[16] and feature moderate-high continuity (i.e., habitat is fairly continuous with some breaks).[17]

[14] Confidence: High
[15] Confidence: High
[16] Confidence: High
[17] Confidence: High

Habitat experts identified land-use conversion, agriculture, grazing, transportation corridors, and fuel clearance/vegetation treatments as barriers to habitat continuity and dispersal for this ecosystem type.[18,19] These landscape barriers have become increasingly common, particularly near human communities, and may additionally facilitate invasive species establishment in chaparral habitats (Vulnerability Assessment Reviewers, pers. comm., 2015).

In coast-facing lower montane and foothill areas in southern California, chaparral is a dominant ecological community, along with coastal sage scrub. Chaparral systems cover a broad elevation gradient, ranging from sea level to roughly 1,524 m (5,000 ft) near the coast (Stephenson and Calcarone 1999). Chaparral communities in interior and montane regions can also occur from mid- to high elevations (Estes 2013; USDA Forest Service 2009). Chaparral systems are typically bound by grassland or scrub communities at lower elevations, and grade into woodlands and forests at higher elevations. Different chaparral associations also grade into each other across the landscape (USDA Forest Service 2009).

Chaparral systems occur on both public and private lands throughout the study region (Stephenson and Calcarone 1999), but habitat connectivity and integrity is impacted by extensive development, human population growth, and associated infrastructure in the region (California Partners in Flight 2004; Spencer et al. 2010). Impacts to habitat integrity are most prevalent at the wildland-urban interface (Syphard et al. 2007, 2009). However, chaparral and other scrub systems have also experienced high levels of collaborative conservation planning to address these continued stressors (California Partners in Flight 2004; Spencer et al. 2010).

Resistance and recovery

Habitat experts evaluated chaparral habitats to have low-moderate resistance to climate stressors and maladaptive human responses,[20] and moderate recovery potential.[21] Chaparral is fairly resistant to climate stressors; disturbance-adapted vegetation allows recovery from most events given sufficient time, with the exception of intense drought and too-frequent fire (Keeley and Brennan 2012). However, interacting stressors across the southern California landscape are likely to affect the resistance and recovery potential of chaparral habitats, ultimately affecting the persistence and distribution of this system (Syphard et al. 2013). Many chaparral species are slow-growing and have limited dispersal potential (Keeley 1991), which may undermine their resilience to climate change impacts and highlights the need to conserve these species where they currently exist (Vulnerability Assessment Reviewers, pers. comm., 2015).

[18] Barriers presented are those ranked most critical by habitat experts. A full list of evaluated barriers can be found at the end of this document.
[19] Not all habitat experts agreed on the latter two barriers.
[20] Confidence: Moderate
[21] Confidence: Moderate

Habitat diversity

Habitat experts evaluated chaparral habitats to have moderate-high physical and topographical diversity,[22] high component species diversity,[23] and moderate functional group diversity.[24] Chaparral types and associations are incredibly diverse within and between coastal, inland, and montane areas in the southern California study area (Stephenson and Calcarone 1999). Chaparral types also differ significantly in species composition from site to site (Gordon and White 1994; Stephenson and Calcarone 1999), and from chaparral communities in central and northern California.

The USDA Forest Service CalVeg Manual identifies numerous specific chaparral alliances for the southern California mountains and coast region (see below for general geographic affiliations).[25] In general, chaparral species diversity is high, but functional group diversity is lower in California chaparral communities than inland chaparral communities (e.g., Arizona; Keeley et al. 2012). Throughout California, and particularly southern California, chaparral is one of the most ecologically important cover types, playing host to a large portion of California's endemic plant species and native fauna (Keeley and Davis 2007; Stephenson and Calcarone 1999), including keystone predators (e.g., coyotes, mountain lions, road runners, bobcats, and rattlesnakes) that provide critical ecosystem services (Vulnerability Assessment Reviewers, pers. comm., 2015).

<u>Coastal and maritime chaparral</u>[26]

The USDA Forest Service CalVeg Manual includes several coastal chaparral alliances in southern California, including: the chamise alliance, ceanothus chaparral alliance, and southern mixed chaparral alliance. Additionally, maritime chaparral is a unique community distinct from coastal chaparral.

- Chamise alliance: this alliance is widespread throughout California and the southern California study region, found in many coastal and foothill locations. Chamise is the dominant species and typically few other species are present, although chaparral yucca (*Hesperoyucca whipplei*) may occur on open sites. Chamise also appears as a non-dominant component in many of the other chaparral associations throughout the study area, but typically declines in abundance at higher elevations.
- Ceanothus chaparral alliance: this alliance is characterized by *Ceanothus* species dominance (dominant species depends on location), and occurs most frequently at low- and mid-elevations. A majority of this alliance's distribution is on private lands (Stephenson and Calcarone 1999).
- Southern mixed chaparral alliance: this alliance can host a variety of low-elevation chaparral and sage scrub species, but common indicator species are woollyleaf ceanothus (*Ceanothus tomentosus*) and mission manzanita (*Xylococcus bicolor*). This

[22] Confidence: High
[23] Confidence: High
[24] Confidence: High
[25] Geographic affiliations based on expert input.
[26] All information in this section was derived from USDA Forest Service (2009) unless otherwise noted.

alliance often also features minor amounts of chamise and scrub oak. Similar to the ceanothus alliance, a majority of this alliance's distribution is on private lands (Stephenson and Calcarone 1999).

- Maritime chaparral: maritime chaparral is a unique chaparral community found within 6-12 miles of the coast, appearing in scattered patches on sandy substrates and in flat or rolling terrain. This grouping harbors high endemism, and features rare endemic *Ceanothus* spp. and *Arctostaphylos* spp. that geographically replace each other along a northward transect, including La Purisima Manzanita (*Arctostaphylos purissima*), Sand Mesa Manzanita (*Arctostaphylos rudis*), Woolyleaf Manzanita (*Arctostaphylos tomentosa*), and Refugio Manzanita (*Arctostaphylos refugioensis*). Chamise may be a co- or sub-dominant (Keeley and Davis 2007).

Montane chaparral[26]

The USDA Forest Service CalVeg Manual includes two montane chaparral alliances in southern California: lower and upper montane mixed chaparral.

- Lower montane mixed chaparral alliance: this alliance can occur simultaneously with other alliances at low elevations and extend upward to 1,646 m (5,400 ft) along the coast and 2,440 m (8,000 ft) in the mountains. It features a diversity of species, including *Ceanothus* spp., manzanita species, scrub oak, canyon live oak (*Quercus chrysolepis*), chaparral yucca, toyon (*Heteromeles arbutifolia*), and others.
- Upper montane mixed chaparral alliance: this alliance generally exists above 1,280 m (4,200 ft) in mountainous portions of the study area, with highest abundance in the San Gabriel and San Gorgonio Mountains. It frequently exists in open areas amongst coniferous forest and woodlands, featuring species such as mountain whitethorn (*Ceanothus cordulatus*), deer-brush (*Ceanothus integerrimus*), bush chinquapin (*Chrysolepis sempervirens*), and several manzanita species.

Inland chaparral[26]

The USDA Forest Service CalVeg Manual includes two inland chaparral alliances: the redshank alliance and the semi-desert chaparral alliance.

- Redshank alliance: Redshank (*Adenostoma sparsifolium*) is typically found at least 50 miles from the coast, although there is one coastal population near the Santa Monica Mountains. This alliance may contain chamise and other drought-adapted species, such as birchleaf mountain mahogany (*Cercocarpus betuloides*).
- Semi-desert chaparral alliance: This alliance can be found on interior mountain slopes between 427-2,256 m (1,400-7,400 ft). As a transitional alliance, it features several common chaparral species such as chamise, birchleaf mountain mahogany, bigberry manzanita (*Arctostaphylos glauca*), and California buckwheat (*Eriogonum fasciculatum*), as well as desert or semi-desert perennial and shrub species.

In addition, the scrub oak alliance can be found throughout the study region on steep, mesic, north-facing slopes from near sea level to roughly 2,745 m (9,000 ft). This alliance is more common in mountainous and inland areas (Vulnerability Assessment Reviewers, pers. comm., 2015), and common species include scrub oak, shrub interior live oak (*Quercus wislizenii* var.

frutescens), canyon live oak (*Q. chrysolepis* var. *nana*), Alvord oak (*Q. x alvordiana*), Tucker or Muller oak (*Q. john-tuckeri*, *Q. cornelius-mulleri*), Brewer's oak (*Q. garryana* var. *breweri*), and leather oak (*Q. durata*) (USDA Forest Service 2009).

Management potential

Habitat experts evaluated chaparral habitats to be of moderate societal value.[27] Chaparral habitats are valued for recreation, watershed protection, environmental stability, slope stabilization, wildlife habitat, and aesthetics (Vulnerability Assessment Reviewers, pers. comm., 2015). However, chaparral systems are also often viewed by the public and media as a fire hazard for human development and/or other regional ecosystems (Vulnerability Assessment Reviewer, pers. comm., 2015). Chaparral habitats provide a variety of ecosystem services, including: biodiversity, water supply/quality/sediment transport, fire regime controls, recreation, carbon sequestration, air quality, nitrogen retention, public health, and flood and erosion protection (Vulnerability Assessment Reviewers, pers. comm., 2015).

Habitat experts indicated that there is moderate potential for managing or alleviating climate impacts for chaparral habitats.[28] Habitat experts identified the following actions as potential management options for chaparral habitats: maintaining habitat connectivity, implementing land-use regulations, restricting fuel manipulation projects, and managing fire frequency and invasive species (Vulnerability Assessment Reviewers, pers. comm., 2015). Habitat experts also noted that drier conditions and reduced precipitation can undermine chaparral restoration efforts. Additional management options identified in the scientific literature include: preserving hydraulic trait diversity among chaparral species and populations to maintain chaparral habitat resilience to drought and moisture stress (Jacobsen et al. 2014); utilizing zoning and land use regulations to enhance existing habitat conservation (Bonebrake et al. 2014); limiting development and managing fire risk (Syphard et al. 2007, 2013); and implementing fire ignition reduction efforts (Syphard and Keeley 2015).

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[27] Confidence: High

[28] Confidence: Moderate

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