Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Chaparral and Serpentine

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Moderate-high
Exposure	Moderate
Adaptive Capacity	Moderate
Vulnerability	**Moderate**

Overall vulnerability of chaparral and serpentine habitat was scored as moderate. The score is the result of moderate-high sensitivity, moderate future exposure, and moderate adaptive capacity scores.

Precipitation amount was identified as a key climate factor for chaparral and serpentine systems, influencing seedling survival, species composition and diversity in chaparral, and exhibiting minor influences on serpentine species composition.

Key non-climate factors include urban/suburban development and invasive and problematic species. Development destroys and fragments habitat, while exotic species compete with native vegetation, particularly under enhanced fire and nitrogen deposition regimes.

Key disturbance mechanisms for chaparral and serpentine systems include grazing, wildfire, and disease. Wildfire and grazing, in particular, influence habitat distribution and composition, including exotic pressure and influence.

Chaparral and serpentine systems are fairly fragmented/isolated in the Central Valley, which may impede their ability to migrate in response to climate change. Both habitats are fairly resistant to climate changes and invasion, but are vulnerable to more frequent fires. Small dispersal distances of component vegetation likely limits migration in response to climate change. Chaparral and serpentine systems support a relatively high diversity of native species, including many rare and endemic flora and fauna.

Management potential for chaparral and serpentine systems was scored as low, and management options identified are minimizing human disturbance (e.g., prescribed fire, grazing) and development.

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Introduction

Description of Priority Natural Resource

Chaparral is characterized by evergreen, hard-leaved vegetation (Keeley & Davis 2007). Serpentine habitats occur on serpentine soils, which are characterized by low vegetative productivity due to high heavy metal levels, low calcium/ magnesium ratios, and low levels of critical plant micronutrients, such as phosphorus and nitrogen (Huenneke et al. 1990).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the chaparral and serpentine habitat as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the habitat's management importance as indicated by its priority in existing conservation plans and lists, and 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing the chaparral and serpentine habitat as a Priority Natural Resource included the following: the habitat has high management importance. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source[1]. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Air temperature	Low	-
Extreme events: drought	Low-moderate	Moderate
Extreme events: storms	Low	-
Increased wildfire	-	High
Precipitation (amount)	Moderate-high	Low-moderate
Precipitation (timing)	Low-moderate	Low-moderate
Soil moisture	Moderate	-
Overall Scores	**Low-moderate**	**Moderate**

Chaparral habitat extent in the Central Valley will likely be affected by climate change, experiencing both habitat losses and new opportunities for expansion (PRBO Conservation Science 2011; Thorne et al. 2016). Modeling by Thorne et al. (2016) indicates that by the end of the century (2070-2099), 16-42% of current chaparral area will become climatically exposed, and 8-54% of current habitat extent will no longer be climatically suitable. Habitat suitability losses are greatest under hotter/drier scenarios and occur predominately in the southern-half to two-thirds of the Central Valley study region (Thorne et al. 2016). Comparatively, the northern section of the study region remains climatically suitable with potential expansions (Thorne et al. 2016). For example, chaparral may be able to colonize areas where oak woodlands are declining, particularly on northeast slopes (minimized heat stress) and western slopes (minimized moisture stress); steep southern slopes will not be ideal habitat[1]. Projections from Thorne et al. (2016) match model predictions made by PRBO Conservation Science (2011), including increases in chaparral habitat in northern California by 2070 due to conversion from conifer ecosystems, and chaparral habitat declines in central western California due to grassland expansion. Similarly, Lenihan et al. (2008) project declines in shrubland area under both warmer/drier and warmer/wetter futures due to reduced moisture and increased fire, and forest encroachment, respectively.

In general, endemic plant diversity (e.g., serpentine) is projected to shift toward more coastal and/or northern locations in California by the end of the century, and roughly 66% of endemic plant taxa will likely experience significant range reductions (>80%) by 2100 (Loarie et al. 2008).

Topographic refugia (e.g., northern aspects, higher elevations) may be available for serpentine species in the future, although refugia quality will likely be moderated by species interactions, pollinator availability, and interactive climate change effects (Spasojevic et al. 2014). In addition, serpentine species may be able to better accommodate increased climatic water deficit relative to adjacent communities on non-serpentine soils (Harrison et al. 2014). Minimum migrations for serpentine species to future suitable habitat are large (663-8275 m), with dispersal distances being larger under warmer-drier scenarios. Large dispersal distances and high soil specificity may undermine serpentine migration (Damschen et al. 2012).

Precipitation (amount)

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Low-moderate (moderate confidence)*

Although many chaparral species are adapted to seasonal summer drought, they do require enough annual precipitation to allow seedling survival; the majority of chaparral habitat occurs in areas receiving 250-750 mm of annual rainfall (Keeley & Davis 2007). Variability in precipitation volume drives elevational, geographical, topographical, and local chaparral species and life history group diversity via differences in soil moisture (Meentemeyer & Moody 2002; Keeley & Davis 2007; Cornwell et al. 2012). Obligate seeding and facultative seeding species are more drought-tolerant than obligate sprouting species, which rely on deeper root systems to survive low precipitation periods. This life history strategy makes obligate sprouting seedlings vulnerable to moisture stress, limiting recruitment to more mesic areas (Meentemeyer & Moody 2002; Keeley & Davis 2007) and translating to higher cover of this life history group in areas with higher precipitation, including the Sierra Nevada and northern California (Cornwell et al. 2012). Comparatively, facultative and obligate seeders are found on more arid sites (Meentemeyer & Moody 2002), and facultative sprouting species, in particular, are more abundant in southern regions of California (Cornwell et al. 2012).

Shifts in precipitation volume may alter seedling survival and cause changes in chaparral life history group abundance and distribution. For example, more precipitation may favor obligate seeding and obligate sprouting species, while reduced precipitation may favor facultative seeding species, which are currently more prevalent in the southern portion of the study region (Cornwell et al. 2012).

Additionally, shifts in precipitation volume may cause slight shifts in serpentine community composition and species richness, but overall, serpentine communities are fairly resilient to annual precipitation variability (Fernandez-Going et al. 2012). Relative to shifts in annual rainfall, nutrient limitation in serpentine systems exerts a larger influence on community composition, including exotic pressure (Eskelinen & Harrison 2014).

Soil moisture

Sensitivity: *Moderate (high confidence)*

Thorne et al. (2015) project that climatic water deficit is expected to increase by 131 mm in the Central Valley (compared to 140 mm statewide) by 2070-2099 under a drier scenario and 44 mm (compared to 61 mm statewide) under a wetter scenario. Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015). Cumulative water deficit may be the most important variable predicting shrub distribution in arid regions (Dilts et al. 2015), including the Central Valley. Serpentine communities may be more resilient to increased climatic water deficit than similar communities on non-serpentine soils (Harrison et al. 2014).

Drought

Sensitivity: *Low-moderate (high confidence)*
Future exposure: *Moderate (moderate confidence)*

In general, the frequency and severity of drought is also expected to increase due to climate change over the next century (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation, causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). Non-serpentine chaparral grows at higher densities, so it is likely more sensitive to drought[1].

Precipitation (timing)

Workshop participants did not further discuss this and the following climate factors beyond assigning a

Sensitivity: *Low-moderate (low confidence)*
Future exposure: *Low-moderate (moderate confidence)*

Air temperature

Sensitivity: *Low (moderate confidence)*

Storms

Sensitivity: *Low (moderate confidence)*

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Non-Climate Factor	Sensitivity	Current Exposure
Agriculture & rangeland practices	Moderate	Moderate-high
Dams, levees, & water diversions	Moderate	Low-moderate
Invasive & other problematic species	High	Moderate-high
Urban/suburban development	High	Low-moderate
Overall Scores	**Moderate-high**	**Moderate**

Invasive & other problematic species

Sensitivity: *High (high confidence)*
Current exposure: *Moderate-high (high confidence)*
Pattern of exposure: *Highly invaded community with widespread impacts. Serpentine habitat is not easy to invade, and thus has lower exposure.*

Intact chaparral canopies are resistant to invasion (Keeley et al. 2003), but exotic annual grasses and forbs can invade and establish in chaparral habitats post-fire (Keeley and Davis 2007) and in areas with high nitrogen (N) deposition (Allen et al. 2000). Annual grass invasion facilitates more frequent burning, which in turn favors exotic annual dominance, perpetuating a pattern of native chaparral displacement and eventually causing conversion to non-native annual grassland (Haidinger & Keeley 1993). It is unknown how to reverse grassland conversion[1]. In addition to altering fire regimes, invasive annual grasses can also alter competition and species composition (particularly for native annuals), and dry out the topsoil, decreasing chaparral shrub germination rates/success[1].

Serpentine soils act as refugia for native species from invasive exotics due to low nutrient levels (Huenneke et al. 1990), but enhanced N deposition facilitates invasion (Huenneke et al. 1990). In serpentine habitats, nutrient addition-mediated increases in exotic grasses contributes to altered serpentine species composition and reduced native species richness, particularly forbs and legumes, due to competition for light and other resources (Huenneke et al. 1990). Paired with shifts in precipitation timing, nutrient increases could cause higher invasion rates of serpentine systems (Eskelinen & Harrison 2014).

Urban/suburban development

Sensitivity: *High (high confidence)*
Current exposure: *Low-moderate (high confidence)*

> ***Pattern of exposure:*** *Localized; within the Central Valley foothills (primarily on the west side of the valley where most chaparral occurs), urbanization impacts are going to be limited to the areas of rapid urban expansion—the San Francisco Bay Area and Sacramento corridor. Because chaparral habitat is found on hillsides, some areas cannot be developed (or only small developments are possible). Development exposure is minimal for serpentine habitats because development is not desirable due to very high asbestos levels.*

Only chaparral habitats are affected by this factor; serpentine habitats have minimal exposure to this factor. Urban/suburban development destroys and fragments habitat, and can contribute to altered ecosystem processes in chaparral (e.g., increased fire ignitions; Regan et al. 2010).

Rangeland practices

> ***Sensitivity:*** *Moderate (moderate confidence)*
> ***Current exposure:*** *Moderate-high (moderate confidence)*
> ***Pattern of exposure:*** *Widespread throughout the area.*

Dams, levees, & water diversions

> ***Sensitivity:*** *Moderate (moderate confidence)*
> ***Current exposure:*** *Low-moderate (low confidence)*
> ***Pattern of exposure:*** *Localized; there are not many dams on the west side where most chaparral occurs. Dams may only be an issue if the proposed Sites Reservoir is built and floods this habitat.*

Other Factors: Recreation

The impact of recreation on chaparral habitat is a problem, and fire roads can allow careless people to ignite fires and introduce invasive plants, especially in Mendocino forestlands facing the valley. Strategy needs to be to remove fire roads on a large scale.

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

> ***Overall sensitivity to disturbance regimes:*** *High (high confidence)*

Wildfire

> ***Sensitivity:*** *High (confidence not assessed)*
> ***Future exposure:*** *High (high confidence)*

Large fire occurrence and total area burned in California are projected to continue increasing over the next century with total area burned projected to increase by up to 74% by 2085 (Westerling et al. 2011).

In chaparral systems, typical wildfire dynamics include crown fires followed by rapid post-fire recovery with higher diversity in burned versus mature stands. Chaparral can act as barricade to fire moving across the landscape and therefore may represent a mechanism for maintaining climate refugia[1]. Chaparral species exhibit three distinct life histories in response to fire: obligate sprouters resprout from root crowns and lignotubers, obligate seeders recruit from soil seedbanks stimulated by fire, and facultative seeders use a combination of both strategies.

Chaparral is vulnerable to more frequent fires (<10 year fire return intervals), which can kill recent seedlings, prevent seedbank replenishment for obligate seeders (Zedler 1995; Keeley & Davis 2007), and prevent obligate-resprouter recruitment, which occurs during fire-free intervals (Keeley & Davis 2007). Too-frequent burning facilitates chaparral type conversion to grassland systems (Haidinger & Keeley 1993). Wildfire intensity has variable impacts on post-fire chaparral recovery, enhancing recruitment of some species and inhibiting recruitment of others (Keeley et al. 2005).

Relative to other habitats (e.g., grassland, chaparral), serpentine systems usually experience lower fire frequency and severity due to reduced productivity and biomass. However, serpentine habitats may be sensitive to too frequent burning because they are slower to recover from fire. Fire stimulates diversity and species richness on serpentine sites, but to a lesser degree than adjacent habitats (Safford & Harrison 2004, 2008).

Grazing

Sensitivity: *Moderate (confidence not assessed)*

Historically, chaparral was burned and replaced with grasslands for grazing and rangeland needs (e.g., see Bentley 1967). However, reduced grazing has led to some shrub expansion at the expense of grasslands in central California (Keeley 2005). Within existing chaparral habitats, grazing may facilitate exotic invasion by disturbing the shrub canopy (Stylinski & Allen 1999). However, overall grazing impacts vary according to stocking rates; moderate grazing can be beneficial, while higher grazing intensity can reduce biodiversity and contribute to erosion and degraded water quality[1].

In serpentine systems, grazing may help mitigate increased thatch from invasive annual grasses, allowing native forbs and legumes to persist even under enhanced nutrient scenarios (Huenneke et al. 1990).

Disease

Sensitivity: *Low-moderate (confidence score not assessed)*

Disease impacts are highly localized[1]. Several chaparral species are susceptible to sudden oak death (pathogen *Phytophthora ramorum*), including manzanita (*Arctostaphylos manzanita*), toyon (*Heteromeles arbutifolia*), and California buckeye (*Aesculus californica*) (Davidson et al. 2003). Shifts in precipitation timing and volume, particularly increased winter precipitation, could increase pathogen survival and sporulation, translating to increased risk for chaparral and adjacent oak ecosystems (Sturrock et al. 2011).

Low calcium levels in serpentine soils may expose serpentine species to higher disease infection rates and severities (e.g., rust fungus, *Melamspora lini*). Higher disease exposure may drive more rapid evolution than adjacent systems and/or alter life history strategies of component serpentine species (Springer et al. 2006).

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Integrity, & Continuity	Low-moderate
Resistance & Recovery	Moderate
Habitat Diversity	Low-moderate
Overall Score	**Moderate**

Extent, integrity, and continuity

Overall degree of habitat extent, integrity, and continuity: *Low-moderate (high confidence)*
Geographic extent of habitat: *Occurs across the state (high confidence)*
Structural and functional integrity of habitat: *Altered but not degraded (high confidence)*
Continuity of habitat: *Isolated and/or quite fragmented (high confidence)*

Chaparral occurs across California, and within the study region, occurs in the Sierra Nevada foothills, northern portions of the Central Valley study region, and bordering the Bay Area (Keeley & Davis 2007).

Serpentine soils occur on roughly 5000 km of California's land area (Safford & Harrison 2008) and typically occupy spatially isolated outcrops (Damschen et al. 2012). Spatial separation between suitable substrates paired with low dispersal ability likely undermines the ability of serpentine species to migrate in the face of climate change (Damschen et al. 2012). Additionally, small populations may make serpentine species vulnerable to extirpation (Loarie et al. 2008).

Landscape permeability

Geologic barriers act as a barrier for serpentine habitats due to their high soil specificity (Damschen et al. 2012), but this is not the case for chaparral[1].

Resistance and recovery

Overall ability to resist and recover from stresses: *Moderate (high confidence)*
Resistance to stresses/maladaptive human responses: *Moderate-high (high confidence)*
Ability to recover from stresses/maladaptive human response impacts: *Low-moderate (high confidence)*

Chaparral is fairly resistant to climate-related stressors, and disturbance-adapted vegetation allows recovery from most events given sufficient time, with the exception of intense drought and too-frequent fire (Keeley & Brennan 2012). However, once chaparral is pushed beyond a threshold (e.g., conversion to annual grassland), it has a hard time recovering from conversion; chaparral does not necessarily return when the disturbance is lowered or removed[1]. Additionally, seed dispersal may be limited, particularly for obligate seeders, while seedling recruitment for obligate sprouters may be limited by moisture availability, undermining the ability of this habitat to migrate in response to climate change (Keeley & Davis 2007).

Serpentine species may be fairly resilient to climate change – particularly increased climatic water deficit – due to historical adaptations to accommodate harsh environmental conditions (Fernandez-Going et al. 2012; Harrison et al. 2014). Additionally, serpentine systems may be more adaptive to climate change because they are under less stress from invasive species (Huenneke et al. 1990) and fire (Safford & Harrison 2004, 2008). However, migration of component serpentine species in response to climate factors is limited by the availability of suitable soil (Damschen et al. 2012).

Habitat diversity

Overall habitat diversity: *Low-moderate (high confidence)*
Physical and topographical diversity of the habitat: *Low-moderate (high confidence)*
Diversity of component species within the habitat: *Moderate (high confidence)*
Diversity of functional groups within the habitat: *Moderate (low confidence)*

Component species or functional groups particularly sensitive to climate change:

- Species that are not stump sprouters will be more sensitive. Chamise can green up after very intense fire, whereas *Ceanothus* or *Arctostaphylos* rely on seed bank to regenerate and hot fire will kill seeds.
- Well-studied and high-risk serpentine species.

Keystone or foundational species within the habitat:

- Dominant vegetation in chaparral (fire-adapted woody shrubs—chamise, manzanita, toyon) determine fire behavior and other major elements of ecosystem function.
- *Ceanothus* is important because it fixes nitrogen and determines soil fertility.
- Many species are highly dependent on chaparral (e.g., wrentit [*Chamaea fasciata*]).

Other critical factors that may affect habitat diversity:

- Human fire ignition at the urban interface
- Local OHV activity
- Major wildfires

Chaparral stands are typically dominated by shrubs and sub-shrubs, but also support annual herbs and perennial bulbs and herbs. Chaparral species composition varies widely across different geographic regions, although chamise (*Adenstoma fasciculatum*) is fairly widespread, and is typically co-dominant with *Ceanothus* and *Arctostaphylos* species. Community diversity is highest post-fire, but declines with the closing of the shrub canopy (Keeley & Davis 2007). Both chaparral and serpentine habitats support many rare and endemic species (Keeley & Davis 2007; Safford & Harrison 2008). Serpentine soils typically feature vegetation adapted to low nutrient conditions, including many perennial grasses and forbs (Safford & Harrison 2008).

Management potential

Workshop participants scored the resource's management potential.

Management Potential Component	Score
Habitat value	Low
Societal support	Low
Agriculture & rangeland practices	Low-moderate
Extreme events	Moderate-high
Converting retired land	Low
Managing climate change impacts	Low
Overall Score	**Low**

Overall management potential: *Low (high confidence)*

Value to people

Value of habitat to people: *Low (high confidence)*

Support for conservation

Degree of societal support for managing and conserving habitat: *Low (high confidence)*

Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat: *Low-moderate (high confidence)*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Moderate-high (moderate confidence)*

Likelihood of converting land to habitat

Likelihood of (or support for) converting retired agriculture land to habitat: *Low (high confidence)*

Likelihood of managing or alleviating climate change impacts on habitat: *Low (high confidence)*
Description of likelihood: *Need to decrease the flammability of landscapes by selecting species that do not burn very hot (e.g., chamise burns very hot). Refugia could be developed by lowering fuel loads and planting specific species with lower fuel contents.*

Minimizing anthropogenic chaparral disturbance (e.g., prescribed fire, grazing) may help prevent invasive species establishment and spread (Keeley & Davis 2007). Limiting development and managing fire risk may help mitigate fire and development impacts on chaparral (Syphard et al. 2007, 2013). Many serpentine soil areas occur on public lands managed by the Forest Service, the Bureau of Land Management, and California State Parks (Safford & Harrison 2008).

Atriplex spp. can be translocated along with other more drought-tolerant chaparral species. South-facing steep slopes along Cache Creek may be good location to translocate to, as current species may not last with climate change. Generally, management trends will be to replace mesic species with more xeric-adapted chaparral and species that are currently more southerly distributed; slope aspect will be important[1].

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