<u>CalVeg types included:</u> **MCP**: *Ceanothus* spp., manzanita (*Arctostaphylos spp.*), bitter cherry (*Prunus emarginata*); **MCH**: Scrub oak (*Quercus* spp.), *Ceanothus* spp., manzanita (*Arctostaphylos spp.*); **CRC**: Chamise (*Adenostoma fasciculatum*), redshank (*Adenostoma sparsifolium*), *Ceanothus* spp.

Sensitivity Assessment

1. Direct sensitivities to changes in temperature and precipitation

- Temperature
    - Means and extremes
        - Historical
            - Chaparral along the coast experiences a temperature range from 53-65^{o}F. Montane chaparral can experience temperatures ranging from 32-60^{o}F.
        - Future
            - Over the next century, average temperatures across California are expected to increase by 2-4^{o}F in winter and 4-8^{o}F in the summer. Models indicate that there may be less warming along the southwest coast but more warming to the north and northeast (Hayhoe et al., 2004).
    - System's sensitivity, composition and response to temperature
        - Warmer temperatures may favor facultative sprouters (Ramirez).
- Precipitation
    - Means and extremes
        - Historical
            - Precipitation averages around 12-40 inches per year and is mostly in the form of rain.
        - Future
    - System's sensitivity, composition and response to precipitation
        - Wetter conditions may favor non-sprouters and post-fire seeding plants while dryer conditions may select for facultative sprouters (Ramirez et al., 2012).

2. Sensitivity of component species

- Dominant species
    - There are three general classifications for chaparral vegetation
        - Obligate resprouter: seeds are killed by fire but plants can resprout from deep roots;
        - Facultative resprouter: employ both deep roots and seeds to repopulate after a fire;
        - Post-fire seeding/non-sprouter plants: produce seeds that are stimulated to germinate after a fire (Ramirez et al., 2012)

- Obligate resprouters are less common in very dry areas and can be found further north and inland. They are more common at sites with high precipitation, low fire probability, low winter temperatures, and high summer temperatures. They have been described as "drought avoiders". These plants are mostly scrub oaks: *Quercus durnosa, Quercus wislizenii*, *Cercocarpus betuloides* and *Hetermeles abutifolia*. (Ramirez et al., 2012)
- Facultative sprouters are most common in the southern and central Sierra Nevada at sites with low precipitation, high fire probability, warmer winter temperatures, and cooler summer temperatures. Common facultative sprouters include: *Adenostoma fasciculation, Artemisia califonica, Salvia spp., Ceanothus, Archostaphylos* (Ramirez et al., 2012). *Adenostoma fasciculation,* a deep rooting facultative sprouter, is more common on drier, south facing slopes while cooler, moist north facing slopes commonly have both post-fire seeding plants and obligate resprouting plants.
- Non-sprouters (post-fire seeding plants) are relatively rare in the Sierra Nevada but can be found at sites with high precipitation and low summer temperatures and are more common in northern California. They may favor less densely vegetated areas to reduce competition between seedlings in the early post fire environment. *Ceanothus* and *Arctostaphylos* are example species. (Ramirez et al., 2012)

- Ecosystem engineers
- Keystone species

3. Sensitivity to changes in disturbance regimes

- Wildfire
  - Generally, within 5 years of a fire, chaparral is able to regenerate in large part by residual species present before the fire, colonization plays a minor role. Shrubs return either by seedling recruitment or by resprouting roots. California lilac (or buckbrush) and manzanita are obligate seeders while scrub oak and coffeeberry (redberry) do not have seeds and regenerate entirely from resprouts. Many chaparral plants have dormant seed banks that are activated post-fire. After a fire, chaparral systems have their highest species diversity. Seed banks that are more than a century old are resilient and able to reestablish chaparral stands after a fire with the notable exception of the California lilac/buckbrush. Thus, chaparral is resilient to long fire-free periods (Keeley, 2005).
  - Chaparral areas that experience very frequent fires (<20 years) favor plant species that are obligate resprouters and survive from underground structures like lignotubers or roots. In areas with large, post-fire gaps though, plants that have a post-fire seeding strategy tend to be favored.
- Disease
- Flooding
- Insects
- Wind

    - Santa Ana wind events may increase the likelihood of a fire in chaparral. Some models indicate that these winds may increase as a result of climate change.
- Drought
    - Post-fire seeding species tend to be more resistant to the stress of drought in their tissues; species with deep roots that can resprout after a fire are more sensitive to drought stress in their tissues but are able to survive by utilizing deep roots to find moisture.

4. Sensitivity to other types of climate and climate-driven impacts

- Altered hydrology
- Altered fire regimes
    - Fire has been suppressed in the Sierra Nevada since the early 1900s. However, most chaparral has experienced a fire in the past 100 years except in the southern Sierra Nevada where roughly 45% of the chaparral landscape has not burned since record keeping began in 1910 (Keeley, 2005). Reduced fire frequency is thought to have catalyzed a conversion of chaparral to grasslands.
- Evapotranspiration and soil moisture
    - Chaparral species are generally well adapted to low water availability and hence, have evolved strategies to reduce water loss due to evapotranspiration.
- Extreme precipitation and temperature
- Water temperature
- Storm frequency and intensity

5. Sensitivity to impacts of other non-climate related threats

- Residential and commercial development
- Agriculture and aquaculture
- Energy production and mining
- Transportation and service corridors
- Biological resource use
- Altered interspecific interactions
- Human intrusions and disturbance
- Natural system modification
- Invasive and other problem species
    - After a fire, non-native species richness and abundance increased. This may be due to the fact that freshly exposed lands can be quickly colonized by neighboring non-native plants (Keely, 2005).
- Pollution and poisons
    - In the south, chaparral ecosystems are experiencing high nitrate concentrations in groundwater.
- Geological events

6. Other Sensitivities

- Management

Adaptive Capacity

1. Extent and Characteristics

- Geographic extent in California
  - Chaparral is the most extensive vegetation type in California, covering 1/20 of the state (Jones and Stokes, 1987).

2. Landscape Permeability

- Barriers to dispersal or fragmentation

3. System Diversity

- Diversity of component species
- Community Structure
  - Chaparral is thought to establish in locations that experienced severe fire. Thus, if fire intensity increases due to climate change it may be able to expand its range. However, in the absence of fire, chaparral stands can be overtaken by conifer (Nagel, 2005).
  - In the Sierra Nevada, climate models estimate future percent chaparral land cover as follows (Safford):

Scenario	Temperature	Precipitation	% Chaparral
Current (1961-1990)			21%
PCM-A2	< 3.1˚C	Same as today	10%
GFDL-B1	< 3.1˚C	Drier than today	14%
GFDL-A2	> 4˚C	Much drier than today	19%

In the Sierra Nevada foothills, climate models estimate future percent chaparral land cover as follows (Safford):

Scenario	Temperature	Precipitation	% Chaparral
Current (1961-1990)			3%
PCM-A2	< 3.1˚C	Same as today	0%
GFDL-B1	< 3.1˚C	Drier than today	0.5%
GFDL-A2	> 4˚C	Much drier than today	1%

Grasslands were expected to replace much of the low to middle elevation chaparral, however, chaparral is also expected to expand into historically forested areas.

Exposure

The forecast for chaparral distribution in response to climate change is not uniform throughout California. The Random Forests algorithm portrays an appealing view of the effects of global warming on the distribution of grasslands, chaparrals, and montane forests. Increases in these habitat types would occur largely at the expense of subalpine forests, tundra, and Great Basin woodlands (Rehfeldt et al. 2006). In northern California, the predominant effects of climate change are similarly predicted to include increases in the distribution of chaparral, oak, pine, and montane vegetation, and a loss of conifer dominated vegetation (Gardali et al. 2011). Rehfeldt et al. (2012) suggest that climates of contemporary biomes in California will be pushed uphill along the west slopes of the Sierra Nevada enough to shift assemblages in in Yosemite National Park to montane, or even chaparral species, rather than subalpine forests.

Conversely, of the three major vegetation groups in the central western California ecoregion projected to 2070, decreases are predicted in areas of chaparral / coastal scrub (19 to 43%) and blue oak (*Quercus douglasii*) woodland / foothill pine (*Pinus sabiniana*) (44 to 55%), while an increase was projected in areas of grassland (85 to 140%) (Gardali et al. 2011).

Chaparral may benefit from increased fire frequency, because in the absence of fire, montane chaparral–dominated landscapes become invaded by fire intolerant species (Beaty and Taylor 2008). In a Sierra Nevada ranger unit, modeled climate change resulted in a 124% increase in escapes and area burned by contained fire in areas covered in chaparral (Fried et al. 2004). However, there is no consensus on how climate change will influence Santa Ana events or fire in southwestern California (Gardali et al. 2011).

Lawson et al. (2010) show that for long-lived obligate seeders, such as barranca brush (*Ceanothus verrucosus)*, climate change poses a greater risk than more proximal threats of altered fire regime or future urban development. This is in contrast to other studies of obligate seeders, which have shown them to be potentially more vulnerable to altered fire regime than climate change (see: Keith et al., 2008; Regan et al., in press) (Lawson et al. 2010). In response to climate change, manzanita may become limited to ephemeral washes during future drought conditions (Gitlin et al. 2006).

Birds

In southern California, the mean maximum temperature in spring has increased by 5˚C since 1961, and there have been upward shifts in elevational distributions of breeding birds over a recent 26 years period. This shift is associated mostly with an upslope encroachment of upper distribution limits of desert scrub birds, rather than a retraction of lower limits of chaparral birds. Although chaparral species were found in this study to be more strongly limited by climate, habitat appeared more important for their within-range patterns, and upward shifts were less likely for these species in the longer-term trends. For desert scrub species, current distribution patterns were less correlated with climate, yet these species were more likely to show upward shifts during the past quarter-century (Hargrove and Rotenberry 2011).

Mountain Quail

No information found

Primary sources

Beaty, R. M. & Taylor, A. H. (2008). Fire history and the structure and dynamics of a mixed forest landscape in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. Forest Ecology and Management, 225, 707 – 719.

Fenn, M.E., M.A. Pth, A. Bytnerowicz, J.O. Sickman, B.K. Takemoto. 2003. Effects of ozone, nitrogen deposition and other stressors on montane ecosystems in the Sierra Nevada. *Developments in Environmental Science*. 2: 111-155.

Fried, J. S., Torn, M. S. & Mills, E. (2004). The impact of climate change on wildfire severity: A regional forecast for Northern California. Climatic Change, 64, 169 – 191.

Gardali, T., Howell, C. A., Seavy, N. E. Shuford, W. D. & Stralberg, D. (2011). Projected effects of climate change in California: Ecoregional summaries emphasizing consequences for wildlife, Version 1.0. Petaluma, CA: PRBO Conservation Science. 68pp.

Gitlin, A. R., Sthultz, C. M., Bowker, M. A., Stumpf, S. Paxton, K. L., … & Whitham, T. G. (2006). Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20 (5), 1477 – 1486.

Hargrove, L. & Rotenberry, J. T. (2011). Spatial structure and dynamics of breeding bird populations at a distribution margin, southern California. Journal of Biogeography, 38, 1708-1716.

Hayhoe, K.; Cayan, D.; Field, C.B.; Frumhoff, P.C.; Maurer, E.P.; Miller, N.L.; Moser, S.C.; Schneider, S.H.; Cahill, K.N.; Cleland, E.E.; Dale, L.; Drapek, R.; Hanemann, R.M.; Kalstein, L.S.; Jones and Stokes. 1987. Sliding toward extinction: the state of California's natural heritage, 1987.

Keeley, J.E. A.H. Pfaff, H.D. Safford. 2005. Fire suppression impacts on postfire recovery of Sierra Nevada chaparral shrublands. *International Journal of Wildland Fire.* 14: 255-265.

Lawson, D. M., Regan, H. M., Zedlers, P. H., & Franklin, J. (2010). Cumulative effects of land use, altered fire regime and climate change on persistence of Ceanothus verrucosus, a rare, fire-dependent plant species. Global Change Biology, 16, 2518-2529.

Leniahn, J.; Lunch, C.K.; Neilson, R.P.; Sheridan, S.C.; Verville, J.H. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences. 101: 12422–12427.

Nagel, T.A. A.H. Taylor. 2005. Fire and persistence of montane chaparral in mixed conifer forest landscapes in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. *Journal of the Torrey Botanical Society.* 132: 442-457.

Ramirez, A., W.K. Cornwell, D.D. Ackerly. 2012. Section 4: Fire, climate and the distribution of Shrub Life history strategies across the California landscape. In Climate change impacts on California vegetation: physiology, life history, and ecosystem change. University of California, Berkeley.

Rehfeldt, G. E., Crookston, N. L., Warwell, M. V., & Evans, J. S. (2006). Empirical analyses of plant-climate relationships for the western United States. International Journal of Plant Science, 167 (6), 1123- 1150.

Rehfeldt, G. E., Crookston, N. L., Saenz-Romero, C. & Campbell, E. M. (2012).North American vegetation model for land-use planning in a changing climate: a solution to large classification problems. Ecological Applications, 22 (1), 119 – 141.

Safford, H.D., M. North, M.D. Meyer. Chapter 3: Climate change and the relevance of historical forest conditions. In Managing Sierra Nevada Forests.