Historic Range of Variability for Chaparral in the Sierra Nevada and South Cascades

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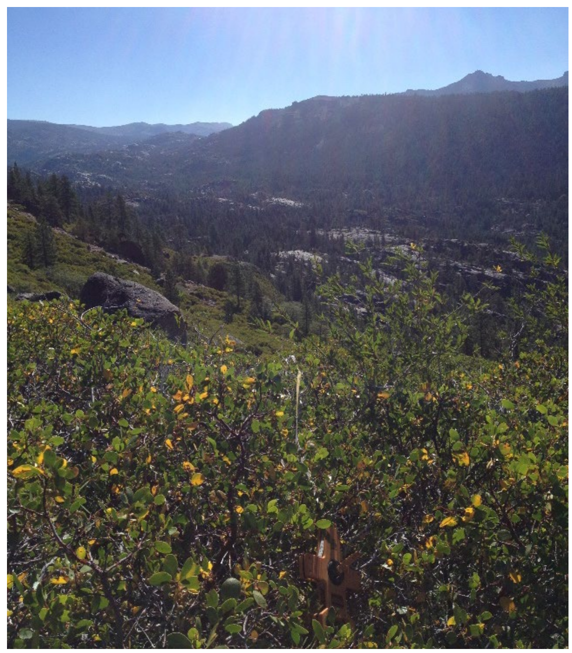

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1 Introduction

Chaparral is one of the most extensive cover types (Wieslander and Gleason 1954) in California, covering a large portion of the state. Although southern California is usually considered the center of the chaparral distribution, it is an important vegetation type throughout the assessment area. Approximately 9% of the assessment area is dominated by four major chaparral types ordered by increasing elevation: chamise-redshank chaparral, mixed chaparral, montane chaparral and alpine dwarf chaparral (Fig. 1). The location of these chaparral types are determined by topographic environmental and disturbance factors such as slope, aspect, elevation, substrate and fire regimes. These factors along with the characteristic Mediterranean climate in California have allowed for the development of these distinct chaparral types that exhibit high plant diversity and harbor many rare and endemic species (Keeley et al. 2008). In this chapter we will be determining the NRV for chamise-redshank chaparral, mixed chaparral and montane chaparral. Alpine dwarf chaparral will be described as a part of the subalpine NRV chapter.

1.1 Physical setting and geographic distribution

In the assessment area, chaparral is widely distributed on variable slope aspects of the Sierra Nevada and the Southern Cascades ranging throughout the foothills and into the Sierran mixed conifer/ red fir zone and the subalpine zone. The chaparral of the South bioregion merges with the southern California chaparral in the Tehachapi Mountains at the southern terminus of the San Joaquin Valley.

Classifications of chaparral have been thoroughly described by Sawyer and Keeler-Wolf (1995) and will be summarized here for purposes of this assessment. Chamise-redshank chaparral is common at low elevations between oak woodlands and conifer forests forming extensive stands (Table 2). It is usually oriented on south and west facing slopes and along ridges characterized by xeric conditions (Skinner and Chang 1996). Chamise –redshank dominated chaparral is uncommon in the assessment area covering less than one percent of the landscape. Mixed chaparral usually occurs below 1520 meters and occupies sites that are more mesic or north facing at low elevations (Table 2) (Hanes 1977). At higher elevations, mixed chaparral can occupy all aspects along ridges and on steep slopes. Common types are manzanita (*Arctostaphylos* spp.) and *Ceanothus* spp. dominated chaparral that occurs at elevations of 150-1850 m on steep ridges and slopes. Serpentine chaparral is found at low to mid elevations along the belt that runs throughout the Sierra Nevada foothills. Serpentine chaparral is strongly associated with soils derived from ultramafic bedrock characterized by low nutrient status which results in reduced productivity and growth (Whittaker 1954). Montane chaparral occur in the mixed conifer and red fir zones at high elevations where precipitation usually falls as snow (Table 2). Typically, these high elevation chaparral types can occupy harsh site conditions and occur as either seral following disturbance such as fire or logging or as the single dominant species (Hanes 1977). Alpine dwarf chaparral is found above timberline at all aspects and occupies most high elevations in the assessment area.

1.2 Ecological setting

Chaparral presence in the assessment area has tracked with climate, increasing during the dry and warm periods and decreasing during the wet and cold periods. Chaparral is often identified by the presence of "sclerophyllous" shrubs that have characteristics that allow them to adapt to harsh growing conditions common in most Mediterranean climates. In addition, chaparral dominated areas create fire regimes that are often self-reinforcing that allow increases in presence and extent (McKenzie et al. 2011). Chaparral is an important vegetation type throughout the assessment area being a diverse community type that supports a number of wildlife species.

1.2.1 Historical distribution of chaparral

The chaparral type was first recorded in the Eocene in the interior of the North America land mass (Axelrod 1977). However, it wasn't until the Miocene that chaparral was observed in the Tehachapi flora in Southern California (Axelrod 1977). This flora recorded the presence of *Arctostaphylus* spp., *Ceanothus* spp., *Cerocarpus* spp. and *Quercus* spp. in large numbers (Axelrod 1977). Chaparral increased in dominance in the assessment area during the late Pliocene in response to the rapid rise in steep mountains which favored growth of shrubs over trees. This increase was also due to the interglacial period that was dry and warm leading to a potential increase in fires favoring chaparral dominated conditions (Axelrod 1977). The glacial periods that followed restricted chaparral to its Southern California range followed by a period of expansion and contraction throughout the Holocene.

1.2.2 Characteristic traits of chaparral

Chaparral has a number of dominant traits that make them highly adapted to the climate and disturbance regime in the assessment area. The dominant shrubs found in chaparral are typically sclerophyllous or often evergreen, with leaves characterized by a thick cuticle and sunken stomata. Not all shrubs found in the chaparral type are evergreen, including certain species of *Ceanothus* (Conard et al. 1985). Chaparral species also have deep root systems that allow them to tap into the water in the dry season (Axelrod 1977).

Other traits common in chaparral are the ability to survive high severity fires and persist in between the occurrence of fires. Three responses chaparral exhibit make them highly adaptable to a recurring fire regime: obligate seeders, obligate resprouters and facultative seeders/sprouters (Keeley 1991, Keeley et al. 2005a). Obligate seeders usually rely on some fire-triggered mechanism (e.g., heat-shock, chemical combustion, smoke) to initiate germination. Following a fire they will germinate and seedlings will grow rapidly to high densities. The seed bank of the most common species in chaparral (*Ceanothus* and *Arctostaphylos*) persist for long fire free periods and can occupy areas where shrubs have been replaced with conifers (Keeley et al. 2005a, Knapp et al. 2012b). The occurrence of chaparral seed in areas absent of actual shrub cover may indicate that chaparral had a larger extent when fire occurred more frequently on the landscape. Obligate resprouters include species in the *Arctostaphylos* genus. This group sprouts from adventitious buds following a fire that consumes the aboveground portion of the plant. There is some evidence that obligate and facultative sprouters continue to reproduce asexually even years after a fire. Both obligate seeders and facultative sprouters require stand replacing fire to germinate, however because sprouters can continue to produce long after a fire they maintain a competitive advantage during periods of fire suppression.

1.2.3 Classification of chaparral

Chamise-redshank, mixed, montane, and alpine dwarf chaparral are the four most common chaparral types found in the assessment area (Fig. 1). In addition, chaparral found on serpentine or ultramafic sites are distributed throughout the foothills in the assessment area and typically exhibit longer successionary trajectories.

Chamise-redshank chaparral is the most abundant type of chaparral in California, but it occurs on <1% of the assessment area. *Adenostoma fasciculatum* (chamise) is the most common indicator species for this chaparral type (Table 1). The shrub canopy is dense and canopy cover ranges from 50% in 10-year old stands up to 90% in mature/old stands (Hanes 1977). This type can be broken down into those areas that are dominated by either chamise or chamise and *Ceanothus cuneatus* (wedgeleaf ceanothus) (Table 2).

Mixed chaparral are often dominated by indicator species such as *Ceanothus* spp., scrub oak (*Quercus* spp.) and manzanita in addition to a number of other shrub and herbaceous species (Table 1). Areas dominated by whiteleaf manazanita or *Ceanothus* spp. usually occur as scattered shrubs or as the sole cover type. This type can either be seral to trees or self-reinforcing on shallow unproductive soils (Table 2). Serpentine chaparral occupies the same range, but is restricted to areas of ultramafic origin. This chaparral type is usually composed of slow growing and drought tolerant plants (Safford and Harrison 2004) with a diverse and unique flora (Table 1).

Montane chaparral is found at higher elevation with shrubs made up of a variety of *Arctostaphylos* and *Ceanothus* species (Table 1). These sites can be stable when occupying areas of poor site quality or where topography or other factors result in recurring high severity fire (Sawyer and Keeler-Wolf 1995). Montane chaparral can be a more compact chaparral type with most shrubs being relatively low growing due to the cold temperatures and shortened growing season (e.g., huckleberry oak (*Quercus vaccinifolia*)) (Table 2). It can also be tree-like such as in whitethorn (*Ceanothus cordulatus*) dominated stands that come in after a stand replacing fire in the mixed conifer zone. Alpine-dwarf chaparral occupies areas above treeline and can be sparse to densely covered in some productive areas. This chaparral type has a very slow successional process as a result of the harsh environmental conditions.

Chaparral successional pathways can be through primary succession that develops on local broken rock surfaces, but more likely exists in some form of secondary succession with disturbance as the primary driver. All chamise-redshank chaparral exist in a stable state and are capable of maintaining dominance in the absence of disturbance. Most montane chaparral establishes following a high severity fire in the mixed conifer zone allowing the early seral stage to become dominant (Leiberg 1902, Collins et al. 2007). This pattern can occur at a time frame at certain topographical positions that the chaparral may appear to be self-reinforcing (Beaty and Taylor 2001, Nagel and Taylor 2005). In addition, any chaparral that occurs on ultramafic sites that are characterized by low nutritional status and therefore poor productivity, are maintained for a longer time period before transitioning to another successional phase (Table 2).

1.2.4 Wildlife associations

Montane and mixed chaparral are adjacent to a number of important vegetation types such as riparian and mixed chaparral and is an early seral stage for Sierran mixed conifer and red fir (Mayer and Laudenslayer 1988). A number of wildlife species are dependent on these chaparral types but most notable is the deer populations that use it for summer and winter range. Mixed and montane chaparral vegetation types found in the Sierra Nevada are also important for a number of shrub dependent Sierran birds (Humple and Burnett 2010) and this early seral stage has been well recognized as important in the literature since the early 1900s (Barlow 1901). Some examples of bird species associated with chaparral both stable and early seral types are the California quail (*Lophortyx californicus*), killdeer (*Charadrius vociferus*), poor-will, (*Phalaenoptilus nuttallii*), Western flycatcher (*Empidonax difficilis*), California thrasher (*Toxostoma redivivum*), loggerhead shrike (*Lanius ludovicianus*), Hutton's vireo (*Vireo huttoni*), Nashville warbler (*Vermivora ruficapilla*), black-throated gray warbler (*Dendroica nigrescens*), Lazuli bunting (*Passerina amoena*), green-tailed towhee (*Pipilo chlorurus*), rufous-sided towhee (*Pipilo erythrophthalmus*), brown towhee (*Pipilo fuscus*), lark sparrow (*Chondestes grammacus*), rufous-crowned sparrow (*Aimophila ruficeps*), black-throated Sparrow (*Amphispiza bilineata*), and sage sparrow (*Amphispiza belli)* (Verner and Boss 1980). Mammals include the brush rabbit (*Sylvilagus bachmani*), desert cottontail (*Sylvilagus audubonii*), black-tailed jackrabbit (*Lepus californicus*), long-eared chipmunk (*Eutamias quadrimaculatus*), broad-footed mole (*Scapanus latimanus*), white-tailed jackrabbit (*Lepus townsendii*), Belding's ground squirrel (*Urocitellus beldingi*), northern pocket gopher (*Thomomys talpoides*), California pocket mouse (*Perognathus californicus*), dusky-footed woodrat (*Neotoma fuscipes*), ringtail (*Bassariscus astutus*), and mule deer (*Odocoileus hemionus*) (Verner and Boss 1980).

1.3 Cultural/socioeconomic setting

1.3.1 Pre-Settlement (prior to 1849)

Before Native American migration to the assessment area the region was largely influenced by a combination of natural processes and climate. Humans have lived in the assessment area for the past 10,000 years (Anderson and Moratto 1996). Population numbers varied from 90,000 to 100,000 throughout this time period resulting in variable influence on land and resource use (Parker 2002).

The majority of the Native Americans were organized into major tribes that were located on the West slope of the assessment area (Parker 2002). These major settlements often supported large populations and were centered at lower elevations. Some authors suggest that the landscape surrounding the permanent settlements would have been heavily influenced by the Native Americans (Shepperd et al. 2006). In the summer months the permanent camps would be abandoned for higher elevations where the indigenous people would have located adjacent to some water course which most likely would have included aspen stands (Anderson and Moratto 1996). They most likely would have had some impact on these areas during their occupation.

Native Americans in the assessment area modified landscapes to promote hunting, fishing and gathering opportunities as well as to provide protection and cultivation of native plants. Presently, there are still a number of plants that are unique to the aspen and riparian vegetation types that remain important to Native Americans. These practices were sustained though different management that included burning, irrigation, pruning, harvesting, sowing and weeding (Anderson and Moratto 1996). Although the majority of these practices occurred in areas where chaparral was not common, the burning practices that the Native Americans employed most likely impacted the adjacent vegetation types.

1.3.2 European-American Settlement (after 1859)

Euro-Americans began to appear in the assessment area at the end of the pre-settlement period (1780 – 1850) as exploration began. At this time, European influence on the landscape was minimal. However, initial contact between Native Americans and Europeans decreased their population as the result of disease and confrontation. This decrease in number would have reflected in altered human influenced disturbance processes. By 1850 the supposed impacts Native Americans had on vegetation was erased as their populations plummeted and their permanent settlements became isolated (Shepperd et al. 2006).

European influence on the chaparral vegetation type began in the mid-19th century with the Gold Rush. This time period brought intensive and abusive extraction of natural resources and water diversion. Timber extraction was another local and widespread activity throughout the 19th century. It had severe impacts on the landscape as whole hillsides were left void of all vegetation. A study by Kim and Rejmankova (2001) showed that a distinct decrease in pollen during the late 19th century and increased sedimentation in the Lake Tahoe basin (Central subregion) coincided directly with the time period of heavy timber removal. There is some evidence that this widespread timber extraction likely increased the presence of chaparral on the landscape (Leiberg 1902).

Grazing throughout the assessment area most likely directly affected chaparral and altered their successional pathways. In the early 1860s, an era of intensive grazing throughout the assessment area began. During this time period, sheep were allowed to graze without any restrictions and often numbering in the millions. Unlike the Native Americans, the sheepherders were not selective about what they burned rather setting fire to everything with the goal of burning everything that could burn.

Contemporary patterns of chaparral were initially influenced at the beginning of the 20th century by the decrease in intensive grazing and implementation of fire suppression policies. Both cattle and sheep (Fig. 2) were regularly grazed throughout chaparral and adjacent vegetation types (e.g., meadows, riparian, red fir, mixed conifer) at the beginning of the 20th century. Grazing remained unregulated until the 1920s, when regulations helped bring livestock numbers within reasonable bounds (Kosco and Bartolome 1981). Current management practices have drastically reduced the number of allotments and stocking rates on Forest Service lands. In addition, fire suppression policies ended burning in and around chaparral and in most of the landscape continuing to impact the existing vegetation even today.

2 Methodology

Types of information used to reconstruct the distribution of chaparral throughout the assessment area from the time period prior to the 1800s, primarily the early and mid- Holocene epoch include records from pollen and macrofossils extracted from lake cores and macrofossils from pack rat middens. Only select variables were interpretable from this data, namely chaparral geographic distribution and chaparral species composition as well as some interpretation of ecosystems functions such as fire frequency (Table 3). The restricted spatial extent of lake and midden samples limits ability to extrapolation across the landscape (Romme et al. 2012).

Determining an NRV for the function (disturbance) of the chaparral vegetation type is difficult due to the nature of the fire regime. Stand replacing events occur within all chaparral types consuming all of the vegetative structures leaving little evidence of past stand conditions. In order to assess disturbance variables, inferences were made from large remnant trees that have survived stand replacing events in adjacent chaparral stands leaving behind a fire record. Although only moderate confidence can be assigned to this method it does allow for a record of fire return interval at the stand level.

Other variables (Table 3) were assessed through historic accounts from the recent past (1880s – 1940s) including written accounts, cover type maps, and aerial photographs. In addition, conditions from current reference conditions (Table 3) provide us the conditions of chaparral under a more "natural" disturbance regime recognizing that this includes both lightning and human caused fires. These data allow only extrapolation to the most current period of the Holocene period namely the Anthropocene Epoch and provide a very narrow window as to the potential shifts of chaparral vegetation under a future projected climate.

Finally, there were certain variables that were impossible to assess based on available information. Variables not assessed may not be appropriate for determining trends in the range of variability.

3 The Natural Range of Variation and Comparison to Current Conditions

3.1 Function

The most common function/disturbance in the chaparral vegetation type is recurring stand replacing fire resetting the succession of the vegetation to an early seral stage. In some situations, chaparral can be stable with fire occurring at a temporal scale that precludes succession to trees. In the past 150 years, fire suppression has allowed some of the stable state chaparral to succeed to even aged trees.

3.1.1 Fire

3.1.1.1 NRV

Charcoal concentrations recorded in lake sediments have a coarse temporal and spatial scale, but provide information on the frequency of fires under different climates during the Holocene (Table 4). Charcoal deposited in sediments usually occurs in years that are dominated by large widespread fires (Beaty and Taylor 2009). Therefore, charcoal concentrations can be interpreted as mean fire return interval within the particular watershed during big fire years (Morris et al. 2012).

Data taken from all three subregions (Lily Lake, Lake Tahoe Basin Management Unit (Beaty and Taylor 2009), Siesta Lake, Yosemite National Park (Brunelle and Anderson 2003), and Flycatcher Basin, Shasta-Trinity National Forest, (Anderson and Koehler 2003)) provided a record of the mean fire return interval that spans from the beginning of the interglacial period (approx. 12,000 YBP) to the present day (Table 4). In the early Holocene, fire frequency was low despite a relatively warm and arid climate (Brunelle and Anderson 2003, Anderson et al. 2008, Beaty and Taylor 2009). During this time period, the mean fire return interval for stand replacing events was approximately 173 years. This high return interval can be attributed to low available fuel as the vegetation was sparse following the last glacial period. A peak around 8,000-9,000 YBP represents a return to glacial conditions as a result of a decline in solar insolation and an increase in volcanic activity, resulting in a decrease in fires (Mayewski et al. 2004). In the middle Holocene, where the climate was dominated by warm and dry conditions fire frequency was high (Brunelle and Anderson 2003, Anderson et al. 2008, Beaty and Taylor 2009) with a mean fire return interval of 87 years (Fig. 3). Fire frequency continued to decrease through the late Holocene coinciding with the cooler and moister conditions, but remained highly variable (Brunelle and Anderson 2003). On a smaller scale a distinct peak was noted with a mean fire return interval of approximately 200 years that occurred during the Medieval Warm Period where temperatures were warmer and precipitation lower (Beaty and Taylor 2009).

Determining the fire history of chaparral is difficult due to the dominant type of fire (crown) which completely consumes the aboveground portion of the shrub. As a result, no fire scar evidence is left behind. In some chaparral types, trees are often interspersed within chaparral as single trees or occupy the periphery of the patch. These trees can serve as surrogates for determining the fire return interval in the larger vegetation matrix (Nagel and Taylor 2005). This estimate may be limited as fires that burned at a lower intensity than the chaparral may not have resulted in fire scars owing to a more conservative estimate of the FRI (Nagel and Taylor 2005). Estimates of the pre-European fire return interval (PFRI) have been developed for chaparral and serotinous pines (chamise-redshank) and montane chaparral from an extensive literature review (Van de Water and Safford 2011). Mean fire return interval in chaparral and serotinous pines is 55 years with a range of 30 to 90 years (Safford and Harrison 2004, Van de Water and North 2010). Estimates of FRI in montane chaparral is a mean of 27 years with a range of 15 to 50 years (Van de Water and Safford 2011). Although, there is limited evidence describing the natural range of the fire regime in chaparral reference sites provide some confirmation of the PFRI. At reference sites in Yosemite and Sequoia/Kings Canyon National Parks, chaparral cover was more common in stands that had short fire return intervals and high incidence of char which may suggest high rates of severity (Lyderson and North 2012). Conversely, stands that had a longer fire return interval and more time between fires and low fire severity as indicated by low char heights had reduced chaparral cover (Lyderson and North 2012). More discussion on the sizes of these patches can be found in the section addressing the natural range of variation of structure.

3.1.1.2 Comparison to Current

The current fire return intervals in chaparral differ from the pre-European fire return intervals, but the direction of departure is largely dependent on the dominant chaparral vegetation type and its location. In chaparral and serotinous pines, landscapes that are burning more frequently than they would have during pre-European settlement have a mean FRI of 18.2 years. Safford and Van de Water (In review) calculated the PFRID which is the percent difference between current fire frequencies and the frequencies that occurred prior to European settlement. The chaparral and serotinous pines (chamise-redshank) had a mean PFRID of -19 with a range of -47 to 24. This increase in the frequency of fire as compared to the PFR reflects the southern California chaparral which is highly susceptible to anthropogenic ignitions. The portion of the landscape that is burning more frequently is subjected to human ignitions and type conversion to annual grasslands, making the probability of a burn more likely and the fuel loading more capable of carrying fire on a shorter return interval. The chaparral and serotinous pines found in Central and Northern California (within the assessment area) are not as susceptible to human caused fires and therefore fires are not occurring as frequently than would have historically (Safford and Van de Water In review). Montane chaparral in areas burning 1/3 less, ½ to 1/3 less, 1.5 to 3 times more and 3 times more than the PFRI has a FRI of 8.9, 18.1, 40.3 and 81.8 years, respectively (Safford and Van de Water In review). Montane chaparral had a PFRID of 61 with a mean of 27 to 77 which means that fires are not occurring as frequently as they would have prior to European settlement. Other types of chaparral such as those that occur on ultramafic rocks usually have lower biomass and cover leading to a longer mean fire return interval than the adjacent chaparral on non-serpentine soils (Safford and Harrison 2004).

A more localized study by Keeley et al. (2005b) noted that in the South bioregion approximately 6,000 hectares of chaparral had no fires recorded in the California Fire History database (CalFire FRAP database) (Fig. 5). He states that this is clearly outside of the NRV, but little data is available to test this hypothesis since chaparral are completely consumed during fires leaving no scars to provide fire dates. Similar decreased fire occurrence in montane chaparral have been observed as the extent and structure of the dominant chaparral type have decreased (Beaty and Taylor 2008, Airey 2012). Expanding this to the assessment area, the California Fire History database (CalFire FRAP database) from 1904 – 2012 show that fire has largely been absent in the early part of the century within areas dominated by chaparral (Fig. 4). Over the past 30 years, both anthropogenic and lightning caused fires have increased in the assessment. This still only encompasses about 9% of the total area recorded by CalVeg as being chaparral (Fig. 4).

Despite reductions in the extent and structure of montane chaparral following fire suppression, the fuel loading is still within NRV (Knapp et al. 2009). Keeley et al. (2005a) makes this same conclusion in chaparral stands that have had recurring fires and stands that have had no recorded fires in the past 110 years. He found that shrub cover was not different between these early seral and ancient stands, but herbaceous cover was higher in the ancient stands.

There is limited data to determine any change in the natural range of variation of fire severity in the chaparral vegetation type. The Regional Monitoring Trends in Burn Severity dataset from 1984 – 2012 provides some indication of current fire severity. The initial assessment conducted immediately after a fire allows a determination of severity in stand replacing vegetation types and as such is what we considered to establish current conditions of fire severity. The post-fire assessment is typically conducted one year after the fire and can detect green up, particularly in vegetation types that readily resprout in the following growing season. Of the fires where severity was recorded, > 60% of the landscape dominated by chaparral burned at high severity (>75% change in canopy cover). This indicates that little change has occurred in chaparral in the assessment area with respect to fire severity. Westerling et al. (2006) and Miller (2008) in two separate studies indicate that landscapes dominated by forests in the West and California are experiencing an increase in both the fire size and severity, particularly at low and middle elevations. Many of these fires are converting to chaparral and may take many decades to transition to tree dominated systems if the prevailing climate is suitable.

All types of chaparral existing prior to the fire are most likely to burn in high severity stand replacing events. However, there is some indication that not all chaparral dominated stands would burn at high severity. At Lassen National Volcanic Park (LAVO) in the North biorgeion, three fires were evaluated for severity in chaparral dominated sites identified in 1941. Of these, only 19% burned at high severity while the remaining landscape burned at variable severities (Airey 2012). These patterns in fires severity in chaparral are closely tied to topographical variation at local scale and fire behavior at the landscape scale. Other studies have noted an increase in fire severity on upper slopes that receive higher incident solar radiation (e.g., south facing upper slopes) (Beaty and Taylor 2001, Keeley et al. 2005b, Beaty and Taylor 2008). This variability in severity could also be attributed to stand age as increases in the age of chaparral tends to increase fire severity (Keeley et al. 2005b). Despite resultant fire severity, chaparral has developed adaptations to overcome high severity fire such as facultative and obligate seeding and resprouting (Axelrod 1977, Kauffman and Martin 1990).

Although no information is available to develop an NRV for the season of fire, there is little evidence to indicate that current conditions differ. (Knapp et al. 2009) identified differences in burning in chaparral vegetation indicating that late summer and early fall burns in the dry season would be more appropriately tied to the natural range of variability. Fires conducted outside of this time period would result in decreases in the abundance of seedling germination and resprouting, particularly for those species that are fire-dependent (Kauffman and Martin 1990, Beyers and Wakeman 1997, Knapp et al. 2009). Most out of season burns are prescribed fires used for to meet a variety of fuel management goals.

3.1.2 Invasive species

3.1.2.1 NRV

Non-native invasive plants are beyond their natural range and historic distribution through human activities (Schwartz et al. 1996). By definition, non-native species in California are those that were introduced after European contact in 1769. It was likely that few invasive species were present in chaparral prior to this. Following this period, settlement led to building of modern roads and other development that has acted as a vector for a number of non-native invasive plants.

3.1.2.2 Comparison to Current

The California Invasive Plant Council has estimated that approximately 36 non-native invasive species occur in the assessment area in chaparral and scrub dominated landscapes (Table 5). Management tools such as fire suppression, fuels management and post-fire management have increased the probability of the spread of non-natives within chaparral dominated communities. For example, fire suppression has resulted in longer fire return intervals in chaparral vegetation types often leading to an increase in non-native species (Keeley et al. 2005b). In addition, management such as mastication or herbicide which are tools used frequently in post-fire plantations and in the wildland urban interface to decrease brush can increase the presence of non-native species or facilitate the spread (Potts and Stephens 2009). Focusing on management with prescribed fire could increase the presence of native shrubs and decrease the propensity for replacement with non-native grasses and forbs (Potts et al. 2010) if applied in the appropriate season (Knapp et al. 2009) .

These invasions have altered the natural ecology of many chaparral species, particularly those related to disturbance regimes. For example, in areas where shrubs are killed non-native grasses are stimulated to grow (McGinnis et al. 2010). Invasion of chaparral by *Bromus* spp. (cheatgrass), an annual grass, increases the frequency of burning particularly in areas where human ignitions are prevelant. Here a highly flammable fine fuel allows for a shorter time between fires and a higher probability of fire spread (McGinnis et al. 2010, Keeley and D'Antonio 2011). This leads to areas that can be permanently type converted from forests and shrublands to non-native grasslands.

3.1.3 Successional patterns

3.1.3.1 NRV and Comparison to Current

There is little evidence detailing the successional pathways of chaparral vegetation types throughout the Holocene. It can be assumed from limited pollen data and climate signals that succession in the early to mid-Holocene when conditions were arid and vegetation was reestablishing following the glacial period, was slow and would have been dominated by chaparral for extensive periods of time (Table 4). In the most recent Holocene when climates were more similar to existing conditions, the successional pathways of chaparral were most likely similar to the present with the noted exception of limited human interference (e.g., fire suppression, timber harvest).

Succession in chaparral in the assessment area is initiated following a stand replacing event. In 1934, Weislander identified in extensive surveys the seral stage of chaparral vegetation. He observed that the initiation of early seral often followed regularly recurring stand-replacing disturbances such as logging or fire (Thorne et al. 2008b). Considerable evidence also alludes to the maintenance of chaparral type through recurring fire events. At the time Wieslander conducted his surveys in 1934, early seral mixed chaparral was created mostly as a result of logging or wildfire likely a result of intensive mining and logging pressures (Table 4) (Thorne et al. 2006, Thorne et al. 2008b). The same was not true for montane and chamise chaparral that exhibited no evidence of recent disturbance probably due to location or a lack of merchantable timber.

After a stand replacing event, chaparral proceeds along two distinct successional pathways depending on the dominant chaparral type. In mixed chaparral, subshrubs and herbaceous plants occupy the growing space with the dominant shrubs present at lower canopy cover levels. Transition to the mid to late seral stage happens quickly (8-15 years) with the dominant shrubs occupying most of the available growing space (>80% canopy cover) with herbaceous species and subshrubs restricted to openings (Borchert 2006). Montane chaparral originates similarly to mixed chaparral establishing after a stand replacing event in conifer forests. This early seral stage can have 0-70% shrub cover with limited conifer seedlings. Often the dense cover of the shrubs act as a nurse plant for conifer regeneration. If fire occurs within 30 years, the presence of chaparral may be self-reinforcing. This is often true of certain aspects with shallow soils and ridgetops where fire behavior is often severe to extreme (Beaty and Taylor 2001, Sugihara et al. 2006). In addition, this early stage may persist on poor shallow soils to form a type of edaphic climax community. After 30 years, the chaparral decreases to 10-50% cover as pole and medium sized trees increase. After 50 years, chaparral decreases as tree cover continues to increase reaching up to 80% cover. Under these low light conditions shrubs may senesce leaving extensive skeletons in the understory.

Suppression of fire over the last 150 years has altered the successional pathways of mixed chaparral and may have shifted the dominant shrubs from obligate seeders to obligate resprouters (Keeley et al. 2005a, Keeley et al. 2005b). Although a number of mixed chaparral areas in 1934 in the Central bioregion had some evidence of fire, the 70 plus elapsed years of fire suppression has most likely shifted these stands to dominance of chaparral species that are capable of continuing to resprout (Table 6) (Thorne et al. 2006, Thorne et al. 2008b). Certain species such as *Arctostaphylos* spp. are capable of developing new sprouts and retain dominance (Keeley et al. 2008). In contrast, *Ceanothus* spp. germinate prolifically following a fire but after this initial establishment are succeeded by more tolerant shrubs as the time since fire increases,

There is some evidence that montane dominated chaparral vegetation types are outside of the natural range of variation of successional transitions, particularly in the past 200 years. When Wieslander conducted his surveys in the Central bioregion, more than 50% of montane chaparral had no recorded disturbance (Table 6) (Thorne et al. 2006, Thorne et al. 2008b). Here shrubs are slowly being replaced by *Abies* spp. after 90 to 100 years (Nagel and Taylor 2005, Airey 2012). Clearly this occurrence of fire is outside of the NRV (see discussion under function – fire). Not only are the *Abies* spp. replacing chaparral, but it is often successful at outcompeting dominant pines. This encroachment of white fir (*Abies concolor)* is particularly evident on ridgetops and upper slopes where montane chaparral would have been dominant because of the fire regime (Fig. 8) (Nagel and Taylor 2005, Airey 2012). These locations on south facing upper slopes would have had historically burned at high severity in stand replacing fires (Beaty and Taylor 2008). Now these locations are characterized by high conifer canopy cover and low shrub cover with a high occurrence of shrub skeletons where conifer covers exceeds 50% (Nagel and Taylor 2005).

3.2 Structure

It is likely that similar to forested systems in the assessment area, chaparral structure has been modified through natural functions such as fire. Human factors such as fire suppression, the introduction of non-native species and timber extraction has also altered the structure of the existing chaparral vegetation type.

3.2.1 Patchiness and connectivity

3.2.1.1 NRV

There are no known studies that allow a definitive determination of structural NRV of chaparral throughout the Holocene period. The reliance on reconstruction studies and several reference sites provide a limited scope of the NRV in the latter half of the Holocene (650 YBP – present) during the period dominated by the Little Ice Age. This is included as part of the discussion in the current conditions.

3.2.1.2 Comparison to Current

In order to establish an NRV in the late Holocene and assess current conditions, reference sites were used. These sites are considered to have not been significantly influenced by either intensive management or fire suppression, allowing them to exist in a more natural state. However, it would be safe to assume that these sites have all been modified by human influence although potentially less than the surrounding landscape. They do however provide structural data at a landscape and stand scale.

Horizontal chaparral heterogeneity, specifically the patchiness (patch size and cause), has been modified by both fire and the local abiotic characteristics (Fig. 8). In the North subregion, montane chaparral in Lassen National Park was mapped in 1941. It was spread over 4000 hectares making up about 8% of the landscape located within 103 patches. These patches had a mean size of 42 hectares with a standard deviation of 121 hectares (Airey 2012). Of these patches, about half are experiencing encroachment from the surrounding forest vegetation resulting in habitat fragmentation (more patches) and a smaller mean patch size as conifer cover slowly infills. However, another 34 patches with a mean of 38.4 hectares and standard deviation of 65 hectares have been created as a result of high severity fire. This recruitment into the chaparral patch dynamic reinforces the presence of early succession. Likewise, stand replacing patch density in the Illilouette Creek basin in Yosemite National Park in the Central subregion, which is often used as a reference site, accounted for 15% of the two recent fires occurring in 72 patches. Of these patches those dominated by chaparral covered 214 acres or approximately 5% of the landscape and ranged from 3 to 9 hectares in size with a mean of 4 hectares (Collins and Stephens 2010).

Currently, newly created chaparral patches in areas where fire suppression has been well documented are exceeding the established NRV for these areas (reference the mixed conifer/yellow pine NRV document). Periods of fire suppression and conducive climate, as evidenced in the discussion of this document, has resulted in an increase in live fuel (e.g., trees) that is burning at higher severity when weather conditions are extreme (Miller et al. 2008). For example, the Freds fire in the Central bioregion, had 56 patches of high severity fire in with the largest patch (4111 acres) accounting for 93% of the high severity fire (Freds Restoration Strategy – how should we cite this). The patch sizes in the entire Freds fire perimeter (which includes private plantations) were well above the largest stand-replacing patches found in fires where a more natural fire regime is predominant (220 acres) (Collins and Stephens 2012).

At the community or stand scale, chaparral cover is dependent on topographic position, aspect and soil type. The interaction of fire severity and topography also plays a distinct role in the structure of chaparral in reference sites that have experienced reoccurring fire. In a recent study, Lyderson and North (2012) documented varying degrees of chaparral cover in Yosemite and Sequoia/Kings Canyon National Park (Central bioregion) after 30 years of recurring fires. Higher cover of chaparral was common at ridge lines (23.1%) and upper slope positions (19.5%) while lower slopes had lower rates of cover (12.1%). There was no difference between Northeast facing slopes (17.8%) and Southwest facing slopes (16.3%). Similar patterns are evident in a number of studies documenting the occurrence of chaparral in areas where fire severity would be predicted to be high (Taylor and Skinner 1998, Beaty and Taylor 2001, Beaty and Taylor 2008). These observations may not apply to all circumstances, but they do support the management of forested and montane chaparral communities using topographic variability and likely fire severity, which is the underlying principles behind both GTR-200 and GTR-237 (North et al. 2009, North 2012).

There has been little change in the structure of chaparral vegetation types in the assessment area through the early to late Holocene. There is however evidence that the horizontal structure of chaparral in the last 150 years has been modified as a result of human disturbance and potentially climate change. As a result of fire suppression, the chaparral vegetation type has experienced 1) a reduction in patch size and increased fragmentation in montane chaparral that are successional to conifers and 2) and an increase in patches of chaparral that have converted to an early successional stage following high severity fires.

3.3 Composition

Changes in the geographic distribution of chaparral vegetation type track broadly with climatic shifts throughout the Holocene. In warm and dry climatic conditions, chaparral expanded. During periods of wet and cool climatic conditions, trees were favored over chaparral leading to a contracted distribution. Existing conditions over the last 150 years, have shown only moderate changes in the distribution of chaparral vegetation types.

The geographic distribution of major chaparral and plant species composition throughout the Holocene has remained remarkably similar. In the early Holocene, chaparral throughout the assessment area was characterized by genera such as sagebrush (*Artemisia* spp.) and bitterbrush (*Purshia* spp) that are now primarily restricted to east of the crest. In the middle Holocene, species distribution and diversity west of the crest began to resemble modern day community types dominated by current species such as *Arctostaphyolus* spp. and *Ceanothus* spp. Composition of the chaparral vegetation type has largely been influenced by the Medittareanen climate and has remained quite diverse. Changes from invasive plants are likely to increase which may disrupt the ecology of this vegetation type.

3.3.1 Geographic distribution and plant species diversity

3.3.1.1 NRV

Qualitative data and to a lesser quantitative data allow limited interpretation of the geographic distribution and species composition of chaparral throughout the Holocene. During the last glacial period when climates were cooler, chaparral vegetation types contracted southward occupying portions of southern California and the southwestern United States (Axelrod 1977).

This distribution of chaparral gradually increased northward following the end of the last glacial period (≈ 12,000 YBP) as the climate became milder allowing chaparral to occupy higher latitudes (Axelrod 1977). The diversity of chaparral reached its peak in the middle Pliocene in west-central California during a time when the climate was dry (Axelrod 1977). This established diversity, particularly that of major chaparral species, changed very little throughout the following Holocene (Leiberg 1902).

The early part of the Holocene (12,000 YBP – 8,000 YBP), which marked the beginning of the interglacial period, was cooler and wetter than the existing climate (Table 4). Trees were largely absent and low growing chaparral, primarily sagebrush (*Artemisia* spp.) and associated herbaceous species (*Ambrosia* spp.) were commonly found across the assessment area (Anderson 1990, Smith and Anderson 1992). These species are now found primarily on the East slope of the Sierra Nevada and the Southern Cascades.

The climate of the middle Holocene was conducive to chaparral dominance. In the middle Holocene (8,000-4,000 YPB) temperature was 2.3°C higher than the existing temperature and precipitation was lower. A northward intensification of the Pacific high pressure led to a pronounced increase in dry summer conditions (Edlund 1994). Chaparral pollen was observed in numerous basins in the south, central and northern bioregions in the assessment area and was most likely at is greatest extent during the middle Holocene (Anderson and Smith 1994) (Table 5). Peaks in common montane chaparral species (*Chrysolepis*, *Quercus vaccinifolia*, *Arctostaphylos* spp.) were also evident across meadow basins in the assessment area (Anderson 1990, Smith and Anderson 1992, Brunelle and Anderson 2003, Anderson et al. 2008) (Table 4 and Table 8). In addition, a montane chaparral (*Chrysolepis* spp.) was present at mid- (>2300 m) elevations during the middle Holocene suggesting a sparse forest cover and low available soil moisture (Anderson and Smith 1994)(Table 8 and Fig. 9).

The mid to late Holocene (4,000-1,100 YBP) had a similar climate to the present one (Table 4). With an increase in available moisture, the geographic distribution of chaparral contracted as the open forest transitioned to a more closed canopy (Table 4). Chaparral continued to be dominant in the understory and in areas where an open tree canopy persisted and in habitats not suitable for tree succession, such as ultramafics (Anderson et al. 2008, Beaty and Taylor 2009, Briles et al. 2011) (Table 4).

During the Medieval Warm Period (1,100-650 YBP), temperatures were higher (up to 3.2°C) and drier than current conditions (Table 4). Similarly to the middle Holocene, chaparral likely expanded in its geographic distribution as peaks in charcoal concentration were high indicating high indicating stand replacing events were frequent (Beaty and Taylor 2009). However, fine scale temporal data on chaparral pollen concentrations during this time period are difficult to interpret so this trend is merely speculative. In establishing an NRV for chaparral it is important to discuss the likely causes of widespread disturbance during this time. There has been considerable debate as to the influence the human population had on the distribution of chaparral and other vegetation types during and after the Medieval Warm Period. The presence of large populations of Native Americans may have manipulated the fire regime on the landscape affecting the likelihood of stand replacing events. This is corroborated by a cooler temperature following the MWP during the Little Ice Age and precipitation that increased to approximately 6 cm more than modern rates (Graumlich 1993) (Table 4). In addition, a period of intense charcoal accumulation continued between 800 and 600 YBP despite the decreased temperatures and increase in precipitation. This increase in disturbance rates despite the mild climate may have increased the likely distribution of chaparral.

There is no data available to establish the NRV for non-native/invasive species in the chaparral vegetation type in the assessment area throughout the Holocene. It is likely that few non-native/invasive species were present in chaparral prior to European settlement.

3.3.1.2 Comparison to Current

The current geographic distribution of chaparral types throughout the assessment area has not changed over the last 112 years, however the extent has been expanding or contracting dependent on the dominant chaparral type. No studies have considered the changes in the extent of chaparral over the assessment area in its entirety with the exception of (Show and Kotok 1924). In the early 1900s, Leiberg (1902) surveyed the extent of chaparral throughout a portion of the assessment area (from approximately 39 to 40 degrees latitude covering the Plumas, Tahoe and small portions of the Lassen and Eldorado). He found that scattered clumps of chaparral were common (*Ceanothus cuneatus*) in the woodland zone, scattered chaparral primarily *Ceanothus* spp. was common in the yellow pine zone, and high cover of *Arctostaphylus patula*, *Chrysothamnus* spp, scrub oak (*Quercus* spp.) with *Ceanothus cordulatus* at high elevations was common in the red fir zone. Leiberg (1902) also noted that chaparral was dominant in areas that had either recent or historic fire scars on the landscape. Chaparral exhibited mostly an increasing trend, but because forest fires had decreased the decade prior throughout the study area trends were largely unknown (Leiberg 1902).

Another study conducted by Thorne et al. (2006) in the Central subregion using Wielsander VTM data from 1934 indicated that an overall decrease in chaparral types was evident (Table 7). However, these changes weren't the same for all chaparral types with mixed chaparral increasing in extent and montane and chamise-redshank decreasing across the study area (Thorne et al. 2006). Similarly, another study by Thorne et al. (2008a) which only considered *Quercus* spp. dominated chaparral identified an increase in those in mixed chaparral and a decrease in those in montane and chamise-redshank chaparral (Table 7). A smaller scale study in the same subregion indicated similar decreases for mixed, montane and chamise-redshank chaparral types (Table 7).

Other data sources from the 1940s aerial photo sets suggest that montane chaparral extent has decreased in the Lake Tahoe Basin (Nagel and Taylor 2005), the Lassen Volcanic National Park (LVNP) (Airey 2012) and Yosemite National Park (Collins and Stephens 2010) (Table 7). Similarly, a 28 percent decrease was noted on the Stanislaus Experimental Forest (STEF) on small plots where the chaparral cover was mapped in 1934 (Knapp et al. 2012a) (Table 7). In the only study that looked at the majority of the assessment area, Show and Kotok (1924) recorded the prevalence of all chaparral across the NFS land allocation. Compared to existing vegetation, only a slight decrease in chaparral was evident across the entire landscape (13%) (Show and Kotok 1924). It is likely that this decrease was most evident in chaparral interspersed with competing conifers or in areas that have been fire suppressed.

There is some evidence that the Mediterranean climate has added to the diversity of post-fire floras in chaparral (Keeley et al. 2012). Chaparral species in chamise-redshank, mixed, and montane chaparral consist of a number of key indicator species that are listed in Table 1. Common non-shrub species belong to genera such as *Adenostoma, Phacelia, Calystegia, Lotus, Helianthemum,* and *Cryptantha* (Keeley et al. 2012) (Table 1). In addition, species composition in serpentine chaparral types has a unique assemblage of non-shrub herbaceous species (Table 1).

Existing distributions of chaparral are likely within the range of variability exhibited throughout the Holocene period. Fluctuations in the dominance of chaparral have occurred as a result of climatic changes in the past and these changes will be projected to continue. These climatic fluctuations alter the disturbance regimes changing successional pathways favoring one functional group of species over another.

4 Projected Future Conditions and Trends

4.1 Climate Change and Fire

The extent of chaparral will likely track with changes to the prevailing climate similarly to the trend that was observed throughout the Holocene. Future distributions of the chaparral vegetation type have been assessed for vulnerability in the South bioregion. Using a GFDL climate model (35% decrease in precipitation and a 4.5°C increase in temperature), Schwartz et al. (2013) scored 28% of existing chaparral distribution as at a moderate or high exposure (Fig. 10). This indicates that chaparral is projected to decrease in distribution in 2070-2099. A similar contraction was observed in the PCM climate model (no change in precipitation, 2.5°C increase in T) which showed only 21% of chaparral scored at moderate or high exposure (Fig. 4). The most at risk chaparral types according to the vulnerability assessment occupy lower elevation habitats (Fig. 10). These climate vulnerability assessments do not reflect the potential for high severity fires creating new early seral chaparral on the landscape, but rather reflect the transition from chaparral to other vegetation types under the different climate scenarios.

It is likely that a similar increase in chaparral was experienced in the Medieval Warm Period (1100-650 YBP) where temperatures were 3°C warmer than existing conditions. During this time, various species were found growing at higher elevations than they are found now (Millar et al. 2006) and many subalpine species shifted upslope. In California, areas dominated by conifers can no longer be able to support trees rather shifting to chaparral dominated systems. It may be more appropriate to manage chaparral within the NRV during the Medieval Warm Period.

The flux of the chaparral cover type throughout the Holocene tracks fairly well with increased charcoal concentrations or more frequent fire. Understanding this interaction provides insight into the potential increases in chaparral under a warming climate with increases in fire frequency. The climate models all indicate an increase in temperature as compared to current conditions and a variable rate of increase of precipitation. In addition, increases in CO_2 will likely result in more fuel production (Safford et al. 2012). All three of these are linked to the fire regime and all modeling studies indicate a continued increase in the extent and severity of fires in the assessment area. For example Lenihan et al. (2008), modeled area burned in fires in 2100 and noted a 5 to 8 percent increase. Likewise, severity is also predicted to increase throughout the next century (Westerling et al. 2006, Lenihan et al. 2008, Miller et al. 2008). Some climate scenarios also indicate a decrease in the fire return intervals with the number of years between successive fires cut in half for chaparral dominated landscapes (Fried et al. 2004).

Changes in the fire regime of chaparral in a changing climate will lead to shifts in the extent of chaparral dominated landscapes. Lenihan et al. (2008) and Schwartz et al. (2013) both produced climate scenarios that take into account the potential increase in fire across California. These scenarios indicate decreasing chaparral as shorter fire return interval, higher fire severity, increased temperature and reduced precipitation could lead to the conversion of chaparral to grasslands, particularly and low to middle elevations. There is the possibility that middle to higher elevations may also be type converted from forested conditions to chaparral conditions. This conversion is evident in the multiple large severe fires the assessment area has been experiencing since severity records were available in 1984. It is largely unknown the area occupied by chaparral in the footprints of these fires prior to European settlement.

5 Summary

A complete description of the determinations of NRV is included in Table 9. Below is a summary of the major NRV for the chaparral vegetation type in the assessment area.

- The NRV of the fire regime within chaparral is limited to indirect information from adjacent vegetation types, general fire adaptations, and existing vegetation patterns at reference sites. Fires in chaparral historically occurred every 30-90 years in mixed chaparral (chaparral and serotinous conifers PFR) and 15-50 years in montane chaparral in high severity stand replacing events. Human caused deviations in NRV are likely in this vegetation type. In chaparral interspersed within the conifer landscape, encroachment has increased due to fire suppression reducing canopy cover and extent. Alternatively, large severe fires that are occurring more frequently in the assessment area are increasing the extent of some chaparral dominance.
- The structure of the chaparral vegetation type throughout the Holocene is largely unknown, however it can be inferred from this data that canopy cover and horizontal structure is within the NRV. Recent declines in seral state chaparral have been noted as fire suppression increases the advancement of encroaching conifers.
- The distributions of dominant species of the chaparral systems are likely within the natural range of variability (NRV) as major species in chaparral were present in the pollen record in a number of lake cores across the assessment area. However, deviations in NRV can be assumed as currently invasive species are widely distributed throughout the assessment area. Invasive species often displace native species altering ecosystem function.

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7 Tables and Figures

Table 1 Chaparral types, and common shrub and herbaceous species associated with each type.

Chaparral Type	Indicator species	Common Shrub/Herbaceous species
Chamise-redshank chaparral	*Adenostoma fasciculatum, Ceanothus cuneatus*	*Elymus condensatus, Erigonum fasciculatum, Salvia apiana, Salvia mellifera, Yucca whipplei*
Mixed chaparral	*Ceanothus cordulatus, Ceanothus integerrimus, Quercus wislizenii, Quercus berberididolia, Quercus wislizenii, Toxicodendron diversilobium, Ceanothus cuneatus, Arctostaphylos viscida*	*Zigadenus fremontii, Chlorogalum pomeridanum, Pedicularis densiflora, Galium spp.*
Serpentine chaparral	*Quercus durata, Arctostaphylos viscida, Cupressul macnabiana, Adenostoma fasciculatum*	*Chlorogalum grandiflorum, Allium sanbornii Streptanthus polygaloide, Streptanthus tortuosus var. opatus, Lupinus spectabilis, Lomatium marginatum, Calystegia stebbinsii, Cryptantha mariposae, Senecio lewis-rosei*[1]
Montane chaparral	*Quercus garryana var. breweri, Chrysolepis sempervirens, Arctostaphylos patula, Quercus vaccinifolia, Ceanothus cordulatus, Ceanothus velutinus, Ceanothus nevedansis, Chrysolepis spp.*	*Symphoricarpos rotundifolius, Cerocarpus betuloides, Eriodictyon californicum, Garrya fremontii, Heteromeles arbutifolia, Rhamnus californica, Ericameria greenei*
Alpine dwarf chaparral	*Holodiscus discolor, Ericameria greenei, Cassiope mertensiana*	*Ranunculus eschscholtzii,* Sibbaldia spp.*, Eriognum spp., Arabidopsis spp.,* Oxyria spp.*,* Castilleja spp.*, Draba paysonii, Epilobium obcordatum, Penstemon davidsonii, Phlox covillei*

[1]These species are listed as endemic to the Sierra Nevada serpentine by (Kruckeberg 1984)

Table 2. Major chaparral types and associated environmental conditions and disturbances responses (adapted from (Hanes 1977, Sawyer and Keeler-Wolf 1995).

CNPS Series	WHR Type	Shrub Indicator Species	Elevation (m)	Abiotic	Sucessional
chamise	Chamise-red shank chaparral	*Adenostoma fasciculatum*	10-1800	all slopes, shallow soils, may be ultramafic	No
chamise-wedgeleaf ceanothus	Chamise-red shank chaparral	*Adenostoma fasciculatum, Ceanothus cuneatus*	600-1500	slopes variable, soils shallow, may be rocky	No
chaparral whitethorn	Mixed chaparral	*Ceanothus leucodermis*	100-1900	south facing slopes, steep, deep soils	Yes
Deerbrush	Mixed chaparral	*Ceanothus integerrimus*	300-2100	ridges, upper slopes	Yes
interior live oak shrub	Mixed chaparral	*Quercus wislizenii*	300-1850	all slopes, may be steep, may be rocky, soils alluvial or bedrock derived	Yes
scrub oak	Mixed chaparral	*Quercus berberididolia, Quercus wislizenii, Toxicodendron diversilobium*	300-1500	all slopes, soils deep or shallow, may be rocky.	Yes
wedgeleaf chaparral	Mixed chaparral	*Ceanothus cuneatus*	15-1800	ridges, upper slopes	Yes
whiteleaf manzanita	Mixed chaparral	*Arctostaphylos viscida*	150-1850	ridges, upper slopes, may be steep and may be ultramafic-dervied	Maybe*
Brewer oak	Montane chaparral	*Quercus garryana* var. *breweri*	600-1800	upper slopes, may be steep, rocky	No
bush chinquapin	Montane chaparral	*Chrysolepis sempervirens*	800-3300	ridges, upper slopes, may be steep, soils shallow, commonly granitic derived, may be rocky	Maybe*
greenleaf manzanita	Montane chaparral	*Arctostaphylos patula*	750-3350	ridges, upper slopes, shallow soils, commonly granitic derived	Maybe*
huckleberry oak	Montane chaparral	*Quercus vaccinifolia*	700-2800	ridges, upper slopes, steep, soils may be shallow and granitic derived	Maybe*
mountain whitethorn	Montane chaparral	*Ceanothus leucodermis*	900-2900	ridges, upper slopes	Yes
tobacco brush	Montane chaparral	*Ceanothus velutinus*	50-3000	ridges, upper slopes	Yes

*These series could be stable or successional to the surrounding vegetation type. They are considered stable on shallow, rocky soils.

Table 3. Indicators assessed in the natural range of variability of chaparral with reference to the the source of information and the time frame of the data source.

Variables Assessed	Source of Information	Time Frame
Geographic distribution	Pollen and macrofossils from lake cores, macrofossils from pack rat middens, mapping efforts in early 1900s, historical photographs	Paleoecological and reference conditions
Plant species diversity	Pollen and macrofossils from lake cores, macrofossils from pack rat middens	Paleoecological conditions
Structure	National Park Service lands (Yosemite National Park, Sequoia/Kings Canyon National Park, Lassen Volcanic National Park), Research Natural Areas (Cub Creek Research Natural Area), historical photographs	Reference conditions
Disturbance	Limited fire scar information, National Park Service lands (Yosemite National Park, Sequoia/Kings Canyon National Park, Lassen Volcanic National Park), Research Natural Areas (Cub Creek Research Natural Area)	Reference conditions

Table 4. Climate, fire frequency, and chaparral distribution and composition throughout the Holocene (12,000 – 650 YBP).

Temporal Scales (YBP)	**Temperature** (difference from current)	**Precipitation** (difference from current)	**Charcoal Concentrations/ Fire Frequency**	**Westside Chaparral Distribution and Structure**	**Westside Chaparral Composition**
650-present	Low[4]	Moist [4]	Low[3,4,7,11,12]	current	current
1100-650	Moderate[1, 7, 8]	Dry[7, 8]	Low[3,4,7,11,12]	Increasing shrub pollen[4,10]	*Prunus, Cerocarpus*[4]
4000 – 1100	Moderate[1, 2]	Moist[4]	Moderate[3,4, 5,7,11,12]	More closed forest, *Pinus* spp. and *Quercus* spp. dominated, lower pollen of montane chaparral[2,10]	Decrease in open ground dominated species such as Poaceae and Asteraceae[7,10]
8000 – 4000	High[1, 4]	Dry[10]	High[2,3,4, 5, 7,9,11,12]	Open forest; Greater shrub component in understory, extensive montane chaparral[4, 7,10]	*Cercocarpus*, Ericaceae (probably *Arctostaphylos*), *Chrysolepis*, *Quercus vaccinifolia, Artemisia, Quercus, ,*[2,4,10,13]
12000 – 8000	Low[4, 5]	Moist[5]	Low[3,7,11,12]	Trees absent, low sagebrush and herbaceous pollen[2],[5]	*Ambrosia, ChenoAm, Cerocarpus, Purshia, Ephedra, Artemisia, Quercus, ,*[2]

[1](Potito et al. 2006)
[2](Anderson 1990)
[3](Beaty and Taylor 2009)
[4](Woolfenden 1996)
[5](Smith and Anderson 1992)
[6](Woolfenden 2003)
[7](Anderson et al. 2008)
[8](Millar et al. 2006)
[10](Anderson and Smith 1994)
[11](Brunelle and Anderson 2003)
[12] (Daniels et al. 2005)
[13](Edlund 1994)

Table 5. Invasive species of high concern associated with chaparral/scrub dominated landscapes in the assessment area (Sierra Nevada, Cascades) as determined by the California Invasive Plant Council.

Scientific Name	**Common Name**
Brassica tournefortii	Sahara mustard, Morrocan mustard
Bromus madritensis ssp. rubens	red brome, foxtail chess
Bromus tectorum	cheatgrass, downy brome
Centaurea solstitialis	yellow starthistle
Cortaderia jubata	jubatagrass, pampasgrass
Cortaderia selloana	pampasgrass, white pampasgrass
Cytisus scoparius	Scotch broom, English broom
Foeniculum vulgare	fennel, sweet fennel
Genista monspessulana	French broom, soft broom
Rubus armeniacus	Himalayan blackberry
Spartium junceum	Spanish broom
Taeniatherum caput-medusae *Elymus caput-medusae*	medusahead
Tamarix ramosissima, T. gallica, T. chinensis	saltcedar, tamarisk

Table 6. Percent change in chaparral distribution in the Central Sierra by associated disturbance (Thorne et al. 2006, Thorne et al. 2008b).

WHR Type	**Early seral due to logging**	**Early seral due to burns**	**No recorded disturbance**
Central Sierra			
Mixed chaparral	23	59	18
Montane chaparral	27	20	53
Chemise-redshank chaparral	<1	<1	99
Placerville Quad			
Mixed chaparral	12	73	15
Montane chaparral	0	56	44
Chemise-redshank chaparral	0	<1	99

Table 7. Percent change in chaparral distribution and range (if available) obtained from historical records collected approximately from 1910-1940.

Location	Bioregion	Time Period	Size of Area Measured (ha)	Percent change in chaparral landscape distribution
Stanislaus Experimental Forest[1]	Central	1929/2008	12	-28
Lake Tahoe Basin Management Unit[2]	Central	1939/2000	unknown	-62
Lassen Volcanic National Park[3]	North	1941/2005	unknown	-68
Yosemite National Park[4]	South	Reference conditions	4285	-15
Central Sierra Province[5]	Central	1934/1996	3 million	-30
Chamise-redshank chaparral	Central	1934/1996	3 million	-57
Mixed chaparral	Central	1934/1996	3 million	+14
Montane chaparral	Central	1934/1996	3 million	-74
Placerville Quad[6]	Central	1934/1996	240812	-57
Chamise-redshank chaparral	Central	1934/1996	240812	-87.9
Mixed chaparral	Central	1934/1996	240812	-16.1
Montane chaparral	Central	1934/1996	240812	-92.7
Central Sierra Province[7]	Central	1934/1996	3 million	-30
Quercus dominated mixed chaparral	Central	1934/1996	3 million	+14
Quercus dominated montane chaparral	Central	1934/1996	3 million	-42
Quercus dominated chamise-redshank chaparral	Central	1934/1996	3 million	-57
Assessment Area[8]	North, Central, South	1924/2013	10 million	-14

[1](Knapp et al. 2012a)
[2](Nagel and Taylor 2005)
[3](Airey 2012)
[4](Collins and Stephens 2010)
[5](Thorne et al. 2006)
[6](Thorne et al. 2008b)
[7](Thorne et al. 2008a)
[8] The percentage change was determined by comparing the percent of total shrub vegetation as reported by (Show and Kotok 1924) to existing CalVeg shrub (mixed and montane chaparral WHR types) vegetation. The total area of FS and private lands was included and it is largely unknown whether the 1924 data included nonvegetated areas. As a result, the 1924 data was only compared to the existing excluding urban, barren, agriculture and water. In addition, slight changes have occurred in the forest boundaries since 1924.

Table 8. Pollen percentages for common chaparral and herbaceous species in several basin sediments located in the Western portion of the assessment area.

Species	12,000-8,000 YBP	8,000-4,000 YBP	4,000-1,100 YBP	1,100-650 YBP	650-0 YBP
Ambrosia spp. [2]	Low	Low	Low	Low	Low
Artemisia spp. [1,2, 3,4, 5]	High	High	Low	Moderate	Moderate
Cheno-*Am*[2, 3]	Moderate	Low	Low	Low	Low
Chrysolepis spp. [1, 3, 5]	Moderate	Moderate	Low	Low	Low
Quercus spp. [2]	Low	Low	Moderate	High	High

[1](Anderson 1990)
[2](Anderson et al. 2008)
[3](Brunelle and Anderson 2003)
[4](Smith and Anderson 1992)
[5](Anderson and Smith 1994)

Table 9. Summary of variables describing chaparral characteristics within the assessment area relative to their estimated natural range of variability (NRV) in the Holocene with an indication of confidence in making each comparison.

Ecosystem Attribute	Indicator Group	Indicator	Variable	Within HRV	Confidence	Pages with discussion	Notes
Function	Disturbance	Fire	fire return interval	no	moderate	8	There is limited information on the FRI of chaparral prior to the Holocene. The FRI is most likely within range for the entire Holocene. However, evidence from the pre-Euro settlement would indicate that we are no longer within NRV for some parts of the landscape that have not had fires in the 108 year fire history record.
Function	Disturbance	Fire	fire severity	yes	moderate	9	Although only ancilliary data is available to assess fire severity it is likely that chaparral would have burned at variable rates of high severity throughout the Holocene and this is still within NRV.
Function	Disturbance	Fire	fire season	yes	moderate	9	Based on fire scar research in adjacent conifer forest, the season of fire is within NRV.
Function	Disturbance	Native vegetation management	Percent cover chaparral affected	maybe	low	10	Current vegetation management could cause type conversion as intensive management of early seral is focused on conifer dominance.
Function	Disturbance	Successional patterns	Conifer encroachment	no	moderate	11	Conifer densities have increased in seral state chaparral as a result of fire suppression and past mangement. Although there is no information on conifer densities throughout the Holocene in, conifer density in the last 150 years is considered outside of NRV. Conifer densities within stable state chaparral are still within NRV.
Structure	Canopy Cover	chaparral cover	Percent cover	no	low	13	This is based on only a small amount of data gathered from reference sites. Most indicate that at least in areas where chaparral is naturally interspersed with conifers there has been a decrease in canopy cover.

Ecosystem Attribute	Indicator Group	Indicator	Variable	Within HRV	Confidence	Pages with discussion	Notes
Structure	Structural class types (continuous canopy, patch-gap, open gap)	patch size	patch size	yes	low	13	This is based on only a small amount of data gathered from reference sites. Most indicate that at least in areas where chaparral is naturally interspersed with conifers patch sizes were highly variable and are within the NRV. Some areas that have experienced fire suppression may be trending toward outside of NRV.
Structure	Density	Conifer Seedling/ Sapling Density	Density of conifers	no	low	13	Conifer seedlings and saplings have increased in seral chaparral types as a result of fire suppression.
Composition	Productivity	Biomass	Herbage	yes	Low	15	Biomass is within NRV in most chaparral vegetation types. An influx of non-native annual grasses may be shifting the amount of herbage in some landscapes.
Composition	geographic distribution of ecosystems	land cover	Total area	yes	low	15	The availability of fine scale pollen data is limited for chaparral species and the fire regime of chaparral limits the NRV to only a few reference sites and no information from pre-European settlement.
Composition	geographic distribution of major species	species composition	species richness	yes	moderate	16	Only general conclusions can be made from available data but according to most pollen records species composition has remained rather stationary throughout the Holocene.
Composition	Invasive species	invasive species patterns	invasive species richness	no	moderate	16	No data exists prior to European settlement but records indicate most non-native/invasive species were introduced post settlement and therefore the trend of non-native invasive diversity is increasing.
Composition	Proportion of growth forms	Presence of reproductive groups	Seeders: Sprouters	maybe	Low	11	Some studies indicate that fire suppression has decreased the proportion of seeders in chaparral particularly those that require fire for germination.

Figures

Figure 1. The current distribution of chaparral in the assessment area by CalVeg WHR type.

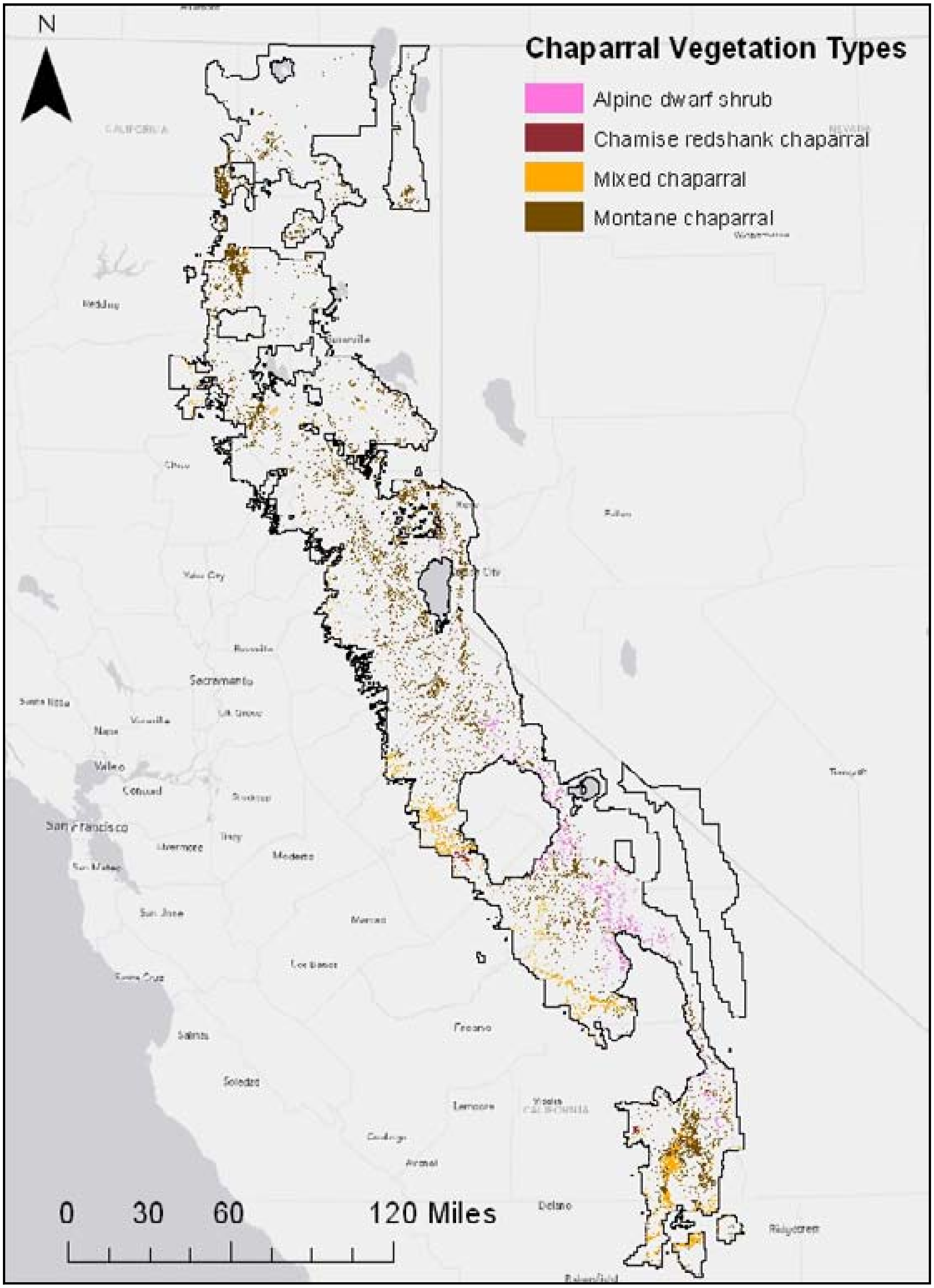


Figure 2. Human caused disturbances that occurred from 100 YBP - present (approx. 1850 – 1940) that influenced the extent of aspen in the assessment area.

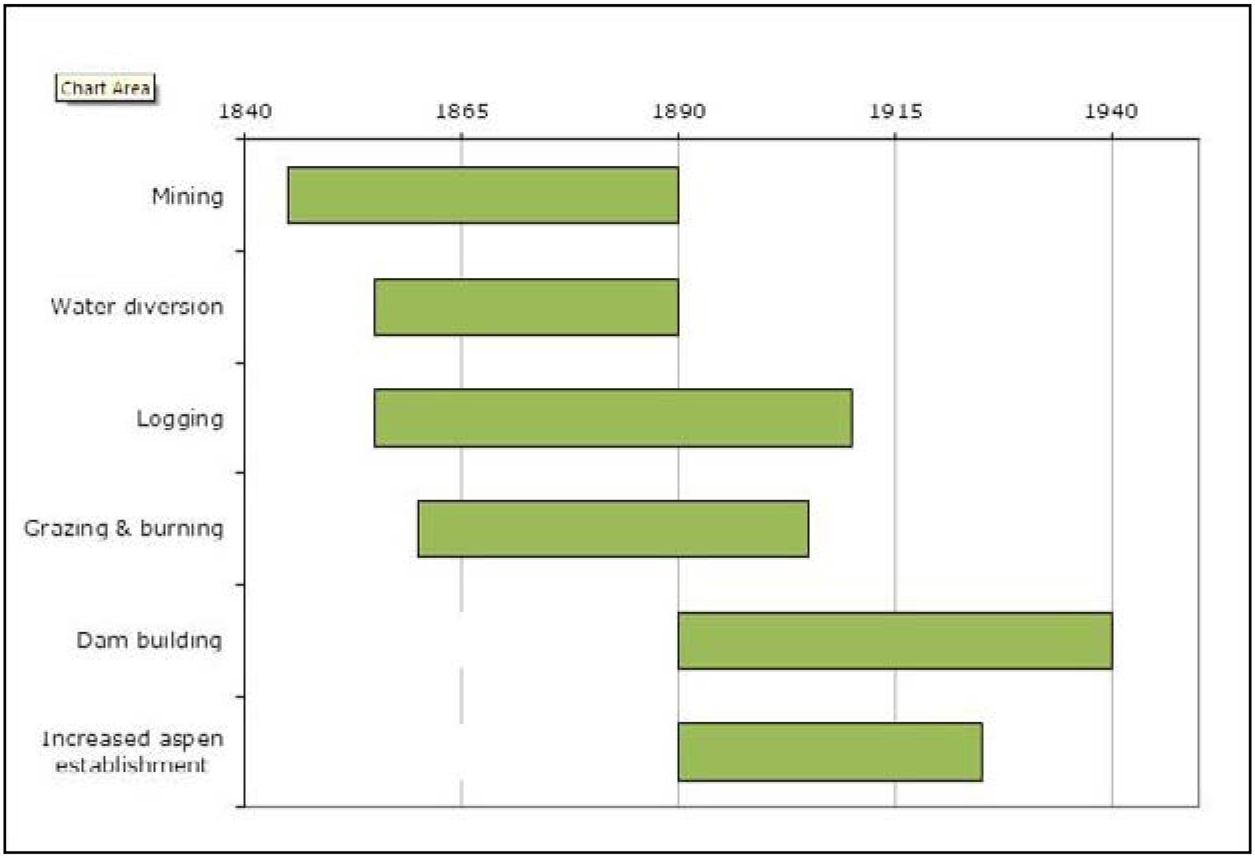


Figure 3. Mean fire return interval estimated using Daniels et al. (2005) and Beaty and Taylor (2009). Note that this only detects years in which multiple fires were burning across the land-scape (i.e., big fire years).

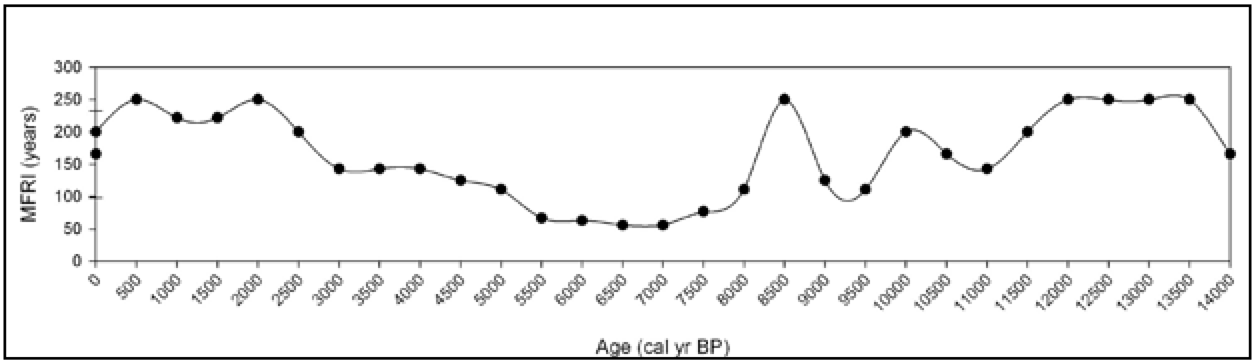


Figure 4. Hectares burned in the chaparral vegetation type (identified using the CalVeg Regional Dominance grouping all chaparral types) by human or lightning ignited fires derived from the FRAP database from 1904-2012.

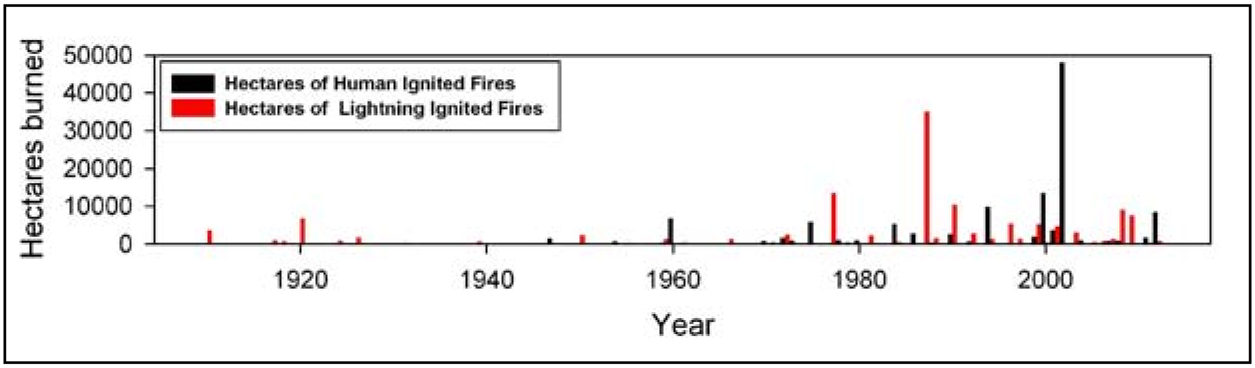


Figure 5. A portion of chaparral in 2005 in the south bioregion had not experienced a fire in over 102 years while the remaining landscape was within NRV, adapted from (Keeley et al. 2005b).

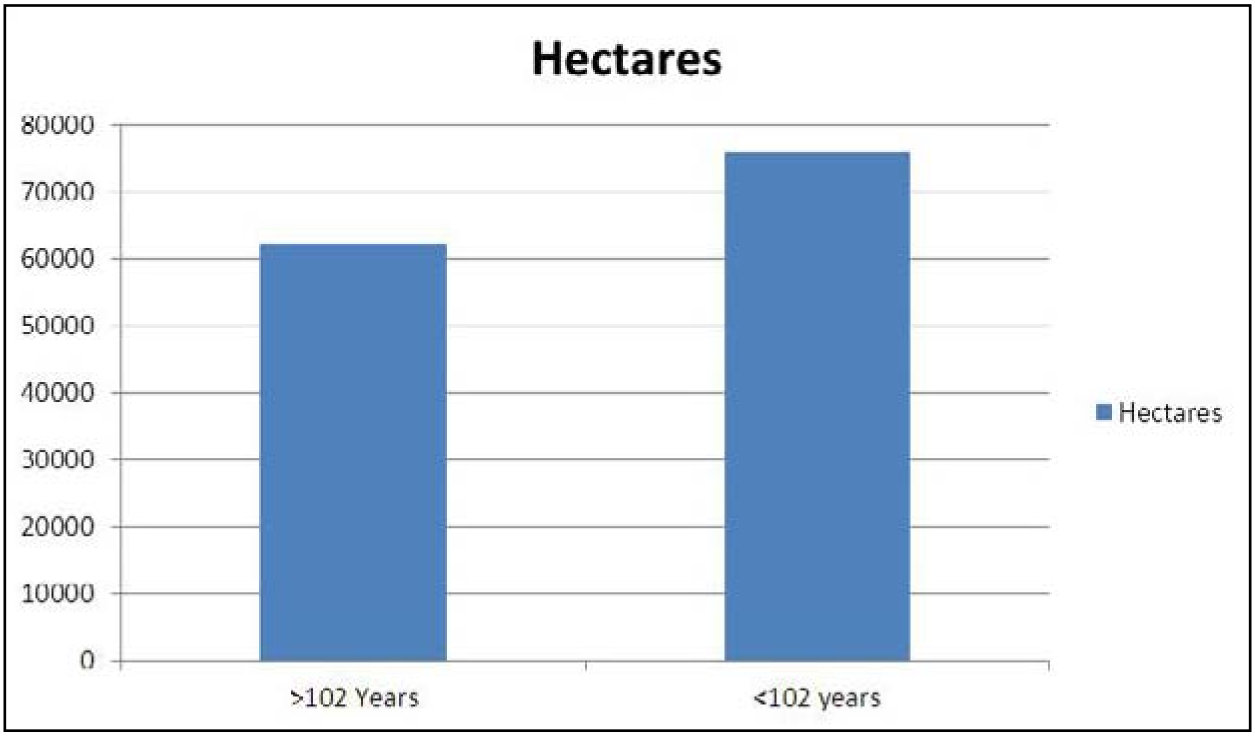


Figure 6. Fire severity (derived from the MTBS dataset initial assessment) from fires that occurred from 1984-2012 within the chaparral vegetation type (identified using the CalVeg Regional Dominance). Fire severity is defined as the percent change in canopy cover.

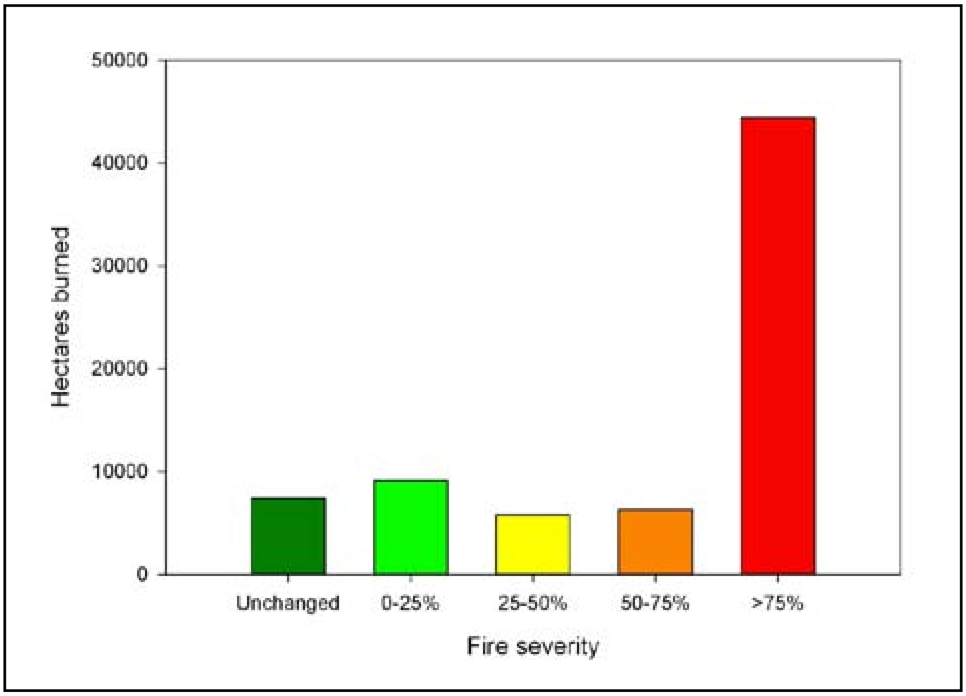
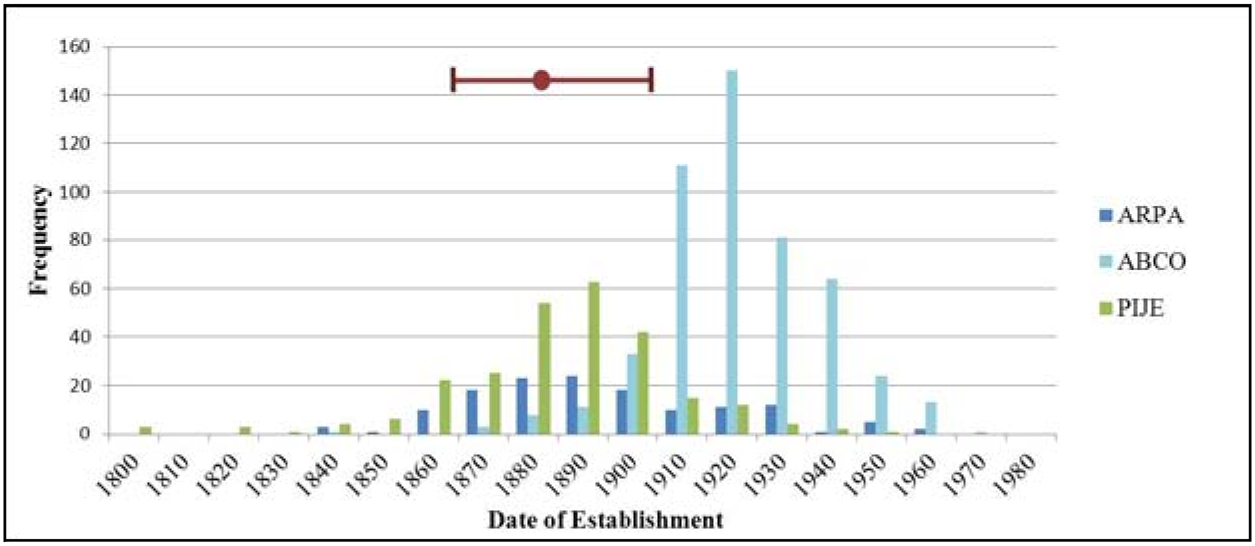


Figure 7. Dates of establishment of *Arctostaphylos patula*, *Abies concolor*, *Pinus Jeffreyi, Abies* spp., *Pinus* spp. at five locations on the a)West Shore of the Lake Tahoe Basin Management Unit (Nagel and Taylor 2005) and b) Lassen Volcanic National Park (Airey 2012). Inset on top indicates the FRI for montane chaparral with the left bar being the time since last fire.



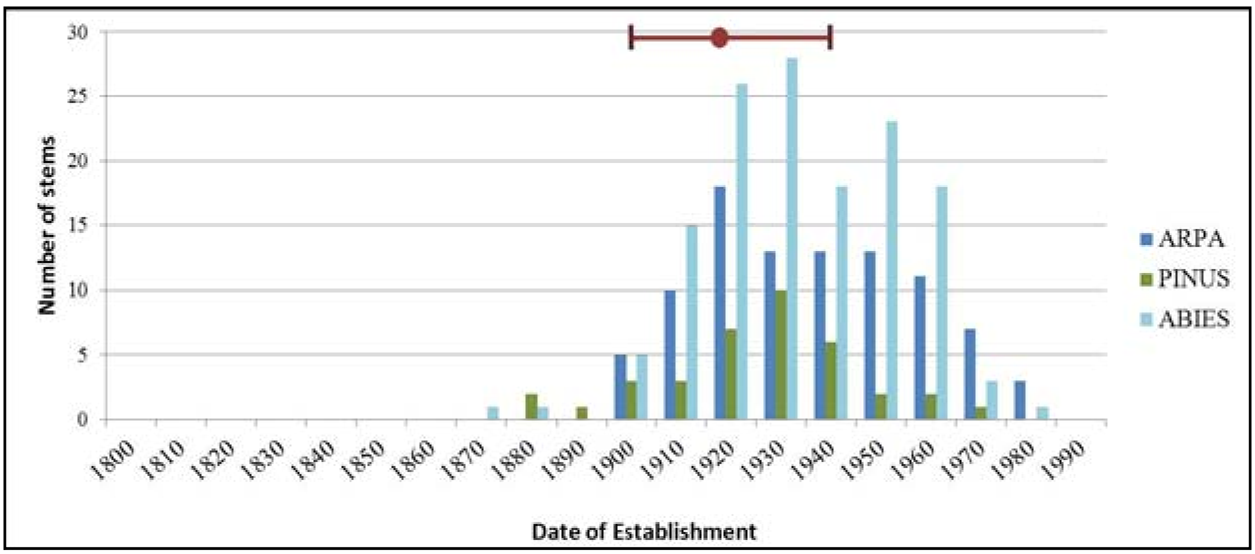


Figure 8. Jeffrey pine-white fir and red fir stands on Flatiron Ridge (foreground) and Saddle Mountain (background) in the southern subregion in the assessment area. In 1925 patches of mature trees of variable size occur in a matrix of brush. This vegetation pattern is probably the result of a series of moderate and high severity fires that killed forest patches and generated chaparral. Shrub cover is much lower in 2010 and the chaparral have been invaded by white fir, Jeffrey pine, red fir, and western white pine. Overall, the forest is now more dense and the forest cover is much more homogenous than it was in 1925.

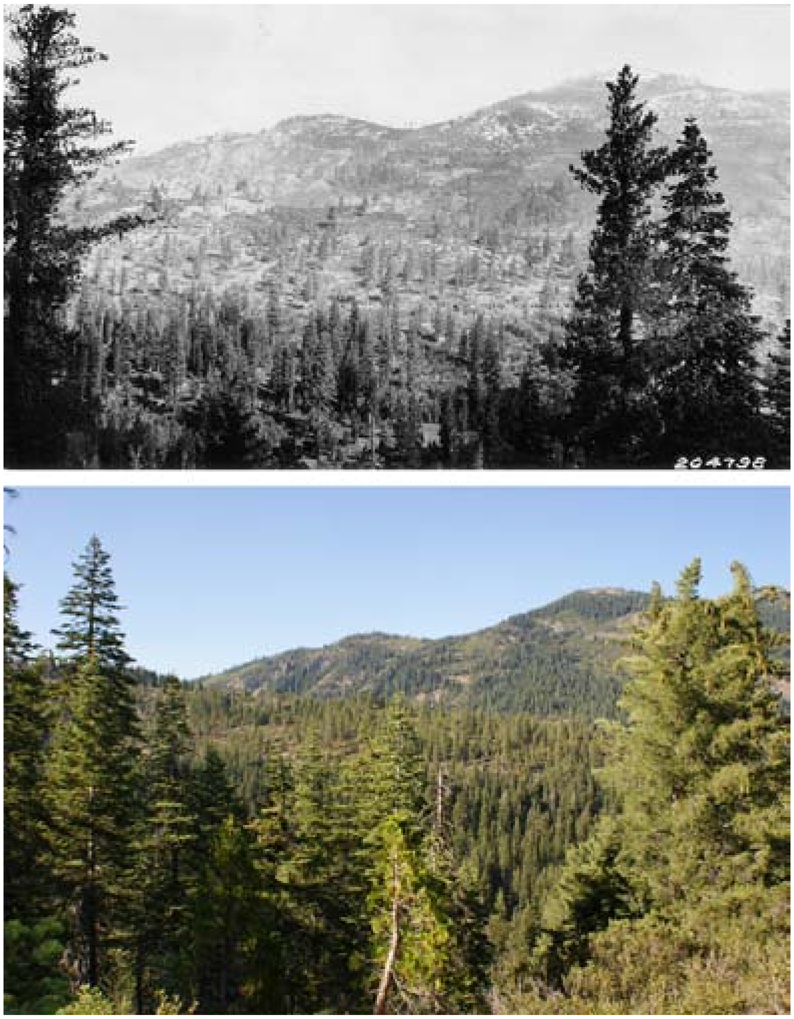


Figure 9. Pollen percent of a common montane chaparral species, *Chrysolepis* spp., by elevation and years before present. Taken from (Anderson and Smith 1994).

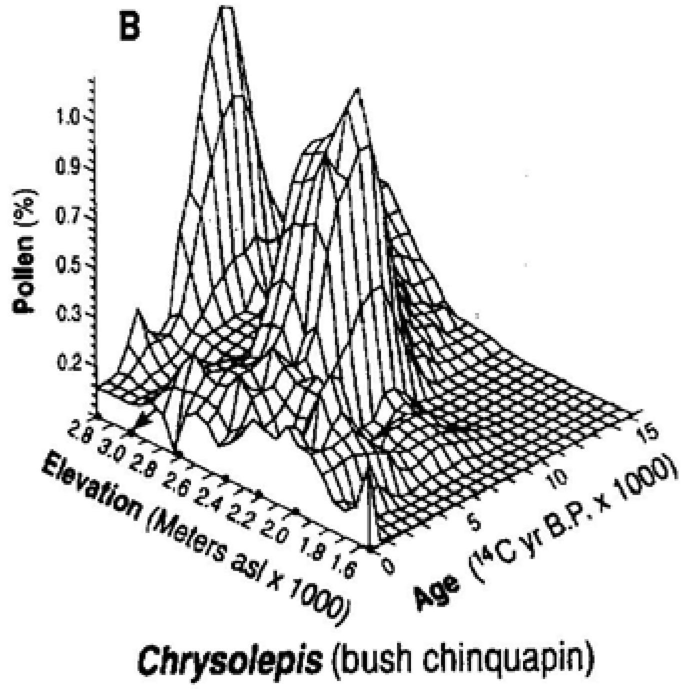


Figure 10. Climate vulnerability assessment for the Southern bioregion (including the Sierra, Sequoia and the Inyo) showing the exposure scores at 2010-2039 for all chaparral types and the exposure scores at 2070-2099 using the GFDL climate model. Taken from (Schwartz et al. 2013).