California Chaparral and Woodlands

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Abstract

California chaparral is one of four sclerophyllous shrublands in North America, each with their own unique climatic patterns, but sharing a common history and similar plant taxa. Traditionally, California chaparral has been viewed in context with other Mediterranean climate plant communities. This view has generally ignored the remarkable relationship California chaparral has with the continent's three other sclerophyllous shrublands: Sonoran chaparral in Arizona, Madrean-Oriental chaparral in west Texas, and mexical in Mexico, reaching as far south as Oaxaca. By comparing chaparral within the context of other North American sclerophyllous shrublands, rich, new areas of research can be facilitated. This is especially important because California chaparral is the most widely distributed habitat within the California Floristic Province, a designated biodiversity hotspot. We present a new model for chaparral ecology that moves away from the current focus on the chaparral's relationship to fire, encouraging a wider examination of many other attributes of chaparral ecology including biodiversity, interactions between plant and animal species, and the value of old-growth chaparral. This wider examination can also enhance new approaches to studying the chaparral's natural fire regime, now limited to comparing pre- and post-European contact periods. Developing a more ecologically-based definition of California chaparral that appreciates all successional processes in the system, as well as its intrinsic value, is crucial to protecting what is left of the region's intact sclerophyllous shrublands.

Drought-hardy shrublands

Biogeography

California chaparral is one of four sclerophyllous shrublands in North America. Sclerophyllous refers to evergreen, woody shrubs that are able to withstand challenging levels of drought with evaporation resistant, thick, leathery leaves.

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California chaparral occurs along the coastal, southwestern edge of the continent, from southern Oregon to northern Baja California, Mexico (Fig. 1). Across this range, California chaparral has been influenced for nearly 2 million years by a Mediterranean climate with hot, dry summers and mild, wet winters.

Chaparral is California's most widely distributed ecosystem. Once the preferred habitat of the now extinct California grizzly bear (*Ursus arctos californicus*), and characterized by shrubs such as the burgundy-barked manzanita and blue- or white-flowering *Ceanothus*, chaparral covers many of the state's hills and mountains with rich biodiversity that reaches its peak on the central coast. In fact, one of the reasons California is renowned for its biodiversity is because of chaparral, which comprises only 9% of the state's wildland vegetation yet contains 20% of its plant species (Parker, 2020). At least 374 faunal species and an unknown number of invertebrates also occur in chaparral, nearly 38% of which are considered sensitive, threatened, or endangered (Jennings, 2018).

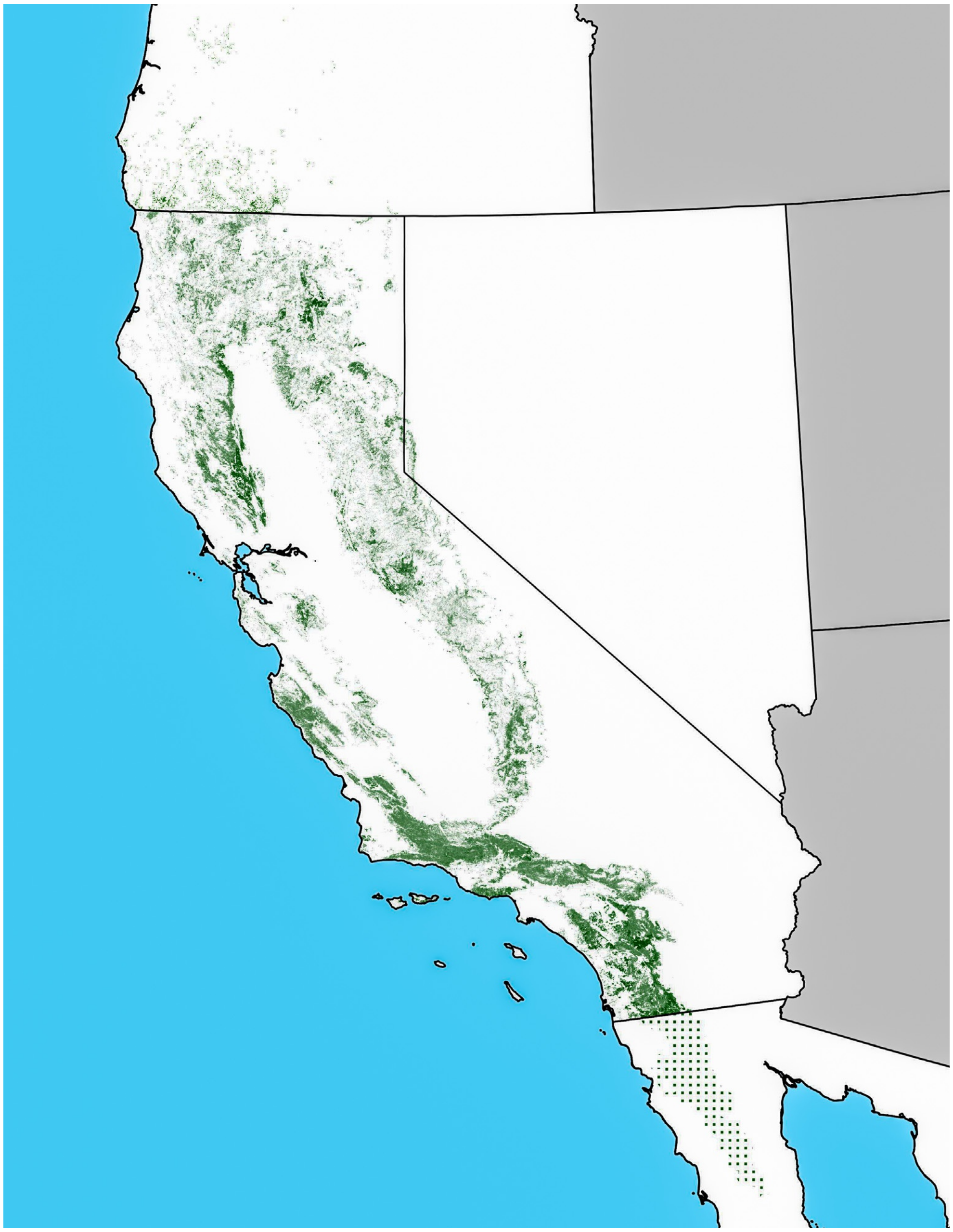

Fig. 1 Extent of California chaparral in the U.S. (California, Nevada, and Oregon) and Mexico (northern Baja California). Chaparral was delineated in California using the Classification and Assessment with Landsat of Visible Ecological Groupings (CalVeg) dataset crosswalked to the California Wildlife Habitat Relationship (CWHR) system. Land cover data from the Gap Analysis Project (U.S. Geological Survey) were used to delineate chaparral in Oregon and Nevada. Only the approximate extent of chaparral is shown for Baja California (in contrast to U.S. states where approximate stand-level data are shown), redrawn from the Baja Ecological Regions map by the San Diego Natural History Museum.

Many of these species are imperiled due to human activity, making the California Floristic Province, where the chaparral is distributed throughout, a biodiversity hotspot.

California chaparral is also the dominant ecosystem surrounding major population centers such as Santa Barbara, Los Angeles, and San Diego, with millions of people visiting chaparral-dominated parks and preserves each year. The ecosystem may have been seen by more people on Earth than any other due to its prominence in Hollywood films and television shows that have been made across the landscapes of southern California over the past century. Yet, despite its use for outdoor recreation and its ubiquitous presence in popular media, the ecosystem remains largely misunderstood by the general public.

The three other sclerophyllous shrublands in North America generally form smaller communities than in California: (1) Sonoran chaparral in central Arizona; (2) Madrean-Oriental chaparral in the Big Bend region of West Texas, southeastern New Mexico (Guadalupe Mountains), and northern Mexico; and (3) mexical shrublands, scattered throughout semi-arid, rain-shadow portions of Mexico's central and eastern mountain ranges as far south as Oaxaca. Mexical has a climate pattern opposite of California with summer rain and winter drought. Sonoran and Madrean-Oriental chaparral have rain occurring during both winter and summer months.

As proposed by Daniel Axelrod (1975) in his classic paper, *Evolution and biogeography of Madrean-Tethyan sclerophyll vegetation*, the widely disparate distribution of North American sclerophyllous shrublands is the remaining legacy of a great, ancient band of sclerophyllous vegetation that once spanned across North America and Eurasia as the climate was beginning to dry during the middle Eocene (45 million years ago). Sclerophyllous shrubs may have formed the understory of woodland forests that included oaks, laurels, and madrones. Many of the traits common to chaparral plant species today, including thick, evergreen leaves, resprouting, and deep root systems, were likely established by this time.

Climate

As the climate continued to dry during the middle Miocene (10 million years ago), sclerophyllous vegetation maintained and likely expanded its range as forests retreated. It was not until the Pleistocene (1.8 million years ago) that California's Mediterranean-type climate began to significantly differentiate coastal chaparral from the other sclerophyllous shrublands on the continent. As deserts expanded, the once nearly contiguous shrubland habitat was separated into its current four separate formations. During interglacial periods, shrublands expanded and contracted depending on regional moisture levels.

Despite the separation and differences in climate, all four sclerophyllous shrublands in North America still share many of the same plant genera. Mexical shares at least 14 genera with California chaparral, seven of which are also found in the Mediterranean Basin (Valiente-Banuet et al., 1998).

At least two species are found in all four North American sclerophyllous shrublands: cup leaved ceanothus (*Ceanothus perplexans*, formerly *C. greggii*) and pointleaf manzanita (*Arctostaphylos pungens*). In California chaparral, both of these species are considered obligate seeders, where the adult population is killed during fire and depend on a dormant, fire-cued seed bank for regeneration. However, both species have been frequently observed germinating from seed in open areas in central/southern Mexico where fire is largely nonexistent (pers. comm. Alfonso Valiente-Banuet). This is in line with Axelrod's insistence that sclerophyllous taxa are better thought of as "generalists" rather than "specialists." The chaparral's plant species ability to adapt to various natural selection pressures has played an important role in its success in semi-arid environments.

An ecologically-based definition for chaparral

Utilitarian viewpoints

How ecosystems and plant communities are defined can shape how they are perceived and valued by the public, scientists, and land management agencies. In the anthropocentric world, Nature is often defined by the resources, or ecosystem services, it can provide. This poses a problem for chaparral because it does not offer timber for sawmills, grass for cattle, or any other easily exploitable resource. This lack of commodification by Euro-American colonizers and present-day commercial interests has had a paradoxical effect: chaparral was often neglected in historical conservation efforts aimed at protecting a valuable resource for future use (e.g., early forest conservation efforts were largely focused on protecting future timber supply), but it has also long been a target for removal so it can be replaced with a different vegetation type considered more economically productive (e.g., grassland for livestock grazing).

The primary utilitarian value of chaparral relates to its function as a cover in areas where other vegetation cannot easily grow—areas where deep-rooted shrubs are important for soil stability. After multiple human-caused fires threatened chaparral-protected watersheds in southern California, the federal government designated four forest reserves at the turn of the twentieth century to maintain proper watershed function. These later became the Cleveland, San Bernardino, Angeles, and Los Padres National Forests. Contrary to the national forest name, all are between 52% and 88% chaparral (Fig. 2).

Avoiding fuel-centrism

Because chaparral is subject to large, wind-driven wildfires that can be destructive to nearby human communities, the ecosystem's relationship with fire has become a major focus. Extensive research has been conducted investigating the impact of fire on chaparral,

Fig. 2 Mixed chaparral in the coastal Santa Ynez Mountains near Santa Barbara, California, U.S.A. The chaparral here is comprised of bigberry manzanita (*Arctostaphylos glauca*), Eastwood's manzanita (*A. glandulosa*), chamise (*Adenostoma fasciculatum*), hoary leaved ceanothus (*Ceanothus crassifolius*), and other shrub species. Photo by Bryant Baker.

how plant species respond to it, and the best methods to protect surrounding communities from fire hazards. So, it is not surprising that fire often dominates discussions about chaparral and is a frequent element in its definition. Descriptors such as fire-dependent, fire-based maintenance, and fire-type, are often used, implying that without fire, chaparral would not exist. Many traits of chaparral plant species are suggested as adaptations to fire when other explanations are better aligned with more constant selection pressures. For example, the aromatic terpene compounds in leaves are seen as supporting the notion that chaparral is born to burn, when in fact they may be more related to preventing evaporation and herbivory. Chaparral that has been fire-free for too long has been labeled as "senescent," "decadent," or trashy. Such a perspective is contrary to the rich habitat old-growth chaparral (>50 years since last fire) can provide.

Viewing a native ecosystem in fuel-centric terms, rather than as a valuable natural resource, can have significant conservation impacts. An immense body of research has demonstrated that when periods between fires in chaparral are shortened (<10–20 years), many species are unable to persist. Overly-frequent fire, rather than its absence, is one of the primary environmental variables that has been shown to threaten chaparral extent and biodiversity (Park and Jenerette, 2019).

Such fire-focused definitions of chaparral, combined with the impact wildfires have had on communities, have caused chaparral to become nearly synonymous with fire, especially in southern California where some of the most destructive (i.e., loss of life and property) fires have occurred. This compounds the effect of chaparral having little commodification because chaparral is seen as either worthless or as a fire threat—two views that were often combined historically to justify its removal over large portions of the landscape. When wildfires do occur in chaparral, fire officials frequently refer negatively to the habitat's age and suggest it would have been better if they had conducted prescribed burns to remove the "fuel" prior to the fire.

The perspective that chaparral needs to burn to remain healthy has provided the fundamental rationale for many chaparral habitat clearance projects that are often based entirely on the amount of time since fire last occurred. This can result in the loss of legacy old-growth stands that provide important habitat to numerous species and the acceleration of type conversion, whereby chaparral is replaced by a less diverse savanna-type plant community usually dominated by non-native forbs and grasses.

Multiple influential variables

Although fire has been an important evolutionary selection pressure on species living in three of the four sclerophyllous shrublands in North America, the mexical formation raises interesting questions about fire, or the lack thereof, and the role it plays regarding the continued presence of the continent's native shrublands. With increasing fire frequencies now threatening California chaparral with type conversion, the notion that chaparral is fire-dependent is overly simplistic and fails to take into account the complexities of natural fire regimes and the impact of human-caused climate change.

To address the conservation issues that arise from traditional definitions of chaparral, fire should be considered as just one of the many variables that have shaped the evolution of the ecosystem and continue to do so on the modern landscape. Other, more constant factors such as intense dry seasons, infrequent frosts, herbivory, low nutrient availability, topography, and edaphic (soil) conditions can have greater evolutionary impacts than episodic fire in the evolution of sclerophyllous shrublands.

Therefore, we encourage researchers to use a more ecologically-based definition of California chaparral that avoids teleological references to fire, recognizes the role played by multiple variables in the ecosystem's past and ongoing evolution, and describes its unique formation in relation to other sclerophyllous shrublands in North America.

Natural vs. indigenous fire regimes

Modifying natural patterns

While we have established too much fire is a threat to the region's remarkable biodiversity, the first step in developing a new, ecologically-based definition of California chaparral is to have a more comprehensive understanding of the changing role of fire and how human activity has facilitated that change.

Researchers have long debated the fire regime of California chaparral. This scientific discussion has focused nearly exclusively on attempting to describe fire trends around two separate points: (1) the European invasion and colonization of the California region and (2) the beginning of modern (early 20th century to present) fire suppression activities. Few studies have attempted describing California chaparral's natural fire regime and its mediating factors prior to the arrival of humans approximately 12,000 years ago.

Native Americans long used cultural burning practices near their population centers for food- and fiber-related purposes, and this likely affected a portion of the chaparral-dominated landscape, particularly at low elevations (Bendix, 2002). These fires were purposeful and localized and may have created vegetation mosaics consisting of shrublands, woodlands, and grasslands near villages (Timbrook et al., 1982). Localized conversion of chaparral by Native Americans in these areas would have resulted in a shift from native shrubs to a different assemblage of native herbaceous plants.

Researchers have also shown that large, landscape-scale (>20,000 ha) fires occurred prior to the European invasion (Mensing et al., 1999), indicating that neither Native American burning practices nor small lightning-caused fires prohibited large fires from occurring. In addition, charcoal records in the Sierra Nevada have shown that the ability for humans to decouple the climate-fire relationship has been limited to the local scale for at least the past 1400 years, with regional burning patterns being driven by climatic conditions (Vachula et al., 2019).

Bendix and Hartnett (2018) found that over the past 25 years, lightning strikes across southern California have been significantly asynchronous with the occurrence of Santa Ana wind conditions. The lag time between lightning occurrences and Santa Ana wind development was substantial (52 days), indicating that the probability of a lightning-caused fire being exposed to these extreme winds is rare. Thus, many of the large pre-colonization fires shown by Mensing et al. (1999) were likely the result of anthropogenic ignitions. However, it is unlikely that these large fires were deliberately set given what is known about cultural burning practices (Timbrook et al., 1982), as chaparral was modified primarily near villages and left to its natural, successional processes elsewhere.

Despite the infrequent occurrence of large, landscape-scale fires as well as the frequent occurrence of small fires at low elevation ecotones (which affected a smaller portion of the landscape), there is no evidence that California chaparral was on a trajectory toward widespread loss prior to European invasion. This period of Indigenous impact likely represents the only time in which humans have been able to co-exist with California chaparral without accelerating its loss.

Pre-human fire regime

Therefore, the currently accepted chaparral fire regime of 30–150 years, with several large fires occurring every century, is missing important context. Rather than being considered a natural fire regime, this may be better described as the Indigenous fire regime. While the Indigenous fire regime appears to result in ecosystem stability over long temporal scales, it does not represent the natural fire regime under which chaparral developed prior to human arrival in North America.

Without anthropogenic ignitions, fire would have been rarer across much of the chaparral-dominated landscape in California. Fires would have been infrequent if lightning strike densities were similar to today. While large fires occurred, they would have been rare due to the low frequency of lightning in California and the asynchronicity between lightning strikes and extreme wind events (Bendix and Hartnett, 2018). As a consequence, fire rotations in chaparral may have been up to several centuries long prior to human arrival, particularly in areas where chaparral is the climax community. The natural fire regime would have also varied with climatic fluctuations (e.g., glacial and interglacial periods) and elevation as lightning strikes tend to be more common at higher elevations.

Landscape changes through history

Colonization impacts

After European colonization of the California region began, several changes occurred at small and large spatial scales. Over the course of a century, the areas in which Native Americans were most populous—where pre-colonization use of fire would have been most significant—were claimed by colonizers. Native grassland-dominated or heterogenous ecotonal areas along coastal plains and in inland valleys were used as pasturage. Rather than being maintained through the use of frequent fire by Native Americans, many of these areas were maintained as grassland by non-native cattle and sheep grazing. In addition, these areas were simultaneously invaded by non-native annual grasses brought by Europeans both purposefully and accidentally.

As the region shifted from European to Mexican and American occupation, these grasslands, now largely dominated by non-native species, were expanded through the rampant use of frequent fire by ranchers in an effort to accommodate the enormous increase of cattle on the landscape, especially around the mid-1800s. This would have directly resulted in the loss of a significant amount of chaparral on the landscape through type conversion. During this same time, grasslands that had been expanded in the previous century began being converted to orchards and crops. Much of these lands were later developed into urban and suburban areas as populations increased, thus covering the areas where Native Americans had the greatest impact on the landscape, representing a colonization-driven form of eco-cultural erasure.

Population growth

During the 1900s, fire frequency in the region, particularly in southern California, continued to increase due to population growth, rapidly expanding suburban areas, and roads, as well as increasing spread of flammable non-native grasses and weeds. A disproportionate number of aging powerline infrastructure-related ignitions under Santa Ana wind conditions have further decreased fire-free intervals in chaparral-dominated areas. Human-caused climate change appears to be making matters worse by creating drier, and hence more flammable, landscapes throughout California. The end result has been a significant departure from the steady state chaparral existed while Native American cultures thrived on the landscape prior to colonization.

Chaparral metamorphosis—Valuing the continuum

The Euro-American view

Chaparral has long been thought to exist in one of three primary states at any given time: burned (or in the process of burning), post-fire growth, or maturity. Traditionally, mature chaparral has been considered "ready to burn" and signals diminished ecosystem productivity, diversity, and in a more anthropocentric view, value. Post-fire chaparral has been viewed as having more value because of its greater use by some wildlife such as deer while also being safer in terms of wildfire risk during non-extreme fire weather.

Post-fire chaparral is seen as recovering, though to what desirable state is often unclear. Once chaparral recovers, it is then considered a fire hazard in need of mitigation. This view of the states of chaparral has largely influenced modern perspectives about its management, resulting in a common objective of keeping chaparral in an early seral, post-fire condition. Unfortunately, this focus has led to decades of damaging activities intended to force the ecosystem into a transient state.

Process vs. stages

Prior to colonization, the presence of post-fire chaparral was a key feature of managed areas near villages due to the importance of resprouting shrubs and fire following herbaceous plants to Native Americans. Similarly, mature chaparral was important in that it provided some staple foods (e.g., *Prunus ilicifolia* cherries and *Sambucus* spp. fruit), fibers (e.g., *Hesperoyucca whipplei*) and strong limbs used as tools. European and American sentiment toward chaparral differed substantially, with more modern attempts to keep chaparral in younger states or to remove chaparral entirely in an attempt to reduce fire risk or increase rangeland for non-native livestock.

Recent perspectives of chaparral have resulted from several assumptions made over the relatively short period of time that chaparral has been researched. One such assumption is that the cycle of fire, growth, and maturity repeats exactly the same way endlessly, with chaparral able to revert back to a specific pre-fire point. Another assumption is that the three states of chaparral described above are clearly separated and have quantifiable differences in value. However, the ecosystem exhibits temporal and spatial complexity that cannot be so easily described.

At any given time, chaparral exists in one of many potential states—not just three—and each is important to biodiversity in different ways. These states may be distinct in some respects, though often no clear separation exists. For example, a difficult question to answer is, at what point does chaparral become mature? More importantly, chaparral (and other ecosystems) may be better thought of as existing on a continuum that experiences constant small and periodic large changes. As no two points along this continuum are exactly the same, the concept of a cycle is too simplistic.

While pyrogenic habitat forms quickly after fire in chaparral, it is somewhat short-lived, the natural successional shift to more mature chaparral is inevitable. Aging chaparral continues to experience subtle changes important for floral and faunal diversity and continues to sequester carbon. Shrubs die for various reasons, either individually or *en masse* during chronic or acute droughts, while others continue to recruit despite the lack of fire (i.e., obligate resprouters). Wildlife alter understory structures, especially rodents (e.g., *Neotoma* and *Peromyscus* spp.), while lichens and fungi colonize older shrubs or dead limbs. Studies have shown that well after a stand of chaparral has matured past 100 years of age, productivity remains high (Luo, 2007).

Unfortunately, old-growth chaparral remains poorly understood by researchers, land managers, and the public (Fig. 3). Because old-growth chaparral is scientifically underrepresented and land managers often publicly convey animosity toward the ecosystem in this older state, the general public may be largely unaware of its existence or perceive it negatively.

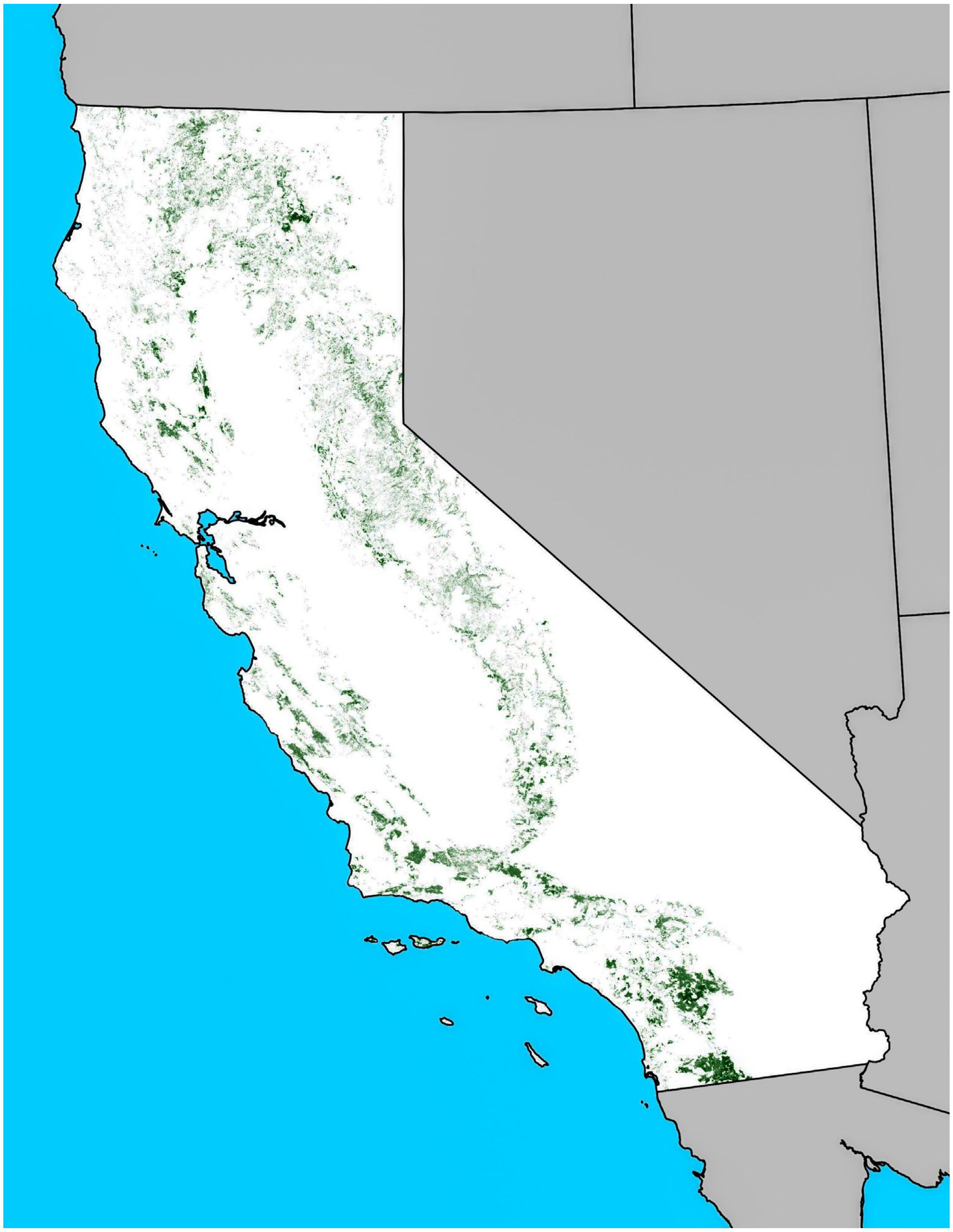

Fig. 3 Current approximate extent of old-growth chaparral stands (>50 years since last fire) remaining in California based on recent fire history data to September 1, 2020. See Fig. 1 for citation/methodology.

Major drivers of chaparral loss in the modern era

In addition to shortened fire free periods, the loss of chaparral has historically been intimately related to livestock grazing and development. Added to this mix is the ever-present and increasingly pronounced impact of the anthropogenic climate crisis and the drive to clear chaparral in an attempt to control or prevent wildfires.

Human-caused climate crisis

By nearly every estimate, anthropogenic climate change will dramatically alter the distribution of chaparral and other native shrublands in California over the next century.

According to a vulnerability assessment of California's terrestrial vegetation, at current rates of carbon emissions, about half of all the natural vegetation in the state is at risk, or up to nearly 200,000 km^2 (Thorne et al., 2016). One consequence of climate disturbance in California will be a shift of biodiversity to the north, meaning that the chaparral's continued existence in southern and central California is imperiled.

In response to climate change, California has established several approaches to increase carbon sequestration. One of these approaches is based on the hypothesis that by reducing wildfires, carbon emissions will be reduced. To accomplish this, the state has embarked on a program of logging forests and removal of native shrubland habitat under the assumption that by removing vegetation, the intensity and scope of wildfires—and associated carbon emissions—will be reduced.

However, the methods state and federal governments use to calculate the emissions impacts of vegetation modification and wildfire emissions has come under serious question. As described in a 2020 letter to the United States Congress, signed by hundreds of scientists, mechanical thinning results in a substantial net loss of carbon storage, and a net increase in carbon emissions that can substantially exceed those of wildfire emissions (Moomaw et al., 2020).

When chaparral is cleared, there may also be a net loss of carbon through the destruction of underground burls/roots and the modification of soil infrastructure, including complex fungal networks. In addition, the invasion of flammable, non-native forbs and grasses in clearance areas increase the landscape's flammability due to their flashy fuel characteristics.

Pyrogenic habitat removal

Post-fire, pyrogenic habitats offer richly biodiverse environments. A significant portion of these habitats is typically composed of dense vegetation, especially chaparral plant species that are able to germinate or resprout after a fire. This dense vegetation serves as habitat for wildlife and creates complex facilitative ecological interactions in which one species enhances the survival of another. For example, *Ceanothus* shrubs help prevent the dehydration of emerging conifer seedlings in episodic chaparral formed after forest fires while also aiding in nutrient cycling through nitrogen fixation. However, the desire to bring the forest back sooner than the natural successional process would allow has led to a number of forest restoration projects that involve a combination of salvage logging, herbicide use, and the clearance of chaparral.

In 2009, California State Parks filed an emergency exemption to the California Environmental Quality Act (CEQA) to clear episodic chaparral formed in Cuyamaca Rancho State Park after the 2003 Cedar Fire in San Diego County, and plant trees in its place. The exemption allowed State Parks to conduct the project without any definitive limit, public review, or environmental assessment.

San Diego County had filed a similar emergency exemption to clear more than 1200 ha 3 months before the state park filing, but the exemption was rejected by the Superior Court of California after being challenged by the California Chaparral Institute. The court found that the project did not qualify as an emergency, defined as an imminent threat of a wildfire, and one that could be mitigated over the short term, not over a period of years. The same finding would have been applicable to the Cuyamaca project, but it was not challenged within the required 35-day window for CEQA exemption objections.

A comprehensive report on the post fire environment at Cuyamaca from the Vegetation and Landscape Ecology Lab at San Diego State University recommended that episodic chaparral dominated by *Ceanothus palmeri* be left unmanaged. "Ceanothus is a nitrogen fixing genus of California shrubs that serves an important ecosystem function," the report stated, "especially following fire on low-nutrient soils in California's montane forests. These shrub stands will naturally thin over time, resulting in lower, patchier cover, and allowing establishment of conifers" (Franklin, 2008).

Despite the report's recommendations, numerous logging, mastication, burning, herbicide applications, and tree planting efforts have occurred throughout Cuyamaca since 2009. Large areas of dense *C. palmeri* and *C. leucodermis* stands have been removed, many of the initial tree planting attempts failed, and invasive cheatgrass (*Bromus tectorum*) has spread throughout project areas. One of the rationales for the effort was that the 2003 Cedar Fire was unnaturally severe, causing an abnormal spread of *Ceanothus*. However, the fact that obligate seeding *Ceanothus* species became a prolific component of the post Cedar Fire episodic chaparral plant community indicates that high-intensity fire has been a normal occurrence in the park in the past. Otherwise, the *Ceanothus* seeds would not have been present in the soil.

Type conversion of chaparral

Type conversion in chaparral occurs when the dominant shrub species are dramatically reduced or extirpated, the shrub canopy is significantly diminished, and non-native grasses are provided an opportunity to colonize and spread due to single or multiple disturbance events. Considering the changing climate and increasing fire frequencies, a fire rotation less than 30 years should be considered as increasing type conversion risk.

Chaparral type conversion can happen over time or after a single event, such as a prescribed fire conducted during the wet season which can compromise the soil seed bank of native species. An example of instantaneous type conversion occurred after a prescribed burn in Pinnacles National Park during the 1990s where a dense chamise chaparral stand was converted to a non-native grassland. Usually, but not always, non-native grasses invade chaparral plant communities compromised by excessive fire, making the area more vulnerable to ignition. The rate of the type conversion can be increased dramatically by unusual periods of drought, grazing, soil type, soil disturbance, and mechanical clearance activities.

Landscape-scale vegetation removal

As part of California's attempt to reduce wildfire risk, the California Board of Forestry and Fire Protection approved a statewide Vegetation Treatment Program (VTP) in 2020. To be administered by Cal Fire, the state's fire agency, the program targets over 100,000 ha of habitat per year for vegetation clearance. A significant portion of that targeted area is chaparral.

Recognizing the threat of increasing fire frequencies, state law only allows vegetation management projects in native shrublands if they do not cause type conversion away from the original chaparral and coastal sage scrub communities present on site. This restriction is problematic because the state legislature did not define type conversion, allowing the Board of Forestry to do so itself. Consequently, the Board considered type conversion in terms of habitat function, which they define in the VTP as an arrangement of vegetation that can provide the resources needed to support a community's plants and animals. The determination of that quality is the responsibility of the local clearance project proponent. The VTP considers the clearance of up to 65% of an intact chaparral plant community as still being capable of supporting proper habitat function.

The VTP has targeted nearly all mature stands of chaparral throughout the state for ecological restoration, via mastication, burning, or some other clearance operation. This objective contradicts the VTP's acknowledgment that California chaparral is threatened by too much fire. The only restriction to conducting ecological restoration in chaparral is that the community's age (time since last burn) should be above the average fire return interval range as determined by VTP (intervals were not supported by adequate research citations). However, that restriction can be ignored if the local project proponent demonstrates habitat function will be improved. Based on previous determinations by government agencies, increasing deer browse by clearing chaparral would likely qualify as improvement.

Defensible space and fuel breaks

Defensible space can be described as an area immediately surrounding a structure where vegetation is altered in a way that improves the odds of the structure surviving a non-wind-driven wildfire. Over the past three decades, recommendations and requirements for defensible space have generally involved removing at least some amount of vegetation 30 m out from the structure in all directions. Unfortunately, local and state requirements often do not provide detailed information about proper defensible space creation and maintenance, leading to excessive shrub and tree removal.

Furthermore, in the wake of large fire events that cause widespread structure loss, policymakers and fire agencies often discuss tripling the recommended or required defensible space radius to 90 m despite the lack of evidence of increased structure survival with defensible space beyond approximately 30 m (Cohen, 2000). While this increase in the defensible space radius may appear relatively low, the areal increase is close to 800%.

Consider that for a single home, 30 m of defensible space would result in a total impact footprint of 0.4 ha (though this can vary depending on the size of the home). If the defensible space radius is increased to 90 m, this footprint increases to over 3 ha. There are approximately 800,000 homes in the intermix wildland-urban interface (WUI) in California where individual defensible spaces have the greatest impact to wildland vegetation. A large proportion of these are in chaparral-dominated areas, especially in the southern part of the state. Thus, increases in defensible space recommendations or requirements could result in substantial losses of chaparral across California without significantly improving the rate of structure survival during wind-driven wildfires.

Beyond defensible space, chaparral is frequently targeted for removal by local, state, and federal land management agencies. This often includes creating fuel breaks, which are swaths of land on which vegetation deemed hazardous is removed in order to facilitate firefighter activity during a wildfire. In chaparral, this typically involves complete removal of shrub vegetation through use of heavy equipment and/or herbicide application—a process that often results in permanent conversion to non-native grasslands in violation of state law. While studies have found that fuel breaks are ineffective in stopping fires under extreme weather conditions when the vast majority of damage to communities occurs, fuel breaks continue to be constructed across the chaparral-dominated landscape.

One such fuel break was proposed by the United States Forest Service within the Los Padres National Forest in 2016. The proposal included constructing a 90-m wide fuel break along nearly 10 km of the crest of the coastal Santa Ynez Mountains. The fuel break was located over 10 km from any community and encompassed approximately 50% of the only known populations of the rare, endemic Refugio manzanita (*Arctostaphylos refugioensis*). The agency characterized the project as timber stand improvement in order to use a loophole that allowed the project to be approved without robust environmental review as required by the National Environmental Policy Act of 1969. As there were no timber stands in or near the project area, environmental organizations filed a lawsuit and the project was eventually dropped. This case, however, is one of many similar cases that occur across the region each year (most of which are implemented), highlighting the incongruence of policy and management with science.

Damaging fire suppression activities

While fire suppression is warranted near communities, whether it should be employed in remote locations is complicated. On one hand, quick suppression of human-caused ignitions in areas where fire frequency has recently increased, or is expected to increase in the near future, could help reduce consequent type conversion of chaparral. This type of suppression is most effective when fires are caught early and occupy only a small area (e.g., <1 ha). However, the probability that these types of small fires occurring under non-extreme weather conditions will develop into landscape-scale conflagrations is low. For large, wind-driven fires that account for most of the area burned in a given year, initial suppression either fails or is never attempted due to rapid fire spread under conditions dangerous for firefighter activity.

Nevertheless, suppression activities are still carried out in an effort to stop the spread of large, fast-moving fires, though this spread is usually driven by the uncontrollable variable of fire weather (i.e., fire spread generally wanes as humidity increases, temperature decreases, and wind subsides). In these cases, suppression often turns to construction of indirect fire lines kilometers ahead of a fire's suspected direction of spread, typically in areas that never end up burning, including federally designated Wilderness. Fire lines are made with the use of bulldozers that can have a major impact on chaparral shrub species as they kill resprouters and non-resprouters alike. Conversely, fire kills a relatively small proportion of resprouting species and enhances seed germination of non-resprouters. Bulldozer lines fragment habitat and spread flammable, non-native plants. In addition, bulldozer lines are often used for massive backburning operations that can increase total burned area far beyond what it would have been otherwise, creating situations where wildlife moving away from a fire front are met with an oncoming backfire.

Between 2004 and 2018, over 1000 km of fire lines were bulldozed in response to wildfires that impacted the Los Padres National Forest in California. Approximately 743 km of these fire lines never encountered the fire. Fire lines in areas that remain unburned can have lasting impacts in their immediate vicinity. Not only do they remove most shrub species, they can introduce flammable, non-native grasses and weeds that can significantly alter chaparral structure and functioning. The creation of these fire lines is often used later as a justification for turning repeatedly bulldozed ridgelines into large fuel breaks. These fuel breaks are also often used as pathways for off-road vehicles which can—due to additional human activity—increase ignition risk, invasive plant spread, and erosion in remote areas.

Backcountry areas dominated by chaparral that have not been as exposed to post-colonization impacts are remarkably resilient to wildfire. However, this resilience can be compromised by the creation of fire lines with heavy, ground-disturbing equipment, or when nutrient-rich fire retardant (e.g., Phos-Chek) is used in tandem.

Implementation strategies for chaparral conservation

There are several strategies that can be implemented to better protect what chaparral remains. These actions will need to take place at both small and large scales, and they will require that society develops a new relationship with the ecosystem, valuing it as an important resource rather than merely a fire hazard.

Chaparral education

First and foremost, the public and government agencies need to know chaparral exists, that it has both intrinsic and utilitarian value, and that it offers the closest intact, native habitat where most Californians can experience and reconnect with Nature. Such awareness is essential to build the constituency necessary for the chaparral's protection.

Exposure to chaparral in public/private school curricula is nearly non-existent. Most volunteer naturalist programs, even those within chaparral landscapes, barely recognize the chaparral ecosystem as a distinct area of study. The few notable exceptions, such as the Placerita Nature Center in Los Angeles County and Mission Trails Regional Park in San Diego County, offer excellent models for others to follow (Halsey et al., 2018).

Publicizing the chaparral's benefits to human communities provides educational opportunities for land management agencies to help visitors see the value of the landscape they are experiencing. Such ecosystem services like watershed protection, climate moderation, and recreation are important quality of life measures most people understand.

Research has confirmed that connecting with Nature is not only essential for our physical health, but our mental health as well. Nature provides us the tools necessary to develop meaningful connections with ourselves and the world around us.

The ecosystem services concept has its limits, however, because of its anthropocentric focus. It fails to recognize that Nature has value regardless of the benefits it offers humans. In addition to providing a significant amount of habitat for a multitude of species, chaparral has intrinsic value, a value that is immutable and based on the life that emerges from it. Chaparral has value for what it is, not only for what it does for human society.

Incorporating the need to appreciate the intrinsic value of Nature, as Indigenous Peoples of California have for thousands of years, is an important component to include in new, chaparral-appreciative curricula.

Combatting climate change

It is critical that major steps be taken to reduce anthropogenic greenhouse gas emissions. Emission reduction strategies will not be enough, however, and many researchers have called for increased attention on natural climate solutions which generally involve increased protection of ecosystems that act as carbon sinks. Chaparral can both benefit from and contribute to natural climate solutions that mitigate climate change.

Carbon cycling in chaparral is still poorly understood, but its potential as a significant carbon sink across its range is high. As type conversion results in a shift from perennial woody shrubs to non-native, annual herbaceous plants, the amount of carbon sequestered in chaparral-dominated areas will be diminished.

Foregoing destruction in the name of fire mitigation

Despite massive undertakings in wildland vegetation management across the region, the number of homes and lives lost to wildfires continues to increase. In 2017 and 2018, nine out of 16,909 fires (0.05%) accounted for approximately 95% of all wildfire-related property damage claims in California. All of these fires occurred under extreme weather conditions, and many burned primarily in native shrublands. Fuel breaks, defensible space, and previously prescribed burned and logged areas did little to stop the spread of these fires or the damage they caused.

In the years following large fires, efforts to remove more wildland vegetation from the landscape are typically increased. Many of these projects involve constructing large fuel breaks in chaparral-dominated areas.

Moving forward, policymakers and land managers must come to terms with the reality that large fires, regardless of what is burning (trees, shrubs, grasses, or homes), are an inevitable feature of the landscapes throughout California. Upon accepting this, the futility of large vegetation removal projects, especially in chaparral far away from homes, can be properly recognized. Notable fire scientist Dr. Jack Cohen has often said, "wildfires are inevitable, but the destruction of our communities is not." We offer another perspective here: wildfires are inevitable, but the destruction of wildland habitat in the name of fire mitigation is not.

Preventing ignitions

Modern wildfires' extent and damage to human communities is the result of several compounding issues that have arisen in the past few centuries since colonization occurred: the spread of highly flammable non-native plants, the rapid expansion of population centers, the construction of a large network of roads, and the placement of hundreds of thousands of flammable homes in dangerous locations, and climate change.

Especially concerning is the role of aging utility infrastructure in igniting many recent fires. At least five of the nine fires most damaging to human communities in California during 2017 and 2018 (see above) were ignited by utility lines or equipment under extreme wind conditions. This source of ignition is most likely when weather conditions are most favorable for rapid fire spread. Undergrounding current utility lines has been a suggested solution to eliminating this hazard. However, such an approach is extremely expensive, causes significant environmental disturbance, and fails to address the actual reason such lines exist—the concentrated, centralized power grid. Decentralizing the energy system with localized renewables such as solar is a long-term solution that will not only reduce fire risk, but will also help combat climate change.

Similarly, public land managers should close roads to certain, high-risk areas during extreme weather conditions. There should also be additional focus and research on ignition prevention systems along roadways, which are a major source of ignitions. And public land management agencies should be properly funded and equipped to enforce campfire, firearm, and vehicular access regulations that are often put in place during the height of fire season.

Rethinking suppression

Fire suppression is currently focused on trying to stop wildfires. Based on the massive loss of life and property during wind-driven fires over the past decade, this approach needs to be reconsidered. Instead, the emphasis needs to be placed on the protection of lives and property rather than trying to stop the fire.

Instead of viewing firefighting as a military-like campaign, attempting to defeat an unstoppable enemy, the focus needs to be placed on defensive actions immediately within and around communities at risk. Embers, rather than the fire front, need to be recognized as the real enemy. Embers, the primary source of ignition for structures, are not defeated by distant suppression activity, but rather by making communities more resistant to embers in the first place. Ember-resistant vents, exterior sprinklers, and the use of non-flammable building materials have been shown to be effective in mitigating wildfire risk.

Expanding research

Much is known about how chaparral burns and post-fire ecological processes, but little is understood about ecosystem functioning in old-growth chaparral. Several aspects of old-growth chaparral should be the focus of future research. For example, an accounting of the different species, especially invertebrates, that occur in chaparral and how these species assemblages change over time is essential. Other elements of the ecosystem such as lichen diversity, the effects of mammals and birds on seed dispersal, and characterization of soil fungal networks should be studied in more detail. Such research would better inform land management practices that currently focus on preventing particular states of chaparral from persisting on the landscape despite the lack of knowledge about the complex floral and faunal relationships that exist in these habitats.

Conclusions

California chaparral is one of the most unique ecosystems on Earth. It shares a lineage with other sclerophyllous shrublands in North America that occur under non-Mediterranean type climates and without the same prevalence of fire. Rather than focusing on the ecosystem as one that is fire-dependent, it should be viewed as an ecosystem shaped by many complex factors, is resilient to a particular fire regime, and thrives by way of an ongoing metamorphosis as it responds to environmental change.

Post-colonization alterations to the landscape have resulted in major shifts in California chaparral's extent and diversity. While some of these changes may never be fully attenuated, there are ways that modern humans can coexist with the ecosystem—but these will require a more comprehensive understanding of the ecosystem itself.

Society must focus on seeing chaparral as a vital ecosystem—one that has intrinsic value and the right to persist on the landscape. Wildfires are inevitable, but the destruction of wildland habitat in the name of mitigation is not. As this view becomes adopted by land managers, policymakers, and the public, humans can learn once again to coexist with chaparral in all its forms and complexities.

References

Axelrod DI (1975) Evolution and biogeography of Madrean-Tethyan sclerophyll vegetation. *Annals of the Missouri Botanical Garden* 62: 280–334.

Bendix J (2002) Pre-European fire in California chaparral. In: Vale TR (ed.) *Fire, Native Peoples, and the Natural Landscape*, pp. 269–293. Washington, D.C.: Island Press.

Bendix J and Hartnett JJ (2018) Asynchronous lightning and Santa Ana winds highlight human role in southern California fire regimes. *Environmental Research Letters* 13: 074024.

Cohen JD (2000) Preventing disaster: Home ignitability in the wildland-urban interface. *Journal of Forestry* 98: 15–21.

Franklin J (2008) *Post-Cedar Fire Mixed Conifer-Hardwood Monitoring at Cuyamaca Rancho State Park, San Diego, California. Interagency Agreement Final Report.* CA, USA: San Diego State University.

Halsey RW, Halsey VW, and Gaudette R (2018) Connecting Californians with the chaparral. In: Underwood E, Safford H, Molinari N, and Keeley KE (eds.) *Valuing Chaparral, Economic, Socio-Economic, and Management Perspectives*, pp. 295–322. Cham, Switzerland: Springer International Publishing.

Jennings MK (2018) Faunal diversity in chaparral ecosystems. In: Underwood E, Safford H, Molinari N, and Keeley KE (eds.) *Valuing Chaparral, Economic, Socio-Economic, and Management Perspectives*, pp. 53–77. Cham, Switzerland: Springer International Publishing.

Luo H (2007) Mature semiarid chaparral ecosystems can be a significant sink for atmospheric carbon dioxide. *Global Change Biology* 13: 386–396.

Mensing SA, Michaelsen J, and Byrne R (1999) A 560-year record of Santa Ana fires reconstructed from charcoal deposited in the Santa Barbara Basin, California. *Quaternary Research* 51: 295–305.

Moomaw WR, Hanson CT, Dellasalla DA, et al. (2020) Scientists concerned about climate and biodiversity impact of logging. *Letter to US House of Representatives and US Senate, May* 13.

Park IW and Jenerette GD (2019) Causes and feedbacks to widespread grass invasion into chaparral shrub dominated landscapes. *Landscape Ecology* 34: 4590471.

Parker VT (2020) Chaparral of California. In: Goldstein MI and DellaSala DA (eds.) *Encyclopedia of the World's Biomes*. vol. 3, pp. 457–472. Elsevier.

Thorne JH, Boynton RM, Holguin AJ, Stewart JAE, and Bjorkman J (2016) *A climate Change Vulnerability Assessment of California's Terrestrial Vegetation*. Davis: University of California, California Department of Fish and Wildlife.

Timbrook J, Johnson JR, and Earle DD (1982) Vegetation burning by the Chumash. *Journal of California and Great Basin Anthropology* 4: 163–186.

Vachula RS, Russell JM, and Huang Y (2019) Climate exceeded human management as the dominant control of fire at the regional scale in California's Sierra Nevada. *Environmental Research Letters* 14: 104011.

Valiente-Banuet A, Flores-Hernandez N, Verdu M, and Davila P (1998) The chaparral vegetation in Mexico under non-Mediterranean climate: The convergence and Madrean-Tethyan hypothesis reconsidered. *American Journal of Botany* 85: 138–1408.