Maritime Chaparral

Climate Change Vulnerability Assessment for the Golden Gate Biosphere Region

This document represents an evaluation of climate change vulnerability for maritime chaparral in the Golden Gate Biosphere (GGB) region of California. The following information is based on stakeholder input provided during and following a winter 2022 vulnerability workshop as well as sources from the scientific literature.

Ecosystem Description

Maritime chaparral is an evergreen shrub-dominated community characterized primarily by manzanita (*Arctostaphylos* spp.) or *Ceanothus* species, and is associated with unique soils (e.g., sand, sandstone, serpentine) in areas influenced by coastal fog (Vasey et al. 2014). These areas receive relatively low annual precipitation, but cloud cover and cooler temperatures typical of maritime climates ameliorate water stress (Vasey et al. 2014). Manzanita and *Ceanothus* are both adapted to a fire regime with relatively long return intervals (30 to 100+ years), which allows stands to mature and build the soil seedbank for robust post-fire regeneration (Keeley 2007; Vuln. Assessment Worksheets, pers. comm., 2022). Dominant chaparral species are typically categorized by mode of post-fire regeneration: *obligate seeders* require fire for germination from stored seedbanks, while *facultative seeders* utilize both vegetative resprouting and seed germination following fire-induced topkill. Some species in genera that require fire can also recruit from seed in the absence of fire (Keeley 1991).

Maritime chaparral in the Golden Gate Biosphere (GGB) region is typically found on coastal ridges in Sonoma County; on Point Reyes, Bolinas Ridge, and the lower slopes of Mt. Tamalpais in Marin County; on the serpentine bluffs of the Presidio in San Francisco; on San Bruno Mountain, Montara Mountain, and the Kings Mtn. Area in San Mateo County; and on some additional sites in the Santa Cruz Mountains (Williams & Vasey 2016; Vuln. Assessment Worksheets, pers. comm., 2022). Coastal bluffs often host smaller patches of maritime chaparral as found in northern Marin and in Sonoma coastlines. Maritime stands are also found on slopes that receive summer fog near the San Francisco Bay estuary in Sonoma and Napa counties, and south of San Mateo County (Vuln. Assessment Worksheets, pers. comm., 2022).

Fine-scale vegetation maps for San Mateo, Marin, and Sonoma Counties were used to identify four vegetation classes that generally represent maritime chaparral within the GGB region (Tukman Geospatial et al. 2018), which occupy a combined total of 2,237 acres (Figure 1, Table 1). Of that, 84% (1,872 acres) is protected, with the largest area of protected lands managed by the San Francisco Public Utilities Commission (558 acres; Table 2). However, lack of detailed vegetation mapping for chaparral communities mean that this estimate likely underrepresents the amount of maritime chaparral present on the landscape.

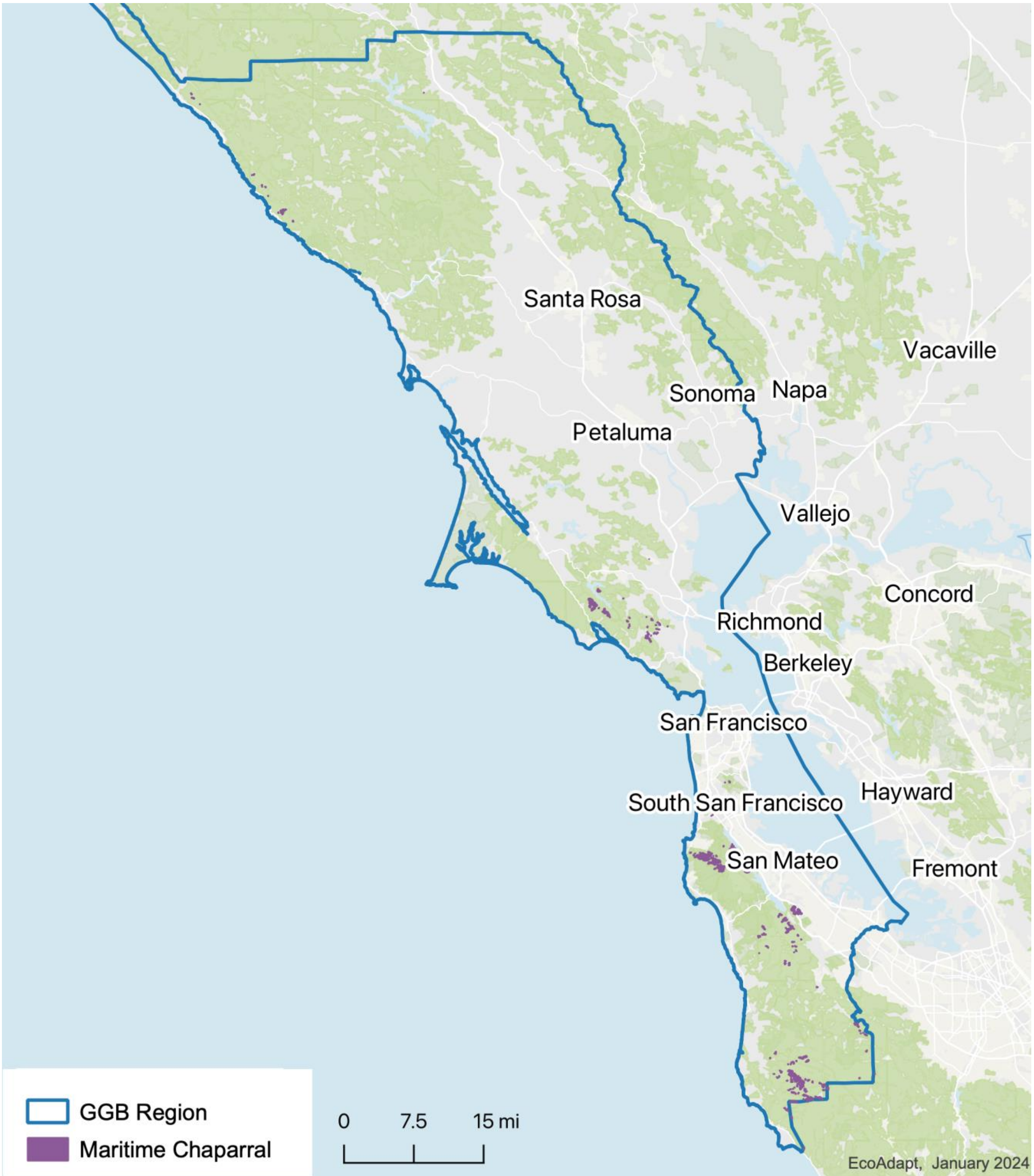

Figure 1. Distribution of vegetation map classes that likely represent maritime chaparral communities within the GGB region, derived from fine scale vegetation maps for San Mateo, Marin, and Sonoma Counties (Tukman Geospatial et al. 2018).

Table 1. Vegetation map classes likely to represent maritime chaparral communities within the GGB region, derived from fine scale vegetation maps for San Mateo, Marin, and Sonoma Counties (Tukman Geospatial et al. 2018).

Vegetation Map Class
Arctostaphylos (*crustacea*, *tomentosa*) Alliance
Arctostaphylos (*nummularia*, *sensitiva*) – *Chrysolepis chrysophylla* Alliance
Arctostaphylos montaraensis Association
Californian Maritime Chaparral Group

Table 2. Total protected acres in the GGB region by land management agency, derived from fine scale vegetation maps for San Mateo, Marin, and Sonoma Counties (Tukman Geospatial et al. 2018).

Land Management Agency	Protected Acres
San Francisco – Public Utilities Commission	558
California Department of Parks and Recreation	332
San Mateo County Parks and Recreation Department	313
National Park Service – Point Reyes National Seashore	185
Midpeninsula Regional Open Space District	148
Marin Municipal Water District	146
Other protected lands	82
Peninsula Open Space Trust	65
National Park Service – Golden Gate National Recreation Area	34
United States Bureau of Land Management	6
Marin County Parks	2
TOTAL	**1,872**

Ecosystem Vulnerability → Moderate *(moderate confidence)*

Vulnerability is evaluated by considering the ecosystem's sensitivity and exposure to various climate and non-climate stressors as well as the ecosystem's adaptive capacity (i.e., ability to cope with these stressors), and is given a ranking of low, moderate, or high. The confidence ranking represents confidence in the accuracy of the ranking based on available scientific knowledge, and is similarly ranked on a scale from low to high.

Summary of ecosystem vulnerability

Maritime chaparral is well-adapted to periods of low water availability, high temperatures, and recurrent fire. However, it is sensitive to changes in the temporal frequency and extent of these climatic variables. In particular, maritime chaparral is sensitive to changes that impact the amount and timing of water availability, such as changes in the frequency of coastal fog and increased drought, which are likely to impact plant survival and recruitment in these ecosystems. Climate-driven shifts in wildfire regimes may also drive changes in the structure and regeneration of maritime chaparral communities, preventing stands from reaching maturity and potentially facilitating the introduction of more interior native species and invasives that can outcompete maritime chaparral shrubs. Non-climate stressors, including development, roads and trails, invasive species, and fire suppression can further exacerbate sensitivity to climate change by causing loss and fragmentation of maritime chaparral systems, introducing invasive species, and disrupting or eliminating interactions with wildlife that rely on these systems and provide important seed dispersal services to chaparral vegetation.

Although maritime chaparral is relatively widespread in maritime-influenced areas of the GGB region, system continuity and integrity has been significantly impacted by development in many areas. Loss and degradation increases the vulnerability of maritime chaparral to biodiversity loss and invasion by exotic grasses, which can then drive further shifts in fire regimes. Management activities that focus on supporting and restoring natural fire return intervals as well as protecting and enhancing connectivity are important to chaparral conservation, and are likely to enhance these systems' resilience to climate change stressors.

Sensitivity and Exposure → Moderate *(moderate confidence)*

***Sensitivity** is a measure of whether and how an ecosystem is likely to be affected by a given change in climate factors, climate-driven changes in disturbance regimes, and non-climate stressors. By contrast, **exposure** is a measure of how much change in these factors an ecosystem is likely to experience. Sensitivity and exposure are combined here into one score representing both components of vulnerability, with high scores corresponding to increased vulnerability and low scores suggesting an ecosystem is less vulnerable.*

Sensitivity and future exposure to climate factors → Moderate *(moderate confidence)*

- Maritime chaparral plant species are sensitive to **increasing air temperatures and heat waves** that increase evapotranspiration and so enhance vegetative water stress, particularly in the summer and fall (Thorne et al. 2017). Higher temperatures also increase the risk of more frequent fires in these systems (Davis & Michaelson 1995; Molinari et al. 2018).
- **Changes in the amount and timing of precipitation** and **soil moisture** may affect maritime chaparral recruitment and community composition. In general, higher species richness and greater shrub growth and regeneration is associated with higher levels of precipitation (Keeley 1991). Precipitation levels are particularly critical in the year that follows fire, as many rare species in this area are obligate seeders that require successful seed germination to reestablish populations (Keeley 2007; Vuln. Assessment Worksheets, pers. comm., 2022). However, very wet years can contribute to the growth of pathogens like *Phytophthora* (Davidson et al. 2005). High levels of precipitation can also facilitate increases in invasive grasses that enhance the risk of wildfire in subsequent years, exacerbating climate-driven changes in wildfire regimes (Bell et

al. 2009; Rao & Allen 2010). Potential changes to fog patterns resulting from climate change could threaten maritime chaparral species that depend on summer fog for moisture (Vasey et al. 2014), though there is still substantial uncertainty as to how these patterns may shift with climate change (Johnstone & Dawson 2010; Werner et al. 2020, 2022).

- **Increases in the severity and length of future droughts**, which are closely associated with changes in temperature and precipitation described above, may lead to substantial dieback and mortality in maritime chaparral communities. Drought stress is particularly problematic for obligate-seeding chaparral species, which tend to be relatively shallow-rooting and more vulnerable to dieback and mortality from drought conditions relative to sprouting species (Paddock et al. 2013; Venturas et al. 2016; Jacobsen & Pratt 2018). Seedlings are also significantly more sensitive to drought than mature plants due to their limited root systems, and the presence of invasive grasses can further exacerbate water stress due to increased competition for near-surface soil moisture (Park & Jenerette 2019). Persistent drought can significantly impair post-fire recovery, and the combination of drought-induced mortality and reduced post-fire recruitment can affect community composition and structure over the long term (Paddock et al. 2013; Jacobsen & Pratt 2018; Nolan et al. 2021). However, it is possible that tree species that compete with and shade out chaparral may be more vulnerable to drought compared to chaparral shrubs, which could limit encroachment and even allow expansion of chaparral communities in some areas (Fellows & Goulden 2012; Menezes-Silva et al. 2019; Vuln. Assessment Worksheets, pers. comm., 2022).
- Climate may also drive **changes in phenology** of maritime chaparral ecosystems, as warmer temperatures and shifts in precipitation disrupt plant-pollinator interactions. Maritime chaparral ecosystems are highly dependent on the services of insect pollinators and exhibit a range of flowering times (e.g., manzanitas mainly flower in winter, while *Ceanothus* spp. in early spring; Rundel 2018). Disruptions in flower-pollinator interactions are likely to occur, as climate-driven shifts in timing differ across plant and pollinator species (Inouye 2022). Additionally, many of these shrub species are extremely long-lived, have flowering dates that are tied to multiple environmental variables, and are unlikely to respond quickly to changes in climate relative to their pollinators (Rafferty 2017; Parker 2021; Vuln. Assessment Worksheets, pers. comm., 2022).

Sensitivity and future exposure to climate-driven changes in disturbances → Moderate *(low confidence)*

- **Changes in the intensity and frequency of wildfire** has the potential to significantly impact chaparral communities. Central California maritime chaparral communities have evolved in a coastal climate, with summer fog in coastal lowlands and higher winter precipitation in uplands that reduce dry season water deficits and contribute to relatively long fire intervals (Keeley 2007; Vasey et al. 2014). Climate-driven increases in wildfire frequency (Williams et al. 2019;

Goss et al. 2020) can kill seedlings and plants before they reach reproductive maturity, interrupting the replenishment of soil seed banks and reducing or eliminating regeneration (Keeley 2007). Reduced regeneration of native shrubs can facilitate the establishment and dominance of flammable invasive annual grasses that reinforce the cycle of increased fire frequency (Syphard et al. 2018), and this process can facilitate conversions from chaparral to invasive annual grasslands (Zedler et al. 1983; Haidinger & Keeley 1993; Keeley 2007; Lenihan et al. 2008).

Climate-driven changes in patterns and extent of disease can impact the survival and composition of chaparral systems. The pathogen *Phytophthora ramorum,* which causes Sudden Oak Death (SOD), can cause disease in *Arctostaphylos* though typically it does not cause significant mortality (Garbelotto et al. 2020; Vuln. Assessment Worksheets, pers. comm., 2022). It has been detected on manzanitas in Marin County (Panorama Environmental 2019; Vuln. Assessment Worksheets, pers. comm., 2022), as well as on multiple rare or endangered manzanita species in Santa Cruz County (Garbelotto et al. 2020). *Phytophthora cinnamomi*, which is deadly to some manzanitas, is also known to be present on Mt. Tam (Williams & Vasey 2016). The direction of climate-driven changes in *Phytophthora* are not fully understood, but it is likely that increased precipitation and more extreme rain events may benefit transmission, while drier conditions might result in reduced incidence of disease (Davidson et al. 2005; Homet et al. 2019). Pathogen-related dieback of large stands of madrone and manzanita are likely to have cascading impacts on the structure and ecosystem functions of chaparral communities, including loss of wildlife habitat, increased erosion from exposed soil, and opportunities for weed invasion in open sites (Vuln. Assessment Worksheets, pers. comm., 2022).

Sensitivity and current exposure to non-climate stressors → High *(high confidence)*

Non-climate stressors can exacerbate ecosystem sensitivity to changes in climate factors and disturbance regimes, and/or can be exacerbated by these changes.

- **Residential and commercial development** is a primary contributor to loss and fragmentation of chaparral communities in California (Jennings 2018a; Syphard et al. 2018), including maritime chaparral. Within the GGB region, many of the coastal lowlands where maritime chaparral is found are proximate to urban and suburban development in the Bay Area, and unprotected areas are under significant development pressure (Ackerly et al. 2018). Documented changes in chaparral habitats near urban development include plant damage and dieback, soil compaction and erosion, and reduced endemic mammal abundance and diversity (Sauvajot et al. 1998). Power lines associated with development also increase the chance of wildfire ignitions (Syphard & Keeley 2015; Syphard et al. 2018), though developed areas are more likely to be prioritized for fire suppression resources (Keeley 2007).
- **Roads, highways, and trails** are closely tied to urban and suburban development, and contribute to disturbance, fragmentation, and loss of maritime chaparral habitat (Sauvajot et al.

1998). Roads can act as a barrier to the movement of small mammals and other wildlife (Jennings 2018a), including those that act as seed dispersers for chaparral vegetation. Transportation corridors also facilitate the spread of invasive species (Coffin 2007). In rural areas, roads can disproportionately account for the impacts of development; for example, although housing density in most of Santa Cruz County is low, a 50m buffer on either side of mapped roads encompasses 25% of the county (Davis & Borchert 2006).

- **Fire exclusion and suppression**, including **fuel reduction activities**, impact maritime chaparral communities through direct removal of vegetation and alteration of natural fire regimes with which these communities have evolved (Barro & Conard 1991), particularly in and around developed areas where risk to property leads to the prioritization of fire reduction (Keeley 2007; Williams & Vasey 2016; Panorama Environmental 2019). Complete fire exclusion is particularly problematic for obligate seeders that require fire to stimulate germination (Keeley 1991, 2007). Lack of fire in these systems can also lead to encroachment and overshading by coniferous species like Douglas-fir (*Pseudotsuga menziesii*), which has been observed in Marin County (Williams & Vasey 2016; Vuln. Assessment Worksheets, pers. comm., 2022). Chaparral does have some capacity to withstand longer intervals without fire; senescent stands have been known to recover after fire-return intervals of more than a century due to the persistence of long-lived soil seedbanks (Keeley 2007; Vuln. Assessment Worksheets, pers. comm., 2022).
- **Invasive species** can outcompete and displace native maritime chaparral vegetation, particularly following disturbances such as wildfire or road construction. Invasive grasses compete with seedlings for resources (Park & Jenerette 2019) and provide fine fuels that contribute to increased wildfire frequencies, especially in drought conditions (Rundel 2018; Syphard et al. 2018). Non-native animals can also pose threats to chaparral ecology. For instance, Argentine ants displace native harvester ants that play an important role in seed dispersal in chaparral systems (Jennings 2018a). Feral pigs are also widespread throughout most of California, including in maritime chaparral, and they can do substantial damage to vegetation by trampling and rooting for food (Jennings 2018a; Williams et al. 2019).

Adaptive Capacity → Low *(high confidence)*

Adaptive capacity *is the ability of an ecosystem to respond to or cope with climate change impacts with minimal disruption. High adaptive capacity corresponds to lower overall climate change vulnerability, while low adaptive capacity means that the ecosystem will be less likely to cope with the adverse effects of climate change, thus increasing the vulnerability of the ecosystem.*

Ecosystem extent, integrity, and continuity → Low (high confidence)

While maritime chaparral occurs throughout California, it is a narrowly distributed system at any given latitude. It is particularly limited where mountains parallel the coast, but expands where openings in the mountain ranges permit maritime influence inland (e.g., San Francisco Bay; Vasey et al. 2014). Maritime chaparral stands in the GGB region are naturally isolated and fragmented at the regional scale (Vasey et al. 2014; Williams & Vasey 2016), and serpentine stands are even more restricted due to their association with small, spatially isolated areas of suitable substrate (Damschen et al. 2012). These natural limitations are overlaid by a high degree of land use conversion and resulting degradation as a result of increased fire frequency, human disturbance, and invasive species (Sauvajot et al. 1998; Jennings 2018a; Rundel 2018; Safford et al. 2018a). These factors can also create barriers to the movement of small mammals that are critical mutualists of manzanitas and aid in burying *Ceanothus* seed (Sauvajot et al. 1998; Vuln. Assessment Worksheets 2022). Smaller areas of chaparral (<100 ha) are particularly vulnerable to the loss of these small mammals relative to larger intact systems (Soule et al. 1992). Together, all of these factors that affect maritime chaparral extent, continuity, and integrity likely reduce the system's ability to recover from disturbances and limit opportunities for range shifts in response to climate change (Damschen et al. 2012; Syphard et al. 2018). However, there may be some opportunity for chaparral systems to shift, which should be considered when prioritizing areas for protection as potential refugia (Thorne et al. 2020; Vuln. Assessment Worksheets, pers. comm., 2022).

Ecosystem diversity → Moderate (high confidence)

Maritime chaparral occurs on steep, topographically heterogenous sites and unique substrates, and its natural discontinuities have supported a high degree of endemism and beta diversity (Vasey et al. 2014; Williams & Vasey 2016). Many of California's chaparral taxa are rare, local endemics (Vasey et al. 2014; Parker et al. 2016); consequently, maritime chaparral communities exhibit exceptionally high diversity among sites (Vasey et al. 2014; CNPS 2023). Species composition and population abundance shifts relative to fire, with higher levels of herbaceous understory diversity occurring in the first few years following a fire (Barro & Conard 1991) as the soil seedbank harbors many species that are able to germinate after the shrub canopy is removed (Rundel 2018; Vuln. Assessment Worksheets, pers. comm., 2022). The fire regime in maritime chaparral systems also influences wildlife diversity, with invertebrates and some bird species re-entering burned areas relatively quickly, while other taxa including herpetofauna and small mammals may have a more variable response (Barro & Conard 1991; van Mantgem et al. 2015).

Hundreds of species of birds, mammals, and reptiles are found in California chaparral systems, including maritime chaparral (Jennings 2018a). About 100 species of mammals and birds are estimated to be year-round residents of this ecosystem, and many of the wildlife species that utilize chaparral habitats state or federally listed for protection as endangered or threatened species (Jennings 2018a). Thousands of invertebrates are also found in chaparral habitats, and a particularly high degree of pollinator specialization and diversity has been documented in California chaparral (Jennings 2018a).

Resistance and recovery → Moderate (moderate confidence)

Maritime chaparral is resilient to the harsh conditions and disturbance regimes to which it is adapted, including low-nutrient soils, recurrent drought, and periodic fire (Keeley 1991, 2007; Vasey et al. 2014; Rundel 2018). Component chaparral species have a variety of physiological and life history strategies that support survival or rapid recovery from disturbances including drought and fire (Keeley 1991; Rundel 2018), and chaparral communities with intact canopies are relatively resistant to invasion by annual grasses (Keeley & Brennan 2012). However, resistance and recovery are reduced following significant alterations in these disturbance regimes, including changes in fire frequency and long-term shifts in the severity and extent of drought. These environmental shifts can make it difficult for obligate seeders to reestablish seedlings, can increase competition from invasive grasses, and can create loss of vigor of re-sprouting species (Zedler et al. 1983; Paddock III et al. 2013; Vuln. Assessment Worksheets, pers. comm., 2022). Ultimately, this can lead to wholesale conversion to invasive-dominated grasslands or desertification (Haidinger & Keeley 1993; Lenihan et al. 2008).

Management potential → Low (moderate confidence)

Maritime chaparral provides many critical ecosystem services, including provision of wildlife habitat, flood and erosion control, water filtration, carbon sequestration, and recreation (Sauvajot et al. 1998; Williams & Vasey 2016; Jennings 2018a; Rundel 2018; Safford et al. 2018a), and it is increasingly being recognized for those services by land managers and some public sectors (Safford et al. 2018a, 2018b). However, it has low value among the general public compared to many other vegetation types because it is perceived as difficult to recreate in, and because it is associated with high fire risk -- though this risk is in fact largely driven by the vast numbers of people who live and recreate in the wildland urban interface (Rundel 2018; Safford et al. 2018a). The segment of the public that is interested in horticulture, insect and bird conservation do highly value maritime chaparral, as do organizations like the California Native Plant Society that are devoted to conservation of these resources (Vuln. Assessment Worksheets, pers. comm., 2022).

Restoring multi-decadal fire return intervals in maritime chaparral is likely to be a high-priority management action that may reduce vulnerability to climate change (Syphard & Keeley 2015; Safford et al. 2018a; Vuln. Assessment Worksheets, pers. comm., 2022). Other active management strategies, such as mechanical removal of encroaching forests, can also be key to restoring maritime chaparral systems and associated ecosystem services (Dougherty & Riggan 1982; Wohlgemuth et al. 1999). However, these management actions can also be expensive and politically and logistically challenging to implement (Vuln. Assessment Worksheets, pers. comm., 2022). Additionally, site-specific factors need to be considered to ensure post-fire chaparral recovery and prevent the expansion of invasive species, particularly as climate stressors increase (Potts et al. 2010). Some organizations and partnerships are currently exploring management tools that can help stabilize fire regimes and reduce stressors in maritime chaparral systems, particularly for protected public lands (Williams & Vasey 2016; Safford et al. 2018a; Panorama Environmental 2019). Land use planning that targets exurban sprawl and development would address many impacts of fragmentation, increased fire frequency, and non-native species, particularly for areas that do not currently have protected status (Safford et al. 2018b; Syphard et al. 2018). Incorporating planning for conservation of areas to which chaparral species may be expected to move (e.g., upslope, cooler microclimates) in association with climate change would be particularly helpful (Safford et al. 2018a; Thorne et al. 2020; Vuln. Assessment Worksheets, pers. comm., 2022).

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Further information on the Golden Gate Biosphere Region Climate Adaptation Project is available on the project page (www.ecoadapt.org/goto/GGBRClimateProject).

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