# Southern California Endemic Habitats

## *Climate Change Vulnerability Assessment Synthesis*

***An Important Note About this Document:*** *This document represents an initial evaluation of vulnerability for endemic habitats based on expert input and existing information. Specifically, the information presented below comprises habitat expert vulnerability assessment survey results and comments, peer-review comments and revisions, and relevant references from the literature. The aim of this document is to expand understanding of habitat vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.*

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## Executive Summary

In this assessment, endemic habitats are considered as one collective habitat grouping, but directed comments are provided for the following systems of interest:[1] serpentine, carbonate, gabbro, pebble plains, and clay lens. In general, these endemic habitats feature specialized vegetative communities that are adapted to harsh and unique conditions derived, in part, from parent soil material (Center for Biological Diversity [CBD] 2002; Damschen et al. 2012; Safford and Harrison 2008; Stephenson and Calcarone 1999; U.S. Forest Service [USFS] 2005). Endemic habitats are typically limited in distribution, occupying distinct areas within the southern California study area.

The relative vulnerability of endemic habitats in southern California was evaluated to be moderate[2] by habitat experts due to moderate sensitivity to climate and non-climate stressors, moderate exposure to projected future climate changes, and moderate adaptive capacity.

| | |
|---|---|
| **Sensitivity and Exposure** | Climate sensitivities: Precipitation, soil moisture, drought, extreme high temperature events<br>Disturbance regimes: Wildfire<br>Non-climate sensitivities: Invasive & other problematic species, recreation, energy production & mining, livestock grazing, fire suppression practices, transportation corridors, land-use conversion/development<br>Other sensitivities: Soil properties, human population growth |

Shifts in precipitation, moisture availability, and temperature may affect endemic habitat composition, survival, and vulnerability to non-climatic stressors. Endemic communities have variable responses to fire, but increasing fire frequencies are unlikely to benefit even the most fire-adapted communities. Endemic habitats face a variety of non-climatic drivers that reduce habitat resilience by increasing fragmentation and/or by exacerbating climate-driven changes. Human population growth may increase the severity/extent of these stressors in the future.

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[1] As identified by the stakeholder committee at the Southern California Focal Resources Workshop.
[2] Confidence: Moderate

Unique soil requirements largely moderate endemic habitat distribution, species composition, and sensitivity to climate and non-climate stressors.

**Adaptive Capacity**

Habitat extent, integrity, and continuity: Low-moderate geographic extent, moderate integrity (altered but not degraded), low continuity
Resistance and recovery: Moderate resistance, low-moderate recovery potential
Habitat diversity: Moderate-high overall diversity
Management potential: Moderate societal value, low-moderate management potential

Small, isolated populations, specific soil requirements, and several landscape barriers limit endemic habitat dispersal and recovery potential in the face of climate change, but specialized vegetation enhances habitat resistance. Endemic systems provide a variety of ecosystem services (e.g., biodiversity, recreation). Potential management options identified by habitat experts largely deal with protecting and restoring current endemic habitat areas.

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## Sensitivity

The overall sensitivity of endemic systems to climate and non-climate stressors was evaluated to be moderate by habitat experts.[3]

**Sensitivity to climate and climate-driven changes**

Habitat experts evaluated endemic habitats to have moderate sensitivity to climate and climate-driven changes,[4] including: precipitation, soil moisture, drought, and extreme high temperature events.[5] Habitat experts also identified reduced snowpack as an important stressor for some endemic systems, particularly pebble plains.[6] In general, endemic habitats are adapted to harsh conditions (e.g., low moisture and nutrient availability) and are fairly resilient to fluctuations in precipitation and temperature due to historical exposure; however, individual species vulnerability varies (Damschen et al. 2012).

Precipitation variability and soil moisture

Endemic communities are largely adapted to water stress and unproductive soils (Damschen et al. 2012), but shifts in soil moisture and precipitation may affect endemic community plant composition, abundance, species richness, fitness, and vulnerability to non-climatic stressors (e.g., invasive species). For example, although clay components of serpentine soils favor water retention (CBD 2002), the overall shallow soils in serpentine areas limit moisture retention and affect plant growth (Huenneke et al. 1990), often favoring highly adapted native species (e.g., short-statured plants with small leaf area; Fernandez-Going et al. 2012) and excluding the majority of exotic invaders (Gram et al. 2004). Serpentine grasslands typically exhibit less variation in species richness and composition in response to changes in mean precipitation than

[3] Confidence: High
[4] Confidence: Moderate
[5] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.
[6] Not all habitat experts identified reduced snowpack as a climate stressor.

other vegetative communities on fertile soils (Fernandez-Going et al. 2012; Harrison et al. 2014). Periods of high rainfall however, have been documented to facilitate exotic invasion in serpentine habitats when paired with nutrient enrichment (Eskelinen and Harrison 2013, 2015; Gram et al. 2004; Hobbs and Mooney 1991). Rainfall also affects serpentine plant communities by affecting soil leaching (Grace et al. 2007). Similarly, saturated soils make pebble plains more vulnerable to soil disturbance (Stephenson and Calcarone 1999; USFS 2005).

<u>Drought</u>

Endemic habitat resilience to multi-year drought largely depends on seedbank persistence, dormancy cues, phenology and resilience of pollinators and mycorrhizae, soil microbes, and other factors. For example, some endemic species (e.g., perennial *Eriogonum*) experienced mortality during recent drought periods, but both pebble plains and carbonate habitats exhibited a species regeneration pulse with the return of more mesic conditions (S. Eliason, pers. comm., 2015). Although reduced rainfall and/or drought may cause mortality or negatively impact germination and recruitment of component species in some habitats (e.g., pebble plains, carbonate areas; Mistretta and White 2001; Sanders 1998b; U.S. Fish and Wildlife Service [USFWS] 1997 and citations therein), other endemic habitats may benefit from drought. For example, in a northern California serpentine grassland severe drought eliminated exotic invaders (Hobbs and Mooney 1991). In general, drought conditions are likely to change rates and patterns of exotic species establishment and conifer and shrub encroachment in endemic habitat areas with unique soils (Vulnerability Assessment Reviewers, pers. comm., 2015).

<u>Temperature</u>

Temperature may influence endemic plant community composition and survival. For example, serpentine communities are adapted to high soil surface temperatures (Damschen et al. 2012). Similarly, large diurnal and annual temperature fluctuations may restrict tree establishment on pebble plains (Derby and Wilson 1979 cited in Stephenson and Calcarone 1999), and low temperatures likely favor pebble plains vegetation over other competing plant communities (S. Eliason, pers. comm., 2015). High physiological tolerance for temperature extremes has historically favored the resilience of pebble plains plant communities, but their heat thresholds are largely unknown, leading to uncertainty around their direct vulnerability to warming air temperatures. Pebble plains may be more indirectly vulnerable to warming temperatures, particularly if they facilitate increased colonization opportunities for trees and shrubs by driving shifts in precipitation and snowpack (S. Eliason, pers. comm., 2015).

<u>Snowpack</u>

Some carbonate species rely on winter snowpack for insulation and to reduce wind desiccation during low-productivity periods (Sanders 1998a). Snowpack was also found to buffer minimum temperatures and facilitate serpentine species survival in a translocation experiment to higher elevations and northern aspects (Spasojevic et al. 2014). In addition, snowpack protects the clay-soil matrix in pebble plains habitats, contributing to soil expansiveness and frost heave in the root zone, which helps exclude tree and shrub colonization. Shifts from snow to rain may make pebble plains more vulnerable to tree/shrub encroachment and motorized vehicle disturbance (S. Eliason, pers. comm., 2015), and may also increase erosion in a variety of endemic habitats (Vulnerability Assessment Reviewers, pers. comm., 2015).

**Sensitivity to disturbance regimes**

Habitat experts evaluated endemic habitats to have moderate sensitivity to disturbance regimes,[7] including wildfire.[8] Flooding, wind, insects, disease and landslides also shape these habitats, but to a lesser degree (Vulnerability Assessment Reviewers, pers. comm., 2015).

Wildfire

Fire affects various endemic communities differently (Safford and Harrison 2004; USFS 2005). Carbonate outcrop vegetation typically has low biomass that does not support extensive fire, and fire can actually cause significant delays in carbonate community recovery (USFS 2005 and citations therein). Conversely, vegetation on serpentine soils is adapted to periodic fire (Safford and Harrison 2004; USFS 2005), albeit at longer return intervals and lower intensities than surrounding habitat types (Safford and Harrison 2008). In addition, post-fire biomass regrowth is slower and post-fire shrub recruitment is lower when compared to surrounding habitats (e.g., serpentine vs. sandstone chaparral), leading to longer recovery times post-fire (Safford and Harrison 2004). Some species may be restricted to serpentine areas because they are intolerant of fire regimes in surrounding habitat types (e.g., grassland, chaparral; Safford and Harrison 2008). Comparatively, fire is a significant driver in gabbro outcrop communities, which are interspersed with chaparral (USFS 2005). Tecate and Cuyamaca cypress, obligate seeders found on gabbro soils, regenerate via stand-replacing fire (Dunn 1987 cited in USFS 2005). However, shorter fire return intervals are reducing the size and extent of these cypress groves, as trees are killed before reaching reproductive maturity and/or reproductive peaks, resulting in a deficient seedbed for regeneration (Stephenson and Calcarone 1999). Future shifts in fire frequency, intensity, and/or use of prescribed fire could facilitate composition shifts in serpentine communities, potentially undermining biodiversity in serpentine chaparral (Safford and Harrison 2004; USFS 2005) and/or causing regeneration failures and type conversion, particularly when followed by drought and high temperatures (S. Harrison, pers. comm., 2015).

Wind

Wind-deposited sediments can affect the reproduction and fitness of carbonate plant communities by altering water infiltration/drainage, soil pH and chemistry, and seed bank light stimulation (USFWS 1997). Although wind can exacerbate moisture stress for established individuals (Sanders 1998a), some threatened carbonate taxa benefit from wind disturbance by utilizing wind-mediated seed dispersal (Mistretta and White 2001). In addition, wind desiccation may help prevent tree establishment on pebble plains (USFS 2005).

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[7] Confidence: High

[8] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

Other (landslides)
Serpentine areas are sensitive to landslides, as they are often found on steep slopes prone to landslide activity, particularly during periods of high precipitation (Vulnerability Assessment Reviewers, pers. comm., 2015).

**Sensitivity and current exposure to non-climate stressors**
Habitat experts evaluated endemic habitats to have moderate sensitivity to non-climate stressors,[9] with an overall moderate exposure to these stressors within the study region.[10] Key non-climate stressors identified for endemic habitats include: invasive and other problematic species, recreation, energy production and mining, livestock grazing, fire suppression practices, transportation corridors, and land-use conversion/development.[11] In general, these stressors may cause destruction, fragmentation, and/or degradation of endemic systems, as well as exacerbate climate change impacts. Further, many of these stressors are likely to be enhanced by human population growth in southern California, which is likely to lead to increased demand for a variety of services (e.g., energy, recreation, transportation corridors) and increased risk for endemic communities as development approaches national forest boundaries (e.g., increased risk of fire ignitions and invasive species introductions; Vulnerability Assessment Reviewers, pers. comm., 2015). Below, non-climate stressors are described in more detail for individual endemic habitat types.[12]

*Serpentine*
Serpentine grasslands are subjected to grazing (Gram et al. 2004), although grazing is declining on southern California national forest lands due to associated costs (Vulnerability Assessment Reviewers, pers. comm., 2015). Serpentine areas are also sensitive to mining development, off-road vehicles, and invasive species (CBD 2002; USFS 2005). Mining was historically a large stressor for this habitat, but is less extensive in modern days (USFS 2005). Off-road vehicle use, particularly illegal trail creation, can lead to trampling and habitat disturbance (Griggs and Walsh 1981; Pepper and Norwood 2001).

Serpentine grasslands are also vulnerable to invasion. Increased water availability combined with nutrient enrichment increases invasion success over the long-term (Eskelinen and Harrison 2013, 2015), while disturbance only enhances short-term invasion success (Eskelinen and Harrison 2015). In the absence of nutrient enrichment, serpentine habitats are fairly resistant to invasion due to a combination of low-fertility soils, low soil moisture retention, and competition from native vegetation (Eskelinen and Harrison 2013), and native species are able to persist on marginal, high-stress habitat (e.g., hummocks) more successfully than exotics (Gram et al. 2004). However, atmospheric nitrogen (N) deposition can facilitate serpentine invasion (Weiss 1999), and southern California experiences some of the highest levels of N deposition in the United States (> 45 kg N per hectare per year; Bytnerowicz and Fenn 1996;

[9] Confidence: Moderate
[10] Confidence: Moderate
[11] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.
[12] No information could be found for clay lens habitats.

Padgett et al. 1999), 80% of which occurs as dry deposition during summer (Bytnerowicz and Fenn 1996).

*Carbonate*

Limestone, sand/gravel, and calcium-carbonate mining are significant threats for carbonate endemics in the San Bernardino Mountains (Sanders 1998a; USFWS 1997). Mining can destroy or fragment habitat, alter local microclimates, lead to direct mortality, affect plant phenology through light pollution, and/or cause undesirable edge effects (UFSWS 1997). Carbonate deposits in the San Bernardino Mountains are the only significant source of calcium-carbonate in California (Brown 1995 cited in USFWS 1997). Road construction, urban and mountaintop development, recreation, hydropower/water diversions, off-road vehicle use, grazing, invasive species, fire suppression, and air pollution also threaten carbonate communities by affecting habitat extent and fragmentation, surface and soil hydrology, soil compaction and erosion, wind deposition, and plant vigor and fitness (CBD 2002; USFS 2005; USFWS 1997). In general, carbonate communities are sensitive to any form of ground disturbance or vegetation removal due to their highly restricted habitat range (CBD 2002; USFS 2005).

*Gabbro*

Mining and land-use conversion (e.g., telephone tower construction) threaten gabbro habitats (CBD 2002; Stephenson and Calcarone 1999). Habitat alterations can undermine or extirpate gabbro-dependent plant species (CBD 2002).

*Pebble plains*

Pebble plains are sensitive to direct vegetation mortality, altered plant productivity, soil disturbance, and/or hydrological alterations from recreation, development, special use permit activities, transportation corridors, illegal grazing, and fire suppression (USFS 2005 and citations therein; USFWS 2001a cited in CBD 2002). For example, recreation (including unauthorized trail or vehicle use) can cause trampling, uprooting, sedimentation, and soil loss (USFS 2005; USFWS 2001a cited in CBD 2002). Car ruts alter surface hydrology through channelization and soil compaction, contribute to removal of the clay soil matrix, destroy vegetation, and invert seedbanks (USFS 2005), and impacts are most severe when soils are unfrozen and saturated, conditions that may increase as a result of climate change (S. Eliason, pers. comm., 2015). Roads are also a major stressor for pebble plains, as they alter natural sheet water flow, cause dust that can disrupt photosynthesis and reproduction, facilitate invasive species establishment (USFS 2005), and provide access points for unauthorized vehicle use. In addition, saline water used for fire suppression can degrade this habitat (USFWS 2001a cited in CBD 2002). Pebble plains may be disproportionately in demand for, and vulnerable to, recreation, road access, and use for fire suppression personnel bases due to their open, flat topography (USFS 2005 and citations therein). Pebble plains are also sensitive to invasive species, which can alter ecological functioning (CBD 2002), compete for moisture and nutrients, and increase surface organics (Vulnerability Assessment Reviewers, pers. comm., 2015). Red brome (*Bromus madritensis* ssp. *rubens*), cheatgrass (*Bromus tectorum*), red-stemmed stork's bill (*Erodium cicutarium*), peppergrass (*Lepidium perfoliatum*), and bur buttercup (*Ranunculus testiculatus*) are primary invaders of pebble plains (CBD 2002; USFS 2005).

**Other sensitivities**

Soil composition and other edaphic factors largely define and determine species composition of endemic habitat types (CBD 2002; Stephenson and Calcarone 1999; USFS 2005), and may exert more of a control on species composition than other factors (e.g., disturbance regimes; Safford and Harrison 2008). For example, invasive species may have a difficult time establishing on clay lenses due to compacted soil and cryptogamic soil crusts (Mattoni et al. 1997), on carbonate outcrops due to high soil pH (Sanders 1998a), and on serpentine soils due to low water retention, macronutrients, calcium levels, and high magnesium levels (Eskelinen and Harrison 2013 and citations therein).

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## Future Climate Exposure

Habitat experts evaluated endemic habitats to have moderate exposure to projected future climate and climate-driven changes,[13] and key climate variables to consider include precipitation changes and increased wildfire (Table 1).[14,15] For a detailed overview of how these factors are projected to change in the future, please see the Southern California Climate Overview (http://ecoadapt.org/programs/adaptation-consultations/socal). Overall, habitat experts evaluated that endemic habitat refugia from climate impacts may be limited due to unique soil requirements and current isolation of existing habitats.

**Table 1.** Anticipated endemic habitat(s) responses to climate and climate-driven changes.

| Climate and climate-driven changes | Anticipated endemic habitat(s) response |
|---|---|
| Hydrology (precipitation, drought, soil moisture)<br>*Variable annual precipitation volume and timing; shifts from snow to rain; increased climatic water deficit; longer and more severe droughts with drought years twice as likely to occur* | • Altered species composition, richness, fitness, germination, recruitment, and survival<br>• Altered vulnerability to non-climatic stressors (e.g., invasive species) and soil disturbance |
| Snowpack<br>*-42% decline in snowpack projected for Los Angeles-region mountains by 2040, particularly at lower elevations* | • Reduced winter insulation for higher-elevation endemics, potentially reducing survival<br>• Enhanced desiccation of some higher-elevation endemics<br>• Pebble plains: reduced soil protection may make habitat more vulnerable to soil disturbance; reduced frost heave may facilitate tree/shrub invasion |
| Air temperature and extreme heat events<br>*+2.5 to +9°C by 2100; heat waves, particularly humid nighttime heat events, will occur more frequently, last longer, and feature hotter temperatures* | • Direct vulnerability (e.g., heat thresholds) unknown<br>• May favor invasion by other habitat types by affecting precipitation and snowpack |

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[13] Confidence: Moderate

[14] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found at the end of this document.

[15] Habitat experts identified these key factors, but did not provide any additional comments, and no supporting information about future changes in endemic habitats in response to these factors could be found in the literature.

| Climate and climate-driven changes | Anticipated endemic habitat(s) response |
|---|---|
| Wildfire<br>*Increased fire size, frequency, and severity* | • All endemic habitats: delayed habitat recovery<br>• Gabbro: too-frequent fire reduces recruitment and habitat extent<br>• Serpentine: too-frequent fire may facilitate species shifts, reduce biodiversity and regeneration, and/or lead to type conversion |

<u>Species distribution</u>

Loarie et al. (2008) project that central western California will maintain endemic species richness through the end of the century, even with significant climate change. Endemic diversity in southwestern California may increase along the coast over the same time period, particularly in mountainous areas, but this likely involves the replacement of current endemics with migrating endemic species from other areas, which raises conservation concerns (Loarie et al. 2008). In a modeling scenario with no dispersal, endemic diversity in southwestern California is projected to decline by the end of the century (Loarie et al. 2008). Overall, endemic diversity, range size, and species migration projections are mediated by dispersal ability, the severity of climate change (i.e., total greenhouse gas emissions), and model sensitivity (Loarie et al. 2008). In general, endemic plant diversity is projected to shift toward more coastal and/or northern locations in California by the end of the century, although some species may exhibit southward movement as they attempt to colonize the coastal mountains of southern California (Loarie et al. 2008). Loarie et al. (2008) project that roughly 66% of endemic plant taxa will likely experience significant range reductions (>80%) by 2100.

However, Damschen et al. (2012) posit that these and other distribution models do not account for the inherent spatial isolation and soil specificity of endemic flora, which will severely limit endemic migration ability to areas of climate refugia. In a modeling exercise that incorporates soil substrates and current habitat patches, Damschen et al. (2012) found that minimum migrations for serpentine species to future suitable habitat ranged from 663-8,275 m, with dispersal distances being larger under warmer-drier scenarios. Similarly, habitat experts stated that refugia for some pebble plains species may exist at higher elevations or more northward latitudes, but it is unlikely there are refugia for the pebble plains community in its current full richness and complexity. Habitat experts also stated that modeled northern refugia may be undermined by shifts in precipitation (Vulnerability Assessment Reviewers, pers. comm., 2015).

In a translocation experiment in the Siskiyou Mountains of Oregon, Spasojevic et al. (2014) found that higher elevations and northern aspects provided suitable climate refugia for two serpentine species, underscoring the importance of including topography in future species distribution models. They found that aboveground interactions with other vegetation facilitated survival of serpentine species by buffering minimum air temperatures, as did snowpack, and belowground variability in soil organic matter in cooler locations also facilitated survival. In general, these mechanisms are likely to influence the buffering capacity of topographical refugia (Spasojevic et al. 2014). However, Spasojevic et al. (2014) also concede that survival in topographic refugia areas will depend on many factors, including species, pollinator availability, and the frequency/intensity of extreme events (e.g., freeze periods) as they coincide with other climate changes (e.g., reduced snowpack).

## Adaptive Capacity

The overall adaptive capacity of endemic habitats was evaluated to be moderate by habitat experts.[16]

**Habitat extent, integrity, continuity, and permeability**
Habitat experts evaluated endemic habitats to have a low-moderate geographic extent (i.e., habitat is quite limited in the study area),[17] moderate integrity (i.e., habitat is altered but not degraded),[18] and feature low continuity (i.e., habitat is isolated and/or quite fragmented).[19] Habitat experts identified land-use conversion, energy production and mining, transportation corridors, grazing, and geologic features as barriers to chaparral habitat continuity and dispersal.[20]

The response of endemic habitats to climate change will likely depend on their dispersal ability (Loarie et al. 2008), habitat availability and condition (e.g., appropriate soil), and current population size and range (Damschen et al. 2012; Loarie et al. 2008; Pimm and Raven 2000; USFS 2005). Natural dispersal rates and distances of endemic species are unlikely to keep pace with climate change (Loarie et al. 2008), particularly as many endemics have limited dispersal capability (average 10-100 m; >1 km rare; Damschen et al. 2012 and citations therein; Sanders 1998b), have low productivity, recover slowly from disturbance, and are outcompeted on all but the most unique and harsh soil types (CBD 2002; Stephenson and Calcarone 1999; USFS 2005). In addition, many endemic habitat groups in southern California exist in small and disjunct locations (CBD 2002; Damschen et al. 2012; Stephenson and Calcarone 1999; USFS 2005), which are generally more vulnerable to extirpation and extinction (Loarie et al. 2008; Pimm and Raven 2000). Spatial isolation combined with specific soil requirements undermines migration potential for endemic flora in response to climate change (Damschen et al. 2012).

*Serpentine*
Serpentine soils cover roughly 285,000 hectares (ha) in California (Gram et al. 2004). Within the southern California study region, serpentine outcrops are found exclusively on the Los Padres National Forest, which hosts roughly 31,470 acres of this habitat type (CBD 2002; Stephenson and Calcarone 1999).

[16] Confidence: High
[17] Confidence: High
[18] Confidence: High
[19] Confidence: Moderate
[20] Barriers presented are those ranked most critical by habitat experts. A full list of evaluated barriers can be found at the end of this document.

*Carbonate*
Carbonate areas occur as disjunct patches on the northern (desert-facing) slopes of the San Bernardino Mountains, following an east-west axis and grouping into distinctive bands disrupted by the granitic Transverse Ranges (USFWS 1997). Carbonate areas can be found from 1,220-2,440 m (4,002-7,847 ft), and span only a 35-mile range (USFWS 1997). Roughly 87% of carbonate areas occur on national forest lands within the study region (CBD 2002). Although carbonate areas are naturally fragmented, additional human-induced fragmentation poses a significant threat to future extent of this habitat (CBD 2002), especially since studies on threatened carbonate taxa indicate limited seed dispersal capability (~30 m; Mistretta and White 2001). Small population sizes also threaten the persistence of carbonate vegetative communities (USFWS 2001a cited in CBD 2002).

*Gabbro*
Gabbro outcrops occur in the Santa Ana Mountains and in the mountains and foothills of San Diego County, covering 81,680 acres (Stephenson and Calcarone 1999). Roughly 41% of gabbro outcrops in the study region occur on national forest lands, with the majority occurring in the Cleveland National Forest (CBD 2002). Gabbro habitats are disjunct, functioning as habitat islands within other substrate and vegetative communities (e.g., chaparral; CBD 2002; Stephenson and Calcarone 1999; USFS 2005).

*Pebble plains*
Pebble plains occur only in a 92 square km area in the San Bernardino Mountains (CBD 2002), ranging in elevation between 1,800-2,000 m (5,905-6,561 ft; USFWS 1995 and citations therein). Roughly 60% of pebble plains habitat occurs on national forest lands within the study region, exclusively in the San Bernardino National Forest (CBD 2002; USFS 2005). Pebble plains are treeless habitats distributed within forest and woodland systems (CBD 2002; USFS 2005).

**Resistance and recovery**
Habitat experts evaluated endemic habitats to have moderate resistance to climate stressors and maladaptive human responses,[21] and low-moderate recovery potential.[22] In general, endemic habitats may be fairly resistant to change due to their unique soil factors and the vegetative communities adapted to such soil. For example, pebble plains are generally resistant to impacts during periods where soils are hard (e.g., frozen or dry), but vulnerable and slow to recover from impacts when soils are wet and soft (S. Eliason, pers. comm., 2015). Similarly, serpentine species can resist invasion under natural climatic fluctuations (e.g., variable precipitation; Gram et al. 2004; Eskelinen and Harrison 2013, 2015; Hobbs and Mooney 1991). In general, however, recovery of endemic habitats is limited, particularly because endemic communities are restricted to very specific habitat locations and conditions and have small, isolated populations (Vulnerability Assessment Reviewers, pers. comm., 2015).

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[21] Confidence: Moderate
[22] Confidence: Moderate

**Habitat diversity**

Habitat experts evaluated endemic habitats to have moderate physical and topographical diversity,[23] moderate-high component species diversity,[24] and moderate functional group diversity.[25] Individual endemic habitat types typically have few populations and low population numbers, contributing to low genetic diversity. Collectively, however, endemic habitats contain high biodiversity (Vulnerability Assessment Reviewers, pers. comm., 2015).

*Serpentine*

Despite being nutrient-limited and having high concentrations of heavy metals (CBD 2002; Gram et al. 2004), serpentine soils harbor many of the remaining native California grassland species (Gram et al. 2004 and citations therein), including 12.5% of all endemic flora species in the state (Safford et al. 2005). There are 669 taxa associated with serpentine soils (Rajakaruna and Boyd 2009), and serpentine soils are dispersed among a variety of habitat types within the study region, typically featuring distinct vegetation from the surrounding habitat (e.g., serpentine soils will feature chaparral species in grassland areas; USFS 2005), a larger component of perennial herbs (Safford and Harrison 2008), and lower species richness and density (Safford and Harrison 2008; Stephenson and Calcarone 1999). Common indicators of serpentine soils are knobcone pine (*Pinus attenuata*) and Sargent cypress (*Cupressus sargentii*), although these species do occur on other substrates (Stephenson and Calcarone 1999). The USDA Forest Service has also identified 10 sensitive species that are found in combination with serpentine soils: San Luis mariposa lily (*Calochortus obispoensis*), San Luis Obispo sedge (*Carex obispoensis*), Santa Barbara jewelflower (*Caulanthus amplexicaulis* var. *barbarae*), dwarf soaproot (*Chlorogalum pomeridianum* var. *minus*), Brewer's spineflower (*Chorizanthe breweri*), talus fritillary (*Fritillaria falcata*), San Benito fritillary (*Fritillaria viridea*), Hardham's bedstraw (*Galium hardhamiae*), adobe sanicle (*Sanicula maritima*), and Cuesta Pass checkerbloom (*Sidalcea hickmanii* ssp. *anomala*) (Stephenson and Calcarone 1999; USFS 2005).

*Carbonate*

Common carbonate species include the threatened Parish's daisy (*Erigeron parishii*), the endangered Cushenbury buckwheat (*Eriogonum ovalifolim* var. *vineum*), Cushenbury milkvetch (*Astragalus albens*), San Bernardino Mountains bladderpod (*Lesquerella kingii* spp. *bernardina*), and Cushenbury oxytheca (*Oxytheca parishii* var. *goodmaniana*) (USFWS 1997). Carbonate communities can be found in the understory of blackbrush scrub, pinyon-juniper woodlands, pinyon woodlands, and Jeffrey pine/western juniper woodlands; these vegetative communities may moderate local climatic and abiotic conditions (e.g., albedo, wind; USFWS 1997). Vegetation distribution is typically sparse on carbonate soils (Mattoni et al. 1997; USFS 2005), and productivity and growth is low relative to surrounding habitats (USFS 2005). Many carbonate outcrops are located in dry areas, and component species (e.g., *E. ovalifolim*) often feature adaptations for arid, desiccation-prone, and high-insolation environments (Sanders 1998a, 1998b).

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[23] Confidence: Moderate
[24] Confidence: Moderate
[25] Confidence: Moderate

*Gabbro*
Gabbro soils are typically mildly acidic, contain various heavy metals (CBD 2002), and have low calcium-magnesium ratios, which limit plant establishment and growth (USFS 2005). In addition, vegetation on gabbro outcrops is typically small and widely spaced (USFS 2005). Gabbro outcrops support unique communities including Cuyamaca cypress (*Cupressus stephensonii*) and Tecate cypress (*Cupressus forbesii*) groves (CBD 2002; Gordon and White 1994 cited in Stephenson and Calcarone 1999), as well as herbaceous species, including the endangered San Diego thorn-mint (*Acanthomintha ilicifolia*) and Mexican flannelbush (*Fremontodendron mexicanum*) (Stephenson and Calcarone 1999). Tecate cypress groves are habitat for the Thorne's hairstreak butterfly (*Mitoura thornei*), an invertebrate species of concern. Gabbro soils can also host chaparral species (USFS 2005).

*Pebble plains*
Pebble plains support a variety of low-growing and widely spaced unique vegetation species including succulents, grasses, small annuals, and cushion-forming species (Stephenson and Calcarone 1999; USFS 2005). Species composition varies widely among sites (USFS 2005); species and functional group diversity is typically high within sites and consistent across sites (Vulnerability Assessment Reviewers, pers. comm., 2015). Pebble plains support three federally threatened species, including Bear Valley sandwort (*Arenaria ursina*), ash-gray paintbrush (*Castilleja cinerea*), and southern mountain buckwheat (*Eriogonum kennedyi* var. *austromontanum*), as well as eight sensitive species and six additional species of concern (USFS 2005). Component vegetation also supports a variety of rare butterflies, including three endemic to pebble plains (USFS 2002b cited in USFS 2005).

*Clay lens*
Species found in clay lens areas include *Dudleya variegata* and endemic *D. multicaulis*. *Acarospora* lichen species dominate the cryptogamic soil crust. Several clay lens species are known to support the Quino checkerspot butterfly (*Euphydryas editha quino*) (Longcore et al. 2003).

**Management potential**
Habitat experts evaluated endemic habitats to be of low-moderate societal value.[26] Endemic habitats are valued for their recreational opportunities, scenic quality, biodiversity, and endemism. Some endemic plants are also valued for their role as insect host plants (e.g., for threatened and endangered butterflies). However, some endemic habitats are also valued for their economic potential (e.g., mining material), which may threaten habitat persistence. Endemic habitats provide a variety of ecosystem services, including: biodiversity, water supply/quality/sediment transport, recreation (including aesthetics), carbon sequestration, nitrogen retention, air quality, public health, fire regime controls, and flood and erosion protection (Vulnerability Assessment Reviewers, pers. comm., 2015).

[26] Confidence: High

Habitat experts identified that there is low-moderate potential for managing or alleviating climate impacts for endemic habitats.[27] Potential management options identified by habitat experts include: curtailing development; controlling recreational use of endemic habitats; increasing restoration activities in degraded areas; and acquiring and conserving lands with endemic communities.

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[27] Confidence: High

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