Central Valley Landscape Conservation Project

# Climate Change Vulnerability Assessment (January 2017 version)

# Dunes

## Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

| Vulnerability Component | Score |
|---|---|
| Sensitivity | High |
| Exposure | High |
| Adaptive Capacity | Low-moderate |
| **Vulnerability** | **High** |

Overall vulnerability of the dunes habitat was scored as high. The score is the result of high sensitivity, high future exposure, and low-moderate adaptive capacity scores.

Key climate factors for dune systems include precipitation amount, soil moisture, and drought. These factors influence vegetation germination, species composition, and survival, as well as wildlife habitat quality. Refugia from climate impacts may be limited for dune species due to the limited distribution of this habitat type (U.S. Fish and Wildlife Service 2011).

Key disturbance mechanisms include wildfire, flooding, wind, and grazing. Wind and flooding drive dune formation and dynamism; wildfire threatens dune vegetation, and grazing can have variable impacts (e.g., facilitate management of invasives, trampling of native species).

Key non-climate factors include urban/suburban development, agricultural and rangeland practices, land use change, invasive and problematic species, roads, highways, and trails, off-highway vehicle use, sand mining, nutrient loading, and impervious surfaces. These factors can fragment and destroy habitat, alter species composition and native vegetation survival, and have contributed to extirpations, extinctions, and federal listings of obligate dune species.

Dunes occupy only a small portion of Central Valley surface area, and have experienced high levels of habitat destruction, fragmentation, and alteration, primarily from agricultural and urban development, mining, and exotic species establishment. Many of the non-climate factors listed above, in addition to energy production/mining and riprap, act as landscape barriers.

Dunes exhibit some resilience to dynamic environmental conditions (e.g., flooding, wind), but are much less resilient to habitat loss, fragmentation, and alteration associated with human activities, although some recovery from human impacts is possible. Small, isolated dune

systems limit gene flow, migration, and recovery potential in response to climate-related stresses and habitat fragmentation, making species vulnerable to extirpation. Dune systems harbor high endemism, as well as many endangered and imperiled species.

Management potential for dune habitat was scored as low, and is likely influenced by policies such as the Endangered Species Act and restoration activities such as native vegetation planting, sand importation, and cattle grazing to mitigate invasive species impacts.

## Table of Contents

## Introduction

## Description of Priority Natural Resource

Central Valley dune habitats include hill-shaped dunes, sandy washes, and alluvial fans; these are distinguished from the San Joaquin Desert habitat by the roles of wind and water in the system. Hill-shaped dunes are shaped by wind and this has a large effect on the ability of non-native grasses to invade and generally shapes the vegetation. Washes and alluvial fan habitats are characterized by infrequent movements of large volumes of water. Species found in dune habitats include kangaroo rat (*Dipodomys spp.*), Jerusalem cricket (*Stenopelmatus* spp.), San Joaquin Valley giant flower-loving fly (*Rhaphiomidas trochilus*) and other *Rhaphiomidas* species, legless lizards (*Anniella* spp.) (Ken Sanchez, pers. comm., 2015), Lange's metalmark butterfly (*Apodemia mormo langei*), and several species of sphinx moths, including the Kern primrose sphinx moth (*Euproserpinus euterpe*)[1].

As part of the Central Valley Landscape Conservation Project, workshop participants identified the dunes habitat as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the habitat's management importance as indicated by its priority in existing conservation plans and lists, and 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing the dunes habitat as a Priority Natural Resource included the following: the habitat has high management importance, and due to the habitat being associated with many endemic species, dependence on alluvial deposition, and uniqueness in that they have low value in conversion to agriculture or rangelands[1]. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

## Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source[1]. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

## Vulnerability Assessment Details

### Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

| Climate Factor | Sensitivity | Future Exposure |
|---|---|---|
| Extreme events: drought | High | High |
| Increased wildfire | - | High |
| Other factors | - | High |
| Precipitation (amount) | High | High |
| Soil moisture | High | - |
| **Overall Scores** | **High** | **High** |

***Potential refugia:*** *Refugia from climate impacts may be limited for dune species due to the limited distribution of this habitat type (U.S. Fish and Wildlife Service 2011).*

#### Precipitation (amount)

***Sensitivity:*** *High (high confidence)*
***Future exposure:*** *High (moderate confidence)*

Although precipitation models for California are highly uncertain, some projections suggest that annual precipitation will remain quite variable over the next century, and may increase slightly in the Sacramento River Basin and decrease slightly in the San Joaquin River Basin by 2050 (Bureau of Reclamation 2015), and precipitation extremes may increase (Toreti et al. 2013).

Precipitation volume influences dune vegetation germination, survival and abundance (U.S. Fish and Wildlife Service 2008), and drives different vegetative composition relative to desert habitats (U.S. Fish and Wildlife Service 2011). Both reduced and significantly increased annual precipitation have been linked with mortality of some vegetation species (e.g., Bakersfield cactus; *Opuntia trealeasi*). Reduced precipitation can increase moisture competition with non-native vegetation (U.S. Fish and Wildlife Service 2011).

#### Drought

***Sensitivity:*** *High (high confidence)*
***Future exposure:*** *High (high confidence)*

Over the coming century, the frequency and severity of drought is expected to increase due to climate change (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation,

causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015). For example, Thorne et al. (2015) project that climatic water deficit is expected to increase by 131 mm in the Central Valley (compared to 140 mm statewide) by 2070-2099 under a drier scenario and 44 mm (compared to 61 mm statewide) under a wetter scenario. Recent studies have found that anthropogenic warming has substantially increased the overall likelihood of extreme California droughts, including decadal and multi-decadal events (Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015).

Compared to the preceding century (1896-1994), drought years in California have occurred twice as often in the last 20 years (1995-2014; Diffenbaugh et al. 2015). Additionally, the recent drought (2012-2014) has been the most severe drought on record in the Central Valley (Williams et al. 2015), with record accumulated moisture deficits driven by high temperatures and reduced, but not unprecedented, precipitation (Griffin & Anchukaitis 2014; Williams et al. 2015). Drought periods have the potential to extirpate small, disjunct populations of rare dune species (Pavlik et al. 1993).

### Soil moisture

***Sensitivity:*** *High (high confidence)*

Between 1951-1980, climatic water deficit increased by 2 mm in the Central Valley, compared to an average of 17 mm statewide (Thorne et al. 2015). Soil moisture changes are likely to influence dune species composition, plant growth, reproduction and survival (U.S. Fish and Wildlife Service 2011). Soil moisture may also be a critical habitat quality indicator for dune insects (Osborne & Ballmer 2014), with deeper, moist sands providing refuge from hot, dry surface conditions (Prentice et al. 2011).

## Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

| Non-Climate Factor | Sensitivity | Current Exposure |
|---|---|---|
| Agriculture & rangeland practices | High | Low-moderate |
| Impervious surfaces | High | Moderate |
| Invasive & other problematic species | High | High |
| Land use change | High | - |
| Nutrient loading | High | Low-moderate |
| Other factors | High | High |
| Roads, highways, & trails | High | Moderate |

| | | |
|---|---|---|
| Urban/suburban development | High | Moderate-high |
| **Overall Scores** | **High** | **Moderate** |

### Invasive & other problematic species

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *Low-moderate (high confidence)*
***Pattern of exposure:*** *Localized. Non-native vegetation includes tree of heaven (Ailanthus althissima), which shades out native species, grasses (where precipitation is high enough), and arundo (in areas where riparian borders dunes or alluvial fans).*

In dune habitats, invasive species can outcompete native vegetation for a variety of resources, including space, moisture, nutrients, and sunlight, leading to lower native germination and seedling survival and overall lower native plant diversity (U.S. Fish and Wildlife Service 2002, 2011). Invasive species also inhibit native plant survival by reducing natural sand movement (Thomson 2005a). By forming dense thatch, invasive plants stabilize dune systems, reducing available open sandy substrate and preventing the dynamic sand movement that drives biodiversity and endemism (U.S. Fish and Wildlife Service 2002, 2008). Invasive species can also increase fire risk by increasing available fuel (U.S. Fish and Wildlife Service 2008, 2011). Common invasive plants in dune systems include ripgut brome (*Bromus diandrus*), winter vetch (*Vicia villosa*), star thistle (*Centaurea solstitalis*), and Sahara mustard (*Brassica tournefortii*).

Loss or replacement of native vegetation species can have serious implications for dune wildlife (U.S. Fish and Wildlife Service 2008; Osborne & Ballmer 2014). For example, invasive species have contributed to population declines of the endangered Lange's metalmark butterfly (*Apodemia mormo langei*) by reducing the abundance of buckwheat, the butterfly's larval host plant (U.S. Fish and Wildlife Service 2008). Similarly, invasive plants are thought to intercept soil moisture important for perennial shrubs that host prey for San Joaquin Valley giant flower-loving fly larvae, as well as disrupt ovipositional and mating behavior by reducing available open sandy substrate (Osborne & Ballmer 2014). Reduced native plant diversity contributes to reduced native insect and pollinator diversity, creating a positive feedback loop further reducing native plant diversity (U.S. Fish and Wildlife Service 2002) and recruitment (Pavlik et al. 1993).

### Off-highway vehicles

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *High (high confidence)*
***Pattern of exposure:*** *Significant threat that is continuous over landscape.*

Off-highway vehicles can trample and cause mortality of some dune species (e.g., San Joaquin Valley giant flower-loving fly; Osborne & Ballmer 2014).

### Sand mining

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *High (high confidence)*

***Pattern of exposure:*** *Sand ridge mining company in Kern County, adjacent to Sand Ridge Preserve.*

Sand mining can destroy and fragment dune habitat, and has contributed to local extirpations, extinctions, and federal listings of dune species (Osborne & Ballmer 2014). Sand mining is a significant threat for the Sand Hill Nature Preserve (U.S. Fish and Wildlife Service 2011) and Sand Ridge near Bakersfield (Osborne & Ballmer 2014).

### Urban/suburban development

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *Moderate-high (high confidence)*
***Pattern of exposure:*** *Generally continuous across landscape; alluvium in southern Central Valley very exposed to channelization of sediment out of mountains.*

Urban/suburban development has contributed to historical habitat loss of many dune systems (CalFed Bay-Delta Program 1999), including the Antioch Dunes system (U.S. Fish and Wildlife Service 2002). In addition, development and human population growth can increase water demand and result in drawdown of regional water tables, affecting groundwater levels and dune vegetation establishment and survival (Laity 2003).

### Impervious surfaces

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *High (high confidence)*
***Pattern of exposure:*** *Widely distributed across habitat.*

### Roads, highways, & trails

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *Moderate (high confidence)*
***Pattern of exposure:*** *Localized. Culverts and bridges are largest issues because they move high volume of water all at once and not frequently; structures impede flows and sediment transport.*

Road, highway, and trail construction can modify and fragment dune habitat, as well as lead to direct removal of dune vegetation (U.S. Fish and Wildlife Service 2011).

### Agricultural & rangeland practices

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *Low-moderate (high confidence)*
***Pattern of exposure:*** *Localized. Typically not good soil for converting to rangeland or agriculture; development and sand mining a larger issue.*

Agricultural conversion for cattle grazing and vineyards has contributed to historical dune habitat loss, contraction, and fragmentation in the Central Valley, including the Antioch Dunes system (U.S. Fish and Wildlife Service 2002), dunes on the Arena Plains (Silveira 2000), and dunes near Bakersfield (Osborne & Ballmer 2014).

### Nutrient loading

Workshop participants did not further discuss this factor beyond assigning a sensitivity and/or exposure score.

***Sensitivity:*** *High (high confidence)*
***Current exposure:*** *Low-moderate (high confidence)*
***Pattern of exposure:*** *Localized. Agricultural water, but not a large issue at all.*

### Land use change

***Sensitivity:*** *High (high confidence)*
***Pattern of exposure:*** *Localized.*

Historical land use change (sand mining, urban/suburban and industrial development, agricultural conversion) has contributed to sand dune habitat loss in the Central Valley region (CalFed Bay-Delta Program 1999; U.S. Fish and Wildlife Service 2002; Thomson 2005b; Osborne & Ballmer 2014).

## Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

***Overall sensitivity to disturbance regimes:*** *High (high confidence)*

### Wildfire

***Future exposure:*** *High (high confidence)*

Large fire occurrence and total area burned in California are projected to continue increasing over the next century with total area burned projected to increase by up to 74% by 2085 (Westerling et al. 2011).

Wildfire contributes to dune animal and plant mortality, alters reproductive activity, and affects dune formation (U.S. Fish and Wildlife Service 2008, 2011). Many rare and imperiled dune species have life stages vulnerable to fire; for example, butterfly eggs and larvae can be incinerated when host plants burn, while many threatened plants have peak growth and reproductive periods during potential fire periods in late spring through mid summer (U.S. Fish and Wildlife Service 2008). Increased fire severity has been linked with reduced reproductive activity in some dune species (e.g., Bakersfield cactus; U.S. Fish and Wildlife Service 2011). Additionally, altered wildfire regimes may affect dune formation by affecting San Joaquin Valley shrubs, which promote dunes[1].

### Wind

**Future exposure:** *High (high confidence)*

Along with flooding, wind largely drives dune formation and dynamism (Arkley 1962), contributing to open sandy substrate that supports a variety of unique dune vegetation (CalFed Bay-Delta Program 1999).

### Flooding

Large flood events help create dune systems (alluvial fans and washes) by depositing sediment. Floods scour and create open alluvial areas, freeing fine, sandy substrate to become supply sources for dunes (Laity 2003).

### Grazing

Grazing – depending on season, duration, and other factors – may facilitate management of invasive plants in sand dune habitats, minimizing thatch and associated stabilization of dune systems (U.S. Fish and Wildlife Service 2008). However, trampling by cattle can cause mortality of some dune species (e.g, San Joaquin Valley giant flower-loving fly (*Rhaphiomidas trochilus* (Coquillett)); Osborne & Ballmer 2014).

## Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

| Adaptive Capacity Component | Score |
|---|---|
| Extent, Integrity, & Continuity | Low-moderate |
| Landscape Permeability | Low |
| Resistance & Recovery | Low-moderate |
| Habitat Diversity | Moderate |
| **Overall Score** | **Low-moderate** |

### Extent, integrity, and continuity

***Overall degree of habitat extent, integrity, and continuity:*** *Low-moderate (high confidence)*

***Geographic extent of habitat:*** *Transcontinental (high confidence)*

***Structural and functional integrity of habitat:*** *Fairly degraded (high confidence)*

***Continuity of habitat:*** *Isolated and/or quite fragmented (high confidence)*

Dune systems occur throughout the world (e.g., see Exeler et al. 2009), but occupy a small land area within the Central Valley study area (CalFed Bay-Delta Program 1999; U.S. Fish and Wildlife Service 2002; Bureau of Land Management 2016). Although historical dune extent in the region may not have been large (CalFed Bay-Delta Program 1999), land use changes (e.g., development, mining) have significantly reduced the extent and integrity of dune systems in the Central Valley, contributing to population declines of many obligate dune species (Osborne & Ballmer 2014). The isolated nature of these habitats may limit gene flow, reduce genetic diversity, and make component species vulnerable to extirpation as a result of stochastic events or climate variability (U.S. Fish and Wildlife Service 2011). Some remnant dune systems are now protected via the National Wildlife Refuge System (e.g., Antioch Dunes, Arena Plains; U.S. Fish and Wildlife Service 2002) or by other land conservation groups (e.g., Sand Hill Nature Reserve, owned and managed by The Nature Conservancy; U.S. Fish and Wildlife Service 2011).

### Landscape permeability

***Overall landscape permeability:*** *Low (high confidence)*
***Impact of various factors on landscape permeability:***
***Urban/suburban development:*** *High (high confidence)*
***Energy production & mining:*** *High (high confidence)*
***Invasive & other problematic species:*** *High (high confidence)*
***Land use change:*** *High (high confidence)*
***Riprap:*** *High (high confidence)*
***Roads, highways, & trails:*** *Moderate-high (high confidence)*

Urbanization, roads/highways/trails, land use change, and other human activities fragment dune habitat, preventing gene flow and species dispersal (U.S. Fish and Wildlife Service 2011).

### Resistance and recovery

***Overall ability to resist and recover from stresses:*** *Low-moderate (high confidence)*
***Resistance to stresses/maladaptive human responses:*** *Low-moderate (high confidence)*
***Ability to recover from stresses/maladaptive human response impacts:*** *Low-moderate (high confidence)*

Dune vegetation species have variable seed dormancy lengths, contributing to variable survival during climatically unfavorable periods (e.g., see Pavlik & Manning 1993). Dunes are resilient to some levels of natural disturbance (e.g., flooding, wind; Arkley 1962; CalFed Bay-Delta Program 1999), but are much less resilient to habitat loss, fragmentation, and alteration from human activity (U.S. Fish and Wildlife Service 2008, 2011; Osborne & Ballmer 2014). However, due to the dynamic nature of dunes, some habitat and species recovery is possible following cessation of harmful land use (e.g., sand mining), although recovery will likely be slow. Recovery may be enhanced if paired with restoration (U.S. Fish and Wildlife Service 2008; Osborne & Ballmer 2014). Dune stewardship and maintenance experiments are on-going in the Monvero Dunes Natural Research Area (Bureau of Land Management 2016).

### Habitat diversity

***Overall habitat diversity:*** *Moderate (high confidence)*
***Physical and topographical diversity of the habitat:*** *Low (high confidence)*
***Diversity of component species within the habitat:*** *High (high confidence)*
***Diversity of functional groups within the habitat:*** *Moderate-high (moderate confidence)*

**Component species or functional groups particularly sensitive to climate change:**

- Endemic insects
- Evening primrose
- Kangaroo rats
- Dune flowers
- Sand loving fly (several *Rhapiomidas* spp.)
- Sphinx moths

**Keystone or foundational species within the habitat:**

- Mormon Tea in Monvero Dunes

**Other critical factors that may affect habitat diversity:**

- Highly endemic biota

Dunes support a variety of unique vegetation and insect species, including many endemic and imperiled species. For example, the Antioch Dunes National Wildlife Refuge was established to protect the federally endangered Antioch Dunes evening primrose (*Oenothera deltoides* subsp. *Howellii*), Contra Costa wallflower (*Erysium capitatum* var. *angustatum*), and the Lange's metalmark butterfly, which are all endemic to this particular dune system (U.S. Fish and Wildlife Service 2002, 2008). Dunes also support a variety of rare and diverse wildlife species, such as the Bakersfield legless lizard (*Anniella grinnelli*; Papenfuss & Parham 2013). Sometimes dunes also support species of adjacent and/or similar but distant systems; for example, the Monvero Dunes in western Fresno County host some sand-dwelling species commonly found in the Mojave Desert (Bureau of Land Management 2016).

## Management potential

Workshop participants scored the resource's management potential.

| Management Potential Component | Score |
|---|---|
| Habitat value | Low |
| Societal support | Low |
| Agriculture & rangeland practices | Low |
| Extreme events | Low |
| Converting retired land | Moderate |
| Managing climate change impacts | Low-moderate |
| **Overall Score** | **Low** |

## Value to people

***Value of habitat to people:*** *Low (high confidence)*
***Description of value:*** *Dunes are valued for recreational (e.g., OHV use) and resource extraction purposes (e.g., cement plants) rather than general habitat value.*

## Support for conservation

***Degree of societal support for managing and conserving habitat:*** *Low (high confidence)*

***Degree to which agriculture and/or rangelands can benefit/support/increase the resilience of this habitat:*** *Low (high confidence)*

***Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action:*** *Low (high confidence)*

## Likelihood of converting land to habitat

***Likelihood of (or support for) converting retired agriculture land to habitat:*** *Moderate (high confidence)*

***Likelihood of managing or alleviating climate change impacts on habitat:*** *Low-moderate (high confidence)*

***Description of likelihood:*** *Mechanical restoration is intensive.*

There is some support for managing dune habitats and associated species through the Endangered Species Act and other regulatory mechanisms (U.S. Fish and Wildlife Service 2008, 2011). Current management actions in Central Valley dune systems include importing sand, managing grazing to target invasive species, and conducting restoration plantings of dune vegetation (U.S. Fish and Wildlife Service 2008).

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