Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Burrowing Mammals

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	**Score**
Sensitivity	Moderate-high
Exposure	Moderate-high
Adaptive Capacity	Low-moderate
Vulnerability	**Moderate-high**

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

Key climate factors for burrowing mammals include drought, precipitation amount and timing, and soil moisture. Drought and precipitation variability influence forage availability and abundance of ground squirrels and kangaroo rats, which impacts kit fox and badger foraging opportunities, reproductive success, and distribution. Soil moisture influences burrowing mammal distribution and habitat quality.

Key non-climate factors for burrowing mammals include agriculture and rangeland practices, urban/suburban development, land use change (oil field development), roads, highways, and trails, and pollutions and poisons. These factors contribute to direct mortality and destroy, fragment, and degrade habitat availability, affecting burrowing mammal recruitment, diversity, abundance, and dispersal opportunities.

Key disturbance mechanisms for burrowing mammals include flooding and grazing. Flooding can drown burrowing mammals, while grazing has variable impacts on rodent populations (e.g., reduces thatch, but may increase competition for herbaceous resources). Burrowing mammals exhibit a low-moderate degree of specialization; most species are forage and prey generalists, but to some degree, rely on open grassland and shrubland, although kit foxes and ground squirrels are able to use modified habitat to some degree.

Burrowing mammal populations in the Central Valley are generally degraded and isolated, with the exception of the ground squirrel. Dispersal capacity varies by species, with rodents generally exhibiting lower dispersal capacity than badgers and kit foxes. Agriculture, roads, energy development and mining, dams/water diversions/levees, and land use change act as landscape barriers, affecting burrowing mammal dispersal and gene flow by fragmenting habitat. This species group exhibits moderate interspecific species diversity; most species exhibit some form of behavioral diversity in response to altered habitat conditions. Kit foxes and ground squirrels may be the most resilient species in this group due to higher behavioral plasticity, while kangaroo rats and badgers exhibit little adaptation to altered conditions.

Management potential for this species group was scored as low-moderate and is likely influenced by regulatory mechanisms (e.g., Endangered Species Act), protecting current habitat and enhancing connectivity, retiring agricultural land, and managing land to maximize suitability for burrowing mammals.

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Introduction

Description of Priority Natural Resource

Central Valley burrowing mammals commonly inhabit arid ecosystems on the valley floor, including annual grasslands, scrub and shrubland, and desert systems (Zeiner et al. 1990; U.S. Fish and Wildlife Service 1998). Species included under the vulnerability assessment of the burrowing mammals species group are California ground squirrels (*Spermophilus beecheyii*), kangaroo rats (*Dipodomys* spp.), the San Joaquin kit fox (*Vulpes macrotis mutica*), and the American badger (*Taxidea taxus*).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the burrowing mammals species group as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the species' 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 burrowing mammals species group as a Priority Natural Resource included the following: the species group has high management importance, the species group's conservation needs are not entirely represented within a single priority habitat, and because the group includes species that are ecosystem engineers, such as kangaroo rats and ground squirrels. 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. 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 flooding	-	Moderate-high
Other factors	-	Moderate
Precipitation (amount)	Moderate-high	Moderate-high
Precipitation (timing)	Moderate-high	Moderate
Soil moisture	Moderate-high	Moderate
Overall Scores	**Moderate-high**	**Moderate-high**

Burrowing mammal populations are likely to be affected by climate-driven shifts in grassland, shrubland, and desert habitat availability. Modeling by Gardali et al. (2012) indicates that grassland habitat in the San Joaquin Valley may decline 6-11% by 2070 due to warmer winter temperatures and variable precipitation, leading to overall drier conditions. Additional modeling by Thorne et al. (2016) indicates that the eastern edge of the Central Valley, particularly in the southern portion of the study region, is projected to become climatically unsuitable for grasslands under drier conditions. Saltbrush shrubs in the Central Valley may become climatically stressed and no longer have climatically suitable habitat by the end of the century if warmer and wetter conditions prevail. Comparatively, under hotter and drier conditions, some current saltbush habitat may remain climatically suitable, although habitat losses will still occur (Thorne et al. 2016). Large habitat areas with topographical diversity provide burrowing mammal refuge from stochastic events such as flood and drought, but habitat fragmentation undermines these characteristics in the study region, enhancing burrowing mammal vulnerability to environmental events (U.S. Fish and Wildlife Service 1998).

Drought

Sensitivity: *High (high confidence)*
Future exposure: *High (high confidence)*
Potential refugia: *Northward movement, but this will cause competition with species that are already further north.*

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). 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). 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).

Drought influences vegetation growth and seed production rates, which can reduce forage for ground squirrels (Van Horne 2007) and kangaroo rats (U.S. Fish and Wildlife Service 1998). Reduced forage may negatively impact kangaroo rat reproduction and survival, although adults may be able to survive 1-2 years of drought by using seeds stored in previous-year caches (U.S. Fish and Wildlife Service 1998).

Reduced rodent and other small mammal populations affect prey availability for the kit fox (Cypher & Scrivner 1992; Goldingay et al. 1997; Dennis & Otten 2000) and badger (Lay 2008), with influences on local abundance, reproduction, and behavioral patterns (Cypher et al. 2003). For example, limited prey availability due to drought has been shown to increase kit fox pup mortality, undermining reproductive success of this species (White & Ralls 1993). Kit foxes may have to expand home ranges and foraging distances during drought periods when prey is scarce (White & Ralls 1993; U.S. Fish and Wildlife Service 1998). Similarly, badger density and distribution is correlated with burrowing rodent population density and distribution, and areas with low prey availability typically have lower badger visitation and denning activity (Lay 2008).

Precipitation (amount)

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Future exposure:*** *Moderate-high (high confidence)*
> ***Potential refugia:*** *Northward movement, but this will cause competition with species that are already further north.*

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).

Burrowing mammals are sensitive to periods of both low and heavy precipitation, and the ideal amount of precipitation varies by location (U.S. Fish and Wildlife Service 1998). Low herbaceous and seed productivity during low precipitation periods can reduce food sources for kangaroo rats and grounds squirrels (U.S. Fish and Wildlife Service 1998; Van Horne 2007), while high or prolonged rainfall events can cause mortality by flooding burrows (Williams & Germano 1992; U.S. Fish and Wildlife Service 1998). High precipitation resulting in high plant cover and height can also reduce kangaroo rat mobility, making them vulnerable to predation (U.S. Fish and Wildlife Service 1998). High plant cover can also be problematic for ground squirrels by reducing their ability to detect predators, and potentially causing them to shift their spatial distribution and burrow entrances (Fehmi et al. 2005). Similar to drought impacts, kit foxes and badgers are vulnerable to shifts in prey base as a result of altered precipitation patterns (U.S. Fish and Wildlife Service 1998; Cypher et al. 2003; Lay 2008).

Precipitation (timing)

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Future exposure:*** *Moderate (low confidence)*

Shifts in precipitation timing may be important if they cause shifts in plant germination and growth that mismatch with burrowing mammal phenology; for example, the California ground squirrel requires herbaceous vegetation when it emerges from hibernation, but transitions to seeds as vegetation dries out (Marsh 1994). Similar to drought impacts, kit foxes and badgers are vulnerable to shifts in prey base as a result of altered precipitation patterns (U.S. Fish and Wildlife Service 1998; Cypher et al. 2003; Lay 2008). Burrowing mammal exposure to changes in precipitation timing is uncertain because it is not known if key food plants would be able to adapt [1].

Soil moisture

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Future exposure:*** *Moderate (low 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). 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.

In general, burrowing mammals prefer habitats with drier soils (Zeiner et al. 1990; U.S. Fish and Wildlife Service 1998), although burrows can collapse in soils that are too[1]. High soil moisture can spoil kangaroo rat seed caches (U.S. Fish and Wildlife Service 1998) and/or cause cached seeds to germinate[1]. Cool and moist burrowing environments have also been linked to higher risk of hypothermia and pneumonia-like diseases in kangaroo rats (U.S. Fish and Wildlife Service 1998). Kit foxes and badgers typically do not den in areas with clay or exceedingly moist soils (U.S. Fish and Wildlife Service 1998; Lay 2008). Changing soil moisture will mainly be an issue if soil moisture decreases causes conversion of grassland to desert, reducing habitat availability[1].

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	High
Land use change	High	High
Pollution & poisons	High	High
Roads, highways, & trails	High	Moderate-high
Urban/suburban development	High	Moderate
Overall Scores	**High**	**Moderate-high**

Agricultural & rangeland practices

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Consistent across the landscape.*

Agricultural development and irrigation historically were the key factors behind extensive burrowing mammal habitat loss, fragmentation, and degradation in the Central Valley, leading to the federal listing of several burrowing mammal species under the Endangered Species Act, as well as listing under state statutes (Goldingay et al. 1997; U.S. Fish and Wildlife Service 1998). Many burrowing species now occupy marginal habitat since prime habitat was lost to agricultural cultivation and irrigation. In many areas, evaporation ponds used to drain excess irrigation water further reduce potential remnant natural habitat for kangaroo rats by increasing flooding (U.S. Fish and Wildlife Service 1998). Habitat fragmentation increases the vulnerability of isolated populations to extirpation due to stochastic events (e.g., drought; (U.S. Fish and Wildlife Service 1998). Agricultural conversion has slowed due to low availability of unaltered land and lack of irrigation water (U.S. Fish and Wildlife Service 1998), but burrowing mammals are still vulnerable to mortality and displacement from agricultural vehicle strikes, disking activities, and pesticide/herbicide use (Cypher et al. 2003). For example, California ground squirrels are considered an agricultural pest, and remnant natural habitat, particularly on agricultural margins, is sometimes fumigated, disked to prevent burrowing, or otherwise treated to reduce ground squirrel abundance (Marsh 1994).

Land use change

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Localized; Carizzo Plain.*

Oil and solar development and associated infrastructure and traffic have emerged as additional and continuing contributors to burrowing mammal habitat loss, fragmentation, and degradation and animal mortality (U.S. Fish and Wildlife Service 1998). Activity associated with these areas, including noise and ground vibrations, can degrade habitat quality, vehicular traffic can increase road kill potential, and exposure to oil spill or pools can increase burrowing mammal mortality (U.S. Fish and Wildlife Service 1998; Cypher et al. 2003). There are some mitigation regulations in place, and kit foxes appear to be able to persist in oil fields with low to moderate disturbance levels (Cypher et al. 2003).

Pollutions & poisons

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Localized; urban areas and high agricultural use areas.*

Many burrowing mammals reside adjacent to lands under intensive agricultural use, and are vulnerable to herbicides, rodenticides, and pesticide use (Williams & Germano 1992; Goldingay et al. 1997; U.S. Fish and Wildlife Service 1998). For example, rodenticide was used in the 1960s-1980s by the agricultural industry to control kangaroo rats and ground squirrels. Although kangaroo rats are not currently as exposed to pollutions and poisons relative to other burrowing mammals, legacy pollution is believed to be the key reason why kangaroo rats do not currently occupy areas that otherwise appear suitable (U.S. Fish and Wildlife Service 1998). Federal and state regulation now limits rodenticide use (U.S. Fish and Wildlife Service 1998), but ground squirrels are still considered as agricultural pests and are subjected to burrow fumigation and other poison treatments (Marsh 1994). Kit foxes are vulnerable to primary, secondary, and prey-related impacts of poisoning; kit fox mortality has been linked to direct consumption of coyote poison, consumption of poisoned prey, and loss of prey base due to rodenticide (U.S. Fish and Wildlife Service 1998). Badgers are similarly sensitive to poison, particularly secondary sensitivity through consuming poisoned ground squirrels (Zeiner et al. 1990; Lay 2008).

Roads, highways, & trails

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

Infrastructure associated with development, agriculture, and energy and mining activities contributes to burrowing mammal habitat fragmentation and loss. Additionally, most burrowing animals are vulnerable to vehicular strikes (U.S. Fish and Wildlife Service 1998; Lay 2008). For example, kit foxes and badgers are frequently killed on roads, highways, and trails[1].

Urban/suburban development

Sensitivity: *High (high confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized; near city general plan areas.*

Urban/suburban development, along with agricultural development, has significantly destroyed, fragmented, and degraded burrowing mammal habitat. While agricultural conversion has slowed, this factor continues to threaten burrowing mammal populations by causing additional habitat loss and fragmentation and animal mortality (U.S. Fish and Wildlife Service 1998). Badgers and kit foxes are more sensitive to urban/suburban development, while development may increase ground squirrel populations[1]. Kit foxes have been found to den adjacent to and utilize urban areas for foraging, and urban populations appear more resilient to environmental fluctuations (e.g., drought) than rural populations. However, urban individuals display altered behavioral patterns (e.g., diurnal foraging) than more rural populations (U.S. Fish and Wildlife Service 1998; Cypher et al. 2003).

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)*

Flooding

Future exposure: *Moderate-high (high confidence)*
Potential refugia: *Higher elevations to avoid flooded areas.*

Flooding during sheet flow from high precipitation events, seasonal flooding of regional rivers and streams, or agricultural flooding can drown burrowing mammals (Marsh 1994; U.S. Fish and Wildlife Service 1998). In the case of kangaroo rats, flooding can also enhance predation risk by forcing burrow evacuation. Flooding is likely a key factor excluding kangaroo rat occupancy of completely flat or regularly flooded areas (U.S. Fish and Wildlife Service 1998).

Grazing

Seasonal grazing may benefit kangaroo rats by controlling vegetation density and thatch depth (Williams & Germano 1992); high plant cover and height increases kangaroo rat predation risk. (U.S. Fish and Wildlife Service 1998). Ground squirrels may also benefit from grazing because it enhances herbaceous growth (Zeiner et al. 1990). Recent grazing studies found no net effect of low to moderate intensity grazing on California ground squirrel abundance or distribution (Fehmi et al. 2005). However, grazing during the dry season when forage is limited could increase competition between cattle and ground squirrels for similar forage (Fehmi et al. 2005). Kit foxes have been found to inhabit grazed annual grasslands, but overall grazing impacts on kit fox populations are uncertain; impacts likely largely depend on how grazing influences prey abundance (U.S. Fish and Wildlife Service 1998; Cypher et al. 2003).

Dependency on habitat and/or other species

Overall degree of specialization*: Low-moderate (high confidence)*
Dependency on one or more sensitive habitat types: *Moderate (high confidence)*

Description of habitat: *Ground squirrels are habitat generalists, but kangaroo rats are highly dependent on low vegetation density.*

Dependency on specific prey or forage species: *Low (high confidence)*

Kangaroo rats eat a variety of seeds, but will also consume some types of greens and insects. They are generally affiliated with annual grassland and scrub areas, and thrive with lower levels of plant cover and density (Zeiner et al. 1990; U.S. Fish and Wildlife Service 1998). Ground squirrels are also forage generalists, eating a variety of plants, seeds, berries, insects, bird eggs and carrion. They are typically found in herbaceous habitats (Zeiner et al. 1990), and successfully colonize and forage in modified habitats, including levees, road embankments, and margins of agricultural areas (Marsh 1994). San Joaquin kit foxes forage in a variety of habitats and are prey generalists, frequently preying on kangaroo rats, ground squirrels, other small rodents, and insects (Cypher et al. 2003). They can den in some modified habitats (e.g., grazed annual grasslands, grasslands hosting wind turbines), but generally avoid denning in highly cultivated areas (U.S. Fish and Wildlife Service 1998). Badgers are carnivorous generalists, eating ground squirrels and a variety of other rodents, and typically reside in open, dry shrub and herbaceous habitats (Zeiner et al. 1990).

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, Status, and Dispersal Ability	Low-moderate
Landscape Permeability	Low
Intraspecific Species Group Diversity	Moderate
Resistance & Recovery	Low-moderate
Overall Score	**Low-moderate**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *Low-moderate (high confidence)*

Geographic extent: *Variable (high confidence)*

Kangaroo rats, kit foxes: Endemic to the study area

Badgers: Occurs across the study region

Ground squirrels: Widespread

Health and functional integrity: *Variable (high confidence)*

Kangaroo rats, kit foxes, badgers: Degraded

Ground squirrels: Robust

> ***Population connectivity:*** *Isolated and/or quite fragmented*[2] *(high confidence)*
> ***Dispersal ability:*** *Moderate (high confidence)*

Burrowing mammals largely occupy uncultivated areas of the valley floor and foothills surrounding the Central Valley. Many of these species are endemic to the study region, including the endangered Giant kangaroo rat (*Dipodomys ingens*), San Joaquin kangaroo rat sub-species the Fresno kangaroo rat (*D. nitratoides exilis*) and Tipton kangaroo rat (*D. nitratoides nitratoides*), and San Joaquin kit fox. In general, burrowing mammals in the Central Valley have experienced declining and highly fragmented populations due to extensive habitat loss to agricultural and urban conversion, with continued habitat fragmentation and degradation occurring due to industrial, urban, and infrastructure expansion (Williams 1986; U.S. Fish and Wildlife Service 1998). Fragmentation threatens gene flow for kangaroo rats, kit foxes, and badgers, and isolated populations are more vulnerable to stochastic events (U.S. Fish and Wildlife Service 1998; Lay 2008). Relative to other burrowing mammals, ground squirrels have more stable populations in the study region (Zeiner et al. 1990; Van Horne 2007).

Dispersal ability varies by species, and dispersal success of many species is affected by habitat availability and fragmentation. For example, giant kangaroo rat dispersal typically averages less than 1 km, but genetic analyses of different populations indicate that larger dispersal distances are possible (U.S. Fish and Wildlife Service 1998). Ground squirrels also typically have small home ranges (<137 m from burrows; Zeiner et al. 1990). Comparatively, the San Joaquin kit fox and badgers have larger home ranges and dispersal ability, but typically experience high mortality during dispersal due to roadkill and fragmented landscapes (U.S. Fish and Wildlife Service 1998; Lay 2008).

Landscape permeability

> ***Overall landscape permeability:*** *Low (high confidence)*
> ***Impact of various factors on landscape permeability:***
>> ***Agricultural & rangeland practices:*** *High (high confidence)*
>> ***Energy production & mining:*** *High (high confidence)*
>> ***Land use change:*** *High (high confidence)*
>> ***Dams, levees, & water diversions:*** *High (high confidence)*
>> ***Roads, highways, & trails:*** *Moderate (high confidence)*

Agricultural, industrial, and urban development areas often do not support proper vegetation types or sufficient vegetative cover to allow kangaroo rat dispersal; these barriers can extend for multiple miles, isolating already fragmented populations (U.S. Fish and Wildlife Service 1998). These barriers also inhibit migration of the kit fox and badger (U.S. Fish and Wildlife Service 1998; Lay 2008), and limit the quality of habitat restoration and protection efforts (Goldingay et al. 1997).

Agricultural and rangeland practices are the most significant landscape barrier and affect all species in this group; shifts from rangeland to agriculture are potentially problematic. Energy production and mining projects include oil and solar, and impact depends on size of project; larger projects significantly affect kit foxes. Dams, water diversions, & levees are localized to

Merced City's streams potential project, Sites Reservoir, and others projects that will increase off channel storage. Reservoirs drown land occupied by burrowing mammals. Road kill primarily affects badgers and kit foxes[1].

Resistance and recovery

> ***Overall ability to resist and recover from stresses:*** *Low-moderate (high confidence)*
> ***Resistance to stresses/maladaptive human responses:*** *Variable (high confidence)*
>> *Ground squirrels: High*
>> *Kit foxes: Moderate*
>> *Badgers, kangaroo rats: Low*
>
> ***Ability to recover from stresses/maladaptive human response impacts:*** *Variable (high confidence)*
>> *Ground squirrels: High*
>> *Kit foxes: Moderate*
>> *Badgers, kangaroo rats: Low*

As indicated by stable population numbers despite significant habitat modification and active eradication efforts, ground squirrels may be fairly resilient species (Marsh 1994; Van Horne 2007). Kit foxes have adapted to some habitat impacts (e.g., foraging in urban areas), but still exhibit reduced populations, indicating they may be less resilient (Cypher et al. 2003). Badgers and kangaroo rats, as documented by declining populations and few apparent adaptations to altered habitat suitability and availability, may be the least resilient species within this group (U.S. Fish and Wildlife Service 1998; Lay 2008). However, even these species may be slightly resilient; for example, kangaroo rats have maintained populations even in extremely fragmented habitats, persisting even when only 4 hectares of natural lands are left unaltered (Williams & Germano 1992).

Species group diversity

> ***Overall species group diversity:*** *Moderate (high confidence)*
> ***Diversity of life history strategies:*** *High (high confidence)*
> ***Genetic diversity:*** *Variable (high confidence)*
>> *Kangaroo rats: Low (due to fragmentation and minimal movement between populations)*
>> *Ground squirrels: Unknown*
>> *Kit foxes: Moderate*
>> *Badgers: Moderate-high*
>
> ***Behavioral plasticity:*** *Variable (high confidence)*
>> *Kangaroo rats: Low*
>> *Ground squirrels: High*
>> *Kit foxes: Moderate-high*
>> *Badgers: Low*
>
> ***Phenotypic plasticity:*** *Low (high confidence)*

Many burrowing mammals, including kangaroo rats, kit foxes, and badgers, are able to utilize or modify burrows constructed by other animals (Zeiner et al. 1990; U.S. Fish and Wildlife Service 1998).

There are several species and sub-species of kangaroo rat in California and within the Central Valley study area (Grinnell 1922; Zeiner et al. 1990; Williams & Germano 1992; Goldingay et al. 1997), including several endemics (Goldingay et al. 1997; U.S. Fish and Wildlife Service 1998). Giant kangaroo rats exhibit some genetic diversity between northern (Fresno and San Benito Counties) and southern (Carizzo Plain) populations, but current gene flow may be limited due to habitat fragmentation (U.S. Fish and Wildlife Service 1998).

Ground squirrels exhibit fairly high behavioral plasticity, as is evidenced by their ability to burrow and forage in modified habitats, including agricultural areas and along transportation corridors (Marsh 1994).

Kit foxes display fairly high behavioral plasticity; for example, they utilize urban areas for foraging, can utilize human-made structures for burrowing, and frequently change dens to avoid predation and pest-pressure and to seek out higher prey numbers (U.S. Fish and Wildlife Service 1998; Cypher et al. 2003). Kit foxes are more k-selective than ground squirrels and kangaroo rats[1].

Due to relatively high dispersal ability of young, even though fragmented habitats, badgers likely maintain some genetic diversity within the study region. Badgers have also been found to utilize fragmented habitats, indicating some degree of behavioral plasticity (Lay 2008). Badgers are more k-selective than ground squirrels and kangaroo rats[1].

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value to people: *Moderate (moderate confidence)*
Description of value: *The kit fox is a photogenic animal that Fresno locals like. Farmers do not like burrowing species.*

Support for conservation

Degree of societal support for management and conservation: *Variable (high confidence)*

Kangaroo rats, badgers, kit foxes: *Moderate*
Ground squirrels: *Low*

Description of support: *Regulatory support for kangaroo rats, badgers, and kit foxes; ground squirrels have no regulatory support.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *High (high confidence)*
Description of support: *Rangelands only – for grass control.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low-moderate (moderate confidence)*
Description of events: *Current drought not affecting urban kit fox population because they have access to urban food sources (e.g., garbage).*

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *Low-moderate (moderate confidence)*

Description of likelihood: *Quality of land will not be high.*

Likelihood of managing or alleviating climate change impacts: *Low (high confidence)*
Description of likelihood: *Difficult to develop actions to manage for climate impacts. Preventing habitat fragmentation is likely a key strategy.*

This species group, excluding the ground squirrel, has regulatory protection through state and federal endangered species listings (U.S. Fish and Wildlife Service 1998). In addition, some of these species are considered keystone (e.g., kangaroo rats) or umbrella species (e.g., San Joaquin kit fox), which may provide incentive for conservation in order to procure benefits for affiliate habitats and component species (Goldingay et al. 1997; U.S. Fish and Wildlife Service 1998). Protecting and managing land with topographical diversity to maximize habitat area, connectivity, and refugia is critical for the resilience of this species group to environmental events such as flood and drought; land protection, acquisition, conservation easements, and land management incentive programs have all been proposed as methods for ensuring long-term habitat protection and connectivity for burrowing mammals (Williams & Germano 1992; U.S. Fish and Wildlife Service 1998). Restoring and managing retired farmland, particularly dryland farms, may provide increased kangaroo rat habitat and provide opportunities for reintroduction (U.S. Fish and Wildlife Service 1998).

Kangaroo rat captive breeding program success varies according to species (Goldingay et al. 1997; U.S. Fish and Wildlife Service 1998), and is a recommended activity for endangered populations threatened by additional development (U.S. Fish and Wildlife Service 1998; Tennant et al. 2013). Kangaroo rat translocations have also been proposed, although many factors influence success of this strategy, including climate changes such as drought (Tennant et al. 2013).

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