Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Bumblebees and Other Insect Pollinators

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	High
Exposure	Moderate-high
Adaptive Capacity	Moderate
Vulnerability	**Moderate-high**

Overall vulnerability of the bumblebees and other insect pollinator species group was scored as moderate-high. The score is the result of high sensitivity, moderate-high future exposure, and moderate adaptive capacity scores.

Key climate factors for bumblebees and other insect pollinators include precipitation timing, drought, storms, and air temperature. Precipitation timing and temperature affect the timing of pollinator emergence in spring; warmer temperatures will likely drive earlier emergence, but may also contribute to phenological mismatches with key plant resources. Temperature also affects adult activity levels and survival, although sensitivity to temperature varies by species. Storms can inhibit foraging activity and/or contribute to pollinator mortality, while drought can influence available food resources.

Key non-climate factors for bumblebees and other insect pollinators include invasive and problematic species, pollutions and poisons, urban/suburban development, and certain agricultural and rangeland practices. Non-native bees can introduce disease and compete for resources, while invasive plants have variable impacts (e.g., may provide additional forage, or may compete with native plant species and reduce forage). Pesticide and herbicide use contribute to pollinator declines through direct mortality and reduced floral and host plant availability. Land use changes (e.g., development, agricultural intensification) also contribute to pollinator declines by destroying, fragmenting, and degrading natural pollinator habitat.

Key disturbance mechanisms for bumblebees and other insect pollinators include wildfire and disease. Fire modifies forage resource availability and can cause direct pollinator mortality, although vulnerability varies depending on fire intensity and species' mobility and life history strategy. Disease can lead to significant pollinator declines. Bumblebees and other insect pollinators exhibit a moderate-high degree of specialization; they depend on abundant floral resources throughout flight and reproductive periods, and many species requires special habitat characteristics (e.g., rodent burrows) or host plant species.

Many pollinator populations are declining in the Central Valley due to habitat loss and disease exposure, and dispersal is limited by habitat availability and continuity. Geologic features and habitat barriers act as landscape barriers. This species group exhibits low-moderate intraspecific diversity; bumblebees, in particular, have limited genetic and life history diversity, utilizing only one nest and producing only one generation per season. Population declines of several iconic pollinators and functional groups (e.g., native bees) in the Central Valley indicate that pollinators may not be very resilient to land use changes and climate impacts.

Management potential for bumblebees and other insect pollinators was scored as moderate-high and is enhanced by the fact that pollination services are necessary for agricultural production. Habitat protection, restoration, and urban/agricultural landscape modifications (e.g., planting hedgerows with multiple drought-tolerant host plants) are likely important management strategies for sustaining native pollinator populations.

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Introduction

Description of Priority Natural Resource

Bumblebees (*Bombus spp.*) and other insect pollinators [e.g., monarch butterflies (*Danaus plexipuss plexipuss*)] inhabit a variety of natural landscapes in the Central Valley and provide critical pollination services to regional agriculture and native plants (Kremen et al. 2002a; Evans et al. 2008; The Xerces Society for Invertebrate Conservation 2016a). Pollinators are highly diverse; they may nest below, on, or above the ground surface, be forage generalists or specialists, and be resident or migratory species.

As part of the Central Valley Landscape Conservation Project, workshop participants identified the species group "bumblebees and insect pollinators" as a Priority Natural Resource in a process that involved two steps: 1) gathering information about the species group's management importance as indicated by its appearance in existing conservation plans and lists and 2) a workshop with stakeholders to create the final list of Priority Natural Resources, which includes habitats, species groups, and species. The rationale for choosing the bumblebees and insect pollinators species group included the following: the species has high management importance, the species group's conservation needs are not entirely represented within a single priority habitat, and for its importance for ecosystem function and for agricultural production. To learn more about how stakeholders identified Priority Natural Resources for the Central Valley Landscape Conservation Project, please see Appendix A: "Priority Natural Resource Selection Methodology".

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
Air temperature	Moderate-high	Moderate
Extreme events: drought	High	High
Extreme events: more heat waves	-	Moderate-high
Extreme events: storms	High	-
Increased wildfire	-	Moderate-high
Precipitation (amount)	-	Moderate-high
Precipitation (timing)	High	Moderate-high
Soil moisture	Moderate	-
Overall Scores	**High**	**Moderate-high**

Drought

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

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). The frequency and severity of drought is expected to increase due to climate change over the next century (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 may reduce the availability of floral resources for pollinators by affecting flower availability (Stevens & Frey 2010), size, and nectar volume (Carroll et al. 2001), and/or plant senescence timing (Bell 1998). For example, the recent drought has been correlated with declines in wildflower diversity (Harrison et al. 2015). Resource availability ultimately affects pollinator population dynamics via bottom-up regulation (Stevens & Frey 2010).

The ability of insect pollinators, particularly host-plant specialists, to respond to or track climate changes will likely depend on host plant responses to climate factors (Schweiger et al. 2008; Stevens & Frey 2010). For example, monarch declines in California have been tentatively linked with drought-induced milkweed reductions, indicating that future drought episodes are likely to continue to exacerbate monarch population declines (Stevens & Frey 2010).

Precipitation (timing)

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

Winter precipitation can delay pollinator emergence timing by either reducing insolation and/or promoting cool and damp conditions for multiple days after a storm (Forister & Shapiro 2003). The Central Valley's clay soils retain moisture for several days following rain, leading to low cloud cover, fog, and cool conditions (Forister & Shapiro 2003).

Storms

Sensitivity: *High (high confidence)*

Storms and inclement weather (e.g., cloud cover, high wind speeds) can inhibit pollinator foraging, recruitment, and survival (Goulson 2003; Mac Nally et al. 2003; Jepsen et al. 2015). For example, storms occurring during initial bumblebee queen foraging and colony-building periods can lead to starvation mortality of the entire colony (Goulson 2003). Similarly, winter storm events can kill over-wintering monarchs in California (Jepsen et al. 2015).

Air temperature

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Moderate (moderate confidence)*
Potential refugia: *Shady and canopy areas.*

Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015).

Air temperatures influence pollinator activity and development. For example, butterfly development and adult reproductive activity are limited by cold temperatures (Mac Nally et al. 2003). Comparatively, bumblebees are some of the most cold-tolerant pollinators because they are able to warm themselves through muscular shivering; cold tolerance allows earlier emergence in the spring (Thorp et al. 2002). Warmer temperatures are projected to cause a northward shift and/or contracting ranges for cold-adapted bumblebees in other parts of the

United States while expanding the range of warm-adapted species (e.g., see Kirilenko & Hanley 2007); it is unknown if California populations will follow similar patterns.

Warmer air temperatures are likely to cause earlier pollinator emergence, particularly for those species that emerge in early spring and/or those that overwinter as larvae (Forister & Shapiro 2003). For example, warmer winter maximum temperatures have been correlated with earlier butterfly appearance in the Central Valley (Forister & Shapiro 2003), likely due to accelerating larval growth and emergence (Ratte 1984). Warmer air temperatures may also indirectly affect pollinator populations by causing phenological mismatches with plant hosts; phenological mismatches result in reduced forage opportunities and can potentially affect recruitment and overall pollinator population abundance (Memmott et al. 2007). Host-specialist pollinators will be most vulnerable to these shifts (Memmott et al. 2007).

Soil moisture

Sensitivity: *Moderate (moderate confidence)*

Precipitation (amount)

Future exposure: *Moderate-high (high confidence)*
Potential refugia: *Canopied areas may provide refuge from increased precipitation.*

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).

Decreased precipitation may reduce forage plant availability (Stevens & Frey 2010), but increased precipitation may limit foraging activity (Goulson 2003; Mac Nally et al. 2003; Jepsen et al. 2015).

Heat waves

Future exposure: *Moderate-high (moderate confidence)*

Some insect species may be vulnerable to heat waves, which can increase direct mortality through high heat or prolonged heat exposure and/or cause population declines by affecting available forage (Rasmont & Iserbyt 2012).

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	Moderate-high	Low-moderate
Invasive & other problematic species	High	High
Nutrient loading	Moderate	Moderate
Pollution & poisons	High	High
Roads, highways, & trails	Moderate	Moderate
Urban/suburban development	Moderate-high	Moderate-high
Overall Scores	**Moderate-high**	**Moderate-high**

Agricultural & rangeland practices

Sensitivity: *Moderate-high (moderate confidence)*
Current exposure: *Low-moderate (moderate confidence)*
Pattern of exposure: *Localized; depends on crop type and pesticide use.*

Agricultural intensification in the Central Valley has contributed to declines in native bee diversity and abundance (Kremen et al. 2002b). Agricultural development of natural landscapes can fragment, destroy, and degrade pollinator habitat, particularly if food resources or nesting and hibernating habitat is reduced (Kremen et al. 2002a; Thorp et al. 2002; Kremen et al. 2002b; Evans et al. 2008). For example, farm machinery may destroy above-ground bumblebee nests in dense grass (Goulson 2003), and agricultural pesticide and herbicide use negatively impact the reproduction and survival of many pollinator species (Kremen et al. 2002a; Evans et al. 2008; Jepsen et al. 2015). Grazing may also have negative effects on bumblebees by reducing available floral forage, reducing nesting habitat via trampling, or having negative effects on burrowing rodents (reviewed in Evans et al. 2008). Commercial bee movement for greenhouse use can also introduce new pathogens to native pollinator populations and/or present opportunities for hybridization (Evans et al. 2008; Williams & Osborne 2009).

However, some agricultural practices can benefit pollinators. For example, many rangelands and agricultural crops utilize attractive host species designed to attract native pollinators (e.g., hedgerows; Morandin & Kremen 2013). Agricultural industries also typically have lands set aside for conservation (e.g., see U.S. Fish and Wildlife Service 2016).

Invasive & other problematic species

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

Non-native bees can spread disease, pests, and/or compete for food and nesting habitat with native bumblebees (Thorp et al. 2002; Evans et al. 2008). For example, honey bee (*Apis mellifera*) introductions for commercial purposes have been shown to reduce bumblebee foraging activity and depress reproduction (Thomson 2004, 2006).

Invasive and non-native plants can have mixed impacts on pollinators. For example, some non-native plants may increase available forage; bumblebees forage on several introduced species, including alfalfa (*Medicago sativa*), rhododendron (*Rhododendron* spp.), and the invasive yellow star-thistle (*Centaurea solstititalis*) (Thorp et al. 2002). However, invasive plants that do not serve as food sources and that compete with native forage plants could be problematic for pollinators (Evans et al. 2008). Additionally, some invasive plants prevent ground access for bumblebee nesting[1].

Nutrient loading

> ***Sensitivity:*** *Moderate (low confidence)*
> ***Current exposure:*** *Moderate (moderate confidence)*
> ***Pattern of exposure:*** *Localized; near Antioch area, power plant facilities.*

Nutrient loading includes nitrogen deposition from power plants, manufacturing, and refining. Impacts depend on the species (i.e., how much nutrient loading it takes to cause an effect). Atmospheric input is more of an issue than water nutrient loading sources from farms, although vernal pool pollinators are possible exceptions[1]

Pollution & poisons

> ***Sensitivity:*** *High (high confidence)*
> ***Current exposure:*** *High (moderate confidence)*
> ***Pattern of exposure:*** *Patchy across the landscape near applications.*

There is very little known about the effects of most chemicals on pollinators [1], but pesticides and insecticides are linked with native pollinator mortality (Kremen et al. 2002a). For example, bumblebees experience mortality when pesticides are absorbed through the skin or ingested (National Research Council 2007), and monarch butterfly mortality patterns overlap with regions practicing pesticide application (Jepsen et al. 2015). Herbicides can also indirectly impact pollinator survival, reproduction, and recruitment (Evans et al. 2008; Jepsen et al. 2015) by reducing native flowers that provide pollen and nectar (Shepherd et al. 2003) and/or by reducing specialist host plants (Jepsen et al. 2015). For bumblebees, pesticide and herbicide impacts are likely greatest in the spring, when the majority of bumblebee foraging takes place and when colonies are smallest (Goulson et al. 2008). In addition to direct impacts, nitrogen levels, especially in the Antioch area, are changing habitat composition, which can affect pollinator foraging opportunities[1].

Roads, highways, & trails

> ***Sensitivity:*** *Moderate (moderate confidence)*
> ***Current exposure:*** *Moderate (moderate confidence)*
> ***Pattern of exposure:*** *Unknown.*

Roads/highways have more of an impact than trails, causing pollinator mortality through collision (Muñoz et al. 2014). CalTrans and PG&E are working on hedgerow crops and easements near infrastructure[1].

Urban/suburban development

> ***Sensitivity:*** *Moderate-high (moderate confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Consistent across the landscape.*

Urban/suburban development contributes to pollinator habitat loss, fragmentation, and degradation by reducing food sources and ground nesting and hibernation sites (Kremen et al. 2002a; Evans et al. 2008) and increasing invasive species introductions, pollution, and chemicals [1]. Habitat fragmentation reduces pollinator abundance and contributes to inbreeding, potentially leading to population extirpation due to demographic stochasticity (Evans et al. 2008). Urban development has been linked with bumblebee declines (Evans et al. 2008), and has contributed to loss of monarch breeding sites in California (Jepsen et al. 2015).

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:*** *Moderate-high (high confidence)*
> ***Potential refugia:*** *None, since many pollinators have small territories.*

Wildfire can lead to insect mortality, depending on flame exposure and species mobility (Swengel 2001). For example, surface- and ground-nesting bees, particularly shallow-nesting bees (<5 cm nesting depth) and egg, pupal, and larval stages, are vulnerable to fire-related mortality (Cane & Neff 2011). Adults may be able to escape via flight, but pollinator eggs, larvae, and pupae are vulnerable to fire-related soil conductive heating, particularly since burns typically occur in late summer after peak pollinator foraging and reproductive periods when eggs, larvae, and pupae are in underground nests (Cane & Neff 2011). Mortality also varies depending on fire severity and temperature, with higher temperatures and prolonged exposure contributing to highest mortality (Cane & Neff 2011).

Wildfire can also indirectly impact native pollinators by affecting post-fire forage availability (Swengel 2001; Cane & Neff 2011). For example, recently burned landscapes may experience a flowering boom the following spring (Seefeldt et al. 2007), enhancing floral resource availability. Comparatively, resources immediately following fire may be scarce, favoring pollinator taxa that thrive in xeric, exposed conditions (Swengel 2001).

Disease

Bumblebees are vulnerable to elevated mortality via several non-native diseases, including the microsporidian *Nosmea bombi*, protozoan *Crithidia bombi* (National Research Council 2007), and the tracheal mite *Locustacarus buchneri*. These diseases were likely introduced through bumblebee rearing and transportation for commercial purposes; the hypothesized mechanism is that when native bumblebee colonies were raised in Europe, they were exposed to pathogens associated with the European buff-tailed bumblebee (*B. terrestris*). Upon return to the United States for commercial greenhouse use, infected bees then spread these diseases to wild populations and other similar bumblebee species through visiting shared floral resources (Evans et al. 2008). Significant population declines in areas using commercial pollination indicate high disease vulnerability amongst regional bumblebees, but definitive links have not been made (Evans et al. 2008).

Dependency on habitat and/or other species

Workshop participants scored the resource's dependency on habitat and/or other species, and these scores were used calculate climate change sensitivity.

> ***Overall degree of specialization****: Moderate-high (high confidence)*
> ***Dependency on one or more sensitive habitat types:*** *Moderate-high (high confidence)*
> > ***Description of habitat:*** *Grasslands, oak woodlands, riparian, wetlands, dunes.*
>
> ***Dependency on specific prey or forage species:*** *Moderate-high (high confidence)*
> ***Dependency on other critical factors that influence sensitivity:*** *Moderate (moderate confidence)*
> > ***Description of other dependencies:*** *Host plants (only some species).*

Bumblebees nest in the ground in abandoned rodent burrows (Thorp et al. 1983) or in clumps of grass in undisturbed grassland (Macfarlane et al. 1994). They depend on nectar and pollen from continual blooms of floral resources from spring through autumn (Evans et al. 2008). Pollen availability is directly linked with queen bumblebee production, and therefore bumblebee population stability (Evans et al. 2008). Bumblebees and other native bee species will forage on a variety of floral resources (Kremen et al. 2002a; Thorp et al. 2002; Kremen et al. 2002b; Evans et al. 2008), but do appear to require some native plants for persistence (Kremen et al. 2002b). Other pollinators may exhibit generalist or specialist tendencies and/or resident or migratory life history strategies; for example, the monarch butterfly requires milkweed (*Asclepias* spp.) for reproduction and larval foraging, and migrates between overwintering habitat in California to regions of the California interior, Nevada, Arizona, Utah, Oregon, and Washington (Jepsen et al. 2015).

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	Moderate-high
Landscape Permeability	Moderate
Intraspecific Species Group Diversity	Low-moderate
Resistance & Recovery	Low-moderate
Overall Score	**Moderate**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *Moderate-high (moderate confidence)*
Geographic extent: *Transboundary (high confidence)*
Health and functional integrity: *Fairly degraded (low confidence)*
Population connectivity: *Patchy, with connectivity between patches (moderate confidence)*
Dispersal ability: *Moderate-high (moderate confidence)*

Bumblebee populations have declined significantly in central California since 1998, almost to the point of being absent from the region (Evans et al. 2008). Western monarch populations have also declined in the recent past (Jepsen et al. 2015), and numerous species of native bees have been shown to decline with agricultural intensification in the study area (Kremen et al. 2002b). Aerial adult life stages facilitate pollinator dispersal (Swengel 2001), but dispersal is likely limited by resource availability and environmental conditions (e.g., temperature; Stevens & Frey 2010). Habitat fragmentation may limit dispersal, and the Central Valley features few remnant patches of native habitat (Kremen et al. 2002a).

Landscape permeability

Overall landscape permeability: *Moderate (high confidence)*
Impact of various factors on landscape permeability:
Geologic features: *Moderate (high confidence)*

Habitat fragmentation may inhibit pollinator foraging, particularly for species such as the Bumblebee, which produce only one nest per season and thus are restricted to foraging around that nesting site (Kremen et al. 2002a).

Resistance and recovery

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

Recent population declines of several iconic pollinators (e.g., bumblebee, monarch butterfly) and native bee populations indicate that pollinators may not be very resistant to pressures including land use change, habitat alteration or fragmentation, and climate change (Kremen et al. 2002b; Evans et al. 2008; Stevens & Frey 2010; Jepsen et al. 2015). Habitat restoration may facilitate recovery of some of these species (Kremen et al. 2002a), although likely not to pre-crash levels (Jepsen et al. 2015).

Species group diversity

Overall species group diversity: *Low-moderate (high confidence)*
Diversity of life history strategies: *Moderate (moderate confidence)*
Genetic diversity: *Low-moderate (moderate confidence)*
Behavioral plasticity: *Low-moderate (high confidence)*
Phenotypic plasticity: *Low-moderate (high confidence)*

Some native bee species are multivoltine (i.e., have multiple reproductive generations and nests per year), which may allow them to track shifts in resource availability throughout the flight season (Kremen et al. 2002a). Comparatively, bumblebees may have more limited dispersal and reproductive and genetic capacity because they produce only one generation per year and have only one nesting site (Kremen et al. 2002a). For example, queen bumblebees only reproduce for one season before dying, and only newly hatched and mated queens overwinter to raise colonies the following year (Thorp et al. 2002). Bumblebees are susceptible to inbreeding due to low effective population size (Packer & Owen 2001) and haplodiploidy sex determination (Evans et al. 2008). Under this system, haploid or unfertilized eggs becomes males, while fertilized and diploid eggs become female (Evans et al. 2008). Inbred populations typically have smaller colony size (Herrmann et al. 2007), and may be more vulnerable to pests, diseases, and habitat fragmentation (Evans et al. 2008).

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value to people: *High (high confidence)*

Support for conservation

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

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *High (high confidence)*

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

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *Moderate-high (high confidence)*
Description of likelihood: *With management to make sure that habitat is in the right place. Place restoration plantings where species already exist, within historical range, and potentially in areas where migration to new habitat is likely. Place proper plants that can maintain target pollinators.*

Likelihood of managing or alleviating climate change impacts: *Moderate-high (high confidence)*
Description of likelihood: *Cannot assume that when habitat is built, pollinators will come. Must have right location and plant assemblages.*

Bumblebees and other pollinators are valuable to society due to their role as agricultural and wildflower pollinators (Kremen et al. 2002a; Evans et al. 2008). For example, native insects provide pollination services valued at $3 billion per year across the United States (Losey &

Vaughan 2006). Pollinators are critical for agricultural production in the Central Valley, a region that produces vegetable, nut, and fruit crops valued at more than $16.45 billion annually (Kremen et al. 2002a).

Protecting natural habitats is likely important for pollinator maintenance and continuation of pollination services (Kremen et al. 2002a; Jepsen et al. 2015), since even pollinators that forage in agricultural areas still depend on native flora to some degree (Kremen et al. 2002a). Agricultural landscapes can be modified to support pollinator populations by planting hedgerows, native flowers (Williams & Osborne 2009; The Xerces Society for Invertebrate Conservation 2016b), and critical host plants (Jepsen et al. 2015). Urban landscapes can be similarly modified with appropriate floral plantings to sustain bee foraging (Thorp et al. 2002). Restoration and enhancement plantings should consider pollinator life histories and climate considerations; for example, Central Valley plantings should include species combinations that will provide continual flower resources for bees from early spring through late summer, and drought-tolerant plants are likely to be more resilient to future water shortages (The Xerces Society for Invertebrate Conservation 2016b).

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