Butterflies

Climate Change Vulnerability Assessment for the Santa Cruz Mountains Climate Adaptation Project

This document represents an initial evaluation of mid-century climate change vulnerability for butterflies in the Santa Cruz Mountains region based on expert input during an October 2019 vulnerability assessment workshop as well as information in the scientific literature.

Species Description

Butterfly communities in the Santa Cruz Mountains region occur across a wide range of habitats, though they are most commonly associated with grasslands and meadows[1]. Butterfly diversity and abundance is correlated with factors such as species richness of plant[2,3], bird[4], ant[5], and beetle[6] communities.

Vulnerability Ranking

Moderate Vulnerability

Low → High

High Confidence

Butterflies may experience direct physiological impacts of climate-driven changes as well as indirect impacts due to changes in host plant and nectar resource availability. Warmer temperatures can increase heat stress and are associated with altered behavior, fecundity, and development rates, as well as shifts in phenology that could result in mismatches between butterfly life stages and plant availability. Butterflies are also vulnerable to direct mortality from wildfire, and climate-driven changes in fire regimes may alter habitat suitability for some species by impacting host plant and floral resource abundance and distribution. Non-climate stressors (e.g., pesticides and herbicides, land-use conversion, invasive plants, nitrogen deposition, livestock grazing) exacerbate species group sensitivity by directly increasing butterfly mortality and/or indirectly by impacting habitat availability and connectivity.

While the species group as a whole is widely distributed across a variety of habitat types in the region, butterfly abundance and species richness has declined in response to stressors such as climate change, land-use conversion, invasive species, and pesticides/herbicides. Small and/or isolated butterfly populations are more vulnerable to extirpation from extreme events. However, some species have exhibited behavioral and phenotypic plasticity in response to changing conditions. Public and societal support for butterfly conservation is generally high, and management activities designed to increase resilience to climate change are likely to focus on increasing the availability of host plants and nectar resources through habitat restoration.

Sensitivity and Exposure

High Impact Low → High

High Confidence

Sensitivity is a measure of whether and how a species is likely to be affected by a given change in climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors. **Exposure** is a measure of how much change in these factors a species is likely to experience.

Sensitivity and future exposure to climate and climate-driven factors

Butterflies are sensitive to warmer air temperatures, which influence behavior, development, fecundity, and phenology.

Climate Stressor	Trend Direction	Projected Future Changes
Air temperature	▲	• 1.5–3.1°C (2.7–5.6°F) increase in annual mean temperature[7,8]

- **Warmer air temperatures** could require more frequent use of thermoregulatory behaviors, decreasing flight activity and reducing the amount of time that can be spent foraging[9,10]. Warmer temperatures are also associated with changes in butterfly body size, egg production and deposition, and larval development[11,12]. Changes in the timing of development, in particular, create the potential for mismatches between butterfly emergence/flight activity and host plant or food resource availability[13,14]. Specialist butterfly species (i.e., those that forage on only a few plant species) are especially vulnerable to phenological shifts that result in significant loss of host plants or food sources[13]. However, the impacts of temperature on both butterfly and plant phenology are complex, and vary depending on species, life stage, and interacting climate drivers[13,14]. Overall, reduced food availability is likely to limit butterfly fecundity and survival, which may ultimately decrease population sizes and/or drive species extinction[15].

Sensitivity and future exposure to climate-driven changes in disturbance regimes

Butterflies are sensitive to changes in wildfire regimes that impact survival and habitat availability or quality.

Disturbance Regimes	Trend Direction	Projected Future Changes
Wildfire	▲	• Slight to moderate increase in wildfire risk, particularly in areas of higher rainfall[7,8]

- **Climate-driven changes in wildfire regimes** may have direct impacts on butterflies due to heat and smoke exposure, though vulnerability is dependent on developmental stage at the time of the fire (i.e., larvae are generally immobile)[16]. Indirectly, habitat simplification and reduced availability of host plants and nectar sources as a result of wildfire can lead to short-term population declines and shifts in community composition towards species typical of more open environments[16]. However, wildflower availability is generally high the spring after a fire[17]. Climate-driven increases in fire frequency and size may extirpate isolated populations of rare species[17] or create prohibitively large foraging and/or migration distances, reducing post-fire recolonization and population recovery[16]. Very frequent fires may also permanently reduce or eliminate plant species used for butterfly nesting or foraging, leading to long-term resource scarcity[16].

Dependency on habitat and/or other species

Butterflies exhibit two general habitat requirements: larval host plants and nectar sources[1]. However, individual species vary widely in their dependence on specific plants to fulfill these requirements, with generalist species able to utilize a wide variety of plants and specialists depending on just one or a few plant species[1]. For instance, monarchs (*Danaus plexippus plexippus*) depend on milkweed (genus *Asclepias*) as larval host plants[18,19], but they are able to utilize multiple species of milkweed which are collectively found under a wide range of conditions in California[18]. By contrast, the Bay checkerspot butterfly (*Euphydryas editha bayensis*) is found only in serpentine grasslands due to its association with a single host plant species, dwarf plantain (*Plantago erecta*)[20]. Because of these restrictions, specialist butterfly species are particularly vulnerable to climate-driven changes in host plant or floral resource availability due to reduced plant abundance, changes in plant distribution, or shifts in phenology[12,18,21].

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate species group sensitivity to changes in climate factors and disturbance regimes by directly increasing butterfly mortality and/or indirectly by impacting habitat availability and connectivity.

- **Pesticides and herbicides** have been associated with reduced butterfly abundance in California[22] as well as monarch declines within both the western and eastern U.S.[23,24]. Beyond correlations at the population level, relatively few studies have documented direct or indirect impacts on individual butterfly species or life stages. However, neonicotinoid insecticides have been tied to reduced longevity of adult monarch butterflies[25]. Extensive use of herbicides such as glyphosate has been associated with the loss of milkweed host plants for monarch butterflies[24]. Grass-specific herbicides commonly used to address invasive species in the western U.S. (e.g., sethoxydim) appear to have some indirect effects as well, but they vary depending on butterfly species, life stage, and the herbicide used[26,27].
- In addition to being associated with the use of pesticides and herbicides, **agriculture** has significantly reduced butterfly habitat availability and connectivity[23,28]. For instance, agricultural intensification has been associated with declines in eastern monarchs, largely due to the loss of milkweed host plants[29]. However, weedy fields and hedgerows can act as migration corridors even though they are not ideal habitat[28].
- **Invasive plants** often outcompete native host plants, reducing habitat quality and availability for butterflies[20,30,31]. While many of California's butterfly taxa have been documented utilizing exotic plants for larval feeding, oviposition, and/or as nectar sources[30], declines in native host plants and floral resources associated with the expansion of invasive plants generally have negative impacts on butterfly foraging and survival, particularly for specialist species[20,30,31].
- **Nitrogen deposition** associated with vehicle emissions from **roads and highways** has impacted butterflies in the San Francisco Bay Area by altering species composition in serpentine grasslands, which provide habitat for endangered species such as the Bay checkerspot butterfly[20]. As nutrient-limited systems, serpentine grasslands are naturally resistant to invasive plants[32]. The addition of nitrogen alters this balance, allowing non-native annual grasses to

outcompete serpentine plants such as dwarf plantain, the Bay checkerspot butterfly's primary larval host plant[20,33].

- **Livestock grazing** impacts plant abundance and community structure, composition, and diversity, indirectly affecting the availability of larval host plants and nectar resources[34]. In general, high-intensity grazing is associated with declines in butterfly abundance and species richness[34,35]. The timing of grazing is also important; for instance, spring grazing can result in direct larval mortality and/or removal of important host plants or nectar plants[36], while fall grazing is less likely to have negative impacts on butterflies[34]. However, appropriately-timed grazing at low to moderate intensities may play an important role in limiting shrub/tree succession and reducing the cover of non-native plants within grassland habitats[20,34,37].
- **Off-trail recreational activity** can result in the trampling of host plants, which could cause a reduction in host plant populations as well as direct impacts on butterflies if trampling occurs while larvae are present[38].

Adaptive Capacity

Moderate Adaptive Capacity

Low → High

Mod Confidence

Adaptive capacity is the ability of a species to accommodate or cope with climate change impacts with minimal disruption.

Species extent, integrity, connectivity, and dispersal ability

Butterflies are widely distributed and occupy a range of habitats within the Santa Cruz Mountains region[18,39], though the distribution of individual species varies from widespread (e.g., western tiger swallowtail [*Papilio rutulus*]) to severely restricted (e.g., Bay checkerspot butterfly). However, populations of many species are in decline due to stressors such as land-use change, pesticide use, and climate change[22,23,28,40–44]. Migratory species are exposed to stressors across a large geographic area, and the loss or alteration of habitat across any part of their range can negatively impact the population[42,45]. Small and/or isolated populations are also more vulnerable to extirpation from stochastic events (e.g., wildfire, storms)[28] and a loss of genetic diversity[38].

Overall, butterflies are a mobile species group, but individual movement distances and dispersal abilities vary by species and life history[38]. Land-use conversion reduces butterfly habitat availability and connectivity, requiring longer dispersal distances and limiting the potential for recolonization of suitable habitat after disturbances[23,28]. Climate change may further restrict the suitability of remnant habitat patches and migration corridors[28].

Intraspecific/life history diversity

Butterflies exhibit some life history diversity across species, with varied patterns of dispersal and migration, timing of emergence, and length and timing of flight activity[38]. Even within a single species, monarchs exhibit varied overwintering and migratory behavior and morphological differences in wing shape, color, and length across their range, which suggests phenotypical and behavioral plasticity that could increase adaptive capacity[19].

While genetic diversity is generally high for common butterfly species as well as for the species group as a whole, gene diversity and gene flow is low for individual species with small and/or isolated populations[38].

Resistance and recovery

Population declines in many butterfly species suggest that the group's resistance to climate change and other stressors (e.g., habitat loss and fragmentation) may be low[19,28,43]. However, like most insects they reproduce rapidly, which allows species to respond quickly to changing environmental conditions following disturbance and/or in response to management activities (e.g., habitat restoration)[17,38,46].

Management potential

Butterflies are highly valued by the public[38], and monarchs in particular are widely-recognized and appreciated[38,47]. Additionally, public support for butterfly conservation has been increasing as media coverage of pollinator declines becomes more pervasive[38]. There is some regulatory support for management of species already state- or federally-listed as threatened or endangered[38], and the monarch is currently under consideration for listing as threatened under the federal Endangered Species Act[48].

Natural habitat protection and restoration, native plant management, and reduction of non-climate stressors (e.g., pesticide use, habitat loss due to land-use conversion, invasive plant species) are likely to present the most significant management opportunities for native butterflies in the face of climate change[17,34,39,44,49,50]. In general, it is important for habitat restoration and other management actions to consider butterfly life histories, forage and nesting requirements, and likely changes in climate conditions[49]. For example, restoration of host plants and nectar sources may focus on areas that are projected to remain climatically suitable for both the plant species and breeding butterflies[18]. Similarly, management practices such as grazing, prescribed burning, and post-fire restoration and habitat management can be tailored to avoid vulnerable life history stages, accommodate foraging and nesting needs, and maintain source populations for later recolonization[17,49–52]. Finally, assisted migration may be considered for some species, and it already occurring in the San Francisco Bay Area[38].

Recommended Citation

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Further information on the Santa Cruz Mountains Climate Adaptation Project is available on the project page (http://ecoadapt.org/programs/awareness-to-action/santa-cruz-mountains).

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