Bats

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 bats 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.

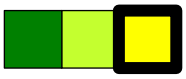
Species Description

The Santa Cruz Mountains region is home to 14 native bat species, including four special-status species: the Townsend's big-eared bat (*Corynorhinus townsendii*), pallid bat (*Antrozous pallidus*), western red bat (*Lasiurus blossevillii*), and western mastiff bat (*Eumops perotis californicus*). Species that are widespread within the region include California myotis (*Myotis californicus*), Yuma myotis (*M. yumanensis*), little brown bat (*M. lucifugus*), big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), hoary bat (*Lasiurus cinereus*), and Mexican free-tailed bat (*Tadarida brasiliensis*), among others.

As a group, bats utilize a wide variety of habitats, including caves, rocky crevices, abandoned mines and man-made structures (e.g., buildings, bridges), and forests[1]. In the Santa Cruz Mountains region, bats are strongly associated with wetlands, complex redwood forests, and mature sycamores and/or cottonwoods in riparian forests[2]. Bats utilize roosts for resting, hibernation (i.e., torpor), and raising their young, with maternity roosts usually requiring specific habitat characteristics (i.e., larger-diameter sycamores within riparian forests)[1]. Bat species also display varied flight and echolocation characteristics depending on foraging strategy. For instance, the calls of bats that forage in open areas are longer in duration and at lower frequencies compared to those of bats, whose short-duration, high-frequency calls allow them to better distinguish insects from background clutter[3].

Vulnerability Ranking

High Vulnerability



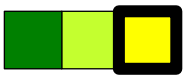
Bats are sensitive to climate stressors such as warmer air temperatures, increased heat waves, changes in precipitation patterns, altered streamflow, and increased drought. These changes impact bats by reducing water availability, increasing energy expenditures, decreasing prey availability, and interfering with hibernation. Disturbance regimes, including disease and wildfire, may also increase the risk of direct mortality. Non-climate stressors (e.g., development, agriculture, timber harvest, fire exclusion/suppression, mining, recreational activity) further exacerbate species group sensitivity by contributing to the disturbance or loss of roosting and foraging areas. Additionally, bats are highly sensitive to contaminants, which can cause both direct mortality as well as sub-lethal physiological and neurological impacts.

Bats are a diverse species group, displaying a wide variety of foraging strategies and habitat/prey specializations. Many species also exhibit behavioral flexibility (e.g., utilizing a wide range of roost sites or foraging habitats), which may improve their ability to cope with increasingly variable conditions. However, several species have experienced severe population declines and extirpation from large

portions of their range, and low reproductive rates result in slow recovery of bat populations from disturbance events. Within the Santa Cruz Mountains region, four bat species receive regulatory protection through state- or federal-listing; cave-dwelling species are further protected by legistlation that prevents cave destruction or disturbance of cave-dwelling animals. Management strategies designed to increase the resilience of bats to climate change may focus on improving habitat availability and complexity in order to increase population stability and support recovery in species that are sensitive to disturbances.

Sensitivity and Exposure

High Impact



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

Bats are sensitive to climate stressors that reduce water availability, increase energy expenditures, decrease prey availability, and interfere with hibernation.

Climate Stressor	Trend Direction	Projected Future Changes
Air temperature	▲	• 1.5–3.1°C (2.7–5.6°F) increase in annual mean temperature[4,5]
Heat waves	▲	• Significant increase in heat wave frequency and intensity[6,7]
Precipitation	▲ ▼	• Shorter winters and longer, drier summers likely, with higher interannual variability[6,8]
Streamflow	▲ ▼	• Generally, wet season flows are projected to increase and dry season flows are projected to decrease[9]
Drought	▲	• Increased frequency of drought years, including periods of prolonged and/or severe drought[6,10]

- **Warmer air temperatures** have been associated with changes in bat migration patterns for some species[11]. However, rapid shifts in plant and insect phenology may outpace shifts in the timing of migration and breeding[12], resulting in mismatches between migration, parturition (i.e., birth), and peak food availability that could result in reproductive failure or starvation[13]**.** Increasing winter temperatures may also reduce torpor depth and duration in hibernating bats, depleting fat reserves and potentially leaving bats more susceptible to fungal infections[14].
- **More frequent and/or intense heat waves** may cause mortality due to heat stress, particularly for young bats that are more sensitive to high temperatures[14,15]. Indirectly, heat waves may be associated with drying of water sources and reduced food supplies[15].

- **Changes in precipitation patterns, altered streamflow, and increased drought** are likely to impact bat reproductive success, which is closely tied to water availability for lactating females[16,17]. Drier overall conditions may reduce the extent of water sources, requiring bats to travel longer distances to reach water even as higher rates of evaporative water loss necessitate more frequent visits[16]. Bats that favor xeric forests and those living along smaller streams may be particularly at risk due to more variable water availability[16,17]. Significant declines in reproductive output (up to 50%) in insectivorous bats have already been observed during years with low precipitation and streamflow[17]. Drought could also drive reductions in insect production, leading to lower prey availability[14].

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

Bats are sensitive to changes in disturbance regimes that directly impact survival as well as those that impact foraging ability and insect prey production.

Disturbance Regimes	Trend Direction	Projected Future Changes
Disease	▲▼	• Uncertain impacts of warmer temperatures and changes in humidity on white-nose syndrome in bats
Wildfire	▲	• Slight to moderate increase in wildfire risk, particularly in areas of higher rainfall[4,5]

- The **exotic pathogen** *Pseudogymnoascus destructans*, an introduced fungal disease from Eurasia, causes the fatal white-nose syndrome that has killed millions of bats nationwide since its discovery in the eastern U.S. in 2006[18]. Although this disease is most prevalent in the eastern and central U.S., it has been documented in Washington since 2016[19]. White-nose syndrome has not yet been found in the Santa Cruz Mountains region, but the disease was reported in a little brown bat maternity colony in Plumas County, California in 2018 and 2019[20], suggesting that it is continuing to spread across the western U.S. Research provides conflicting information about the effects of warmer temperatures on white-nose syndrome, with studies suggesting that higher temperatures and humidity are associated with both higher[21] and lower[22] mortality rates.
- Climate-driven changes in **wildfire regimes** are likely to impact bats within the Santa Cruz Mountains region, both directly due to injury or mortality and indirectly by altering habitat or prey availability. Existing research suggests that heat and smoke during fires can disturb roosting bats, and intense fires can cause injury or mortality in young bats that are still incapable of flight[23,24]. Most studies suggest that fire has an overall neutral or positive effect on bats, likely by maintaining more open forest conditions[24–26]. Higher-intensity fires that lead to overstory tree mortality can create snags used for roosting[23–26], while post-fire nutrient pulses can increase insect prey production[27]. Additionally, existing studies suggest that the extent of high-severity fire appears to have little or no impact on foraging site selection at the landscape scale[26], and species adapted to foraging in open habitats are positively associated with areas of higher fire frequency and burn severity[26,28]. Thus, climate-driven changes in wildfire regimes could potentially shift bat species composition towards greater dominance of open-adapted species and those that benefit from post-fire increases in snags and insect prey[28].

Dependency on habitat and/or other species

All bats are dependent on the quantity and quality of insect prey and on particular habitat elements for resting, raising young, and hibernation[29]. Lactating bats also require close proximity of adequate water sources[16,30]. However, the degree of dependence on specialized prey varies widely among bat species, with some foraging opportunistically and others on specific types of insects[31]. Similarly, some bats are able to utilize a range of roosts (e.g., *Yuma myotis*), including those within man-made structures that resemble natural crevices or cavities. Others are more narrowly associated with specific habitat characteristics[32] such as tree foliage in deciduous riparian forests[2].

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 increasing bat mortality and/or contributing to the disturbance or loss of roosting and foraging habitat.

- **Land-use conversion to residential/commercial development** has reduced the presence of trees and open areas, resulting in habitat loss and increased susceptibility of bats to predation[33,34]. The continued expansion of the wildland-urban interface (WUI), in particular, has fragmented forage and roost habitat[35]. Extirpation of local populations can occur where the energetic costs of travel to foraging areas exceeds the benefits of a particular roost[35].
- **Agriculture** is generally associated with reduced bat activity and a greater proportion of open-adapted bats compared to natural areas[36]. Conventional farms characterized by monocultures of annual crops and little non-crop vegetation are also associated with slight decreases in bat species diversity, likely due to less variability in habitat features[36]. In addition to the impact of agriculture on habitat availability, pesticide applications in agricultural areas reduce the abundance of insect prey[36].
- **Contaminants** can cause mortality in bats exposed to high concentrations directly or indirectly, by ingesting contaminated prey[37]. Low levels of many contaminants can build up in bat tissues, causing sub-lethal physiological and neurological effects that include immune suppression, reproductive failure, and behavioral changes that may impact survival[37]. The use of pesticides also reduces insect prey availability[36]. Organochlorine pesticides and other contaminants have been implicated in bat population declines over the past several decades, although their use has declined since the implementation of restrictions in the 1970s[37]. Before that time, pesticides were sometimes applied directly to bat roosts in an attempt to exterminate them[38].
- Both **timber harvest** and **fire exclusion/suppression** can result in significant changes to forest structure[39,40], with variable responses across bat species depending on foraging strategy[41]. Generally, activity in open-adapted species increases around heavily-logged areas and forest edges, though this advantage likely disappears as dense, even-aged forest regenerates within clearcuts[41]. The removal of large-diameter trees preferred by cavity-roosting bats can limit the availability of maternity roosts[33,41,42].
- **Recreational activity** has contributed to the decline of cave-dwelling species such as the Townsend's big-eared bat, as they are easily disturbed from their roosts[43,44]. Because arousal from torpor is associated with lost body fat and increased vulnerability to disease, disturbances in and around hibernaculae can potentially reduce fitness and survival[45,46].

- **Historic mining** decreased bat habitat availability and contributed to the pollution of water sources utilized by bats[30,44]. However, inactive mines are frequently utilized by cave-dwelling bats, particularly where they are displaced by recreational activities in and around caves[44].

Adaptive Capacity

Moderate Adaptive Capacity

High 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

Many bat species found within the Santa Cruz Mountains region have experienced severe population declines and extirpation from large portions of their range, primarily due to habitat loss[14]. While population declines are most common in species that are already rare or have small range sizes[13], declines have also been observed in species that remain widespread. These include the little brown bat, which is heavily impacted by white-nose syndrome in the eastern U.S.[19].

Bats have a high dispersal ability, and their mobility has contributed to their diversity and widespread distribution[13,29]. Species-specific traits and habitat requirements play a role in the degree to which bat movement and dispersal is impacted by anthropogenic land uses and other barriers (i.e., specialists are likely to be affected by barriers to a greater degree)[2].

Intraspecific/life history diversity

Across the species group, bats display diverse morphological and call adaptations, depending on foraging strategy and habitat/prey specializations[31]. In general, open- and edge-adapted foragers exhibit greater overall flexibility[31], and are more likely to tolerate or benefit from increasingly severe disturbances projected to occur under climate change[28]. Species that exhibit higher behavioral flexibility (e.g., those that utilize a variety of roost sites, lack colony formation, and/or have low site fidelity) may also be better able to accommodate increasingly variable conditions without experiencing significant population declines[11]. By contrast, species that have a high fidelity to roost sites regardless of temperature may be more vulnerable to declines in reproductive output during dry years[16,17].

Resistance and recovery

Although bats are unusually long-lived compared to other mammals of similar size[47], they have low reproductive rates and often produce only 1–2 young per year[48]. As a result, population dynamics are largely driven by adult mortality, and populations have limited ability to recover from disturbance events[11,14]. Special-status species, which generally have small and/or isolated populations and narrow ranges, are particularly at risk of population declines or local extirpation following severe environmental stress or extreme disturbances[2].

Management potential

Bats are considered pests by some people and are often associated with negative public perception[2,44]. However, this species group provides valuable ecosystem services such as seed dispersal, pollination, and pest control in agriculture landscapes[49,50]. Four of the 14 bat species found in the Santa Cruz

Mountains region are provided with some regulatory protection through state- or federal-listing[2]. The California Cave Protection Act also prohibits the destruction of caves and disturbance of cave-dwelling species, including bats[44]. Overall, there is a relative lack of information on bats compared to many other species groups, largely because their nocturnal foraging strategy makes them difficult for biologists to observe[2].

Many projected climate impacts on bats are difficult to control (e.g., increasing temperature stress), which may necessitate greater management focus on non-climate stressors that interact with climate changes or reduce the ability of bats to accommodate change[2]. Management options for bats in the Santa Cruz Mountains region may focus on improving habitat availability and complexity in both natural and agricultural/urban areas[2,36]. For instance, crop diversification and reduced use of pesticides are associated with increased bat activity and greater prey availability, and simultaneously benefit growers by improving bat-mediated pest control[36]. Habitat restoration of riparian forests may also increase roost availability, and studies have demonstrated bat occupation of restored riparian forests within a decade, in part because of the rapid growth of floodplain tree species[51]. Monitoring efforts suggest that protection of known bat maternity roosts and hibernaculum may increase population stability in species that are sensitive to disturbances, such as the Townsend's big-eared bat[34,52]. However, increased long-term monitoring is necessary to better understand both current population trends and how future climate changes may impact California bats[52].

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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