Mission Blue Butterfly (*Icaricia icariodes missionensis*)

Climate Change Vulnerability Assessment for the Golden Gate Biosphere Region

This document represents an evaluation of climate change vulnerability for mission blue butterfly in the Golden Gate Biosphere (GGB) region of California. The following information is based on stakeholder input provided during and following a winter 2022 vulnerability workshop as well as sources from the scientific literature.

Species Description

The mission blue butterfly (*Icaricia icariodes missionensis*) is a small, diurnally active, univoltine (one generation per year) butterfly that is one of twelve subspecies of Boisduval's blue butterfly found in western North America (Arnold 1987). Its life cycle is closely aligned with three host plant species of lupine that are found in coastal prairie and coastal scrub ecosystems: silver lupine (*Lupinus albifrons*), summer lupine (*L. formosus*), and many-colored lupine (*L. variicolor*; Arnold 1987), although the last of these is possibly less preferred as a host plant (Vuln. Assessment Worksheets, pers. comm., 2022). The species has additionally been documented making use of coastal bush lupine (*L. arboreus*) in the Marin headlands (USFWS 2022). Mission blue butterflies emerge between March and mid-June, depending on the population and the surrounding topography, with populations in cooler microclimates emerging later than those in warmer areas (Weiss & Murphy 1990; USFWS 2022). The adult lifespan is typically 7–10 days, and they lay eggs only on lupine host plants; the eggs hatch after a few weeks and larvae feed exclusively on the host lupines. The caterpillars enter diapause, a period of inactivity, in mid-summer in duff at the base of these plants, then emerge for a four- to six-week feeding period the following spring before they metamorphose and give rise to the adult (Arnold 1987; USFWS 2010). The adults feed on the nectar of a variety of grassland plant species (Arnold 1987).

Mission blue butterflies are not strong fliers, with typical adult ranges of 500 meters (0.3 miles), and metapopulations (clusters of populations) are defined as occurring with maximum nearest-neighbor distance of 2.5 km (1.6 mi) or connected by stepping stones of suitable habitat with host and nectar plants no more than 1 km (0.6 mi) apart (USFWS 2010; Vuln. Assessment Worksheet, pers. comm., 2022). Mission blue butterflies are federally endangered, and within the Golden Gate Biosphere (GGB) region they occur in metapopulations in Marin, San Francisco, and San Mateo Counties (Figure 1; USFWS 2010; Lindzey & Connor 2011). In Marin County, most of the mission blue habitat is located on National Park Service lands, with important sites including Oakwood Valley, the Marin headlands including Hawk Hill, and Fort Baker (MacDonald et al. 2012; Vuln. Assessment Worksheets, pers. comm., 2022). In San Francisco, the primary population at Twin Peaks was restored through translocations from San Bruno Mountain (USFWS 2022; Vuln. Assessment Worksheets, pers. comm., 2022). In San Mateo County, the species' range extends from Milagra Ridge, where translocations were conducted from 2017 to 2020 (NPS 2021), south through the San Francisco Peninsula Watershed

(USFWS 2010) where SF Public Utilities manages several important sites for this species (Vuln. Assessment Worksheets, pers. comm., 2022). A population was also translocated in 2022 from San Bruno Mountain to Sweeney Ridge in Pacifica, where the butterflies had previously been extirpated (Fujikawa 2022).

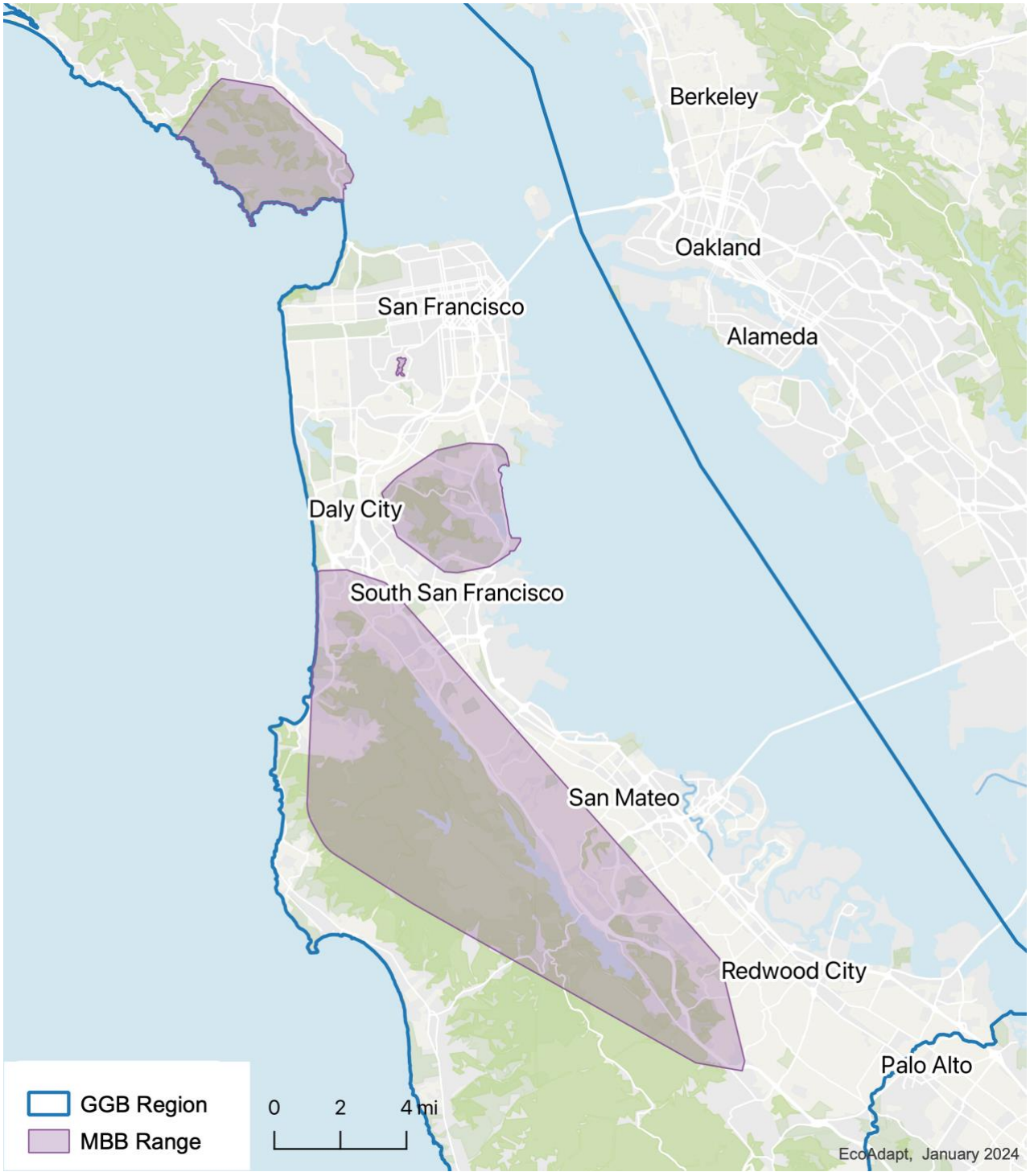

Figure 1. Range of mission blue butterfly (MBB) within the GGB region, based on datasets published by the U.S. Fish and Wildlife Service Environmental Conservation Online System (ECOS).

Species Vulnerability → High *(moderate confidence)*

Vulnerability is evaluated by considering the species' sensitivity and exposure to various climate and non-climate stressors as well as the species' adaptive capacity (i.e., ability to cope with these stressors), and is given a ranking of low, moderate, or high. The confidence ranking represents confidence in the accuracy of the ranking based on available scientific knowledge, and is similarly ranked on a scale from low to high.

Summary of species vulnerability

The mission blue butterfly is highly susceptible to climate stressors and disturbances that affect the health and availability of the host lupine species to which their life cycle is closely tied. Increasing temperatures and precipitation variability are likely to cause direct stress on the species as well as on its host plants. Increased precipitation in wetter years may also exacerbate outbreaks of a fungal pathogen that has caused significant mortality in the butterfly's host lupine populations, particularly *L. albifrons*. Lupine are a disturbance-associated plant that thrives in the early seral stages of vegetative communities, and can be impacted by shifts in grazing patterns, fire suppression and exclusion, and competition from and displacement by invasive plant species.

The mission blue is a federally-endangered butterfly that exists in small metapopulations within the GGB region and has limited capacity for dispersal due to their small size and limited flying capability. Dispersal is also challenged by poor weather and by fragmentation of their habitat by vegetation types that do not contain the host plants, such as forested or tall scrub areas. Conservation efforts that prioritize restoring habitat, controlling invasive species, supporting historic, low-intensity fire regimes where possible, and translocating individuals to enhance gene flow and connectivity will all be crucial for supporting the species' resilience to climate change. Protecting cooler microclimates that may serve as thermal refugia is also likely to be increasingly important. Although mission blue butterflies are protected, continued development pressure, disturbance, and fragmentation of the surrounding landscape is an ongoing challenge both for maintaining integrity of intact habitat and for restoration of degraded lands.

Sensitivity and Exposure → High *(moderate confidence)*

Sensitivity *is a measure of whether and how a species is likely to be affected by a given change in climate factors, climate-driven changes in disturbance regimes, and non-climate stressors. By contrast,* ***exposure*** *is a measure of how much change in these factors a species is likely to experience. Sensitivity and exposure are combined here into one score representing both components of vulnerability, with high scores corresponding to increased vulnerability and low scores suggesting a species is less vulnerable.*

Sensitivity and future exposure to climate factors → High *(moderate confidence)*

- **Rising air temperatures** and **heat waves** can impact mission blue butterflies, which are adapted to a cooler maritime climate. Increasing temperatures may drive declines in grassland habitat (Thorne et al. 2016) and potentially in their lupine hosts, with models suggesting that related species of coastal lupine are extremely susceptible to temperature increases of just a few degrees (Compagnoni et al. 2021). The caterpillar stage is particularly likely to be vulnerable to extreme heat, and these risks are likely greater in more inland areas further from the modulating temperatures of the coast (Vuln. Assessment Worksheets, pers. comm., 2022).
- Excessive moisture as a result of **changes in the amount and timing of precipitation** may increase the risk of a fungal pathogen *Colletotrichum lupini* that can infect lupines, particularly xeric-adapted species like *L. albifrons* (MacDonald et al. 2012), which increases the uncertainty of outcomes for host plant species under the more variable precipitation conditions projected as a result of climate change. Excessive host plant die-back that results from high fungal pathogen loads can lead to large decreases in the butterfly population that may take several years to recover (NPS 2021; Vuln. Assessment Worksheets, pers. comm., 2022). Late spring rains can delay the onset of the flight season, with potential consequences for the timing and success of mating and egg laying (Vuln. Assessment Worksheets, pers. comm., 2022). Climate change projections for California coastal grassland and coastal scrub habitat suggest that both of these vegetative communities are vulnerable to mortality and type conversion as a result of precipitation changes, particularly under warmer and wetter future scenarios (Thorne et al. 2016).
- **Increased drought** is likely to impact the host plants and nectar sources of mission blue butterflies, and may also contribute to conversion of the grassland habitat they rely on to greater dominance of non-native species (Vuln. Assessment Worksheets, pers. comm., 2022). Lower soil moisture has been shown to favor invasive annual grasses over perennials in California grasslands (Everard et al. 2010), although drier conditions may to some degree favor xeric-adapted species like *L. albifrons* (MacDonald et al. 2012).

Sensitivity and future exposure to climate-driven changes in disturbances → High *(moderate confidence)*

- **Increased frequency and/or intensity of storms** and related **wind** are likely to adversely impact the mission blue butterfly. Adult butterflies are impacted by stormy weather, as they are not strong fliers and have a hard time flying in wind and rain (USFWS 2010). Strong winds, in particular, may limit their ability to successfully disperse and access food and mating opportunities (USFWS 2010).
- Mission blue butterflies are at risk from **disease-related dieback** of *L. albifrons* as a result of the fungal pathogen *C. lupini*, which can have lasting impacts and delay recovery of butterfly populations (Kobernus 2008; MacDonald et al. 2012; USFWS 2019; NPS 2021). Mortality of *L.*

albifrons due to pathogen outbreaks is particularly high during El Niño years (MacDonald et al. 2012; USFWS 2019), suggesting that projected increases in annual precipitation and the frequency/intensity of heavy rainfall events may exacerbate current issues with this disease.

- **Climate-driven changes in wildfire regimes** can impact mission blue butterflies by altering host plant abundance. Although lupine is a disturbance-adapted species that readily colonizes disturbed sites (USFWS 1984; Weiss & Murphy 1990), wildfires that occur too frequently can limit reestablishment and persistence of perennial plants (Park & Jenerette 2019). Changes in wildfire regimes are associated with reduced germination by host plant and nectar-producing annuals, and have driven landscape conversion to invasive grasses and coastal scrub habitat, which can lead to loss of lupine host plants (Arnold 1983, 1987; USFWS 1984; Kobernus 2011). These impacts have been exacerbated by fire exclusion that leads to thatch buildup and shrub encroachment in grasslands which can set the stage for more severe wildfires when they do occur (Edson et al. 2016; USFWS 2022).

Dependency on habitat and/or other species → High *(high confidence)*

Mission blue butterflies are highly dependent on coastal grasslands and low scrub habitats that contain at least one of the three larval host plants, *L. albifrons*, *L. varicolor*, and *L. formosus.* In the Marin headlands, mission blue butterflies have additionally been documented using *L. arboreus* across all life stages (USFWS 2022). The larvae feed only on lupine host plants; adults can make use of a wider range of nectar flowers, but do not tend to wander far from areas containing the host plants (USFWS 2019). Lupines are adapted to disturbance and as a nitrogen-fixing plant can make use of marginal soils, so they are often among the first plants to recolonize disturbed areas (Weiss & Murphy 1990). However, they are at risk from climatic changes including increased temperatures, and heavy rains and flooding may drive fungal outbreaks (USFWS 2019; Compagnoni et al. 2021; NPS 2021). Mission blue butterfly larvae also have a facultative mutualistic relationship with native ant species, whereby the larvae secrete honeydew for the ants and the ants provide some amount of protection from predation and parasitism (USFWS 2010).

Sensitivity and current exposure to non-climate stressors → Moderate *(moderate confidence)*

Non-climate stressors can exacerbate ecosystem sensitivity to changes in climate factors and disturbance regimes, and/or can be exacerbated by these changes.

- **Residential and commercial development** has led to significant historic loss of mission blue butterfly habitat (Arnold 1987). With the federal listing of the species and the ensuing protection and management of many of the major remaining populations and habitat areas, development pressure is seen of less of a primary threat (USFWS 2010, 2019; Kobernus 2011). However, ongoing development and associated impacts still have the potential to impact the butterfly's habitat and limit possibilities for range restoration or extension. In particular, **roads, highways, and trails** can eliminate habitat and create barriers to butterfly movement, which is

particularly problematic for a species that does not travel long distances (Vuln. Assessment Worksheets, pers. comm., 2022). **Recreational activity and off-trail movement** can also lead to harassment and trampling of butterflies and their habitat (NPS 2023).

- Several **invasive and problematic species** increase risks to mission blue butterfly populations. Woody invasive plants that can compete with and shade out lupine host plants and nectar-producing native species include *Cotoneaster* spp., *Acacia* spp., blue gum (*Eucalyptus* spp.), brooms including French broom (*Genista monspessulana*) and Portugese broom (*Cytisus striatus*), and many others that are found in and near mission blue habitats (Kobernus 2008; NPS 2017; Vuln. Assessment Worksheets, pers. comm., 2022). In addition to host plant impacts, invasive Argentine ants (*Linepithema humile*) are believed to be increasing parasitism in mission blue butterfly larvae by interrupting the protective function of native ants that care for these larvae (USFWS 2010).
- **Excessive host plant herbivory** by high populations of deer and voles can cause severe declines in available lupine (USFWS 2019; Vuln. Assessment Worksheets, pers. comm., 2022), and in some areas within the region (e.g., Oakwood Valley in Marin) deer have been documented exerting considerable browsing pressure on lupine inflorescences (B. Merkle, pers. comm., 2023). However, moderate browsing by ungulates can also promote lupine in disturbed areas, and loss of elk from coastal grasslands within the GGB region has removed this natural disturbance regime (Vuln. Assessment Worksheets, pers. comm., 2022).
- **Pollution and poisons** present ongoing threats to mission blue butterflies. High rates of atmospheric nitrogen deposition is known to facilitate invasion by exotic annual grasses in California coastal scrub and prairie ecosystems (Fenn et al. 2010), leading to declines in native host and nectar plant species. Pesticide use also directly impacts native plants used by the mission blue butterfly, although managers are generally careful about herbicide use in areas that are managed as butterfly habitat (Kobernus 2008; Vuln. Assessment Worksheets, pers. comm., 2022). However, drift of herbicides and insecticides from proximate areas remains a potential threat (USFWS 2019).
- **Fire exclusion** impacts mission blue butterfly habitats, particularly at the urban-wildland interface where there is political and economic pressure to suppress fire (Cohen 2010; Edson et al. 2016). Significant reduction in fire frequency associated with exclusion has negative impacts on coastal scrub and grassland ecosystems, where fire is necessary to help reset succession that keeps grasslands open (Florence 1987; Barro & Conard 1991). In the absence of fire, encroachment of shrubs and trees can shade out and compete with early-successional plants (Westman 1981; Williams & Vasey 2016).

Adaptive Capacity → Low *(high confidence)*

Adaptive capacity *is the ability of a species to respond to or cope with climate change impacts with minimal disruption. High adaptive capacity corresponds to lower overall climate change vulnerability, while low adaptive capacity means that the species will be less likely to cope with the adverse effects of climate change, thus increasing the vulnerability of the species.*

Species extent, status, connectivity, and dispersal ability → Low (high confidence)

The mission blue butterfly is extremely restricted in its range, which extends from Oakwood Valley just north of the Marin headlands south to San Mateo County (USFWS 2019). Populations have been impacted by habitat loss and fragmentation, illegal poaching, and decline of their host plants as a result of pathogens, invasive species, and alterations to natural disturbance regimes (Kobernus 2011; USFWS 2022). However, recent restoration and translocation efforts have resulted in many populations that are now stable or increasing (NPS 2021; USFWS 2022).

Prior to urbanization of the San Francisco Bay Area, mission blue butterfly habitat was likely far more widespread (Arnold 1987). Coastal grasslands in the GGB region have declined significantly due to widespread land-use conversion and fragmentation (Arnold 1987; USFWS 2010) as well as exclusion of cultural burning practices used to maintain grassland habitat by area tribes (Stromberg et al. 2007). Federal listing of the species and the protection and management of public lands on which the species is currently found (USFWS 1984) has reduced the direct threat of development to this species' current habitat (USFWS 2019). However, mission blue butterfly habitat continues to be threatened by encroachment and succession of these grasslands to coastal scrub and invasive species (Kobernus 2011; USFWS 2019). Climate change projections for the region's vegetation communities suggest the potential for an increase in grassland, particularly in the southern extent of the mission blue butterfly's range (Lenihan et al. 2008), but increasing temperatures may also drive a competitive advantage for invasive plants that could reduce native grassland habitat (Sandel & Dangremond 2012) and facilitate more frequent and intense wildfires (D'Antonio & Vitousek 1992; Westerling & Bryant 2008). The interplay of these projections with development pressures in the region are likely to complicate how these impacts manifest for mission blue habitat.

As mission blue butterflies are poor fliers and have very limited dispersal ability (Arnold 1983), they cannot navigate discontinuous habitat, whether interrupted by human development or vegetation types such as forested areas (USFWS 2019). As a result, distinct populations are completely isolated from each other unless they are purposefully translocated by land managers (Arnold 1987; NPS 2017).

Intraspecific/life history diversity → Low (moderate confidence)

Mission blue butterfly life history is closely tied to its reliance on a small group of lupine host plants and a somewhat more diverse group of flowering plants used for nectar by adults (Arnold 1983, 1987; USFWS 1984). However, there are some indications that this species can make use of additional host plants, such as has been shown for Marin populations of mission blues on *L. arboreus* (USFWS 2022).

There is also some documented variability in the timing of emergence and egg laying that may be linked to varying microclimates across which the populations are distributed, with butterflies located on cooler north-facing slopes exhibiting slightly later emergence and oviposition compared to those in warmer, sunnier locations (Weiss & Murphy 1990).

The isolated populations and low abundance of mission blue butterflies suggests low genetic diversity in this species, particularly within populations, but the genetics of this species has not been studied (Vuln. Assessment Worksheets, pers. comm., 2022). Inbreeding depression due to small numbers within populations is a concern for managers and a basis for considering continued translocation that supports genetic exchange among populations (Kobernus 2008; NPS 2021). A study of mission blue population genetics has been recommended in the most recent update to the species recovery plan (USFWS 2022).

Resistance and recovery → Low (high confidence)

Mission blue butterflies are host plant specialists within a coastal grassland ecosystem that is under multiple threats, including climate change. The species has relatively low reproductive rates, and recovery from past perturbations seems to be slow (USFWS 2022; Vuln. Assessment Worksheets, pers. comm., 2022). Even after listing, populations such as the one at Sweeney Ridge have been extirpated, though this site was identified for a translocation effort (USFWS 2022) and initial translocations in 2022 and 2023 have been successful (B. Merkle, pers. comm., 2023). The butterfly's host plants are disturbance-associated, and the suppression of natural disturbances such as wildfire and ungulate browsing, together with shifts in climate that may facilitate invasive plants and woody vegetation encroachment, are likely to threaten the butterfly's habitat (D'Antonio & Vitousek 1992; Cohen 2010; Thorne et al. 2016; Vuln. Assessment Worksheets, pers. comm., 2022). Lupines are relatively difficult to establish and labor-intensive to plant, and restoration has been hampered by nursery pathogen issues (USFWS 2022). However, recent efforts with seed amplification and direct seeding are starting to yield better results (USFWS 2022; Vuln. Assessment Worksheet, pers. comm., 2022).

Management potential → Moderate (high confidence)

The mission blue butterfly is afforded significant regulatory protection and resources due to its status as a federally-endangered species (USFWS 1984). Over the more than forty years since its listing, significant efforts have been made to protect known mission blue butterfly habitat and conduct public outreach to raise awareness about the importance of species protection (USFWS 2019; NPS 2023). More recently, there has been a concerted effort towards standardizing monitoring protocols for detecting and enumerating populations (MacDonald et al. 2012; USFWS 2022) and a shift towards active management of the species, including multiple translocation projects to re-supply declining or extirpated populations (NPS 2021; USFWS 2022). The U.S. Fish and Wildlife Service is also moving forward with the development of a captive rearing facility that can support reintroduction and supplementation efforts (USFWS 2022; Vuln. Assessment Worksheets, pers. comm., 2022).

Additionally, there have been more efforts to map and diversify lupine host plants throughout the species range, in part due to concerns of threats to these plants from the fungal pathogen *C. lupini* (USFWS 2022). This extensive work on recovery actions has increased stability in key metapopulations, and as a result the mission blue butterfly may be downlisted from endangered to threatened in a subsequent status review (B. Merkle, pers. comm., 2023).

Climate change projections support the potential for warmer, seasonally wetter conditions in central coastal California (Thorne et al. 2016) that could intensify outbreaks of lupine fungal pathogens, so efforts to diversify and restore lupine host plants are important to meeting this challenge (USFWS 2022). Increasing temperatures associated with climate change also mean that cooler microclimates such as north-facing slopes that could provide refugia for mission blue butterflies and their host plants may be an increasingly important focus for habitat conservation and restoration efforts (Weiss & Murphy 1990). While the mission blue butterfly receives federal protection in its current core habitats, development pressure and associated impacts in this highly urbanized area of central California are likely to continue, and sources of disturbance in proximity to protected areas (e.g., poaching, trampling, pesticide drift, invasive species) are threat multipliers that will need to be constantly managed and mitigated (Kobernus 2011; MacDonald et al. 2012; USFWS 2022).

Recommended Citation

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Further information on the Golden Gate Biosphere Region Climate Adaptation Project is available on the project page (www.ecoadapt.org/goto/GGBRClimateProject).

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