5-YEAR REVIEW

Mission blue butterfly (*Icaricia icarioides missionensis*)

GENERAL INFORMATION:

Species: Mission blue butterfly (*Icaricia icarioides missionensis*)
Date listed: June 1, 1976
Federal Register (FR) citation: 41 FR 22041
Classification: Endangered

State Listing:
Not listed. Currently, there are no insects listed as threatened or endangered under the California Endangered Species Act.

BACKGROUND:

Most recent status review:

[Service] U.S. Fish and Wildlife Service. 2010. San Bruno elfin butterfly (*Callophrys mossii bayensis*) and mission blue butterfly (*Icaricia icarioides missionensis*) 5-year review: summary and evaluation. Sacramento Field Office, Sacramento, CA. 39 pp.

We did not recommend a status change in the 2010 status review.

FR notice citation announcing this status review:

[Service] U.S. Fish and Wildlife Service. 2020. Endangered and threatened wildlife and plants; initiation of 5-year status reviews of 66 species in California and Nevada. Federal Register 85:4692-4694.

We did not receive any information from the public regarding the mission blue butterfly.

ASSESSMENT:

Information acquired since the last status review:

This 5-year review was conducted by the U.S. Fish and Wildlife Service's (Service) Sacramento Fish and Wildlife Office. Data for this review were solicited from interested parties through a Federal Register notice announcing this review on January 27, 2020 (Service 2020a). We used personal communications with species experts, obtained data from partners, and reviewed information from our own files, much of which was compiled during a recent Recovery Plan amendment for the species.

Since the last 5-year review, new or updated species' information has become available including or related to: translocations of adult butterflies from San Bruno Mountain to Twin Peaks and Milagra Ridge; lupine (host plants for the mission blue butterfly), including mapping and diversification; oviposition and egg phenology; and a preliminary metapopulation modelling using historical data from Milagra Ridge. Site specific monitoring efforts are mentioned below in **Distribution and abundance** and summarized in Appendix A.

Translocations

Translocations of mission blue butterfly adults have occurred at two locations in the species' range: Twin Peaks in San Francisco County, and Milagra Ridge in San Mateo County. Both translocation projects source adults from San Bruno Mountain. Coordination among partners and

results from biennial monitoring at San Bruno Mountain determine the dates and locations at San Bruno Mountain from which adults will be collected (Ormshaw in litt. 2019). Protocols/permits dictate the number of adults that can be collected per transect and time period (i.e., per week), and are self-limiting based on the number of males and females that must be left in place. The number of adults translocated to the respective sites is shown in Table 1.

Table 1. Adult mission blue butterflies translocated to Twin Peaks and Milagra Ridge from 2009 through present.

	Twin Peaks			Milagra			TOTAL
Year	Females	Males	Total	Females	Males	Total	
2009	22	0	22	-	-	-	22
2010	0	0	0	-	-	-	0
2011	40	20	60	-	-	-	60
2012	11	5	16	-	-	-	16
2013	38	20	58	-	-	-	58
2014	0	0	0	-	-	-	0
2015	13	9	22	-	-	-	22
2016	29	15	44	-	-	-	44
2017	0	0	0	20	10	30	30
2018	0	0	0	30	15	45	45
2019	20	10	30	20	11	31	61
2020	18	9	27	20	10	30	57
2021	38	21	59	0	0	0	59

Translocations at Twin Peaks began in 2009 and have continued in most years through the present. Managers from San Francisco Parks and Recreation, combined with other species experts and in communication with San Mateo County Parks and the Service, recommend additional translocations in end-of-year reporting if warranted based on analysis of annual monitoring results.

Translocations at Milagra Ridge began in 2017 and continued through 2020; translocations were not conducted at this site in 2021. The abundance of mission blue butterflies at Milagra Ridge crashed several times in the proceeding decade following fungal pathogen outbreaks that caused silver lupine diebacks in 1998 and 2010. Translocations of adult mission blue butterflies to this site was done in concert with habitat restoration, including lupine augmentation (Correa and Crooker 2019, pp. 11–14).

Partners have also discussed the potential for future translocations to Sweeney Ridge, a population that may have been locally extirpated by a lupine fungal pathogen and/or other factors (Bennett and Russo 2016, p. 7; Coast Ridge Ecology 2019, pp. 4-5). The last positive detection of mission blue butterflies at Sweeney Ridge occurred in 1987 (Bennett and Russo 2016, p. 2).

Lupine mapping and diversification

Since the last status review, there has been an increase in lupine diversification efforts and lupine mapping throughout the species' range. Host plants for mission blue butterflies mainly include silver lupine (*Lupinus albifrons*), summer lupine (*L. formosus*), and manycolored lupine (*L. variicolor*). Documentation of all life stages of mission blue butterflies using the purple variety of coastal bush lupine (*L. arboreus*) has been reported in the Marin Headlands, including eggs, larvae, larval feeding damage, and adults (Crooker 2019a, p. 4). The interest in lupine diversification is in part related to the threat of a fungal pathogen (*Colletotrichum lupini*, which causes anthracnose) that predominantly affects silver lupine and has been linked to mission blue butterfly declines across multiple sites and years (e.g., Correa et al. 2018, pp. 5, 12). Amended recovery criteria include a provision about the importance of maintaining multiple host plant species within habitat occupied by mission blue butterfly populations.

Lupine diversification efforts have included both outplanting and seeding; seeding is currently the recommended method (Weiss 2020, p. 17). Planting lupines is extremely labor intensive, with the application of herbivory cages and snail repellant on each plant and watering required (Correa et al. 2018, p. 9), plus hundreds of staff or volunteer hours. Further, outplanting is limited by problems with pathogens in nurseries and low survival of plants in some years. Direct seeding is more cost effective and has higher success than outplanting, and has the added benefit that seeds can be planted in locations where outplanting would be difficult (e.g., rock crevices, steep slopes, or bare ground). Seed amplification efforts are underway by multiple partners (Crooker 2019a, p. 40; Merkle pers. comm. 2018; Weiss pers. comm. 2018). Lupine diversification highlights are summarized below:

- Seeding in the Golden Gate National Recreation Area is led by the Golden Gate National Parks Conservancy. Seed treatment plots at Milagra Ridge include different seed treatments (rock tumbling, coffee soaking, and nicking the seed coat) and seeding methods (bury and rake). Putting seeds in the rock tumbler was the most effective seed treatment, while seeding methods were equivalent. Germination was more successful in grasslands or areas with scrub removal compared to disturbed habitat (Crooker 2019b, pp. 34–35).
- Lupine propagation is underway at Twin Peaks through collaboration between Creekside Science, San Francisco Recreation and Parks Department, and Root Wisdom, with funding from the Disney Butterfly Conservation Initiative. Experimental seed plots compare lupine survival in untreated vs. sandpaper scarified lupine seeds, and additional plots were seeded in order to increase lupine numbers at the site. In addition to seeding, over 2,000 lupine plants have been planted at Twin Peaks between 2002 and 2019 (Weiss et al. 2020, pp. 15–17, 20).
- Seeding in experimental treatment plots is also underway at San Bruno Mountain, with second year survivorship data anticipated soon (Weiss in litt. 2020).

Lupine mapping goes hand in hand with lupine diversification in order to assess need and develop restoration targets.

Lupine mapping has occurred at the following sites by multiple partners:

- Detailed lupine maps for Milagra Ridge from 2015 include 38 patches ranging from 0.001 to 1.0 hectares (0.0025 to 2.5 acres), with the largest patch having 782 lupines (Weiss 2020, p. 20).

- Lupine maps at Twin Peaks were recreated in 2013 from 2008 baseline maps, with an increase in lupine abundance by about 25 percent. Although silver lupine is still the most abundant of the host plants, there were also increases in summer and manycolored lupine (Weiss et al. 2013, p. 11).
- Coarse-scale lupine mapping at San Bruno Mountain occurred in 2017 (Ormshaw 2018, p. 8). Lupine maps for San Bruno Mountain were updated/created in 2019 and 2020, including the entire Northeast Ridge, Owl-Buckeye Canyons, the main ridge above the Owl-Buckeye Canyons area, and the road to West Peak (Cole 2020, p. 8; Weiss 2020, pp. 6–7).
- Summer lupine mapping at Oakwood Valley occurred in 2018. Groups of lupines or individual lupines separated by more than 20 feet were regarded as separate patches (McDonough and Crooker 2018, p. 9).

Oviposition and egg phenology

Since the last status review, new information has become available related to the number of eggs laid by female mission blue butterflies and the amount of time that passes between oviposition and hatching, as well as additional questions related to both areas. Previous research on mission blue butterflies did not include estimates of the number of eggs laid per female, but indicated that mission blue butterfly eggs hatch in four to seven days in the lab (Arnold 1983, p. 26) and six to ten days in the field (Downey 1957 in Arnold 1983, p. 26).

Weiss et al. (2016, p. 14) estimated that the number of eggs laid by females was 80. This estimate used data from the first Twin Peaks translocation, in which half of the eggs were assumed to be laid prior to translocation. Additional assumptions that went into the estimate include: there were no resident females at Twin Peaks in 2009, such that all eggs were laid by the translocated females; there was complete egg turnover from week to week, so there was no double-counting eggs during egg surveys; and, the number of eggs counted on random lupine plants was representative across the habitat (egg counts on random lupine plants were extrapolated across all lupine plants for an overall egg count estimate). Weiss et al. (2017, p. 8) used an observation of 10 eggs laid in one day on a caged plant at Milagra Ridge during a translocation event (Kwan pers. obs. in Weiss et al. 2017) multiplied by the eight day average lifespan of females (Arnold 1983, p. 44) as additional support for the estimate of 80 eggs per female. Estimates of eggs laid using similar analysis methods (i.e., counting eggs on a subset of lupine and multiplying across the site) suggest that translocated females at Milagra Ridge deposit 20 to 25 eggs each on average (Weiss 2019, pp. 6–7) compared to the estimate of 40 eggs per female at Twin Peaks. We are not aware of specific information about egg-laying lifespan or variation (or lack thereof) in day-to-day oviposition patterns of mission blue butterflies to compare against these assumptions, other than a rough estimate by Dr. Richard Arnold that the reproductive effort entails about 200 eggs (Arnold pers. comm. in Thomas Reid Associates 1982, p. III-4).

Mission blue butterfly egg surveys often presume complete turnover of eggs from week to week (i.e., hatching time less than 1 week) (e.g., Weiss et al. 2019, p. 5). As part of surveys conducted to assess effectiveness of the translocation from San Bruno Mountain to Milagra Ridge, tracking individual eggs over time has resulted in updated information on the time from oviposition to hatching. At Milagra Ridge, many of the eggs tracked on the release plants took from 21 to 32 days to hatch (Correa et al. 2018, p. 23). Photomonitoring in 2019 during approximately weekly surveys indicated that although some eggs hatched in about a week, the majority of tracked eggs

hatched between 15 to 21 days after they were initially found (Correa and Crooker 2019, p. 20). Analyses comparing observations of unhatched vs. hatched eggs estimated that the time to hatching at Twin Peaks ranged from seven to 10 days or 11 to 16 days depending on the analysis method (Weiss et al. 2020, pp. 10, 15). These estimates used both the "weighted mean egg date" comparing unhatched and hatched eggs, and the program Insect Count Analyzer (INCA), which fits a model of emergence and disappearance dates to model count data (Longcore et al. 2003, entire). The model includes four parameters: N (total estimate), alpha (daily disappearance rate), beta (spread of oviposition), and mu (peak day). Weiss et al. (2020, p. 15) specifies that a higher alpha corresponds to a shorter development time, with alphas of 0.136 (2017) and 0.101 (2019) roughly corresponding to development time of seven days and 10 days respectively. Applying INCA to the Milagra egg counts, using manual fit of the model instead of default parameters, gave estimates of time to hatching of 12 days in 2017 and 21 days in 2018 (Weiss 2019, pp. 2, 6).

Weiss et al. (2020, p. 8) posits that higher average temperatures and solar radiation as well as distance from the coast at Twin Peaks relative to Milagra Ridge may account for faster time between oviposition and hatching at the former site. Coarse temperature analysis showed that Twin Peaks was approximately 0.1 to 0.8 degrees Fahrenheit warmer than Milagra Ridge in April and May (Weiss et al. 2020, p. 8). Cooler conditions in 2018 relative to 2017 were also suggested as a reason for the 21 vs. 12 day time to hatching estimated for Milagra Ridge (Weiss 2019, p. 2). The lab rearing of mission blue butterfly eggs, which resulted in eggs hatching in four to seven days, maintained temperature and humidity at 70 degrees Fahrenheit and 70 percent humidity (Arnold 1978, p. 30). We are not aware of research comparing mission blue butterfly time to hatching in relation to climate variables.

We supplement the above data with comparisons to published information from other similar butterfly species. The closely related Fender's blue butterfly (*Icaricia icarioides fenderi*) lays approximately 350 eggs in a maximum lifespan of 15 days, and eggs hatch a few weeks after oviposition (Schultz et al. 2003, p. 64–67). Puget blue butterflies (*Icaricia icarioides blackmorei*) brought into captivity to research captive rearing laid approximately 39 eggs each (1,851 eggs produced by 48 females) (Dzurisin 2005, p. 49). However, it is not known how many eggs these females may have laid prior to capture, and, because they were released into the wild after the observations, the total number they may have laid over their lifetime. Descriptions of time to hatching for Puget blue butterflies include ranges of five to ten days (Potter unpubl. data in WDFW undated, p. 5) and two to four weeks after oviposition (Schultz et al. 2009, p. 310).

Because egg monitoring is used to monitor some mission blue butterfly populations, increased information about egg phenology, potential correlates between egg development and microclimate, and proportions of eggs laid on lupine by other Lycaenidae butterfly species would be useful. Mission blue butterfly eggs are identified based on shape, size, color and location of eggs on the plants (e.g., Coast Ridge Ecology 2019, p. 7). Although monitoring reports state that mission blue butterfly eggs are distinctive (e.g., Weiss et al. 2020, p. 2), the Twin Peaks Recovery Action Plan (Wayne et al. 2009, p. 4) states that egg survey data may over-represent population size because of difficulties distinguishing between mission blue butterfly eggs and eggs of similar species. Misidentification of at least some eggs has been identified as a potential problem in past reports (e.g., Correa and Crooker 2019, p. 20), and egg monitoring data collected in at least one year at Milagra Ridge included counts of yellow eggs in addition to white eggs (Leagnavar et al. 2013, pp. 9, 33). Eggs resembling mission blue butterfly eggs apart from a

yellowish tinge have also been noted at the San Francisco Peninsula Watershed (Coast Ridge Ecology 2018, p. 11). Other co-occurring butterflies that could lay eggs on lupine species include acmon blue butterflies (*Icaricia acmon*) and silvery blue butterflies (*Glaucopsyche lygdamus*). Acmon blue butterflies have been observed ovipositing on a summer lupine during mission blue butterfly surveys (Coast Ridge Ecology 2019, p. 11), and their eggs are reported to be almost indistinguishable from mission blue butterfly eggs (Coast Ridge Ecology 2019, p. 7). Acmon blue butterfly larvae have been observed on summer lupine also hosting mission blue butterfly larvae, but larvae between the two species are easily distinguishable (Coast Ridge Ecology 2019, p. 7). We are not aware of information regarding if acmon blue butterfly use of silver lupine differs. Silvery blue butterflies are rare or potentially extirpated at some of the mission blue butterfly sites, and their eggs are almost always laid on lupine buds and flowers (Labar 2014, p. 1) instead of leaves.

Metapopulation modeling

A preliminary metapopulation model by Creekside Science was funded by the Service in 2019. By overlaying survey data collected on transect from 1994 to 2011 with lupine maps at Milagra Ridge, combined with dispersal data from mark-capture at San Bruno Mountain (described in Thomas Reid Associates 1982), Weiss (2020, pp. 1–12) modeled metapopulation dynamics at Milagra Ridge. Weiss (2020, pp. 12–14) also extended the model to San Bruno Mountain and Twin Peaks, but cautions that the model is not yet a complete Metapopulation Viability Analysis. The model is complex and sensitive to minor changes, and will likely be improved with additions including, but not limited to, more detailed lupine mapping and incorporating wind (Weiss 2020, pp. 18–19). Highlights for consideration in the document include:

- The Milagra Ridge metapopulation appears to be viable (95 percent chance of persistence over 100 years) based on simulation runs, but minor changes in the model (e.g. increase in extinction rate or decrease in dispersal distance) can lower rates of survival considerably. For example, decreasing dispersal distance from 167 m to 100 m reduced expected metapopulation persistence to only 4 percent. Dispersal distance in the model was based on data from San Bruno Mountain, and it is not clear how those data translate across sites.
- Preliminary application of the model to Owl-Buckeye Canyons and the Northeast Ridge at San Bruno Mountain predict viability in both metapopulations.
- Preliminary application of the model to the patch network at Twin Peaks suggested low viability given current habitat conditions, but demonstrated restoration potential. Not surprisingly, hypothetically increasing the number of lupines in patches increases both likelihood of population persistence and patch occupancy.
- Small lupine patches play an important role in metapopulation persistence by increasing connectivity.
- Habitat restoration should set 100 to 150 lupine per patch as a minimum target. This target is based on use of the number of lupines as a surrogate for area in the model (which is in turn used as a surrogate for potential population size). The minimum target of 100 lupines in a high quality patch aligns with habitat restoration guidelines in the San Bruno Mountain Habitat Management Plan. More specifically, the habitat restoration guidelines in the San Bruno Mountain Habitat Management Plan is 2.5% over 0.125 acre or 100 plants in high quality patches, with approximately one high quality patch per acre (TRA Environmental Sciences 2008, p. B-3). This translates to 250 plants/hectare, which is the

recommended average lupine density in downlisting criteria for mission blue butterflies (Service 2019, p. 10).

Distribution and abundance:

The current distribution of mission blue butterfly is the same as described in the Recovery Plan amendment, consisting of metapopulations in Marin, San Francisco, and San Mateo Counties (Service 2019, p. 3).

At the time of its listing in 1976, we considered there to be only two locations with metapopulations of mission blue butterflies: Twin Peaks in San Francisco County and San Bruno Mountain in San Mateo County (Service 1976, p. 22042). In the recovery plan we also included a metapopulation at Fort Baker in Marin County (Service 1984, p. 1). Since then, additional metapopulations have been documented in San Mateo and Marin Counties (Service 2010, pp. 9–11). In the Marin Headlands, mission blue butterflies are found west and north of Fort Baker (Appendix A in Coast Ridge Ecology 2017), and as far north as Oakwood Valley (Arnold and Lindzey 2003, pp. 4–5). In San Mateo County, the species' range extends from Milagra Ridge through Sweeney Ridge and south through the San Francisco Peninsula Watershed (Service 2010, pp. 10–11). Additional observations of butterflies matching the mission blue butterfly phenotype have also been reported in both Marin and San Mateo Counties, including to the north and west of Oakwood Valley in Marin County (Bennett in litt. 2008), on private property near Milagra Ridge (Wang 2018, pp. 2–3), and at Montara Mountain and Scarper Peak in San Mateo County (Arnold in litt. 2013).

Annual or biennial monitoring surveys occur throughout the range of the mission blue butterfly. Monitoring of adults occurs using a variety of survey methods, including fixed transects and presence/absence surveys aligned with a grid. Additional monitoring occurs for other life stages of the species (i.e., eggs and larvae). Survey techniques are most useful for relative comparisons across years rather than absolute abundance estimates, and normal fluctuations in abundance across transects and years can make it difficult to determine trends. There have not been mark-recapture survey estimates of abundance since 1981 and 1982, which occurred at San Bruno Mountain (Thomas Reid Associates 1983, pp. II-2–II-19), but not other occupied sites. Additional information on site-specific monitoring is included in Appendix A.

Threats:

At the time of listing, the primary threat to the mission blue butterfly was destruction of habitat through private development (Service 1976, p. 22042). Although no longer considered an imminent threat because most habitat is on publicly protected lands, development is still a threat on habitat that is privately owned. In the 2010 5-year review, habitat degradation was considered the most serious threat, including degradation via encroachment of coastal chaparral, coastal scrub succession, non-native grasses, and associated thatch build-up. Additional threats identified in the previous status review include: a fungal pathogen that infects host plants, primarily silver lupine; public infrastructure projects; pollution, including nitrification that can exacerbate non-native grass production; poaching; parasitism and predation of larvae, potentially exacerbated by the presence of Argentine ants; small population size; recreation resulting in trampling; and climate change (Service 2010, pp. 13–24). Additional threats noted in the recovery plan amendment include pesticide use and vole herbivory of host plants (Service 2019, p. 5). There is no indication that the status of threats to the species has significantly changed since the Recovery Plan amendment.

Recovery criteria:

The Recovery Plan amendment included quantitative criteria regarding downlisting and delisting the species (Service 2019, pp. 9–12), fulfilling a recommendation in the previous status review (Service 2010, p. 29). Downlisting criteria relate to: habitat management; target numbers for host and nectar plants, including multiple lupine species; occupancy across the historical range of the species, including metapopulations in San Mateo, San Francisco, and Marin County (with requirements for populations in specific locales within these counties); suitable habitat acreage and trends; and population viability. Status of metapopulations at San Bruno Mountain (San Mateo County), Twin Peaks (San Francisco County), and the Marin Headlands (Marin County) are summarized in Table 2. These are not the only known sites for the species (for example, Oakwood Valley is also in Marin County), but are representative of the overall status for each county in relation to the recovery criteria. Downlisting criteria are only partially met, thus delisting criteria are not considered here.

Table 2. Status of mission blue butterfly in comparison to recovery criteria (Service 2019) at three sites across three counties. Criteria are abbreviated slightly from those in the Recovery Plan Amendment, with numbers at the start of each criteria aligning with those given in the amendment; note that some complicated criteria are divided over multiple rows. "Yes" denotes when criteria are met.

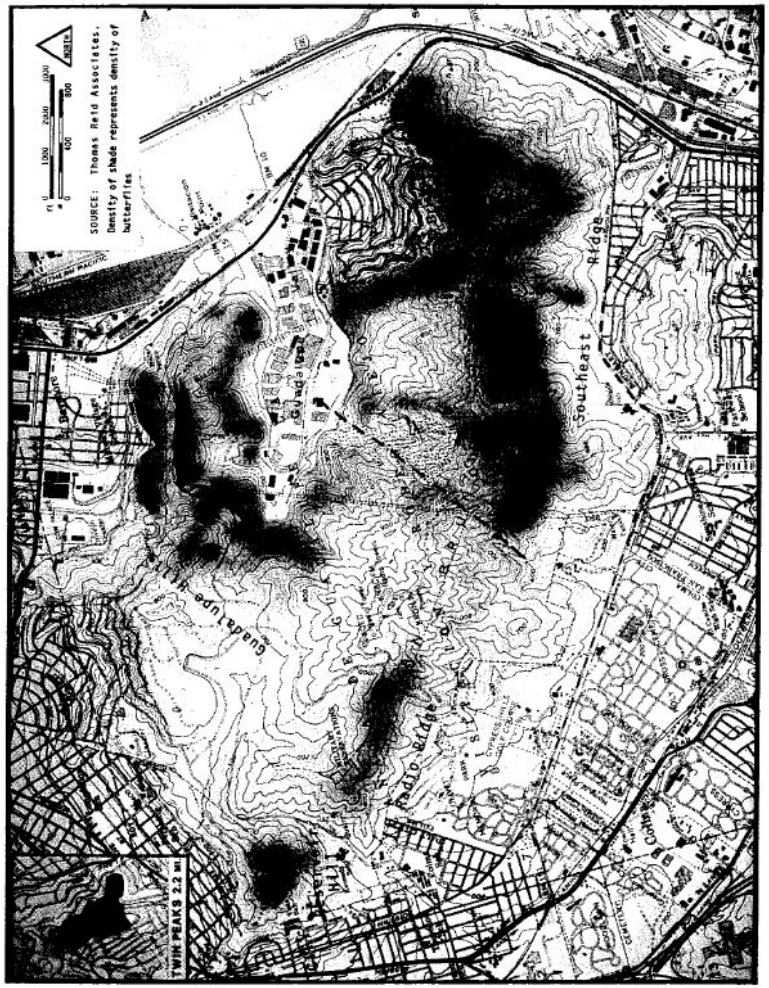
Criteria	Overall	San Bruno Mountain	Twin Peaks	Marin Headlands
A1: Site managed to ensure the maintenance of habitat that includes host plants and a diversity of nectar plants. Service-approved management plan that supports grasslands and controls other threats to the species and its habitat. Long-term maintenance of the site financially sustainable.	Yes	Yes. San Bruno Mountain State and County Park is managed by San Mateo County Parks according to a management plan associated with the Habitat Conservation Plan for the area (TRA Environmental Sciences 2008).	Yes. The site is managed by San Francisco Recreation and Parks. Although there is not a "Service-approved" management plan, the habitat is managed to ensure long-term-maintenance for the species.	Yes. Mission blue butterfly habitat in the Marin Headlands is mostly on lands managed as part of the Golden Gate National Recreation Area. Although there is not a "Service-approved" management plan, the habitat is managed to ensure long-term maintenance for the species.
A2: Monitoring determines that sites support populations of both silver and summer lupine, including a variety of size and/or age classes. Monitoring over a 15-year period demonstrates natural recruitment of both lupine species and an average of 250 lupine plants/hectare.	Partially met	Partially met. Lupine has been mapped, but not monitored over a 15-year period. The number of lupine plants per hectare is unclear from available reports, but previous transects in high quality patches had lupine estimates in line with the criterion (TRA Environmental Sciences 2008, p. B-3).	Partially met. Lupine maps are available from 2008 and 2013, and coverage is increasing due to diversification/planting efforts. The number of lupine plants per hectare is unclear from available reports.	Partially met. Habitat maps in the Golden Gate National Recreation Area in the Marin Headlands were updated in 2019, but there is not quantitative monitoring data on lupine available (Merkle in litt. 2021).
A2: Mission blue butterflies documented using both species of lupine.	Partially met	Yes. Arnold (1983, p. 48) refers to different ecotypes of mission blue butterflies that use three host plant species including summer and silver lupine.	Yes. Mission blue butterfly eggs observed on both species (but not manycolored lupine) in 2020 (Weiss et al. 2021, p. 10).	Partially met. Silver (Coast Ridge Ecology 2020, p. 1) and summer (Merkle in litt. 2021) lupine are both documented in the Marin Headlands, with silver lupine being the predominant host plant.

Criteria	Overall	San Bruno Mountain	Twin Peaks	Marin Headlands
				We are not aware of documentation of mission blue butterflies using summer lupine at this site.
A3: Suitable habitat has a minimum of 250 nectar plants/hectare.	Possibly met	Possibly met. Qualitative analysis in Service (2020) found that nectar plants condition was high for callippe silverspot butterfly. Because callippe silverspot butterflies also use some of the same grassland areas as mission blue butterflies, this qualitative analysis can likely be extended to mission blue butterfly habitat. However, we are not aware of quantitative monitoring of nectar plants at this site.	Unclear. Monitoring reports discuss planting additional nectar plants, but we are not aware of quantitative monitoring.	Unclear. We are not aware of quantitative nectar plant monitoring.
E1: Metapopulations are maintained or re-established in suitable habitat, including at least one metapopulation each in Marin, San Francisco, and San Mateo Counties.	Partially met	Yes, this metapopulation meets the San Mateo County portion of this criterion.	Not met. The population at Twin Peaks is not yet self-sustaining, with ongoing translocations. This site is in San Francisco County.	Yes, this metapopulation meets the Marin County portion of this criterion.
E1: The San Mateo County metapopulation must be maintained on San Bruno Mountain and contain populations across Guadalupe Hills, Southeast Ridge, Radio Ridge, and Reservoir Hill. (Note that these names are carried over from the original Recovery	Partially met	Partially met. Monitoring shows persistence of populations across Guadalupe Canyon and the Southeast Ridge (monitoring transects 6–9 and 11–12). The transect (T2) through Reservoir Hill is now mostly scrub, with few sightings, and the transect (T1) closest to the area historically	NA	NA

Criteria	Overall	San Bruno Mountain	Twin Peaks	Marin Headlands
Plan (Service 1984), but current management has different names for these areas; see Figures 1–4).		referred to as Radio Ridge has not had observations in recent years (see Figure 4).		
E1: The metapopulation in Marin County must contain at least three populations.	Yes	NA	NA	Yes, monitoring reports demonstrating presence in grid cells throughout this site support presence of at least three populations in the Marin Headlands.
E2: Patches of suitable habitat must be at least 6 hectares (15 acres) to support each of the populations designated in E/1…San Bruno Mountain must have a minimum of 1,200 acres of grassland as designated in the Habitat Management Plan.	Partially met	Not met. The most recent estimate of grasslands at San Bruno Mountain is 944 acres, using visual analysis of aerial imagery (Weiss et al. 2015, pp. 57-58).	Unclear. Egg monitoring at 4 areas within the site (Gardenside, Mission Ridge, Mission Bowl, and Mission Flats) and habitat restoration within these areas occurs, and may be approaching the target size, but suitable habitat acreage is not readily available.	Yes. Map in Coast Ridge Ecology (2020, p. 15) shows lupine distribution and 250 m^2 grid cells used for monitoring.

Criteria	Overall	San Bruno Mountain	Twin Peaks	Marin Headlands
E/2: Suitable habitat patches must have stable or increasing grassland acreage over at least a 25-year period. For each site, woody vegetation should make up no more than 15 percent of the absolute vegetative cover at the metapopulation level.	Not met	Not met. Grassland acreage is declining (Weiss et al. 2015, p. 57, Table 5-1).	Not met. We are not aware of long-term monitoring of grassland acreage. However, habitat restoration appears to be increasing the amount of suitable habitat at this site.	Possibly met. Although we are not aware of quantitative grassland monitoring, our understanding of potential suitable habitat has increased as monitoring switched from transects of known sites to grid cell monitoring/lupine mapping across a larger range.
E/3: Population viability analysis determines that mission blue butterflies have a 90% probability of persistence over a 25-year period across all three counties.	Not met	A preliminary metapopulation model is promising but not yet complete (see Metapopulation modeling). The model predicts viability at this site but the author cautions that the model is complex and sensitive to minor changes.	A preliminary metapopulation model is promising but not yet complete (see Metapopulation modeling). The model predicts low viability at this site but highlights restoration potential that could increase viability.	The preliminary metapopulation model has not yet been applied to this site.

FIGURE S - 4
GENERAL POPULATION AND HABITAT DISTRIBUTION — MISSION BLUE ADULTS 1981

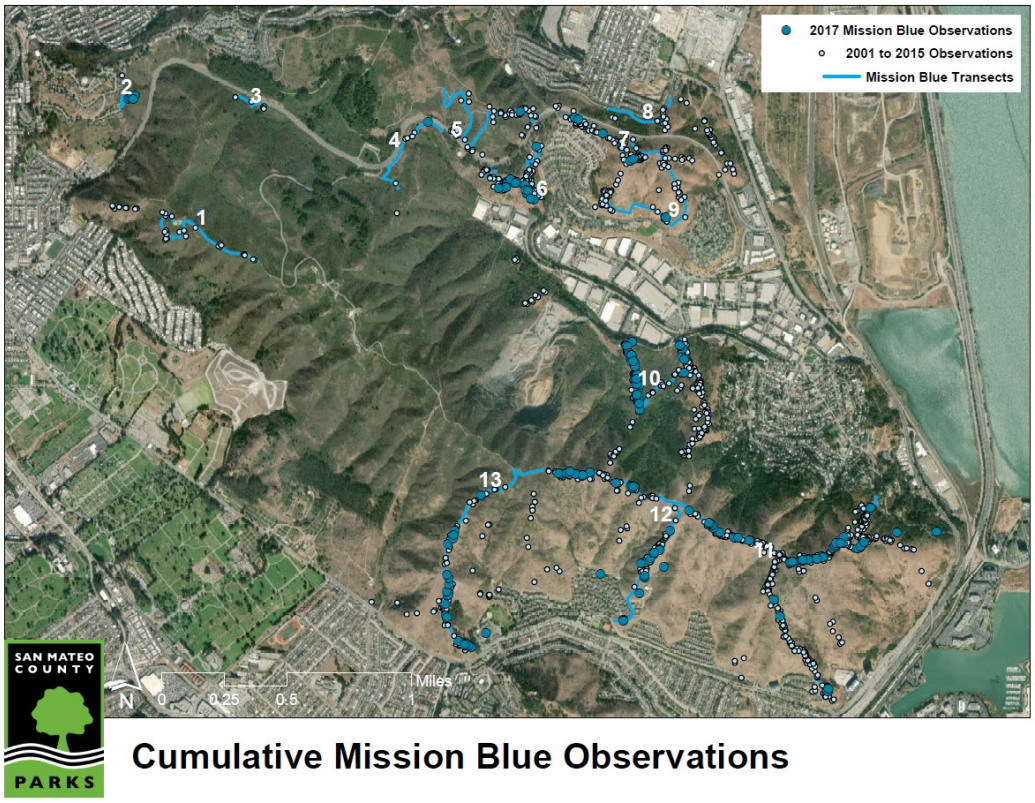


5/28/82

FIGURE II-1
STUDY AREA BOUNDARIES

4/15/83


Village
Reservoir Hill
Saddle
North Saddle
PG&E Substation
Colma Creek
Carter-Martin
West Peak
April Brook
Wax Myrtle Ravine
Northeast Ridge
Dairy Ravine
Olivet Ravine
Devil's Arroyo
Serbian Ravine
Quarry
Owl Canyon
Buckeye Canyon
Poison Oak Ravine
Brisbane Acres
South Slope West
Hillside
South Slope East
Southeast Ridge
SAN MATEO COUNTY
PARKS
N
0
0.25
0.5
1
Miles
SBM HCP Management Units
Management Units


2017 Mission Blue Observations
2001 to 2015 Observations
Mission Blue Transects
1
2
3
4
5
6
7
8
9
10
11
12
13
SAN MATEO COUNTY
PARKS
N
0
0.25
0.5
1
Miles
Cumulative Mission Blue Observations

Conclusion:

After reviewing the best available scientific information, we conclude that mission blue butterfly remains an endangered species. The evaluation of threats affecting the species under the factors in 4(a)(1) of the Act and analysis of the status of the species in our 2010 5-year review remains an accurate reflection of the species current status.

RECOMMENDATIONS FOR FUTURE ACTIONS:

We recommend the following actions, including some from the 2010 5-year review or the 2019 recovery plan amendment that remain valid:

1. **Create a mission blue butterfly working group or Recovery Implementation Team.** Recent mission blue butterfly regional summits in January 2019 (Root Wisdom 2019) and 2021 included many partners and presentations, and continued regular coordination would likely benefit recovery of the species. Synergies between the regional mission blue butterfly partners and other groups working on other *Icaricia icarioides* subspecies (*e.g*., Fenders blue and Puget Sound blue butterflies), or other rare or at-risk butterfly species, are likely to be beneficial towards advancing recovery objectives.
2. **Establish captive breeding, rearing, or headstarting of mission blue butterflies at a captive breeding facility and create plans for population augmentation and reintroduction.** This action will assist in the recovery of mission blue butterflies by further protecting existing populations and allowing for population augmentation in an effort to maintain and re-establish self-sustaining populations to persist in the long-term. Permitting and construction of a facility that is expected to include mission blue butterflies is underway; this facility will hold other listed species as described in Service (2020b, p. 62). Captive rearing of other closely related butterflies could be useful to inform methods for the facility, when appropriate. Captive rearing Puget blue butterflies (*Icaricia icarioides blackmorei*) (a subspecies of the mission blue butterfly species) collected eggs from the wild and used eggs laid by females brought into captivity (Schultz *et al*. 2009, p. entire). Laboratory rearing of the Karner blue butterfly (*Lycaeides melissa samuelis*), also in the Lycaenidae family, collected wild adults in the spring and reared eggs and larvae in growth chambers (Herms *et al*. 1996, entire).
3. **Follow best practices for conservation translocations.** Translocations of at-risk butterflies are discussed in Daniels *et al*. (2018), which were developed and tested based on the International Union for Conservation of Nature's Guidelines for Reintroductions and Other Conservation Translocations (IUCN 2013). Current translocation methods should be adapted to more closely align with these guidelines.
4. **Continue population viability analyses for metapopulations of the mission blue butterflies, and/or analyses of existing butterfly monitoring data.** This action will assist in the recovery for the species by determining the target populations, minimum populations, or occupancy at each population or metapopulation site needed to achieve recovery criteria.
5. **Continue lupine propagation and diversification across the range of the mission blue butterfly.** Lupine diversification research and techniques are important for successfully establishing multiple lupine host plant species at all sites.

6. **Continue efforts to understand egg phenology and oviposition rates in mission blue butterflies.** This information will improve our interpretation of egg monitoring data from monitoring mission blue butterflies at some sites.
7. **Monitor habitat needs for sites where quantitative data are not readily available.** For some recovery criteria where status in relation to the recovery criteria is unclear or possibly met, particularly those relating to grassland acreage and nectar plants, additional data collection or analysis may help track progress towards recovery. Information needs include: quantification or mapping of nectar plants, and mapping or analysis of grassland acreage and trends.
8. **Continue habitat restoration and connectivity efforts.** Scrub encroachment continues to reduce and fragment available mission blue butterfly habitat across the range of the species.

Field Supervisor, Sacramento Fish and Wildlife Service

Approve MICHAEL FRIS Digitally signed by MICHAEL FRIS Date: 2022.03.31 12:17:01 -07'00' _____ Date _____

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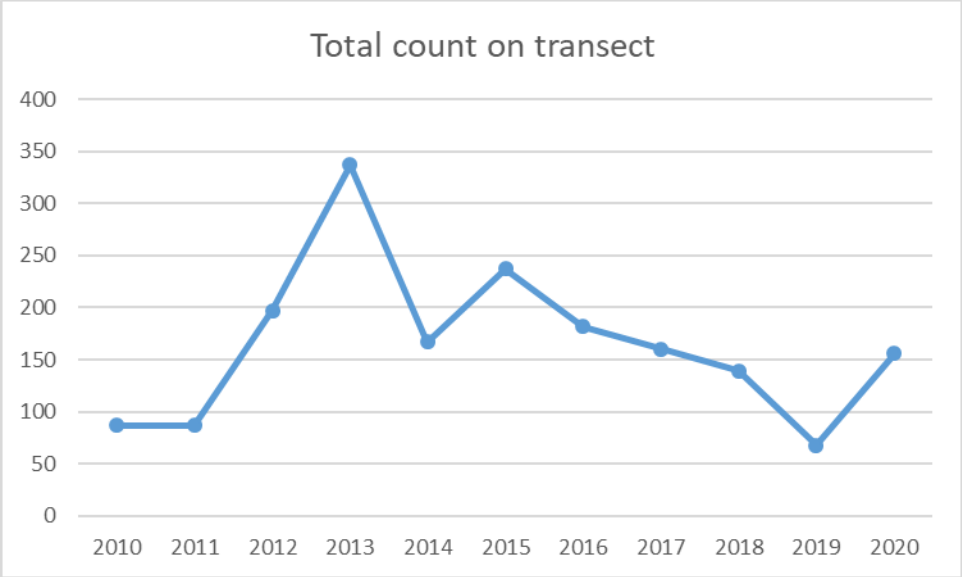
APPENDIX A

As discussed in the **Distribution and abundance** section of this status review, this appendix provides information on site-specific monitoring for mission blue butterflies. Locations are organized geographically from North to South.

Oakwood Valley

Mission blue butterflies were taxonomically identified as such in Arnold and Lindzey (2003, entire). The 2019 survey marked the lowest number of mission blue butterflies observed on transects since they were initiated in 2010 (Macias and Crooker 2019, p. 11), although the numbers rebounded in 2020 (Shaw and Crooker 2021a, p. 9) (Figure A1). The peak abundance of mission blue butterflies during the monitoring period has declined slightly since 2010 (Shaw and Crooker 2021a, p. 9).



Marin Headlands

Mission blue butterfly monitoring at the Marin Headlands has taken place annually from 1994 through present, with the exception of 2007. From 1994 through 2014, monitoring occurred on 17 permanent transects within five regions on the Marin Headlands, with the highest numbers prior to a fungal pathogen outbreak in 1998. Beginning in 2008, monitors began recording mission blue butterflies observed off-transect as well as those on the fixed transects, although the informal nature of these observations makes comparisons difficult. Reports suggested that low abundances recorded on-transects (after initial improvement following the 1998-2002 rapid decline) were in part because of habitat change, with transects no longer tracking available lupine habitat (Bennett 2014, p. 10).

A new monitoring method was implemented in 2015 using a presence-absence grid method in 250 m^2 grid cells (Figure A2). Priority, secondary, tertiary, or auxiliary rankings were assigned based on historical occupancy and perceived habitat condition in 2015 and the first year of occupancy surveys in 2016; auxiliary cells are adjacent to cells with other rankings and visited as

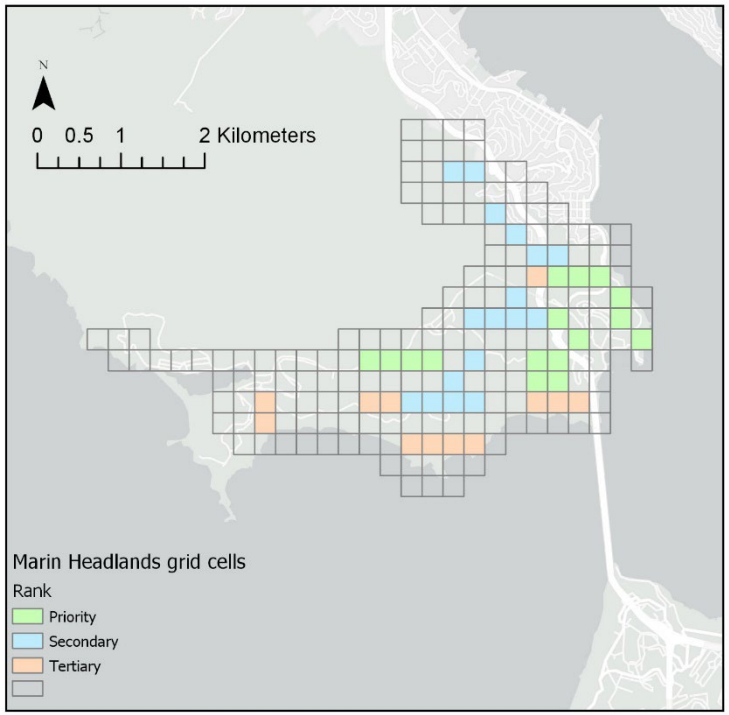


Figure A2. Mission blue butterfly 250 m^2 grid cells for occupancy surveys in the Marin Headlands beginning in 2015. Figure shows priority, secondary, and tertiary rankings; auxiliary cells are adjacent to other ranked cells. Data from Golden Gate National Recreation Area.

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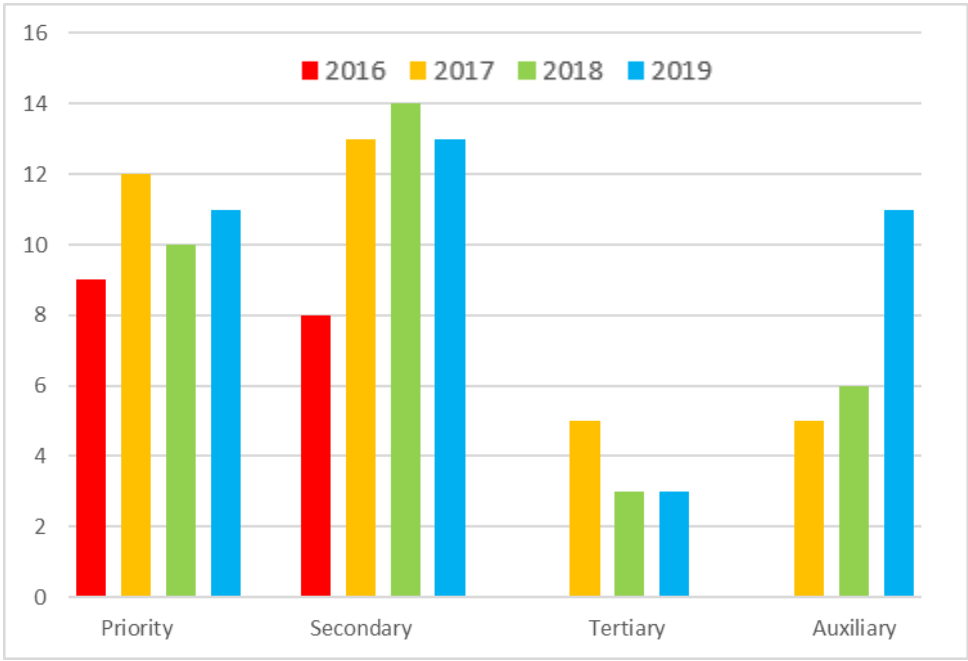

Figure A3. Number of occupied grid cells in the Marin Headlands by year and priority ranking. Data from Coast Ridge Ecology (2019, p. 9).

time allowed. Grid cells were surveyed based on ranking and visited up to three times per season. If a positive detection was made within a cell, the cell was considered occupied and the biologist moved on to other cells in an effort to survey as many cells as possible during the flight season (Coast Ridge Ecology 2019, pp. 1–2). A comparison of surveys conducted from 2016-2019 found the highest number of occupied cells (38) in 2019. Occupancy in priority and secondary cells was consistently high over the last four years, and the increase in occupancy in 2019 was largely in auxiliary cells (Figure A3; Coast Ridge Ecology 2019, pp. 6–10).

Twin Peaks

Although the Twin Peaks translocation success has been measured using surveys of adult, larval, larval feeding, and egg surveys throughout the project period, in 2016 the main monitoring method switched to annual counts of eggs using a stratified random design (Weiss et al. 2017, p. 6). Briefly, egg counts are conducted on 30 random lupine plants in each of 4 management areas on Twin Peaks, extrapolated to total egg estimates by multiplying based on the number of lupine across the site, and converted to mission blue butterfly adult females by dividing the number of estimated eggs by 80 estimated eggs per female to give the number of estimated females (Table A1). The number of lupines were based off of lupine censuses in 2013 and 2018, with the most recent available map used in each of the reports (Weiss et al. 2018, p. 5; Weiss et al. 2019, p. 7). Eggs are not distributed evenly across the site, with variation across the management areas. In 2016, eggs were found on 22.2 percent of randomly searched lupine (Weiss et al. 2017, p. 5); this percentage is not reported in more recent annual reports.

Both fresh eggs and hatched eggs are counted during egg counts, and from 2016 through 2018, data collection and analysis assumed complete turnover of eggs between sampling periods. In 2016 and 2017, hatched eggs were included in the egg counts and extrapolation to estimated number of females. The 2016 report stated that shells from hatched eggs only last a few days after hatching and can represent a high proportion of eggs over the sampling period (Weiss et al. 2017, p. 6). The 2019 report included an analysis comparing the number of fresh vs. hatched eggs observed in surveys from 2017 through 2019 (Weiss et al. 2020, p. 9–11). Also in this report, Weiss et al. (2020, p. 7) revised the estimated number of females from the 2017 report to only include data from fresh eggs (and to exclude hatched eggs from the estimate); the revised estimated number of females using the extrapolations in the preceding paragraph was 89, down from 173.

Egg counts were delayed in 2020 because of local shelter-in place orders and occurred after translocations of adult mission blue butterflies from San Bruno Mountain. Because of the late start, over 4 times as many hatched eggs were observed compared to fresh eggs, and the combination of both fresh and hatched eggs was again used in the estimation of total females on the site (Weiss et al. 2021, pp. 6–7). Weiss et al. (2021, p. 7) states that the 2020 female estimate should be considered more uncertain than those from previous years because of the late survey start date and the inclusion of both fresh and hatched eggs.

Table A1. Total number of eggs counted across the survey periods from 2016 through 2020. Total number of eggs counted are "fresh" eggs (not hatched) on 30 random lupine plants across approximately weekly surveys (time between surveys and number of surveys varied across years). Note that in the 2017 report number of fresh eggs and hatched eggs was included in the estimate of females in that year, which was corrected in the 2019 report.

	Total number of eggs counted	Number of count periods	Estimated number of females	Source
2016	491	8	61	Weiss et al. 2017, p. 8
2017	474	4	89	Weiss et al. 2020, p. 7
2018	164	9	37	Weiss et al. 2019, p. 5
2019	368	10	75	Weiss et al. 2020, p. 8
2020	354	6	78	Weiss et al. 2021, p. 7

Adult surveys conducted in 2014, 2015, and 2016 resulted in an observed 18 males and 5 females (Weiss et al. 2014, p. 6), 15 males and 6 females (Weiss et al. 2016, p. 8), and 11 males and 2 females, respectively (Weiss et al. 2017, p. 3). Different numbers of survey attempts were conducted in the various years, and translocations in 2015 and 2016 may have partially overlapped with some surveys. In recent years, observations of adults have occurred incidentally: 2 mission blue butterfly adults were observed in 2018 (Weiss et al. 2019, p. 3) and 1 adult was observed in 2019 (Weiss et al. 2020, p. 3).

San Bruno Mountain

Surveys at San Bruno Mountain are conducted biennially in odd years using fixed transects created on high quality habitat in 2006. Average and maximum sightings per hour are presented in Figures A4 and A5, respectively. In 2019, no mission blue butterflies were observed in transects 1, 2, 3, 4, 5, and 8 (Cole 2020, p. 18). The Southeast Ridge and South Slope continue to provide habitat for the species (Cole 2020, p. 21).

The western portion of San Bruno Mountain has had notable declines in mission blue butterfly observations since 2013, which is likely related to scrub encroachment and declines in high quality grassland habitat. San Bruno Mountain Watch estimated that grassland habitat was being converted to coastal scrub at a rate of 5 acres per year from 1982 to 2007 (TRA Environmental Sciences 2008, p. III-3). A 2015 assessment indicated that grassland loss through 2002 occurred at a rate of 9.5 acres per year. Using this rate, they estimated that grassland acreage had decreased from 1,419 acres to an estimated 1,180 acres because of encroachment or succession since the Habitat Conservation Plan was approved in 1983. This estimate was conservatively high based on the mapping technique; a corrected estimate assuming an overestimation in a 2002 mapping process yielded 944 acres (Weiss et al. 2015, pp. 45–55, 57). It is unclear to what extent scrub encroachment has impacted mission blue butterfly population abundance in relation to site-wide estimates of 18,000 individuals in 1981 (Thomas Reid Associates 1982, p. III-4).

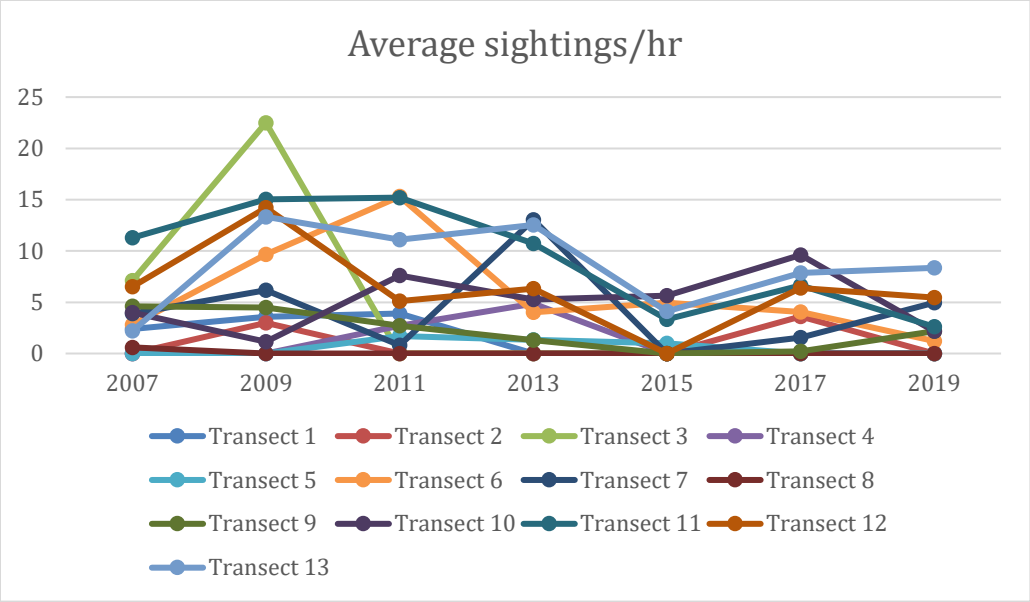

Figure A4. Average sightings per hour at fixed transects on San Bruno Mountain during biennial surveys conducted from 2007 through 2019 (data from Cole 2020, p.18).

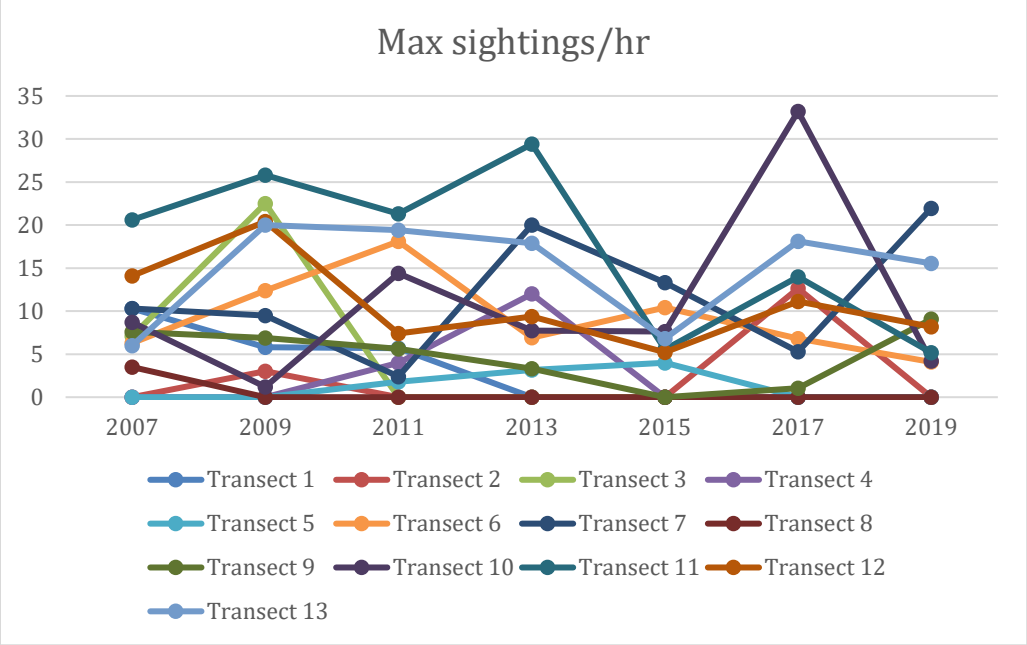

Figure A5. Maximum sightings per hour at fixed transects on San Bruno Mountain during biennial surveys conducted from 2007 through 2019 (data from Cole 2020, p. 18).

Milagra Ridge

Monitoring at Milagra Ridge includes: fixed transects surveyed for mission blue butterfly adults every 8 to 10 days; fungal pathogen monitoring of silver lupine; nectar species monitoring; and egg surveys (Shaw and Crooker 2021b, pp. 4–8). Thirteen fixed transects were established in 1995, one was decommissioned in 2006 due to lack of observations for over a decade, and three were added in 2012 (summarized in Shaw and Crooker 2021b, p. 4). Of the 15 transects

surveyed in 2020, 10 are 50 m in length and 5 are 100 m in length (Shaw and Crooker 2021b, p. 6). Observations from fixed transects are shown in Figure A6.

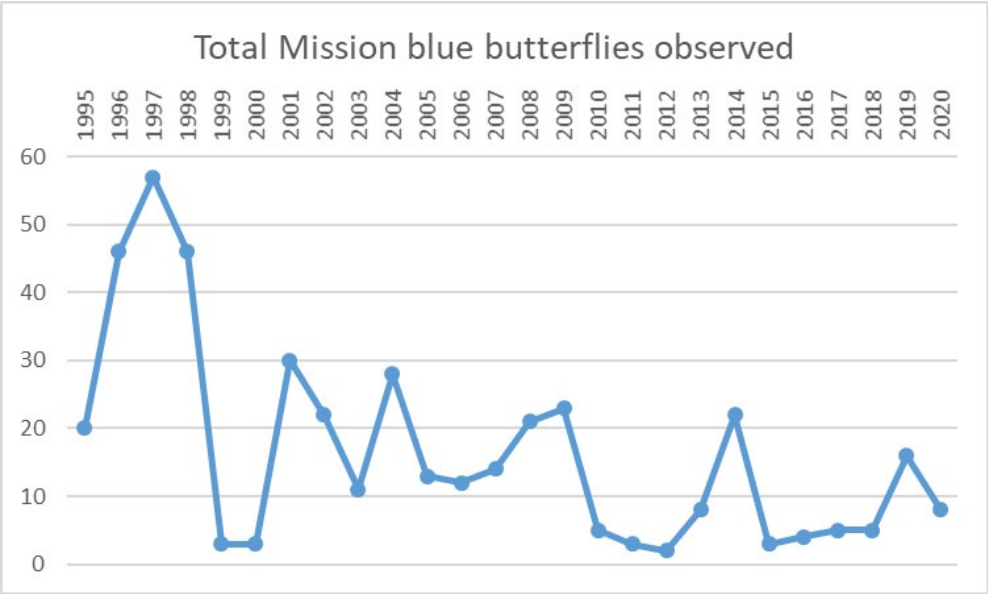

Figure A6. Milagra Ridge mission blue butterfly adults observed on-transect (data from Shaw and Crooker 2021b, p. 9). The large decline in the late 1990's is associated with a fungal pathogen outbreak. Translocations of adults from San Bruno Mountain occurred each year from 2017 through 2020.

Analysis of egg counts using similar methodology to that described above for Twin Peaks, in combination with the observation of post-diapause larvae, suggests that resident females have been established on several transects at Milagra Ridge. For example, the number of eggs found on several transects exceeded the number of eggs that would be expected from translocated females, and eggs were found on transects that did not have translocations. Parameters in INCA were manually fit for the Milagra Ridge data because of small sample sizes, compared to default parameters used with Twin Peaks data (Weiss 2019, p. entire).

Sweeney Ridge

The last positive detection of mission blue butterflies at Sweeney Ridge occurred in 1987; no mission blue butterflies were observed during surveys in 2016 or 2019 (Bennett and Russo 2016, p. 4; Coast Ridge Ecology 2019, p. 4).

San Francisco Peninsula Watershed

Surveys within the San Francisco Peninsula Watershed (SFPW) have been conducted annually since 2003. Monitoring in recent years included surveys for eggs, larvae, and adult mission blue butterflies at 23 established sites on the Fifield-Cahill Ridge service road, and presence-absence surveys to determine mission blue butterfly occupancy at host plant locations throughout the rest of the SFPW.

Mission blue butterfly adult counts across the season are shown in Figure A7. Watershed-wide host plant surveys and mapping continue to identify areas with lupine species. Mission blue butterfly presence was determined at 85 out of 158 host plant patches in 2017, 86 out of 167 patches in 2018, and 89 out of 170 patches in 2019. The increase in host plant patches surveyed each year for occupancy is a result of increased host plant mapping. Most mission blue butterfly

observations occurred on summer lupine, with limited activity on manycolored lupine; the species has not been observed using surveyed patches of silver lupine since 2013 (Coast Ridge Ecology 2018, p. 3).

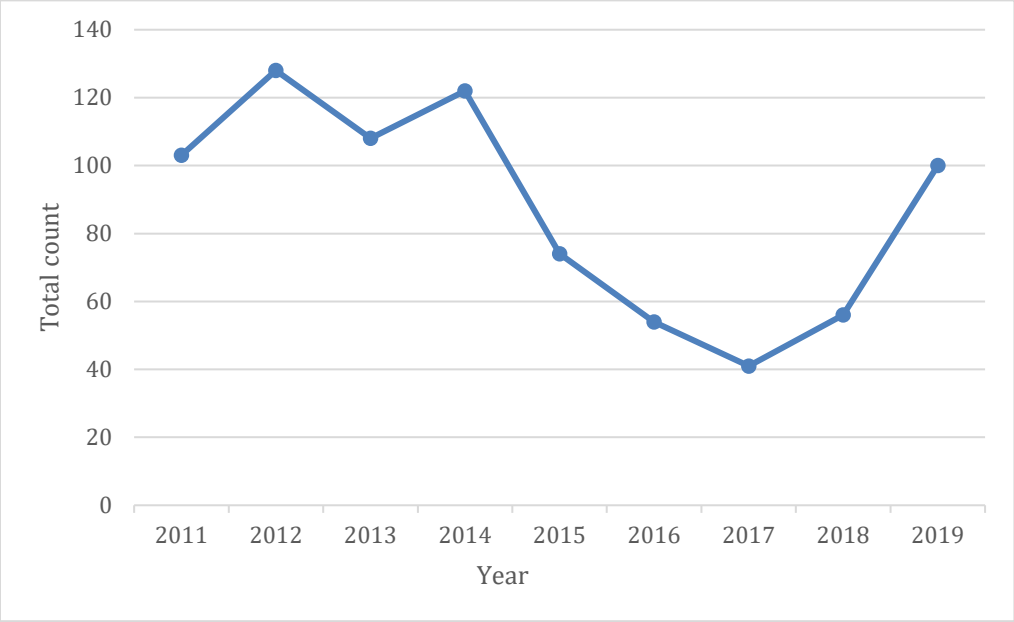

Figure A7. Mission blue butterfly adult count total across the flight period from 2011 to 2019. Data from annual reports (Arnold 2011-2015, Coast Ridge Ecology 2015-2019).

Reports also include counts of mission blue butterfly eggs and larvae. We do not include that information here because reports note that egg counts may not be entirely attributable to mission blue butterflies (because of observed oviposition of nearly identical acmon blue butterfly eggs on summer lupine during mission blue butterfly surveys) (Coast Ridge Ecology 2019, p. 11) and that larvae may have been counted multiple times on subsequent visits (Coast Ridge Ecology 2019, p. 12).