Species Status Assessment for the Hermes copper butterfly (*Lycaena* [*Hermelycaena*] *hermes*) Version 1.1

Hermes copper butterfly. Photo credit Mike Couffer (used with permission).

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Executive Summary

The Hermes copper butterfly is a small-sized butterfly currently found in San Diego County, California, United States, and northwestern Baja California, Mexico. The Hermes copper butterfly has been a candidate for listing under the Endangered Species Act of 1973, as amended (Act), since the 12-month finding published in 2011 (Service 2011). This Species Status Assessment (SSA) is an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain species viability. We begin the SSA with an understanding of the species' unique life history, and from that evaluate biological requirements at the scales of individuals, populations, and species using the principles of population resilience, species redundancy, and species representation. All three concepts (or analogous ones) apply at both the population and species levels, and are explained that way below for simplicity and clarity as we introduce them.

While most recent scientific studies support recognition of Hermes copper butterfly as belonging to the monotypic genus *Hermelycaena,* Hermes copper butterfly was recognized as *Lycaena hermes* (subgenus Hermelycaena) in the peer-reviewed taxonomic treatment (Pelham 2008, p. 191). Therefore, we recognize Hermes copper butterfly as *Lycaena hermes* throughout this assessment and subsequent documents. Adults are active May through July, when females deposit single eggs exclusively on *Rhamnus crocea* shrubs (spiny redberry; Thorne 1963, p. 143; Emmel and Emmel 1973, p. 62) in coastal sage scrub and chaparral vegetation. Adult occupancy and feeding are also associated with presence of the shrub *Eriogonum fasciculatum* (California buckwheat).

The conceptual model presented here is the result of collaboration among a working group of local experts (Lewison *et al.* 2012, pp. 46–55; Strahm *et al.* 2012, pp. 8–16; Figure 3; Appendix I). The working group set management and monitoring goals to guide model construction; the management goal was to ensure persistence throughout the range.

Species resource needs include movement corridor connectivity among populations or sub-populations to maintain metapopulation dynamics. Species-level redundancy can be

characterized as relatively low. Out of 95 historically recorded occurrences, there are currently 45 considered or presumed extant. In order to maintain viability, the species should be represented by populations distributed in a variety of habitats so that some populations are always experiencing environmental conditions that support reproductive success. Populations should be represented across a continuum of elevation levels from the coast (approximately sea level) to the mountain foothills approximately 1,340 meters (m) (4,400 feet (ft)) in elevation. In the United States, there is currently only one known extant occurrence with marine climate influence, three with montane climate influence, and the remainder at intermediate elevations and a more arid climate.

While Hermes copper butterfly permanent population and habitat loss due to development is still a significant stressor, and population numbers have been depressed by the recent drought (one monitored core population was not detected in 2017 or 2018; Marschalek and Deutschman 2017 p. 9; Marschalek 2018, pers. comm.), the primary cause of population loss over the past 15 years has been wildfire. It is well-documented that wildfires in occupied Hermes copper butterfly habitat result in loss of Hermes copper butterflies (Klein and Faulkner 2003, pp. 96, 97; Marschalek and Klein 2010, pp. 4, 5). Additionally, wildfires are considered a factor in 35 estimated historical occurrence extirpations, only one of which occurred before 2003, and only four of which appear to have been naturally re-established (Table 1). Hermes copper butterflies rarely survive wildfire because all immature life stages inhabit host plant foliage, and spiny redberry typically burns to the ground and resprouts from stumps (Deutschman *et al.* 2010, p. 8; Marschalek and Klein 2010, p. 8). The primary means to reduce and mitigate the stressor of wildfire is thought to be assisted recolonization. Eggs and adults were translocated in 2015 to a burned area where the species had been extirpated and at least one adult was observed there in 2016, but there were no documented breeding or adult detections in 2017 or 2018. Thus, the outcome of the translocation experiment remains uncertain.

We analyzed fire frequency data to determine the effect on occurrence status and likelihood of extirpation over the next 30 years. During the past 15 years (2002–2017), there were six megafires within Hermes copper butterfly's possible historical range, a significant increase compared to none during the two previous 15 year periods (1987–2001 and 1972–1986), and only one during the 15-year period prior to 1972. This represents a more than six-fold increase in the rate of megafire occurrence over the past 15 years. At the current megafire rate (6/15 years), 12 megafires could impact Hermes copper butterfly over the next 30 years, and that assumes no further increase in the rate. If the trend does not at least stabilize, the frequency of megafires could continue to increase with even more devastating impacts to the species.

In the absence of data required for a population viability analysis, we determined the best quantitative analysis was a relatively simple viability index. In our index calculations, the contribution of a population to species-level redundancy depends on likely population resilience, and contribution to representation depends on how rare a population is in the habitat type it occupies. In this model, species redundancy and representation are assumed to equally influence species' viability. We assign a 100% species viability index value to the baseline state of all known historical population occurrences in the United States. Our index of species' viability uses population resilience, species redundancy, and species representation to quantify changes in species' viability, but does not predict probability of persistence.

Using our viability index, we estimated the species currently retains not more than 43% of its estimated historical viability. We present changes to the species viability index under four possible future conditions, including stressor-mitigating measures resulting in no change. One potential future scenario would be a continued warming, drying trend and an inability to minimize wildfire impacts or assist recolonization. Resulting changes to the population redundancy and representation model values would cause an approximate drop from 43% to 14% species viability relative to historical conditions. If there was a megafire comparable to the 1970 Laguna Fire, many occurrences would likely be extirpated, and due to the number of occurrences already lost, the likelihood of recolonization would be low. These changes would result in an approximate drop in species viability relative to historical conditions from the current 43% to 24%. In the most positive, but least likely, potential future scenario environmental stressors such as fire and drought decrease in frequency and magnitude relative to the past 30 years, and management actions such as continued conservation and translocation efforts are fully successful. This final scenario resulted in an increase from 43% to 68% species viability relative to presumed historical conditions.

It is clear Hermes copper butterfly has lost significant viability over the past 50 years. Many populations lost since 2002 have not been recolonized or replaced. While we know fire, drought, and climate change are serious stressors that continue to affect species viability, we have much to learn about the species ecology, making the probability of unexpected ecological emergent properties and overall uncertainty level for future condition relatively high, While we estimated Hermes copper butterfly has lost approximately 43% of its known historical species-level viability, it is important to keep in mind that even if environmental conditions remain unchanged, the species may continue to lose populations, so that viability declines by virtue of maintaining the current trend.

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1.1 Introduction

The Hermes copper butterfly is a small-sized butterfly currently found in San Diego County, California, United States, and northwestern Baja California, Mexico. The Hermes copper butterfly has been a candidate for listing under the Endangered Species Act of 1973, as amended (Act), since the 12-month finding published in 2011 (Service 2011). The Species Status Assessment (SSA) is intended to be an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability.

1.2 Methods and Background

This document draws scientific information from resources such as primary peer-reviewed literature, reports submitted to the U.S. Fish and Wildlife Service (Service) and other public agencies, species occurrence information in GIS databases, and expert experience and observations. It is preceded by, and draws upon analyses presented in other Service documents, including the 12-month finding (Service 2011) and the Species Assessment and Listing Priority Assignment Form associated with the most recent Candidate Notice of Review (Service 2015). Finally, we coordinate closely with our partners engaged in ongoing research and conservation efforts. This assures consideration of the most current scientific and conservation status information.

1.3 Analytical Framework

The SSA analytical framework is designed for assessing a species' biological condition and level of viability. The document is temporally structured, walking the reader through what is known from past data, how data inform current species' status, and what potential changes to this status may occur in the future based on data and models. The future condition analysis includes the potential conditions that the species or its habitat may face and discusses the most probable scenarios if those conditions come to fruition. These most probable scenarios includes consideration of the sources most likely to impact the species at the population or rangewide scales in the future, including potential cumulative impacts.

For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in the natural ecosystem beyond a biologically meaningful timeframe—in this case, 30 years. We chose 30 years because it is within the range of the available climate change model forecasts, fire hazard period calculations, vegetation association fire return intervals, and uncertainty terms used by the IPCC (see below discussions for more details). Additionally, 30 years encompasses approximately 30 generations of Hermes copper butterflies, the length of time we are confident estimating the likelihood of future scenarios for this species, given its short life span and our ability to predict environmental changes. Using the SSA framework (Figure 1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of resilience, redundancy, and representation (Wolf *et al*. 2015, entire).

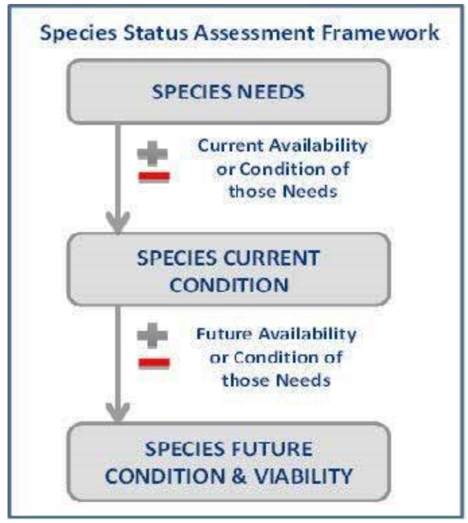

Figure 1. Flowchart of Species Status Assessment framework.

We begin an SSA with an understanding of the species' unique life history, and from that evaluate a species' resource needs or biological requirements at the scales of individuals, populations (in this document we discuss "occurrences," because population distributions for the Hermes copper butterfly are not well mapped or understood in some areas), and species using the principles of resilience, redundancy, and representation These three concepts (or analogous ones) apply at the population and species levels, and are explained that way below for simplicity and clarity as we introduce them.

1. <u>Redundancy</u> at the population level can be quantified by the range within which population size naturally fluctuates (see <u>Climate Change and Drought sections</u> below for

Hermes copper butterfly population fluctuation discussion). Species-level redundancy is quantified by the range within which the number of populations in a species' range fluctuates. Redundancy spreads risk among multiple individuals or populations to minimize the potential loss of the population or species from catastrophic events.

2. Representation has two components: genetic and environmental. It is defined by the amount of genetic and habitat diversity within a population distribution (population-level representation) and among populations within the species' range (species-level representation).
3. Resilience is the capacity of a population or species to withstand stochastic disturbance events, that is, to rebound from relatively extreme numerical lows (individuals at the population-level and populations at the species-level) during a given time period. Resilience depends primarily, or entirely, on representation and redundancy. Population-level resilience depends on the minimum size of a population within its natural range of fluctuation and on how diverse the existing gene pool and occupied habitats are (determines the likelihood of persistence). Species-level resilience depends on the minimum number of populations within a species' natural range of fluctuation, and on degree of genetic and habitat diversity among them. All else being equal, average resilience over a given time period does not change, regardless of a species' current size and distribution. The only time average resilience shifts is when all else is not equal, and the minimum population size or number of populations within its range of fluctuations over that period is reduced by longer-term changes in environmental circumstances. The quantitative concept of population viability (calculated in population viability analyses) is the probability that a population will be extirpated within a given number of years. In this context, it is qualitatively equivalent to population-level resilience, and analogous to species-level resilience. Because in species status assessments we analyze what the species needs to maintain viability, species-level resilience will be hereafter referred to as "species viability." Another way to describe a species' viability is the ability of a species to sustain populations in the wild; by increasing viability, species-level extinction risk is reduced (Wolf *et al.* 2015, p.204).

Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of the resilience of its populations and its redundancy and representation.

1.4 Modeling

We include a conceptual model created as a product of a workshop convened by the Institute for Ecological Monitoring and Management (Lewison *et al.* 2012, pp. 46–55; Strahm *et al.* 2012, pp. 8 –16). This workshop brought together species and ecology experts from around southern California to create conceptual ecology models for species of concern. This model illustrates interactions among species' biological attributes, resources, and stressors.

We also constructed a relatively simple viability index (see **Species Viability Index** below). In our index calculations, the contribution of a population to species-level redundancy depends on its resilience, and contribution to representation depends on how rare populations are in the habitat type it occupies. Species redundancy and representation are assumed to equally influence species' viability. Our index of species' viability is proportional to, but not equal to, the ability of a species to sustain populations in the wild, and therefore inversely proportional to extinction risk. Because we do not know the baseline extinction risk represented by the historical "100% viability" index value, the index is useful for estimating percent change in species extinction risk, but is not a direct measure of it. It is also important to note that there can be thresholds related to synergistic factors that the viability index does not consider that, once crossed, may disproportionally increase extinction probability.

Chapter 2. Ecology

2.1 Background

2.1.1 Description

The Hermes copper butterfly (*Lycaena hermes*) is a small, brightly-colored butterfly in the family Lycaenidae. It is approximately 2.5 to 3.2 centimeters (cm) (1 to 1.25 inches (in)) in length, with one tail on the hindwing. The forewing upperside is brown with a yellow or orange area enclosing several black spots, and the hindwing upperside has orange spots that may be merged into a band along the margin. On the underside, the forewing is yellow with four to six black spots, and the hindwing is orange fading to almost white with three to six black spots (USGS 2006; Marschalek 2017, pers. comm.). Mean last instar (caterpillar life stage between molts) larval body length is 15 millimeters (mm) (0.6 in) (Ballmer and Pratt 1988, p. 4). Emmel and Emmel (1973, pp. 62, 63) provide a full description of the early stages of the species (eggs, larvae, and pupae).

2.1.2 Taxonomy and Nomenclature

Hermes copper butterfly was first described as *Chrysophanus hermes* by Edwards (1870, p. 21). Scudder (1876, p. 125) then placed this species in the genus *Tharsalea* based on the presence of hindwing tails. Freeman (1936, p. 279) placed Hermes copper butterfly in the genus *Lycaena* based on the assessment of the male genetalia, finding it was distinctly a lycaenid and not typical of the other taxa of the genus *Tharsalea.* Miller and Brown (1979, p. 22) erected a monotypic genus to accommodate Hermes copper butterfly as *Hermelycaena hermes.* Its unique use of a host plant in the Buckthorn family, Rhamnaceae, the broadly-based morphological assessment of Miller and Brown (1979, p. 97), the allozyme work of Pratt and Wright (2002, p. 225), and the larval morphology analysis of Ballmer and Pratt (1988, pp. 4), have been used to support recognition of Hermes copper butterfly as belonging to the monotypic genus *Hermelycaena* (Shepard and Guppy 2001, p. 188; Marschalek 2015a, pers. comm.). Furthermore, recent mitochondrial DNA work indicates the Hermes copper butterfly ancestor evolved first in North America, then spread to Asia and evolved to *Phoenicurusia* and other genera (Yago in Faulkner and Klein 2012, p. 28). This means Hermes copper butterfly is an isolated "relict species," with its closest modern, more derived, relatives found in Asia (not in the genus *Lycaena*). Nevertheless, Hermes copper butterfly was recognized as *Lycaena hermes* (subgenus Hermelycaena) in the peer-reviewed taxonomic treatment (Pelham 2008, p. 191). The name *Lycaena hermes* is also predominantly used in other literature (Scott 1986, p. 392; Faulkner and

Brown 1993, p. 120; Emmel 1998, p. 832; Opler and Warren 2005, p. 22; Marschalek and Deutschman 2008, p. 97; Marschalek and Deutschman 2009, p. 400; Marschalek and Klein 2010, p. 1); and Pelham 2012. Therefore, we recognize Hermes copper butterfly as *Lycaena hermes* throughout this assessment and subsequent documents. In this document, we have corrected the nomenclature used in past assessments. In some instances the name may be written as *Lycaena* [*Hermelycaena*] *hermes*, for historical clarity. Hermes copper butterfly has always been recognized as a distinct species regardless of what genus it has been assigned to. No nomenclatural changes have affected its description, range, or threat status.

2.1.3 Habitat and Life History

Hermes copper butterflies are active May through July, when females deposit single eggs exclusively on *Rhamnus crocea* (spiny redberry; Thorne 1963, p. 143; Emmel and Emmel 1973, p. 62), often where a branch splits or on a leaf (Marschalek and Deutschman 2009, p. 401; Figure 2). In 2014, researchers typically only found one egg per shrub and on one occasion two were observed (Marschalek 2015b, pers. comm.). Eggs overwinter, with larvae reported from mid-April to mid-May (Marschalek and Deutschman 2009, p. 400) followed by pupation on the host plant (Emmel and Emmel 1973, p. 63). Not much is known regarding larval biology, as this life stage is little-studied and extremely difficult to find in the field (Marschalek and Deutschman 2009, pp. 400, 401). Hermes copper butterflies have one flight period (termed univoltine) typically occurring in mid-May to early July, depending on weather conditions and elevation (Marschalek and Deutschman 2008, p. 100; Marschalek and Klein 2010, p. 5). Emergence appears to be influenced by weather; however, this relationship is not well understood. For example, weather conditions in the spring of 2010 were cool and moist and late adult emergence was recorded at monitored sites; however, the spring of 2006 was hot and dry and late emergence was also recorded (Deutschman *et al.* 2010, p. 4).

Hermes copper butterfly individuals diapause (undergo a low metabolic rate resting stage) as eggs during the late summer, fall, and winter (Deutschman *et al.* 2010, p. 4). Although multiple year diapause typically occurs in butterfly species that diapause in stages more advanced than the egg, such as pupae or larvae (Service 2003, p. 8; Gullan and Cranston 2010, p. 169), two year diapause was documented by San Diego State University researchers in 2015. They reported one egg located in the field in January 2014 (deposited in 2013) did not eclose (hatch) until 2015 (Marschalek 2015b, pers. comm.). Two year diapause is unlikely to be common in Hermes copper butterflies, because they diapause as eggs (which cannot store many nutrients). Furthermore, their host plant is a relatively dependable perennial shrub. Butterflies with unreliable annual host plants are more likely to have multi-year diapause, as it allows them to persist through fluctuations in host plant availability, as compared to species like Hermes copper, for which host plant material is always available.

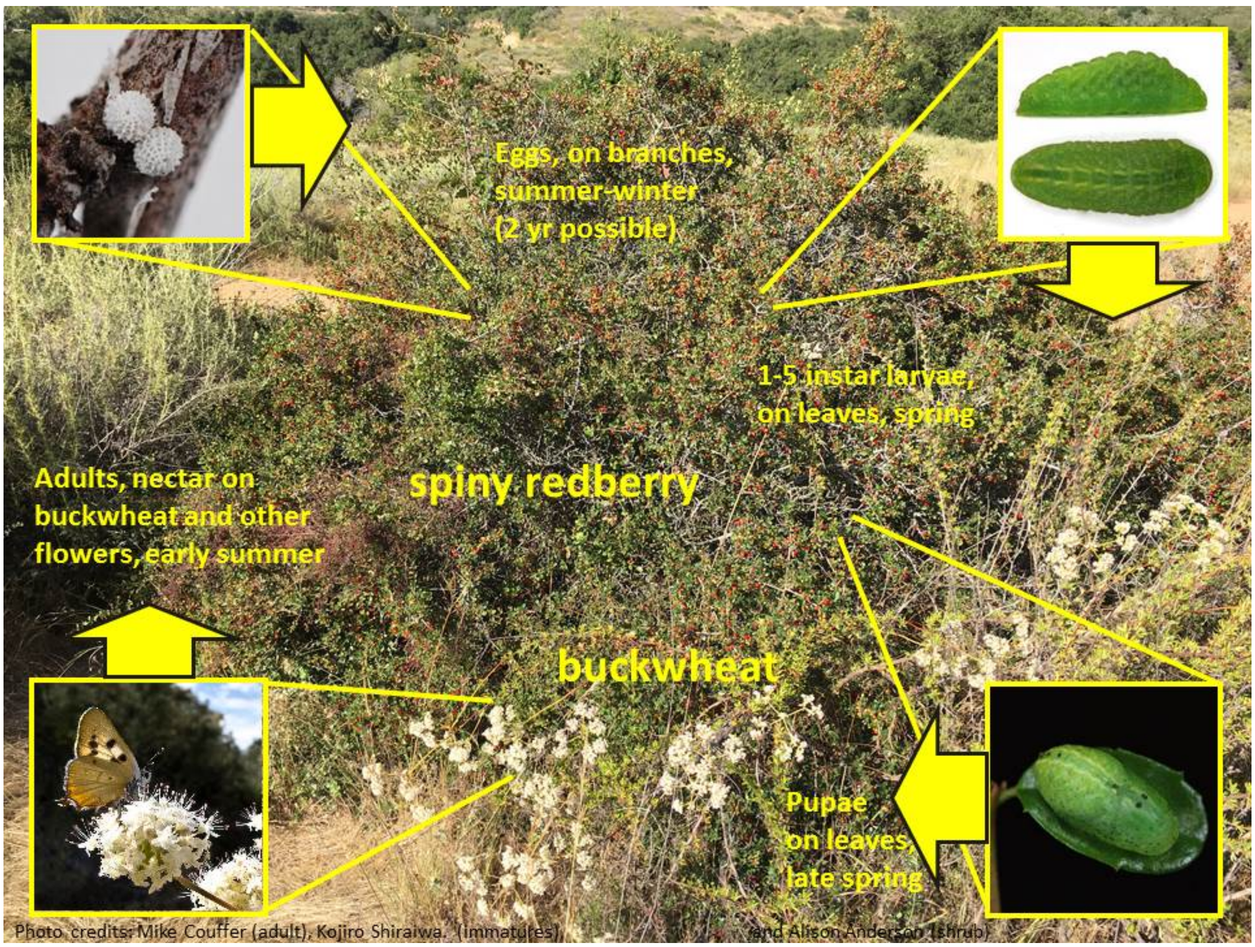

Figure 2. Hermes copper butterfly life cycle.

Hermes copper butterflies inhabit areas of coastal sage scrub and southern mixed chaparral (Marschalek and Deutschman 2008, p. 98). Spiny redberry typically (but not always) occurs in "well-drained soil of better than average depth, yet not deep enough to support trees …along canyon bottoms and on hillsides with a northern exposure" (Thorne 1963, p. 143). The range of spiny redberry extends throughout coastal northern California, as far north as San Francisco (Consortium of California Herbaria 2010); however, Hermes copper butterfly has never been documented north of San Diego County (Carlsbad Fish and Wildlife Office (CFWO) GIS database). Therefore, some unknown factor other than host plant species availability has historically limited or currently limits the range of the species. Researchers report adults are rarely found far from spiny redberry (Thorne 1963, p. 143) and take nectar most frequently from *Eriogonum fasciculatum* (California buckwheat) (Marschalek and Deutschman 2008, p. 5), but they will opportunistically take nectar from other flowering plants in the vicinity. The densities of host plants and nectar sources required to support a Hermes copper population are not known.

Where Hermes copper butterflies occupy stands of spiny redberry, habitat use has been characterized in a number of ways. Marschalek and Deutschman (2008, p. 3) recorded densities of Hermes copper butterfly adults on paired transects along edges and within the interior of host plant stands in rural areas. Their study indicates that Hermes copper butterfly densities are significantly higher near host plant stand edges than in the interior (Marschalek and Deutschman 2008, p. 102). Adult males have a strong preference for openings in the vegetation, including roads and trails, specifically for the north and west sides of canopy openings (Marschalek and Deutschman 2008, p. 102). These areas capture the first morning light and may reach the temperature threshold for activity, around 72 degrees Fahrenheit (°F) (22 degrees Celsius (°C)) (Marschalek and Deutschman 2008, p. 5), more quickly than other areas (Deutschman *et al.* 2010, p. 4). Hermes copper butterflies tend to remain inactive under conditions of heavy cloud cover and cooler weather (Marschalek and Deutschman 2008, p. 5). Across all four sites sampled by Marschalek and Deutschman, Hermes copper butterfly presence was positively associated with California buckwheat, but negatively associated with *Adenostema fasciculatum* (chamise) (Marschalek and Deutschman 2008, p. 102). Therefore, woody canopy openings within stands of spiny redberry and adjacent stands of California buckwheat appear to be characteristic of habitat used by Hermes copper butterfly.

Hermes copper butterflies are typically sedentary, but movement propensity is difficult to measure (Marschalek and Klein 2010, p. 1). They appear to have limited directed movement ability (Marschalek and Klein 2010, p. 1) although lyceanids can be dispersed relatively far by the wind resulting in occasional, but significant, long distance dispersal events (Robbins and Small 1981 p. 312). Marschalek and Klein (2010) studied intra-habitat movement of Hermes copper butterflies using mark-release-recapture techniques. The highest median dispersal distance was 44.5 m (146 ft), and maximum recapture distance was 1.1 kilometers (km) (0.7 mile (mi)) (Marschalek and Klein 2010, p. 1). They found no adult movement across non-habitat areas, such as type-converted grassland or riparian woodland (Marschalek and Klein 2010, p. 6). Studies infer that most individuals typically move less than 200 m (656 ft) (Marschalek and Deutschman 2008, p. 102, Marschalek and Klein 2010, pp. 725–726). Genetic research has not allowed researchers to develop a description of Hermes copper butterfly population structure (Deutschman *et al.* 2010, p. 16; Strahm *et al*. 2012, p. 23; Marschalek *et al.* 2016 pp 327–337). More information is needed to fully understand movement patterns of Hermes copper butterfly; however, dispersal is likely aided by winds, and inhibited by lack of habitat connectivity in many areas (Deutschman *et al*. 2010, p. 17).

2.2 Conceptual Model

Conceptual population ecology models are useful for conservation planning. In February 2012, the Institute for Ecological Monitoring and Management convened a workshop to help local managers and experts develop conceptual models for five topics of regional importance, including the Hermes copper butterfly. The conceptual model presented here is the result of collaboration among a working group of local experts (Lewison *et al.* 2012, pp. 46–55; Strahm *et al.* 2012, pp. 8–16; Figure 3; Appendix I). The working group set management and monitoring goals to guide model construction; the management goal was to ensure persistence throughout the range and the monitoring goal was to address critical biological uncertainties. Abundance of Hermes copper butterfly through all stages of development is likely impacted by land use change, habitat fragmentation, and fire, and to a lesser degree invasive plants, roadkill, recreation, and possibly Argentine ants. Availability of resource needs (spiny redberry and California buckwheat) and suitable environmental conditions also affect productivity of each life stage. The group identified six biological uncertainties (A–F) and four management actions (G–J) important to Hermes copper butterfly persistence (not prioritized):

Biological Uncertainties

A. *Sex Dependent Habitat Use and Dispersal***.** Male and female Hermes copper adults seem to use habitat differently and contribute differently to dispersal, which has implications for reproduction and movement corridor connectivity. It is unclear what triggers dispersal and if dispersal is wind-aided or directed flight. Genetic work suggests landscape features impede movement, but occasional long distance dispersal occurs within the central portion of their range.

B. *Larval Biology and Secondary Diapause*. Very little is known about larval biology, physiology, habitat requirements, and behavior. We have little information on the potential for multiple-year diapause, but given large annual fluctuations in adult population size, it may be a factor. If captive rearing is conducted, a better understanding of larval requirements is needed.

C. *Predators, Parasitoids, and Other Sources of Mortality*. We have little information on predators and parasitoids of Hermes copper butterfly, in part because larvae and eggs are difficult to locate in the field. Two observations of adult mortality have been made in the field, one due to a jumping spider and one by road kill, but frequency of such mortality events is unknown.

D. *Vegetation Community Structure*. In spiny redberry patches, it is not clear what determines when and where Hermes copper will occur. Many seemingly suitable sites are not occupied. These sites may simply be unoccupied as an accident of history, but the possibility that other factors are at work cannot be eliminated. It is also not clear if the distribution of California buckwheat and other nectar sources impact behavior. [Marschalek 2017, pers. comm. clarification: "Prior to the 2003 and 2007 fires, most redberry patches within the Hermes copper butterfly's range were occupied. It seems most patches that have not burned in the last 15 years support Hermes. Now fire is the primary reason for unoccupied redberry patches within the range. It is unknown why Hermes is so restricted compared to redberry"].

E. *Climatic Conditions*. Spring rainfall, temperature regimes, and other factors seem to influence annual population sizes and emergence. They may also represent important factors when considering the potential influence of changing climatic conditions on the species.

F. *Undiscovered Populations and Corridors*. Undiscovered populations of Hermes copper butterfly likely exist, especially on private property. In addition, what constitutes a movement corridor is not yet understood. Defining potential movement corridors can be based on genetics work and the study of dispersal behavior.

<u>Management Actions</u>

Some Management Actions are contingent on biological uncertainties being resolved prior to implementation.

G. *Fire Management*. Possible actions include fuel breaks, fire suppression, fuel manipulation, weed abatement, and other measures to protect occupied spiny redberry stands (such as reducing the risk of ignitions due to recreation) from fire in the short term. [The Service concludes the most effective way to mitigate megafire as a stressor is to maintain maximum species redundancy; that is, to maintain as many resilient populations as possible].

H. *Habitat and Corridor Enhancement*. Selection of strategic areas and corridors for enhancement in order to facilitate dispersal throughout its range. This could also include prioritizing areas for conservation to ensure that suitable habitat is within dispersal distance.

I. *Assisted Dispersal/Translocation*. Perform controlled reintroduction to previously occupied sites extirpated by wildfire.

J. *Captive Rearing*. Rearing of Hermes copper for release and preservation of genetic diversity is a priority, although prior attempts have not been successful. This may become necessary if the species declines further or if assisted dispersal becomes necessary.

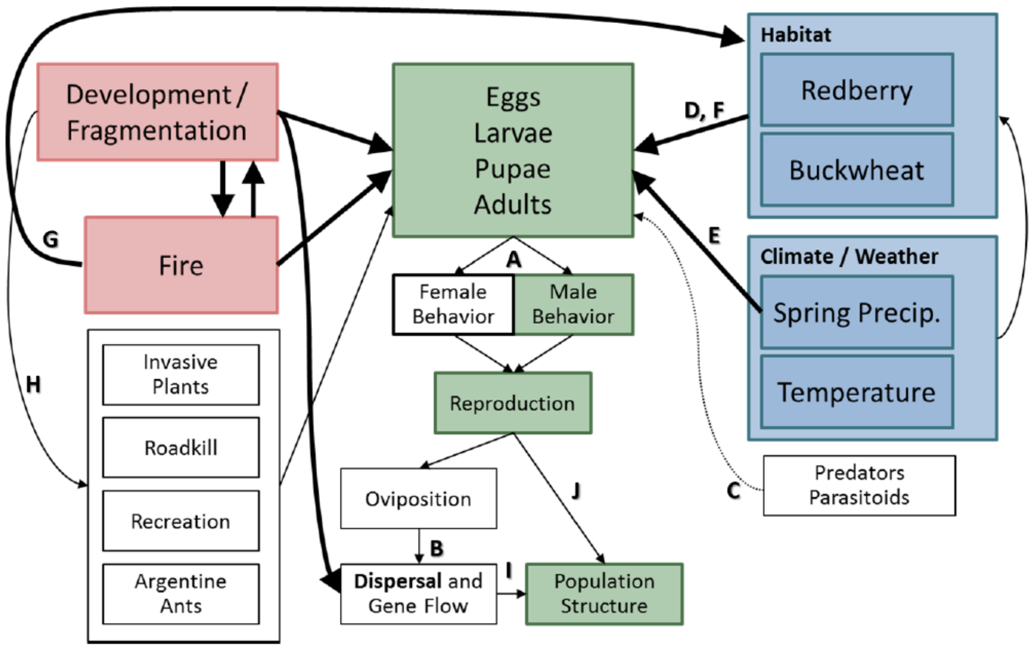

Figure 3. Hermes copper butterfly conceptual model from Strahm *et al.* (2012 p. 16). Colors correspond with narrative labels (Appendix II). Green = species variables, blue = natural drivers (including resources), red = stressors. Thickness of arrows indicates strength of effect.

<u>Distribution</u>

The Hermes copper butterfly is endemic to southern California, United States, and Baja California, Mexico, primarily occurring in southern San Diego County, California (Thorne 1963, p. 143; Marschalek and Klein 2010, p. 4). Historical data indicate Hermes copper butterflies ranged from the vicinity of the community of Bonsall, California, in northern San Diego County to approximately 29 km (18 mi) south of Santo Tomas in northwestern Baja California, Mexico, and from Pine Valley in eastern San Diego County to coastal mesas in southwestern San Diego County, California (CFWO GIS database; Thorne 1963, pp. 143, 147; Figure 4). While Hermes copper butterflies have never been recorded immediately adjacent to the coast, the lowest elevation record is approximately 46 m (150 ft) in elevation (Vernardo group 2015, p. 23), and have been recorded on the western slopes of the Cuyamaca Mountains to an elevation of approximately 1,300 m (4,264 ft) (Marschalek and Klein 2010, p. 4; Marschalek *et al.* 2016, p. 7; Marschalek and Deutschman 2017, p. 6). Therefore, the possible historical range of the Hermes copper butterfly is between approximately 33° 20’ 0” North latitude and 31° 50’ 0” North latitude from approximately 30 m (100 ft) to 1,340 m (4,400 ft) in elevation (Figure 4). There are 95 known historical or extant Hermes copper butterfly occurrences in southern California, United States and northwestern Baja California, Mexico; 45 are extant or presumed extant (all in the United States), 40 are presumed extirpated, and 10 are permanently extirpated (Table 1). Wildfires in 2003 and 2007 caused or contributed to 29 of the 51 historical extirpations (Table 1).

The primary gap in our knowledge of Hermes copper butterfly distribution is the extent of the species occurrence in Mexico. Of the two museum specimens from Mexico, one collected in 1936 was labeled “12 miles north of Ensenada,” and another collected in 1983 was labeled “Salsipuedes” (Marschalek and Klein 2010, p. 4). Assuming older specimens were usually collected relatively close to roads that existed at the time (Thorne 1963, p. 145), these Mexican locations probably were collected from approximately the same location, which is a popular surf destination known as “Salsipuedes,” located approximately 19 km (12 mi) north of Ensenada off the Esconica Tijuana-Ensenada (coastal highway to Ensenada). Spiny redberry distribution in Mexico is relatively contiguous with that in the United States, extending to approximately (312 km) 190 mi south of the border into Mexico along the western Baja California Peninsula (Little 1976, p. 150). Hermes copper butterflies have been recorded as far south into Mexico as 29 km (18 mi) south of Santo Tomas, which is approximately half the distance of the extent of spiny redberry’s Mexican range (Thorne 1963, p. 143). Two experts conducted surveys for rare butterflies over a 4-year period starting in 1979, focused on determining if Hermes copper butterfly was distributed similarly to the United States (Brown 2017, pers. comm.; Faulkner 2017, pers. comm.). Together and separately they visited hostplant herbarium record locations during Hermes copper butterfly flight season, about twice per month. Faulkner eventually discovered two occurrences close to Ensenada (Salsipuedes and Santo Tomas), the city listed on the single 1936 museum specimen label. Brown personally never saw any Hermes copper butterflies, and stated “…if Hermes had been [as] common or widespread [in Baja as in the United States], we certainly would have stumbled upon it a few times” (Brown 2017, pers. comm.). Furthermore, the “North Ensenada” occurrence may be the same as one of the other two recorded by Faulkner. Both researchers frequent Baja for museum specimen collecting every year or two, always looking for Hermes copper butterfly, but have reported no new records (approximately 37 years' worth of effort).

One possible explanation for habitat suitability in the Ensenada area is the unusually high rainfall relative to the rest of Baja California, Mexico (Oberbauer 2017, pers. comm.). More exploration of redberry stands in Mexico, starting with areas closest to the U.S. border and where specimens have been historically collected, should be undertaken. This will perhaps be best informed via genetic analyses of museum specimens (Sethuraman 2017, pers. comm.). Although the distribution of Hermes copper butterfly occurrences in Mexico is not well understood, it includes only 3 out of 95 known historical occurrences, and all are likely extirpated (Table 1).

We conducted an analysis to best determine the historical range of Hermes copper butterfly within the United States. We mapped all Hermes copper butterfly observation records that had a verifiable source and accuracy, and seemed accurate enough to map (at least a specific place-name for lowest accuracy code 3; Table 1; Figures 4, 5, and 6). We grouped butterfly records likely to belong to the same sub-population of a metapopulation as "occurrences." Occurrences were mapped as intersecting areas within 1 km (0.6 mi) of low geographic accuracy records (code 3; Table 1), or within 0.5 km (0.3 mi) of high geographic accuracy records (codes 1 and 2; Table 1). We also included areas within 0.5 km (0.3 mi) of any spiny redberry records within 1 km (0.6 mi) of a butterfly record. Because of their low geographic accuracy and possibility of redundancy with more accurate records, no low accuracy butterfly records (code 3; Table 1) falling within 1 km (0.6 mi) of an occurrence based on high accuracy records (Codes 1 and 2; Table 1) were mapped. Therefore no single occurrence was mapped using a combination of high and low accuracy butterfly records.

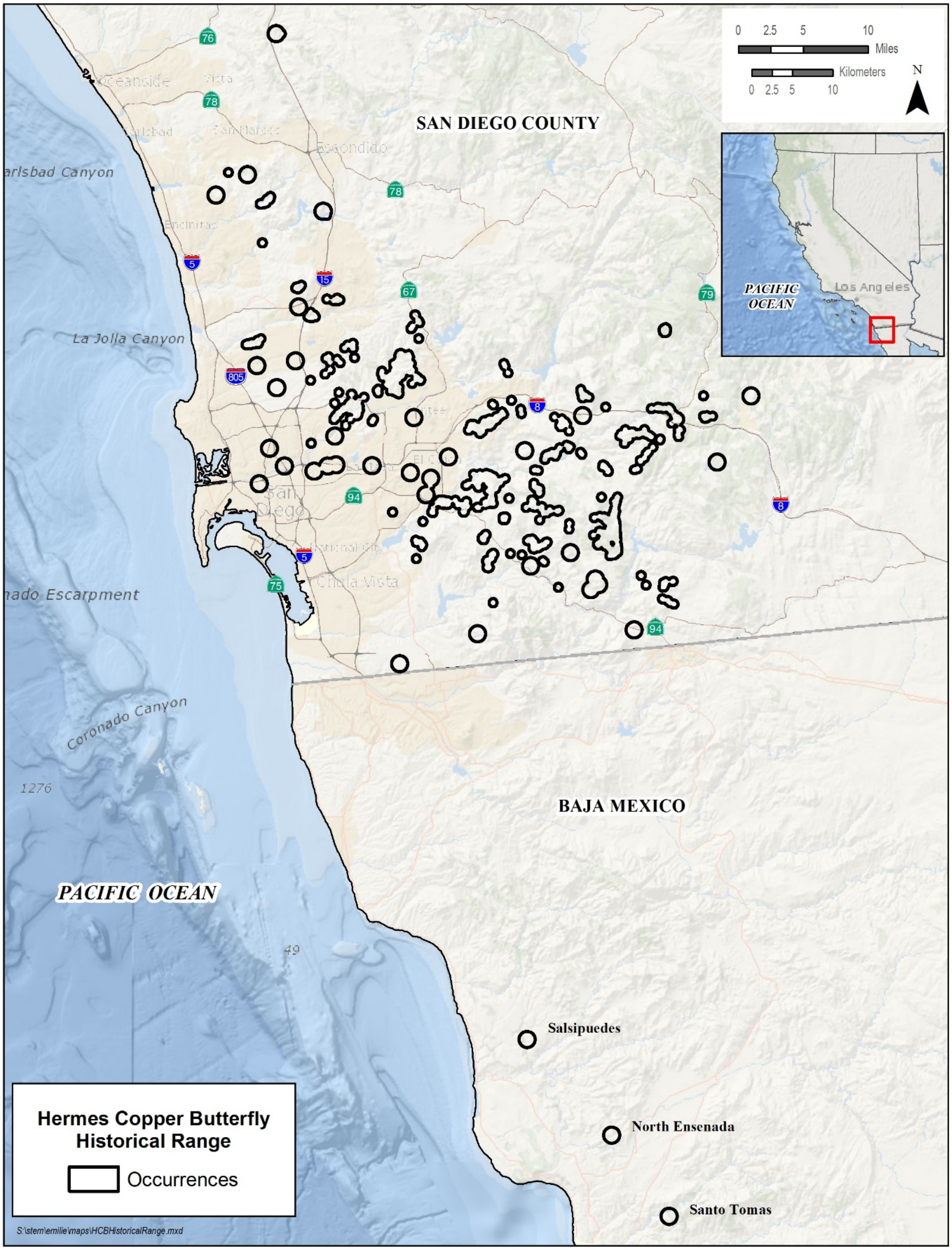

Figure 4. Hermes copper butterfly historical range in San Diego County, California, and Baja California, Mexico.

Table 1. Hermes copper butterfly occurrences in the United States and Mexico. Year is given for any known megafire that impacted an occurrence; approximate % affected by last fire is given if occurrence is extant or presumed extant.

Map #	Occurrence name	EU[1]	Size[2]	Last record	Accuracy[3]	Status[4]	Megafire Yr (%)	Reason Extirpated
1	Bonsall	WGF	NC	1963	3	Presumed Extirpated		Development Isolation
2	East San Elijo Hills	CH	NC	1979	2	Presumed Extirpated		Development Isolation
3	San Elijo Hills	CH	NC	1957	3	Extirpated		Development Isolation
4	Elfin Forest	CH	NC	2011	1	Extant		
5	Carlsbad	CH	NC	Pre-1963	3	Extirpated		Development
6	Lake Hodges	CH	NC	1982	3	Presumed Extirpated	2007	Development Isolation Fire
7	Rancho Santa Fe	CH	NC	2004	1	Presumed Extirpated	2007	Development Isolation Fire
8	Black Mountain	CH	NC	2004	1	Presumed Extant		
9	South Black Mountain	CH	NC	Pre-1963	3	Extirpated		Development
10	Van Dam Peak	CH	NC	2011	1	Extant		
11	Sabre Springs	CH	NC	2001	1	Presumed Extirpated		Development Isolation
12	Lopez Canyon	CT	Core	2011	1	Extant		
13	Mira Mesa	CT	NC	Pre-1963	3	Extirpated		Development
14	West Mira Mesa	CT	NC	Pre-1963	3	Extirpated		Development
15	Northeast Miramar	CH	Core	2000	1	Presumed Extirpated	2003	Fire
16	Southeast Miramar	CH	NC	1998	2	Presumed Extirpated	2003	Fire
17	Miramar	CH	Core	2000	1	Presumed Extirpated	2003	Fire
18	West Miramar	CT	NC	1998	2	Presumed Extirpated	2003	Fire
19	Miramar Airfield	CT	NC	Pre-1963	3	Presumed Extirpated	2003	Fire
20	South Miramar	CH	NC	2000	1	Presumed Extirpated	2003	Fire
21	Sycamore Canyon	WGF	Core	2003	1	Presumed Extirpated	2003	Fire

22	South Sycamore Canyon	WGF	NC	2000	1	Presumed Extirpated	2003	Fire
23	North Santee	CH	Core	2005	1	Presumed Extant	2003 (60%)	
24	Santee	CH	NC	1967	3	Extirpated		Development
25	Santee Lakes	CH	NC	2001	1	Presumed Extirpated	2003	Development Fire
26	Mission Trails	CH	Core	2010	1	Extant	2003	Fire (pre-2003, recolonized)
27	North Mission Trails	CH	NC	2003	1	Presumed Extirpated	2003	Fire
28	Cowles Mountain	CH	NC	1973	2	Presumed Extant		
29	South Mission Trails	CH	NC	1978	3	Presumed Extirpated		Development Isolation
30	Admiral Baker	CH	NC	2015	1	Extant		
31	Kearny Mesa	CT	NC	1939	3	Extirpated		Development
32	Mission Valley	CT	NC	Pre-1963	3	Extirpated		Development
33	West Mission Valley	CT	NC	1908	3	Extirpated		Development
34	San Diego State University	CT	NC	Pre-1963	3	Presumed Extirpated		Development
35	La Mesa	CH	NC	Pre-1963	3	Presumed Extirpated		Development
36	Mt. Helix	CH	NC	Pre-1963	3	Presumed Extirpated		Development
37	East El Cajon	CH	NC	Pre-1963	3	Presumed Extirpated		Development
38	Dictionary Hill	CT	NC	1962	2	Presumed Extant		
39	El Monte	CH	NC	1960	2	Presumed Extirpated	2003	Development Fire
40	BLM Truck Trail	WGF	Core	2006	1	Presumed extant	2003 (90%)	Fire (recolonized?)
41	North Crestridge	WGF	NC	1981	2	Presumed Extirpated	1970, 2003	Fire
42	Northeast Crestridge	WGF	NC	1963	2	Presumed Extant	2003 (25%)	
43	East Crestridge	WGF	NC	2003	1	Presumed Extant	1970, 2003 (50%)	
44	Crestridge	WGF	Core	2014	1	Extant	1970, 2003 (80%)	

45	Boulder Creek Road	PC	Core	2017	1	Extant	2003 (100%)	Fire (recolonized?)
46	North Guatay Mountain	PC	NC	2004	1	Presumed Extant	2003 (10%)	
47	South Guatay Mountain	PC	NC	2010	1	Extant	1970	
48	Pine Valley	PC	NC	Pre-1963	3	Presumed Extant		
49	Descanso	PC	Core	2017	1	Extant	1970, 2003 (50%)	
50	Japutal	WGF	Core	2012	1	Extant	1970	
51	East Japutal	WGF	NC	2010	1	Extant	1970	
52	South Japutal	WGF	Core	2010	1	Extant	1970	
53	Corte Madera	PC	NC	Pre-1963	3	Presumed Extant	1970	
54	Alpine	WGF	Core	2011	1	Extant	1970	
55	East Alpine	WGF	NC	Pre-1963	3	Presumed Extant	1970	
56	Willows (Viejas Grade Road)	WGF	NC	2003	1	Presumed Extirpated	2003	Fire
57	Dehesa	CH	NC	Pre-1963	3	Presumed Extant	1970	
58	Loveland Reservoir	WGF	Core	2012	1	Extant	1970	
59	East Loveland Reservoir	WGF	NC	2011	1	Extant	1970	
60	West Loveland Reservoir	CH	NC	2009	1	Extant	1970	
61	Hidden Glen	WGF	NC	2010	1	Extant	1970	
62	McGinty Mountain	CH	Core	2014	1	Extant	1970	
63	East McGinty Mountain	WGF	NC	2001	2	Presumed Extant	1970	
64	North Rancho San Diego	CH	NC	Pre-1963	3	Extirpated	1970	Development Isolation
65	Rancho San Diego	CH	Core	2011	1	Extant	1970, 2007 (5%)	
66	South Rancho San Diego	CH	NC	2007	1	Presumed Extant	1970, 2007 (50%)	
67	San Miguel Mountain	CH	Core	2007	1	Presumed Extirpated	1970, 2007	Fire

68	South San Miguel Mountain	CH	NC	2004	1	Presumed Extant	1970, 2007 (50%)	
69	North Jamul	CH	Core	2004	1	Presumed Extant	1970, 2003 (5%)	
70	North Rancho Jamul	CH	NC	2007	1	Presumed Extirpated	2003, 2007	Fire
71	Rancho Jamul	CH	Core	2003	1	Presumed Extirpated	2003, 2007	Fire
72	East Rancho Jamul	CH	NC	2007	1	Presumed Extant	1970, 2003, 2007 (5%)	
73	Sycuan Peak	WGF	Core	2016	1	Extant	1970	
74	Skyline Truck Trail	WGF	Core	2017	1	Extant	1970	
75	Lyons Peak	WGF	NC	2003	1	Presumed Extant	1970, 2007 (50%)	
76	Gaskill Peak	WGF	NC	2010	1	Extant	1970	
77	Lawson Valley	WGF	Core	2017	1	Extant	1970, 2007 (40%)	
78	Bratton Valley	WGF	NC	Pre-1963	3	Presumed Extirpated	1970, 2007	Fire
79	Hollenbeck Canyon	WGF	Core	2016[5]	1	Presumed Extirpated[5]	1970, 2007	Fire
80	Southeast Hollenbeck Canyon	WGF	NC	2007	1	Presumed Extirpated	1970, 2007	Fire
81	South Hollenbeck Canyon	CH	NC	Pre-1963	3	Presumed Extirpated	1970, 2003, 2007	Fire
82	West Hollenbeck Canyon	CH	NC	2007	1	Presumed Extirpated	1970, 2007	Fire
83	Otay Mountain	WGF	NC	1979	2	Presumed Extirpated	2003, 2007	Fire
84	South Otay Mountain	WGF	NC	Pre-1963	3	Presumed Extirpated	2003, 2007	Fire
85	Dulzura	WGF	NC	2005	1	Presumed Extirpated	2007	Fire
86	Deerhorn Valley	WGF	NC	1970	3	Presumed Extirpated	2007	Fire
87	North Hartley Peak	WGF	NC	2010	1	Extant	2007 (100%)	Fire (recolonized?)
88	South Hartley Peak	WGF	NC	2010	1	Extant	2007 (50%)	
89	North Portrero	WGF	Core	2010	1	Extant	2007 (25%)	

90	South Portrero	WGF	Core	2012	1	Extant		
91	Tecate Peak	WGF	NC	1980	3	Presumed Extirpated	2007	Fire
92	Otay Mesa	CT	NC	Pre-1920	3	Presumed Extirpated		Development Isolation
	Mexico[6]							
93	Salsipuedes	n/a	NC	1983	3	Presumed Extirpated	2014	Fire
94	Santo Tomas	n/a	NC	Pre-1920	3	Presumed Extirpated	2003	Fire
95	North Ensenada	n/a	NC	1936	3	Presumed Extirpated	2005 2014	Fire

[1] California Ecological Units: CH= Coastal Hills; CT = Coastal Terraces; WGH = Western Granitic Foothills; PC = Palomar-Cuyamaca Peak.

[2] NC means "non-core." "Core"/large geographic footprint defined by a total area within ½ km of Hermes copper butterfly records greater than 176 hectares (435 acres).

[3] Geographic accuracy categories: 1 means recorded GPS coordinates or accurate map; 2 means relatively accurate specimen collection site label or map; 3 means site name record or map only accurate enough for determining species' range (not used to determine size, or in mapping if within 1.5 km of a higher accuracy record).

[4] "Extirpated" means associated habitat has all been developed. "Presumed extirpated" means the record location is developed but there is a significant amount of remaining undeveloped habitat, or all records within a 2003 or later fire footprint and no post-fire butterfly records. "Presumed extant" means unburned or post-fire record > 10 years old. "Extant" means there is a record < 10 years old in unburned habitat.

[5] At least one adult observed after 2015 translocation, may not represent breeding.

[6] Although records are low accuracy, extirpation of populations in Mexico is presumed due to numerous large fires in the area between 2003 and 2014 (NASA imagery).

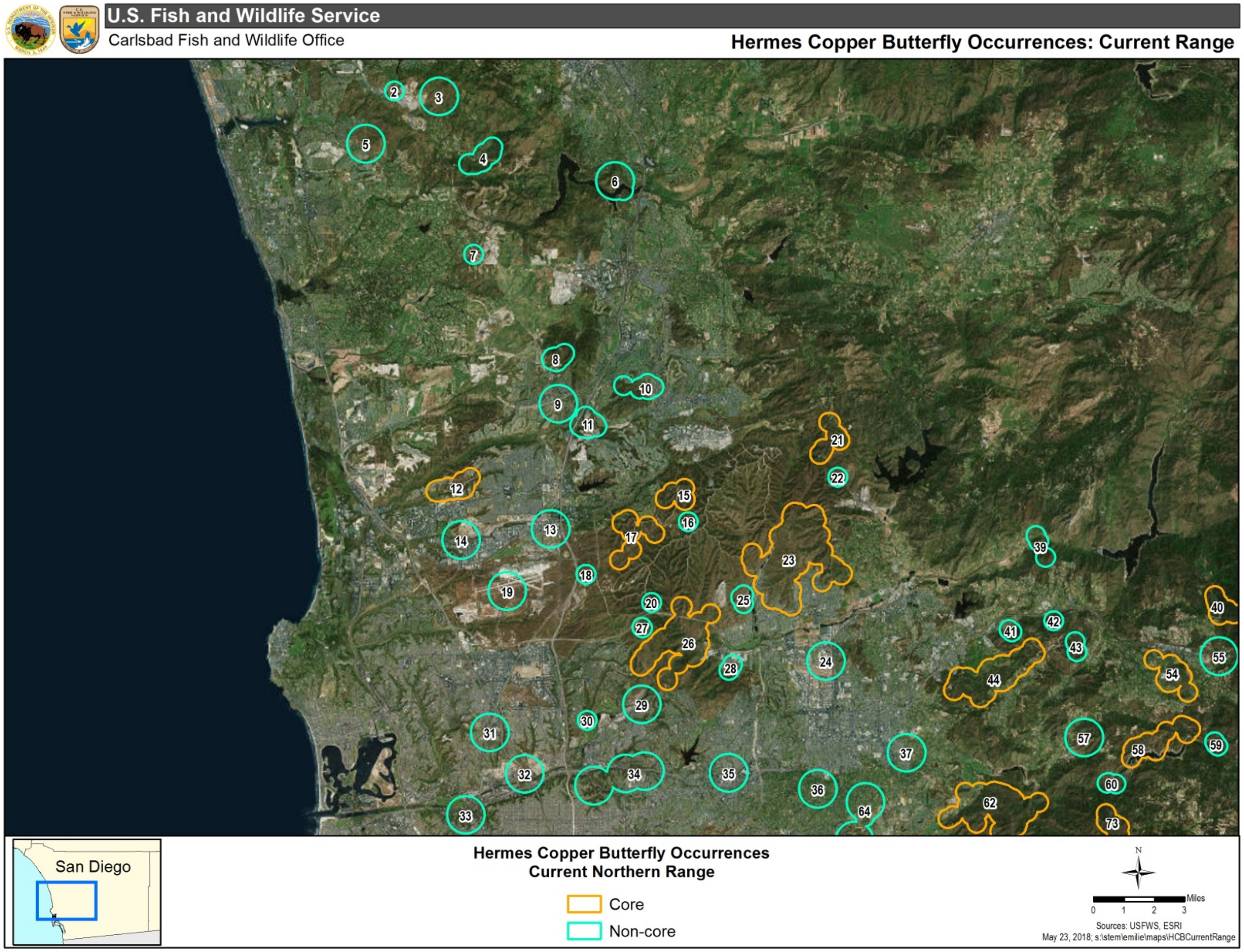

Figure 5. Current northern range of the Hermes copper butterfly in the United States, with numbered occurrences

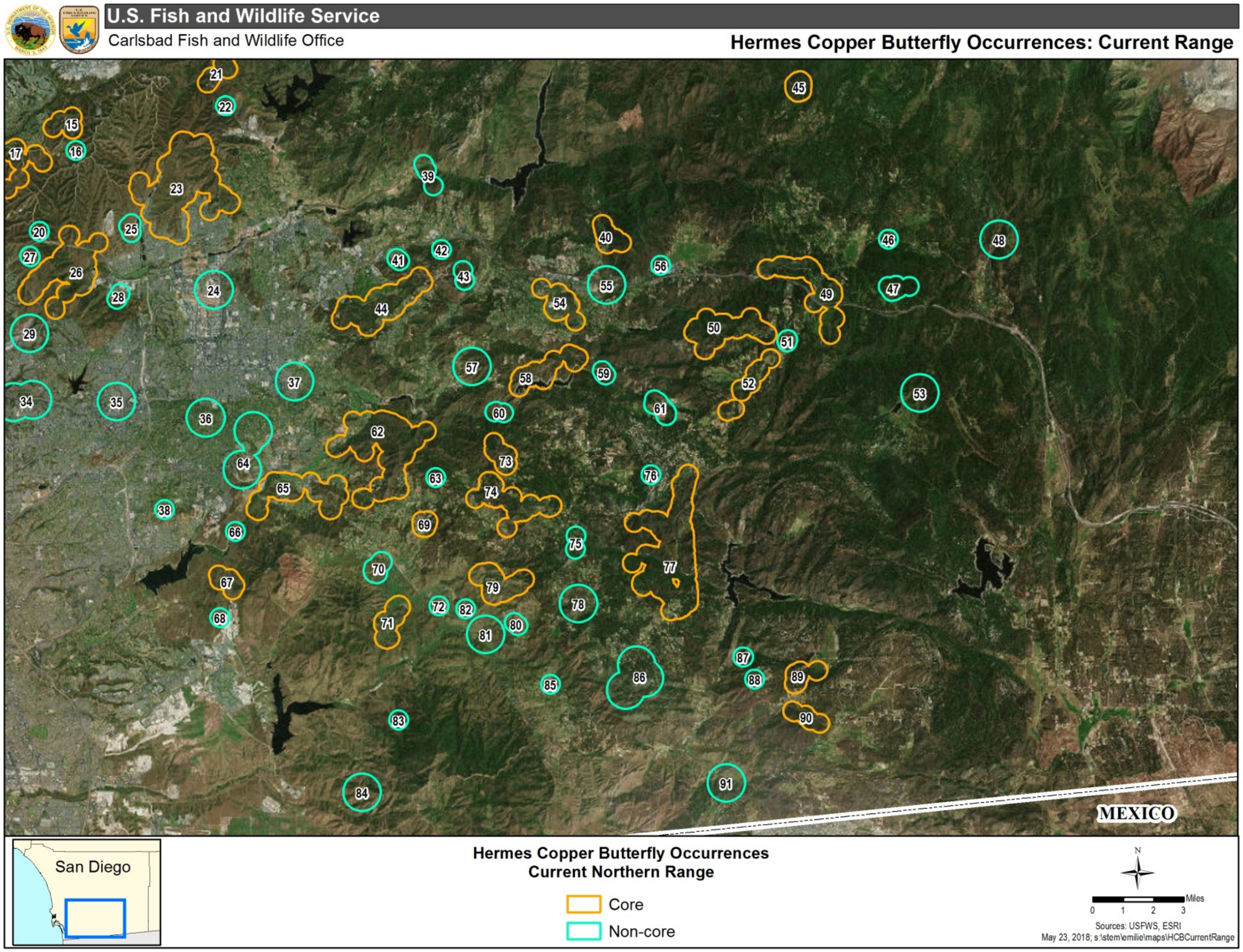

Figure 6. Current southern range of the Hermes copper butterfly in the United States, with numbered occurrences.

2.3 Ecological Needs

In this section, we describe Hermes copper butterfly ecological needs at the hierarchical levels of individual, population, and species. There are also spatial and temporal components to hierarchical resource needs, reflected in the average area occupied by and "life expectancy" of each ecological entity. Individual needs are met and resource availability should be assessed at the adult male territory scale on an annual basis, reflecting the life span of an individual (from egg to adult). Population-level resilience needs are met and resource availability should be assessed on the habitat patch or metapopulation (interconnected habitat patches) scale over a period of decades. Populations or sub-populations persist until they are extirpated by stochastic events such as wildfire, to eventually be replaced as habitat is recolonized (estimated recolonization time is 4–18 years based on documented events, North Descanso and Mission Trails). Species-level viability needs must always be met and assessed on a range-wide scale for perpetual maintenance if the species is to avoid extinction.

1. Individual Resource Needs:

a. Egg: spiny redberry stems for substrate.
b. Larvae: spiny redberry leaf tissue for development.
c. Pupae: spiny redberry leaves for pupation.
d. Adults: spiny redberry stem tissue for oviposition; nectar sources (primarily California buckwheat); mates.

2. Population Needs

2.1. Resource Needs and/or Circumstances: Habitat elements required by populations include spiny redberry bushes (quantity unknown, but it must be a stand, not isolated individuals) and associated stands of California buckwheat and similar nectar sources.

2.2. Population-level redundancy: Populations must have enough individuals (population growth) in "good years," that after reproduction is limited by poor environmental conditions such as drought in intervening "bad" years that they can still find mates. This includes the possibility of enough eggs diapausing for two years to wait out a bad year and restore the average adult population size or greater in subsequent years. That is, populations are always large enough to persist through periods of "worst-case" negative population growth.

2.3. Population-level representation: It is unclear how susceptible Hermes copper butterfly is to inbreeding depression and therefore how important genetic diversity is. A mix of open, sunny areas and stands of California buckwheat for nectar in the vicinity of spiny redberry host plants should be present in a habitat patch. Additionally, individuals must be distributed over a large enough area (population footprint/distribution) that not all are likely to be killed by stochastic events such as wildfires that do not encompass the entire population distribution.

3. Species Needs

3.1. Resource Needs and/or Circumstances: Movement corridor connectivity among populations or sub-populations to maintain metapopulation dynamics. For the Hermes copper butterfly, this means suitable movement corridor habitat with suitable intervening vegetation structure and topography between habitat patches, which is close enough to other habitat patches that individual movement among habitat patches is likely. Apparent impediments to dispersal include forested, riparian, and developed areas.

3.2. Species-level redundancy: Currently there are 27 occurrences considered extant and 18 of unknown status (presumed extant). Loss and low abundance of remaining isolated north San Diego County populations indicates a threshold number of extant, connected populations to maintain a metapopulation long-term; however, it is not clear what that threshold is, and it will likely depend on proximity, juxtaposition, and size of subpopulations. Population modeling should inform this need.

3.3. Species-level representation: Populations must be distributed in a variety of habitats so that there are always some populations experiencing conditions that support reproductive success. In especially warm, dry years, populations in wetter habitats should experience the highest population growth rates within the species' range, and in colder, wetter years, populations in drier habitats should experience the highest growth rates. Populations should be represented across a continuum of elevation levels, from the coast to the mountain foothills. There is currently only 1 extant or presumed extant occurrence with marine climate influence, 6 with montane climate influence, and the remainder (38) at intermediate elevations with a more arid climate (for a more detailed description see ecological unit discussion below under **Species Viability Index** and

Appendix II). Populations in higher elevation, cooler habitats, and coastal habitats with more marine influence that are less susceptible to a warming climate are especially important to maintain.

Chapter 3. Current Species Condition

Stressors negatively affect Hermes copper butterfly populations and habitats, which may then prevent needs from being met. Stressors reduce population-level resilience, which in turn reduces species-level redundancy and representation, lowering overall species viability (see species viability model discussion below).

3.1 Wildfire

The vegetation types that support Hermes copper butterfly, chaparral and coastal sage scrub, are prone to relatively frequent wildfire ignitions (Figures 7 and 8), and many plant species that characterize those habitat types are fire-adapted. The historical fire return intervals for Hermes copper butterfly habitat vegetation associations are 15–30+, and 30–60 years (Sawyer, Keeler-Wolf and Evans *et al.* 2009, pp. 325, 529, 1294). The pre-historical fire regime in southern California likely was characterized by many small, lightning-ignited fires in the summer and a few, infrequent larger fires in the fall (Keeley and Fotheringham 2003, pp. 242–243). Infrequent, large, high-intensity wildfires burned the landscape long before Europeans settled the Pacific coast (Keeley and Zedler 2009, p. 90). As such, historical fire regimes in southern California “have much in common with historical regimes” (Keeley and Zedler 2009, p. 69); however, large areas are burning at higher frequencies in recent years (Safford and Van de Water, 2014, p. 34). C.J. Fotheringham (unpublished data) calculated that the 90-year fire return interval in undeveloped Hermes copper butterfly habitat decreased from 68 years (1910–2000) to 49 years (1925–2015), and the average total area burned/year increased by 2,428 ha (6,000 ac).

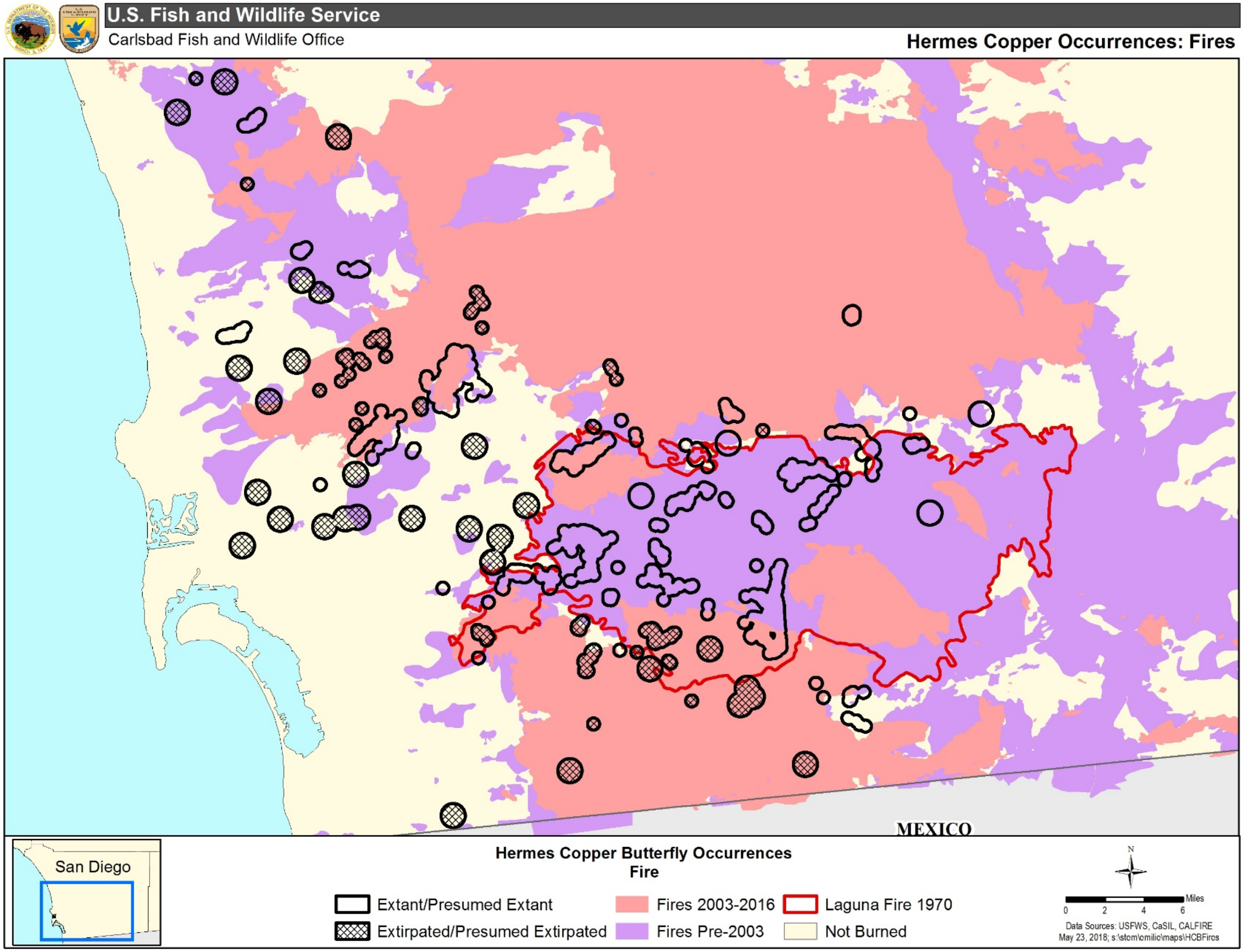

Figure 7. Hermes copper butterfly occurrences with wildfire footprints.

The most frequent cause of Hermes copper butterfly population loss is so-called "megafires" (defined in this SSA as those greater than 16,187 hectares (ha) (40,000 acres (ac)) in size). It is difficult to predict where and when the next megafire will occur. We examined mapping data showing recent high fire hazard severity zones in San Diego County (Cal Fire 2007; Figure 7). Areas identified as most vulnerable include most occupied and potentially occupied Hermes copper butterfly habitats in San Diego County within the southern portion of the range bordered on the north and south by the 2003 Cedar Fire and 2007 Harris Fire perimeters. Twenty-eight potential source occurrences for recolonization of habitats burned in the past 10 years (extant or presumed extant) fall within a contiguous area that has not recently burned (southeastern occurrences in Figure 7), and where the fire hazard severity risk is considered very high (Cal Fire 2007; Figure 8). Most of these potential source occurrences also fall within the 70,426 ha (174,026 ac) 1970 Laguna Fire megafire perimeter (similar in size to the 2003 and 2007 fires; Figure 7). There were numerous large wildfires in 2014 in Hermes copper butterfly's range and although none reached megafire proportion, some impacted habitat associated with extant occurrences. The Cocos and Bernardo fires burned approximately 809 ha (2,000 ac) and 607 ha (1,500 ac) of potentially occupied Hermes copper butterfly habitat near the Elfin Forest and the Black Mountain occurrences (Figure 7). A smaller unnamed fire burned approximately 38 ha (95 ac) of potential habitat near the extant core Mission Trails occurrence in Mission Trails Regional Park (Burns *et al.*, 2014; City News Source 2014). In 2017, the largest fire in southern California recorded to-date burned in Ventura and Santa Barbara counties of southern California (the Thomas Fire), and the Lilac Fire burned 1,659 ha (4,100 ac) of potentially occupied Hermes copper butterfly habitat between the Bonsall and Elfin Forest occurrences. Finally, the West Fire in July of 2018 burned over half of the known historical distribution of the semi-isolated Alpine core occurrence, damage that could result in extirpation.

Annual mean area under extreme fire risk has increased steadily in California since 1979, and 2014 ranked highest in the history of the state (Yoon *et al.* 2015, p. S5). Although precipitation in the winter of 2016–2017 was relatively high and the multi-year drought was temporarily interrupted, higher rainfall typically increases the fuel load for wildfires that start later in the year. All extant Hermes copper butterfly occurrences fall within the "very high" fire hazard severity zone for San Diego County (Figure 8). Fire hazard severity zones evaluate "hazard," not "risk." Both of these assessments analyze likely impacts to human property and safety. The fire "hazard" assessment is based both on existing fire behavior modeling techniques used by fire scientists throughout the United States and new methodologies and data developed by the Fire Center at UC Berkeley. The assessment evaluates an area using characteristics that affect the probability it will burn and fire behavior expected should it burn. Factors considered include fire history, existing and potential fuel (vegetation), flame length, blowing embers, terrain, and typical weather (Cal Fire 2007, pp. 1–2). Fire hazard and fire "risk" assessments differ in that risk assessments consider modifications that protect human property such as fuel breaks; irrigation and sprinklers; and building construction, while fire hazard assessments do not (Cal Fire 2007, pp. 1–2). The difference between the two categories is less important for our analysis, as megafire risk to wildlands in San Diego County is not significantly affected by landscape modifications designed to protect development.

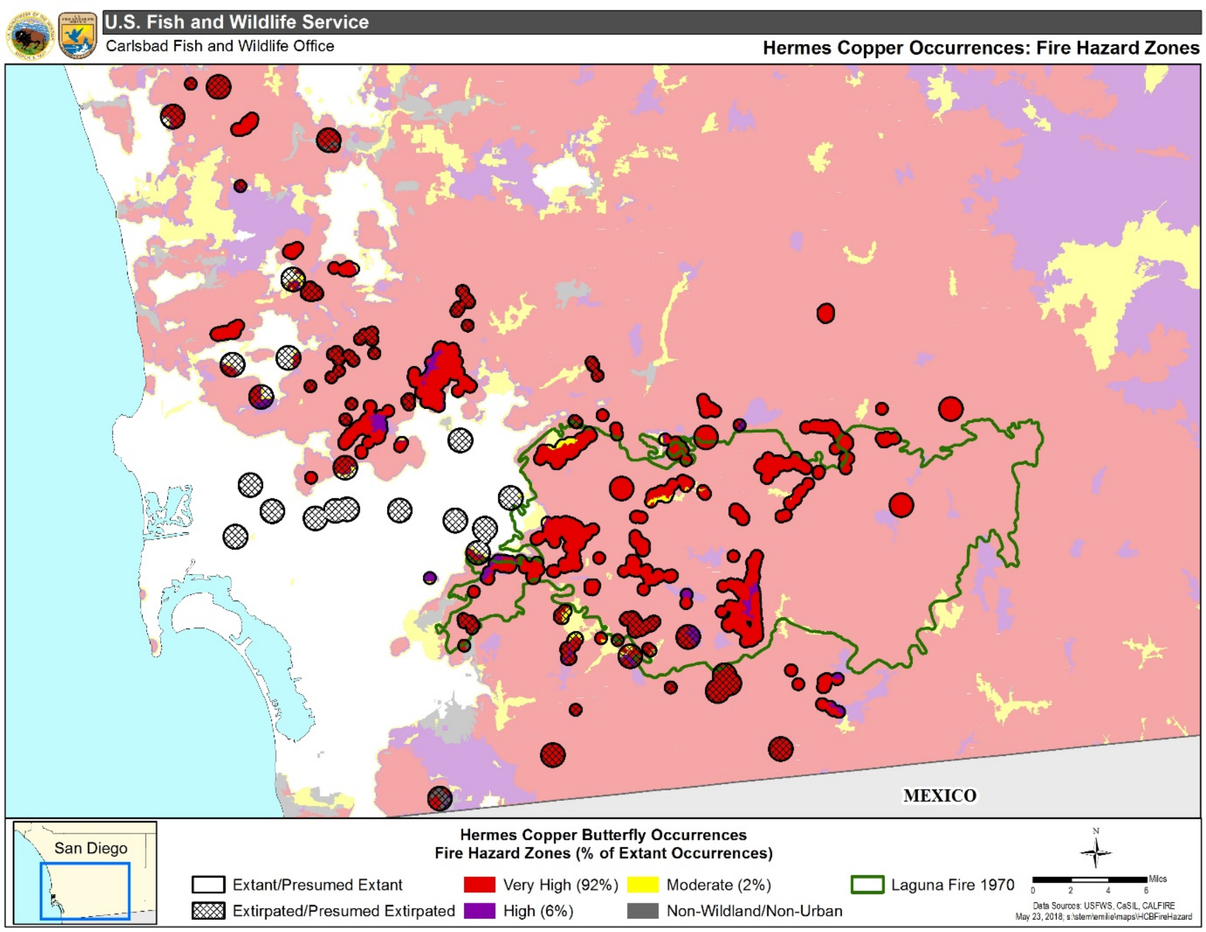

Figure 8. San Diego County 2017 fire hazard severity zones with Hermes copper butterfly occurrences.

The current fire regime in Mexico is not as well understood. Some researchers claim chaparral habitat in Mexico within Hermes copper butterfly's range is not as affected by megafires, because there has been less fire suppression activity than in the United States (Minnich and Chou 1997, pp. 244–245; Minnich 2001, pp. 1549–1552). Nevertheless, Keeley and Zedler (2009, p. 86) contend the fire regime in Baja California mirrors that of Southern California, similarly consisting of ''small fires punctuated at periodic intervals by large fire events.'' Some local experts hypothesize the difference in suppression activities appear to reduce the risk of occurrence extirpation due to megafire (Oberbauer 2017, pers. comm.; Faulkner 2017, pers. comm.). However, the state of Baja California has one of the highest incidences of wildfire in Mexico, ignition sources are similar to those in the United States, and climate change and drought effects on wildfire in Mexico should also be similar (Syphard *et al.* 2018, p. 17). Examination of satellite imagery from the 2000s indicates impacts from large wildfires in Mexico were similar to those in San Diego County. Two large wildfires in 2014 appear to have burned habitats associated with the Hermes copper butterfly records near Ensenada (NASA 2017a; 2017b).

3.1.1 Habitat modification

The current fire regime in southern California consists of numerous small fires and periodic megafires driven by extreme "Santa Ana" weather conditions of high temperatures, low humidity, and strong erratic winds (Keeley and Zedler 2009, p. 90). The primary difference between the current and historical fire regimes in southern California is that human-induced or anthropogenic ignitions have increased the frequency of fires in general, and megafires in particular, above historical levels. Frequent fires open up the landscape, particularly coastal sage scrub, making the habitat more vulnerable to invasive, nonnative plants and vegetation type-conversion (Keeley *et al.* 2005, p. 2117). However, the primary concern with frequent megafires is the mortality associated with these extensive and intense events (see the *Direct Mortality Stressor* discussion below) that can isolate habitat from potential source populations and reduce the recolonization likelihood of burned areas by Hermes copper butterfly.

The Hermes copper host plant, spiny redberry, resprouts after fires and is relatively resilient to frequent burns (Keeley 1998, p. 258). Although Keeley and Fotheringham (2003, p. 244) indicated that continued habitat disturbance, such as fire, will result in conversion of native shrublands to nonnative grasslands, Keeley (2004, p. 7) also noted that invasive, nonnative plants will not typically displace obligate resprouting plant species in mesic shrublands that burn once every 10 years. Therefore, because spiny redberry is a resprouter, it will likely recover in those areas that do not exceed this burn frequency.

The effect of wildfire on Hermes copper butterfly's primary nectar source (California buckwheat) is more complicated than impacts to its host plants. California buckwheat is a facultative seeder, so high proportions of this nectar source are likely killed by fire and densities are reduced the following year within burned areas (Zedler *et al.* 1983, p. 814). However, California buckwheat does show minimal resprouting capability (approximately 10%) if individuals are young (Keeley 2006, p. 375). The extent of invasion of nonnative plants and type conversion in areas specifically inhabited by Hermes copper butterfly are unknown. However, information clearly indicates that wildfire results in at least temporary reductions in suitable habitat for Hermes copper butterfly and may result in lower densities of California buckwheat (Zedler *et al.* 1983, p. 814; Keeley 2006, p. 375; Marschalek and Klein 2010, p. 728). Where spiny redberry resprouts after fire, the quantity of California buckwheat necessary to support a Hermes copper butterfly subpopulation may be temporarily unavailable, and nonnative grasses commonly compete with native flowering plants that would otherwise provide abundant nectar after fire. Marschalek and Deutschman (2016a, p. 12) found that while habitats burned 8 to 12 years earlier had similar abundance of redberry and buckwheat to unburned habitats, they were characterized by reduced percentage of bare ground.

3.1.2 Direct Mortality

Extensive and intense wildfire events are the most recent primary cause of direct mortality and extirpation of Hermes copper butterfly occurrences. The magnitude of this stressor appears to have increased over the past 15 years due to a number of megafires created by extreme "Santa

Ana" weather conditions of high temperatures, low humidity, strong erratic winds, and human-caused ignitions (see habitat wildfire discussion above; Keeley and Zedler 2009, p. 90).

The 2003 Otay Mine and Cedar fires and the 2007 Harris and Witch Creek fires in particular have negatively impacted the species, resulting in or contributing to the extirpation of 34 occurrences (Table 1). It is well-documented that wildfires that occur in occupied Hermes copper butterfly habitat result in loss of Hermes copper butterflies (Klein and Faulkner 2003, pp. 96, 97; Marschalek and Klein 2010, pp. 4, 5), and fire is considered a factor in over half of historical occurrence extirpations (Table 1). The butterflies rarely survive wildfire because all immature life stages inhabit host plant foliage, and spiny redberry typically burns to the ground and resprouts from stumps (Deutschman *et al.* 2010, p. 8; Marschalek and Klein 2010, p. 8). This results in at least a temporary loss of habitat (until the spiny redberry and nectar source regrowth occurs) and the presence of butterflies (occupancy) in the area. Furthermore, large fires can eliminate source populations before previously burned habitat can be recolonized, and can result in long-term or permanent loss of butterfly populations. For example, in Mission Trails Park the 2596 ha (7,303 ac) "Assist #59" Fire in 1981 and the smaller 51 ha (126 ac) "Assist #14" Fire in 1983 (no significant overlap between acreages burned by the fires), resulted in an approximate 18-year extirpation of the Mission Trails Hermes copper butterfly occurrence (Klein and Faulkner 2003, pp. 96, 97). More recent examples include extirpations of the Rancho Jamul, Anderson Road, Hollenbeck Canyon, and San Miguel Mountain occurrences (Table 1; Marschalek and Klein 2010, pp. 4, 5; Deutschman *et al.* 2010, p. 36; Marschalek and Deutschman 2016a, p. 10; Figure 5). Only 3 of the 34 occurrences thought to have been extirpated in whole or in part by fire since 2003 appear to have been naturally re-established, or were not entirely extirpated (Table 1; Figure 7; Winter 2017, pers. comm.). Another consideration with regard to occurrence status and fire is that large portions of some extant occurrences were burned in 2003 and 2007, such as the core Crestridge and Lawson Valley occurrences, may not yet be recolonized (Table 1).

This analysis of current fire danger and fire history illustrates the potential for catastrophic loss of the majority of remaining butterfly occurrences should another large fire occur prior to recolonization of burned habitats (per discussion above, recolonization at Mission Trails did not occur for up to 18 years). As discussed by Marschalek and Klein (2010, p. 9) and Deutschman *et al.* (2010, p. 42), there is a risk that one or more wildfires could extirpate the majority of extant Hermes copper butterfly occurrences. Marschalek and Deutschman (2016b) initiated a translocation study in 2015 to try and assist recolonization of habitat formerly occupied by the Sycamore Canyon core occurrence. While it is not clear this attempt will be successful, and evaluation was hindered by drought, in 2016 there were signs of larval emergence from eggs and at least one adult was observed, indicating some level of success (Marschalek and Deutschman (2016b, p. 10). Regulatory protections such as ignition reduction measures do exist to reduce fire danger, however, megafires that are the primary stressor of concern for Hermes copper butterflies are considered resistant to control (Durland pers. comm., in Scauzillo 2015).

3.1.3 Summary

Only 3 of the 33 occurrences thought extirpated by fire since 2003 are now considered extant. We recognize that wildfire is an ongoing annual stressor of varying intensity with potential to extirpate the majority of extant occurrences in a single year. Based on our analysis above and on what we know about the species, we believe wildfire has been the most significant source of Hermes copper butterfly population decline and loss. This stressor has a species-level impact, affecting all Hermes copper butterfly populations and habitat across the species' entire range.

3.2 Land Use Change

Current Hermes copper butterfly habitat distribution relative to historical conditions in San Diego County has been reduced by urban development within coastal and interior San Diego County; this development has resulted in the loss and fragmentation of Hermes copper butterfly habitat (CalFlora 2010; Consortium of California Herbaria 2010; San Diego County Plant Atlas 2010). Of the 50 known Hermes copper butterfly occurrence extirpation events, loss and fragmentation of habitat as a result of development has contributed to 23 of those (46%; Table 1). There is still uncertainty regarding the Hermes copper butterfly’s condition within its southernmost known historical range in Mexico; however, one expert estimated that development pressure in known occupied areas near the city of Ensenada was similar to that in the United States (Faulkner 2017, pers. comm.). Since the year 2000, occupied habitats containing Hermes copper butterfly's host plant, spiny redberry, were lost due to urban development in the community of Rancho Santa Fe and the community of Sabre Springs. In the City of San Marcos, one spiny redberry stand near Jack's Pond was lost to development (Anderson 2010a, pp. 1, 2) and another was significantly reduced in the vicinity of Palomar College (Anderson 2010b, pp. 1, 2).

In our analysis of high-accuracy Hermes copper butterfly occurrences (accuracy codes 1 and 2, Table 1), approximately 64% of the remaining undeveloped areas within occurrence footprints are currently protected from destruction by development due to their presence on conserved or Federally-owned lands (Figure 9). Nevertheless, some habitat areas vulnerable to development are more important than others to species' viability. Of particular concern is potential extirpation due to development north of the City of Santee (e.g. North Santee core occurrence and recent loss of Santee Lakes non-core occurrence), and in rural eastern areas supporting the Loveland Reservoir, Skyline Truck Trail, North Jamul, and South Japutal core occurrences (Table 1; Figure 9).

The County of San Diego has two ordinances in place that restrict new development or other proposed projects within sensitive habitats. The Biological Mitigation Ordinance of the County of San Diego Subarea Plan (County of San Diego 1998, Ord. Nos. 8845, 9246) regulates development within coastal sage scrub and mixed chaparral habitats that currently support portions of 10 extant Hermes copper butterfly populations on non-federal land within the boundaries of the County's MSCP subarea plan. The County of San Diego Resource Protection Ordinance (County of San Diego 2007) regulates development within coastal sage scrub and mixed chaparral habitats that currently support all extant Hermes copper butterfly populations on non-federal lands throughout the county. County regulations mandate surveys for Hermes copper butterfly occupancy and habitat and to the extent it is a significant impact under the California Environmental Quality Act (CEQA; see **Appendix II,** p. 89), mitigation may be required. These local resource protection ordinances may provide some regulatory measures of protection for the remaining 36% of extant Hermes copper butterfly habitat throughout the species' occupied range. Although past development in occupied Hermes copper butterfly

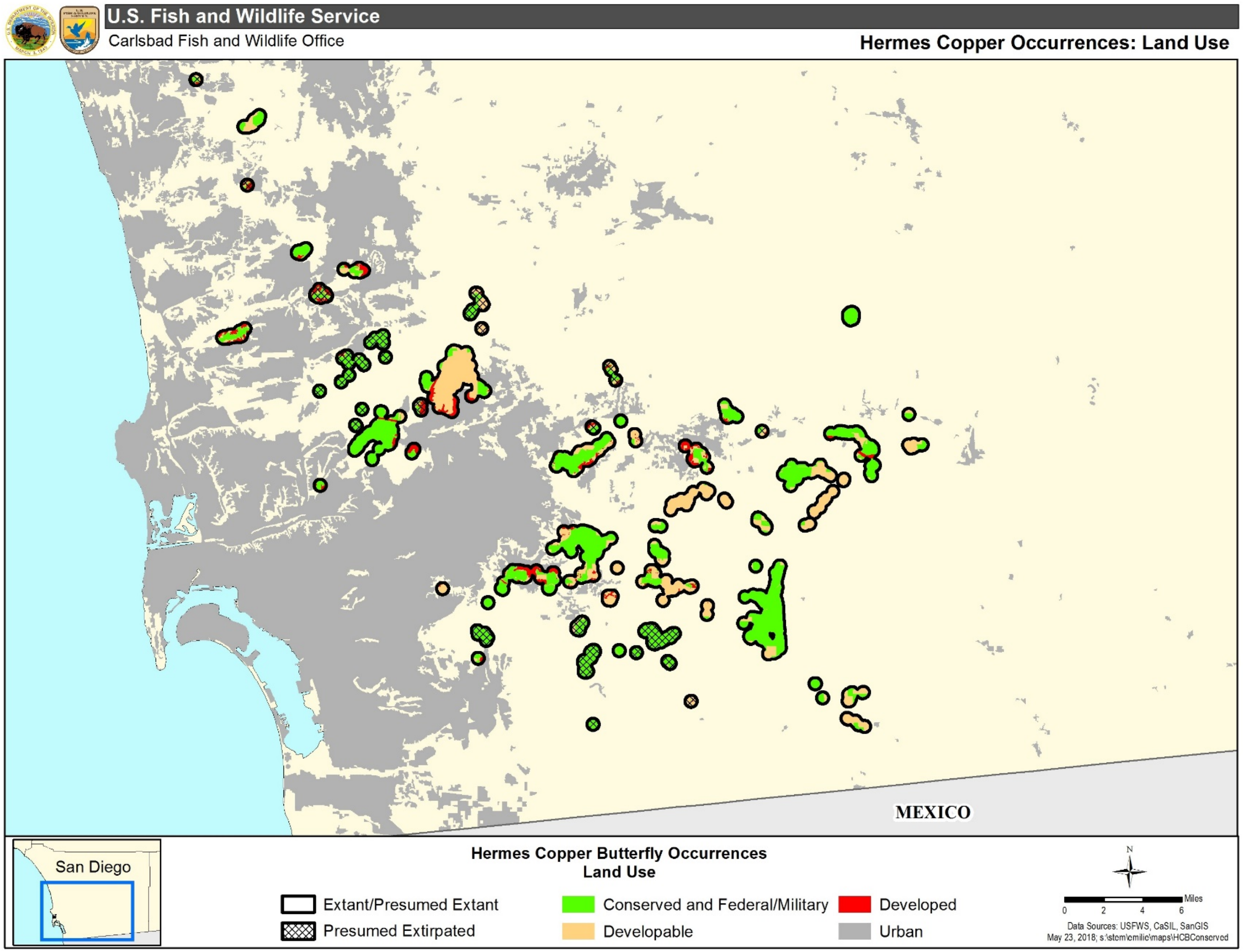

Figure 9. Land use change with Hermes copper butterfly occurrences (high accuracy records only). Only presumed extirpated records shown.

habitat resulted in a substantial number of extirpations of Hermes copper butterfly occurrences, restrictions are now in place may minimize impacts to Hermes copper butterfly habitat and provide some compensatory mitigation for habitat loss. We conclude development has contributed and is contributing to reduction and especially isolation and fragmentation of remaining Hermes copper butterfly habitat on non-federal lands at this time.

3.2.1 Summary

Land use change, while considered a current stressor resulting in ongoing and significant habitat loss, is not the primary cause of population loss. A significant amount of remaining Hermes copper butterfly habitat has been conserved within the United States; approximately 64% of the remaining undeveloped habitat within known occurrence footprints is currently protected from destruction by development. Some regulatory protections are in place on undeveloped lands that may help conserve Hermes copper butterfly habitat.

3.3 Habitat Fragmentation and Isolation

Habitat fragmentation and isolation can result in smaller, more vulnerable, and isolated Hermes copper butterfly populations, and is caused by land use change as described above. The presence of suitable habitat on which Hermes copper butterflies depend will determine the size and range of a local population and of the species. Development has caused habitat fragmentation that divides extant occurrences and isolation that inhibits movement among habitat patches by creating gaps that Hermes copper butterflies are unable or unlikely to traverse. The contiguity of a habitat patch occupied by a butterfly population is not defined by host plant distribution at the scale of stands, but rather by adult butterfly movement within and among stands that result in frequent interbreeding (see Service 2003, pp. 22, 162−165). Any loss of resource contiguity on the ground that does not affect butterfly movement, such as burned vegetation, may degrade but not fragment habitat. Therefore, in order for habitat to be fragmented, movement must either be inhibited by a barrier, or the distance between remaining host plants where larvae develop must be greater than adult butterflies will typically move to mate or deposit eggs. It is important to note that although movement may be possible, the newly occupied habitat must be suitable at the time Hermes copper butterflies arrive to ensure successful recolonization.

Comparison of Hermes copper butterfly occurrences and host plant distribution with mapped wildfire perimeters indicates that Hermes copper butterfly habitat patches in San Diego County have been more and more isolated due to the progression of development over the last 50 years, particularly in the vicinity of the City of Santee where it has effectively separated the northern and southern portions of the range (Figure 9). Analysis of the Hermes copper butterfly occurrences indicates that in the northern portion of the U.S. range, the habitat has been fragmented and isolated by development, contributing to permanent extirpation of at least 9 Hermes copper butterfly occurrences (Table 1). For example, the Rancho Santa Fe Hermes copper butterfly occurrence in the northern portion of the range was lost to fire in 2003. This area is not expected to be recolonized because it is mostly surrounded by development and the nearest potential "source" occurrence is Elfin Forest 4.3 km (2.7 mi) away, where a single individual was last detected in 2011 (Marschalek and Deutschman 2016c, p. 8). Farther to the south, Black Mountain, Lopez Canyon, and Van Dam Peak are isolated from other occurrences by development. Habitat isolation directly affects the likelihood of Hermes copper butterfly population persistence in portions of its range, and exacerbates other effects of fire and development.

3.3.1 Summary

The combination of habitat loss and existing dispersal barriers as a result of past and future urban development have fragmented, isolated, limited, and degraded Hermes copper butterfly habitat throughout its range. The effects of these stressors are evidenced by the loss and isolation of many populations; those remaining extant populations fall within very high fire hazard severity areas.

3.4 Climate Change and Drought

3.4.1 Climate Change

The terms “climate” and “climate change” are defined by the Intergovernmental Panel on Climate Change (IPCC). The term “climate” refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements (IPCC 2013a, p. 1450). The term “climate change” thus refers to a change in the mean or variability of one or more measures of climate (for example, temperature or precipitation) that persists for an extended period, whether the change is due to natural variability or human activity (IPCC 2013a, p. 1450).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has increased since the 1950s. Examples include warming of the global climate system, substantial increases in precipitation in some regions of the world, and decreases in other regions (for these and other examples, see Solomon *et al*. 2007, pp. 35–54, 82–85; IPCC 2013b, pp. 3-29; IPCC 2014, pp. 1–32). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate and is “very likely” (defined by the IPCC as 90% or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (Solomon *et al*. 2007, pp. 21–35; IPCC 2013b, pp. 11–12 and figures SPM.4 and SPM.5). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75% of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl *et al*. 2007, entire; Ganguly *et al*. 2009, pp. 11555, 15558; Prinn *et al*. 2011, pp. 527, 529). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after that time period, the overall trajectory of all the projections is one of increasing global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (Meehl *et al*. 2007, pp. 760–764, 797–811; Ganguly *et al*. 2009, pp. 15555–15558; Prinn *et al*. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23). See IPCC 2013b (entire), for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation.

Various changes in climate may have direct or indirect effects on species. These effects may be positive, neutral, or negative, and they may change over time, depending on the species and other relevant considerations, such as threats in combination and interactions of climate with other variables (for example, habitat isolation) (IPCC 2014, pp. 4–11). Identifying likely effects often involves aspects of climate change vulnerability analysis. Vulnerability refers to the degree to which a species (or system) is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the type, magnitude, and rate of climate change and variation to which a species is exposed, its sensitivity, and its adaptive capacity (Glick *et al*. 2011, pp. 19–22; IPCC 2014, p. 5). There is no single method for conducting such analyses that applies to all situations (Glick *et al*. 2011, p. 3). We use our expert judgment and appropriate analytical approaches to weigh relevant information, including uncertainty, in our consideration of the best scientific information available regarding various aspects of climate change.

Global climate projections are informative, and, in some cases, the only or the best scientific information available. However, projected changes in climate and related impacts can vary across and within different regions of the world (IPCC 2013b, pp. 15–16). Therefore, we use "downscaled" projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used for analyses of a given species (see Glick *et al*. 2011, pp. 58–61, for a discussion of downscaling).

Southern California has a typical Mediterranean climate. Summers are typically dry and hot while winters are cool, with minimal rainfall averaging about 25.4 cm (10 in) per year. The maritime influence of the Pacific Ocean combined with the coastal and inland mountain ranges creates an inversion layer typical of Mediterranean-like climates, particularly in southern California. These conditions also create microclimates, where the weather can be highly variable within small geographic areas at the same time. Therefore, Hermes copper butterfly's ability to adapt to a changing climate may depend on species' representation in a variety of habitats throughout the species' range.

We evaluated the available historical weather data and the species biology to determine the likelihood of effects assuming the climate has been and will continue to change. The typical effect of a warmer climate, as observed with Hermes copper butterfly in lower, warmer elevation habitats compared to higher, cooler elevations, is an earlier flight season by several days (Thorne 1963, p. 146; Marschalek and Deutschman 2008, p. 98). Marschalek and Klein (2010, p. 2) noted that past records suggest a slightly earlier flight season in recent years compared to the 1960s. The earliest published day of flight prior to 1963, after "30 years of extensive collecting," was May 20 (Thorne 1963, pp. 143, 146), but adults began flying on May 1 and May 3 in 2015 and 2016, respectively (Marschalek and Deutschman 2016a, p. 7 and 9), and were reported as early as April 29 in 2003 (CFWO GIS database). The record early observation on April 29 was from Fortuna Mountain in Mission Trails Park, a well-collected occurrence with records dating back to 1958, including collections by Thorne (called "Mission Gorge" or "Mission Dam" on museum specimen labels) where May 21 was the earliest documented record from the 1960s and early 1970s (before climate change trends were reasonably detectable as described by the IPCC (2013b, p. 4)).

The historical temperature trend in Hermes copper butterfly habitats for the month of April (when larvae are typically developing and pupating) from 1951–2006 can be calculated with relatively high confidence (*p* values from 0.001 to 0.05). The mean temperature change in occupied areas ranged from 0.04 to 0.07 ^{o}C (0.07 to 0.13 ^{o}F) per year (Climate Wizard 2016), which could explain the earlier than average flight seasons. The latest published observation date (presumed end of flight season) of an adult prior to 1970 was on July 30, 1967 (museum specimen collected by Thorne at "Suncrest"); however, the latest observation date from monitoring data and other records in the past 16 years was almost a month earlier on July 2 in 2016, despite an uncharacteristically late start to the flight season (May 29). Shorter flight seasons are also consistent with higher average temperatures, as a higher metabolism in these exothermic short-lived invertebrates typically results in faster growth and earlier death. Nevertheless, given the temporal and geographical availability of their widespread perennial host plant, and exposure to extremes of climate throughout their known historical range (Thorne 1963, p. 144), Hermes copper butterfly and its host and nectar plants are not likely to be negatively affected throughout the majority of the species' range by phenological shifts in development of a few days (unlike species such as Edith's checkerspot (*Euphydryas editha*) that depend on annual host plants; Service 2003, pp. 63, 64).

3.4.2 Drought

Drought has been a major factor affecting southern California ecosystems, most recently the drought from 2012 through 2016 (Syphard *et. al.* 2018, p. 16) and the driest 12-month period on record in 2013–14 (Swain *et al.* 2014, p. S3), followed by another unusually dry year in 2018. Systematic monitoring of adult abundance at occurrences since 2010 indicates that the past 6 years of mostly drought conditions negatively affected habitat suitability and suppressed adult population sizes, most noticeably the Sycuan Peak monitored core occurrence, which has dropped from the highest daily counts to the lowest. Sycuan Peak has remained at record low numbers for 4 years in a row (1, 1, 0 and 0 maximum daily count), and may even be extirpated (Figure 10; Marschalek and Deutschman 2017, p. 9; Marschalek 2018, pers. comm.). The highest elevation, wettest occurrence (Boulder Creek Road) was the largest in 2016 and 2017 (Figure 10). This higher elevation site got more rain than lower sites, indicating representation in higher elevation inland habitats is important to species' viability. No Hermes copper butterflies were detected at 7 northern occurrence sites during 2017 and 2018 surveys (Marschalek and Deutschman 2017, p. 10).

Based on this information, we believe drought is a significant stressor on its own, but is of most concern with regard to its synergistic relationship with drier climate conditions and increasing fire hazard (See <u>Combined Stressor Effects</u> below).

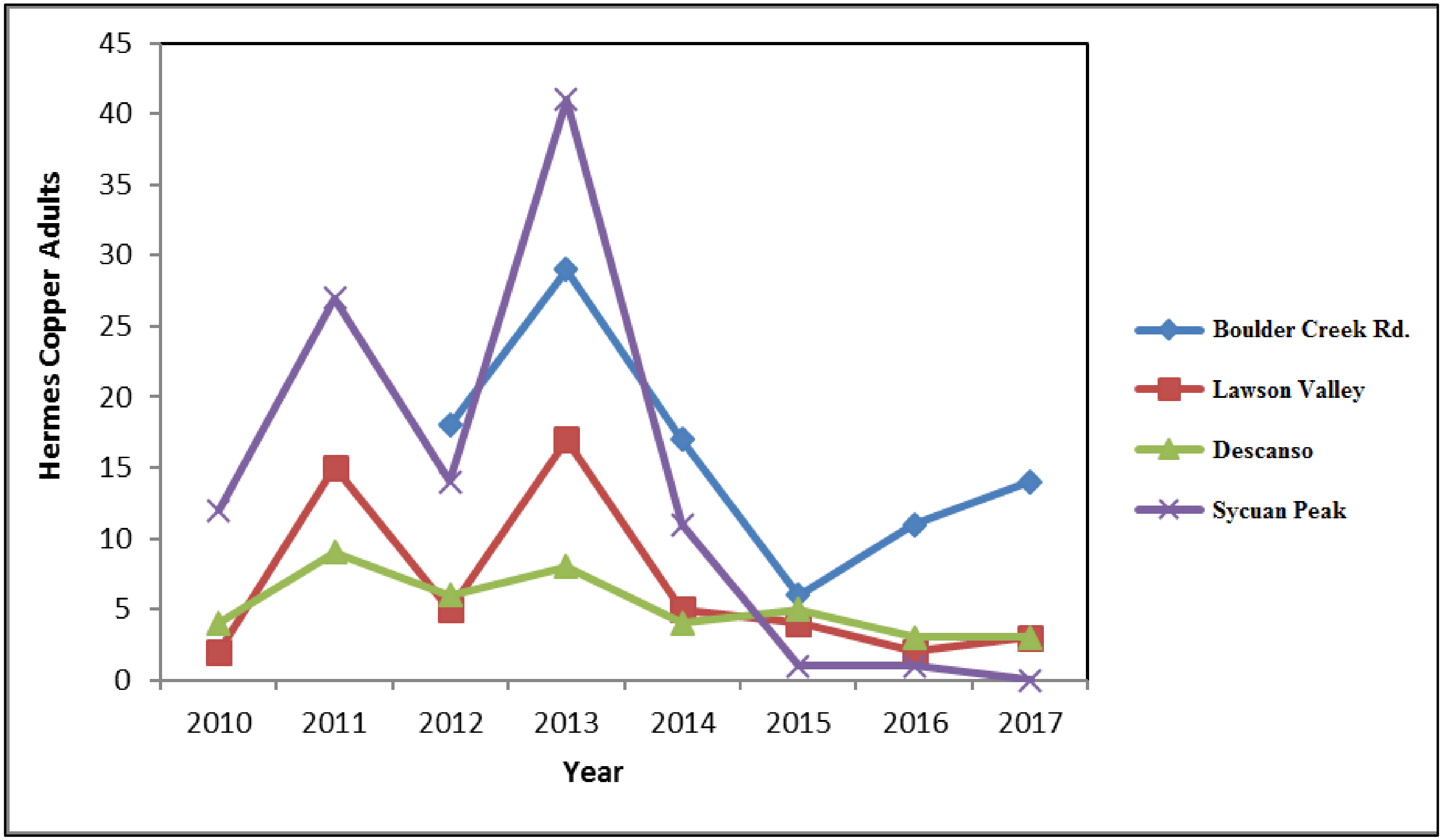

Figure 10. Hermes copper butterfly maximum daily counts at monitored core occurrences (Marschalek 2017 p. 2).

3.4.3 Summary

The information indicates that climate change significantly exacerbates other stressors (see Combined Stressor Effects below), especially wildfire and drought. Therefore, it continues to be a significant source of Hermes copper butterfly population decline and loss.

3.5 Other Stressors

Potential stressors, including disease, predation, roadkill, and overutilization have been identified in previous species assessments (Service 2015, pp. 7 and 8). When we investigated internet listings offering to sell specimens of Hermes copper butterfly (Service 2015, p. 7, Anderson 2017, personal observation), we found no evidence that Hermes copper butterflies, whole or in parts, were being used in commercial business activities. Through literature research, we evaluated the potential of disease to threaten Hermes copper butterfly rangewide and found no information indicating disease to be a current stressor for Hermes copper butterfly. Predation (including parasitism) is a factor known to cause mortality in butterflies, and therefore could potentially threaten any butterfly species. Faulkner and Klein (2012, p. 5) stated that “no papers have reported any parasites or predators for the Hermes copper butterfly, though they obviously exist.” Birds may consume Hermes copper butterfly larvae, although we are not aware of any data that indicate bird predation is a significant threat to Hermes copper butterfly. To our knowledge, disease, predation, roadkill, and overutilization have not impacted the species to such an extent that they would have a negative impact on species’ viability, and so are not discussed further.

3.6 Combined Stressor Effects

All stressors that act above the individual level have at least an additive effect; for example, habitat loss and isolation due to land use change combined with wildfire may together have a greater impact on the species than wildfire alone. Multiple stressors at a given hierarchical level have combined effects that emerge at the next higher level. For example, at the population level, habitat loss significantly reducing the resilience of one population, combined with wildfire affecting resilience of another, has a greater effect on Hermes copper butterfly species-level redundancy, and therefore species' viability than either stressor would individually (see **Species Viability Model** discussion below).

Stressors that alone may not significantly reduce species viability have not only additive, but sometimes synergistic, effects on species viability. For example, investigators have found that wildfire, human population growth, and habitat modification (type conversion) typically have a synergistic effect on habitat suitability in Mediterranean-type climate zones (Keely and Brennan 2012 entire; California Chaparral Institute 2017 entire; Syphard *et al.* 2018, entire). Wildfire increases the rate of nonnative grass invasion, a component of the habitat modification stressor, which in turn increases fire frequency, also a direct mortality factor. Overall, these factors increase the likelihood of megafires on a landscape/species range-wide scale. The relationship between habitat patch fragmentation and type conversion is in part synergistic, as fragmentation increases the rate of nonnative plant species invasion and type conversion through disturbance, nitrogen deposition, and seed dispersal. Synergistic effects are a type of emergent property. Simply put, properties of the system that cannot be entirely explained by individual components and are often hard to predict (Ponge 2005, entire; Vesterby 2011, entire). At each hierarchic ecosystem level, there are properties (possibly stressors) that did not occur at or influence lower levels; however, these properties do affect the ecosystem at the level they emerge, and also at levels above. At higher hierarchical ecosystem levels, thousands of factors can be involved in the process of property emergence. In the case of interaction between wildfire and nonnative grass invasion, there are two emergent properties: increased fire frequency and accelerated invasion rate. In the case of habitat fragmentation, the emergent property is accelerated type conversion relative to more intact/connected habitat patches. Although difficult to predict, we have come to understand some synergistic effects through observation and hindsight. It is important to understand the full extent and impact of emergent properties resulting from stressors may not be fully understood or appreciated. While it is also possible that emergent properties may have positive effects on a species, there is no information to indicate any exist for Hermes copper butterfly.

Combined effects, when synergistic, generally increase the likelihood of significant and irreversible loss of populations, compared to individual effects. If fewer source populations are available over time to recolonize burned habitat when host and nectar plants have sufficiently regenerated, the synergistic interaction between reduced species-level redundancy and other stressors could result in a dramatic increase in species extinction risk (see **Possible Future Conditions** below).

3.7 Current Conservation Measures

As described above, the County of San Diego implements ordinances within the County that require Hermes copper butterfly surveys in potential habitat and specific measures to offset impacts to occupied Hermes copper butterfly habitat. In addition, presence of Hermes copper butterflies is a factor within San Diego County for prioritizing land acquisitions for conservation from Federal, State, and private funding sources. SANDAG has provided funding for Hermes copper butterfly surveys and research since 2010, as well as grants for acquisition of two properties that have been (or are) occupied by Hermes copper butterfly. Of particular importance is the SANDAG-funded translocation research undertaken by San Diego State University (Marschalek and Deutschman 2016b), which, if successful, would provide a means to mitigate and reverse wildfire impacts to populations.

The most obvious way to capitalize on the potential for cooperative, collaborative planning and decision making in Hermes copper butterfly conservation is through scenario planning. Scenario planning (Rowland *et al.* 2014) can serve multiple purposes, including education and outreach, decision support, and research. It is particularly appropriate in complex situations where drivers are not controllable and introduce irreducible uncertainty, such as the wildfire stressor for Hermes copper butterfly. Other drivers of change external to species' resources and beyond managers' direct control include population growth and demographic changes, land use patterns, and financial resource availability. Such uncertainties that cannot be reduced within a decision timeframe because they are beyond managerial control and/or outside current scientific knowledge make it difficult or even impossible to develop informative predictive models. Scenario planning offers an alternative approach to considering future conditions as uncertainties and the level of complexity of a situation increases, the longer one looks into the future. Our objective is for this SSA to be a significant first step in the scenario planning process, which we believe has the potential to increase Hermes copper butterfly viability.

Chapter 4. Potential Changes

4.1 Introduction

To analyze species' viability, we consider the current and future availability or condition of resources. The consequences of missing resources are assessed to describe the species' current condition and to project possible future conditions. Characterization of viability is enhanced by a straight-forward theoretical probability model and three probable scenarios to describe possible viability changes over time and characterize uncertainty.

For the purpose of this assessment, we generally define viability as the ability of the species to sustain populations in the natural ecosystem beyond a biologically meaningful timeframe, in this case, 30 years. We chose 30 years because it is within the range of the available climate change model forecasts, fire hazard period calculations, habitat vegetation association fire return intervals, and uncertainty terms used by the IPCC (see above discussions).

Development – future impacts

Possible future development, still in the preliminary planning stage (Service and CDFW 2016), could destroy occupied or suitable habitat on private land within the North Santee (Fanita Ranch) occurrence, further fragmenting remaining habitat and isolating the largely conserved Lakeside Downs and Mission Trails (Mission Gorge, Mission Dam) occurrences. Habitat fragmentation is discussed further below (for geographic context see Figures 5, 6, and 9). Habitat isolation is a continuing concern for Hermes copper butterfly, as development outside of occupied habitat can still negatively affect the species. Within U.S. Forest Service (USFS) lands, we anticipate future development, if any, will be limited, and the USFS has incorporated measures to address threats to Hermes copper butterfly and its habitat as it implements specific activities within forest lands.

The limited number of Hermes copper butterfly occurrences within Bureau of Land Management (BLM) lands is also unlikely to face future development pressure. Based on our analysis, we conclude land use change, while significant when combined with the stressor of wildfire (for more information see **3.6 Combined Stressor Effects** above), will not be the most significant future source of Hermes copper butterfly population decline and loss.

Wildfire – future impacts

As discussed above, wildfire can permanently affect habitat suitability. If areas are reburned at a high enough frequency, California buckwheat may not have the time necessary to become reestablished, rendering the habitat unsuitable for Hermes copper butterfly (Marschalek and Klein 2010, p. 728). Loss of nectar plants is not the only habitat effect caused by wildfire; habitat type conversion increases flammable fuel load (nonnative grasses, etc.) and fire frequency, further stressing Hermes copper butterfly populations. Fire management plans are not expected to provide protection from megafires such as those that occurred in 2003 and 2007. Therefore, habitat modification due to wildfire is cause for both short and long-term habitat impact concerns.

Wildfire probably has the greatest impact on Hermes copper butterfly populations through direct mortality. The significant effect of wildfire on the Hermes copper butterfly species' viability can be seen in the current compared to historical distributions of the species in southern California. Analysis of GIS information indicates approximately 51% of the extant and presumed extant occurrences are found within the footprint of the 1970 Laguna megafire (Figure 7). In contrast, areas north and south of the extant Hermes copper butterfly occurrences, where extirpations are concentrated, burned in the 2003 and 2007 megafires (Figure 7), indicating a similar fate could befall 51% of extant occurrences should another fire similar to the Laguna megafire occur. As discussed above, amount of habitat under extreme fire risk has increased steadily in California since 1979, and 2014 ranked highest in the history of the State (Yoon *et al.* 2015, p. S5). As climate continues to warm, rainstorms are becoming more intense, but less frequent, so that year-to-year rainfall is more volatile. The recent years of historic drought (2012–2016, followed by the record dry fall and early winter and then the extremely wet winter of 2017 is an example of such volatility. These patterns are expected to increase the number of large fires in the region (Syphard *et al.* 2018; entire). In light of the recent drought-influenced wildfires in southern California, a future megafire affecting most or all of the area burned by the Laguna Fire in 1970 (40-year-old chaparral) would encompass the majority of extant occurrences and result in significantly reduced species' viability (Figures 7 and 8).

In the case of Hermes copper butterfly, the primary limiting species-level resource is movement corridor connectivity of formerly occupied to currently occupied habitat patches, on which the likelihood of post-fire recolonization depends. We further analyzed fire frequency data to determine the effect on occurrence status, and likelihood of extirpation over the next 30 years. We defined megafires as being at least as large as the smallest of the large fires that extirpated multiple occurrences in 2003 and 2007, approximately 40,000 ac (16,187 ha). During the past 15 years (2002–2017), there were six megafires within Hermes copper butterfly's possible historical range (Poomacha, Paradise, Witch, Cedar, Otay Mine, and Harris), a significant increase compared to none during the two previous 15 year periods (1987–2001 and 1972–1986), and only one during the 15-year period prior to 1972 (Laguna). This represents a more than six-fold increase in the rate of megafire occurrence over the past 15 years. At the current megafire rate (6/15 years), 12 megafires could impact Hermes copper butterfly over the next 30 years, and that assumes no further increase in rate. If the trend does not at least stabilize, the frequency of megafires could continue to increase with even more devastating impacts to the species.

4.2 Species Viability Index

In the absence of population dynamics data required for a population viability analysis (PVA), we constructed a relatively simple viability index (Figure 9). In our index calculations, the contribution of a population to species-level redundancy depends on population-level resilience, and contribution to species-level representation depends on how rare populations are in the habitat type it occupies (California Ecological Units; Figure 10). Species redundancy and representation are assumed to equally influence species' viability. We assign a 100% species viability index value to the baseline state of all known historical population occurrences in the United States. For this index calculation, we do not consider Mexican occurrences, because there are only 3 (possibly 2) of out of a total of 95 and all are presumed extirpated. Our index of species' viability is proportional, but not equal to, the ability of a species to sustain populations in the wild (i.e., it is an index that should change proportionally with the likelihood of persistence, but is not itself a probability value). The baseline state represented by the calculated historical viability index may be less than the actual historical value (for example, there were likely more coastal populations prior to urban development), but also may be greater than the viability level required for species persistence for another 30 years. As such, our viability index uses population resilience, species redundancy, and species representation to quantify changes in species' viability (Figure 11), but does not predict probability of persistence.

The baseline historical 100% species viability index assumes 100% redundancy and 100% representation, and equal influence of each factor. Under 100% historical baseline redundancy, we assume all 92 known U.S. occurrences (Table 1) were extant and on average as large (core size) and connected as at least the smallest, most isolated one in that category today (see categories below and Appendix II). Under 100% historical baseline representation, we assume all 92 known occurrences in the United States (Table 1) were extant and distributed as mapped. Although historically, populations may have never all been extant at the same time, we can assume there were a number of undocumented, extirpated historical populations based on the large amount of fragmented and developed former coastal habitat where a few scattered specimens were historically collected from extirpated occurrences (Figure 9). Therefore, we believe attributing higher influence to some known populations than they historically had is reasonable for baseline species viability estimation.

To estimate a current species redundancy value, we ranked each occurrence's resilience value using a scale of 0–4; 0 = extirpated or presumed extirpated (0% resilient), 1= presumed extant (1–25% resilient, uncertain status), 2 = extant non-core and isolated (26–50% resilient), 3 = extant non-core but connected, or extant core but isolated (51–75% resilient), 4 = core and connected (76–100% resilient). Population resilience ranks were based on occurrence status (Table 1) and general movement corridor connectivity or distance from other known occurrences as visible in satellite imagery (Figures 5 and 6). We then summed the weighted ranks for a total redundancy value.

In order to model species representation, we used California Ecological Units (Goudey and Smith 1994 [2007]) as a measure of habitat diversity (Figure 12). In San Diego County, these units take the form of irregularly shaped bands aligned north to south that change as you move across the county from east to west. Baseline historical 100% representation is equal to 11 occurrences in the Coastal Terraces Ecological Unit (CT), 41 in the Coastal Hills Ecological Unit (CH), 35 in the Western Granitic Foothills Ecological Unit (WGF), and 6 in the Palomar-Cuyamaca Peak Ecological Unit (PC) (Figure 12; Appendix II). Because each unit is given equal representation weight, but has a different number of occurrences, occurrence influence is proportional to frequency within each unit. Loss of an occurrence in the CT unit (two extant or presumed extant; Table 1) would therefore decreases species representation by almost seven and a half times as much as loss of one within the CH unit would (15 extant or presumed extant; Table 1). All non-extirpated occurrences are equally ranked. We did not consider population resilience in species representation value calculations, because resilience ranking based on information available to us (population size and connectivity) would reduce the value of the occurrences in the most unique habitats that may also be the most genetically distinct. That is, the least resilient populations may have the highest species representation value because they contribute the most to habitat and possibly genetic diversity at the species level. The species representation value is therefore the percent total occurrence representation within ecological units relative to historical baseline.

Using this viability index model, we estimated current species' viability relative to historical viability. A 100% Hermes copper butterfly viability rating relative to historical conditions would have a 100% redundancy value of 368 (on average all 92 U.S. occurrences as large and connected as the smallest, most isolated ones with a current resilience rank of 4; contributing half of total viability) and 100% representation (all 92 documented U.S. occurrences extant; contributing the other half of total viability). There are currently 18 presumed extant occurrences (rank sum of 18), 3 extant non-core isolated (total rank score of 6), 11 extant non-core connected or core isolated (rank sum of 33), and 13 extant core connected (rank sum of 52) occurrences for a total current species redundancy value of 109. Based on the resulting redundancy value ratio of 109/368, the species currently retains 30% of its historical population redundancy. Occupancy in the CT ecological unit has been reduced to 18% (2/11 occurrences not extirpated), in the CH unit to 40% (16/40 not extirpated), in the WGF unit to 63% (22/35 not extirpated), while the PC unit remains at 100% (none extirpated). Based on these proportional values, the species retains 55% (18+40+63+100/400) of its historical species representation. Therefore, we estimate that overall, the species currently retains not more than 43% (30+55/200) of its estimated historical viability.

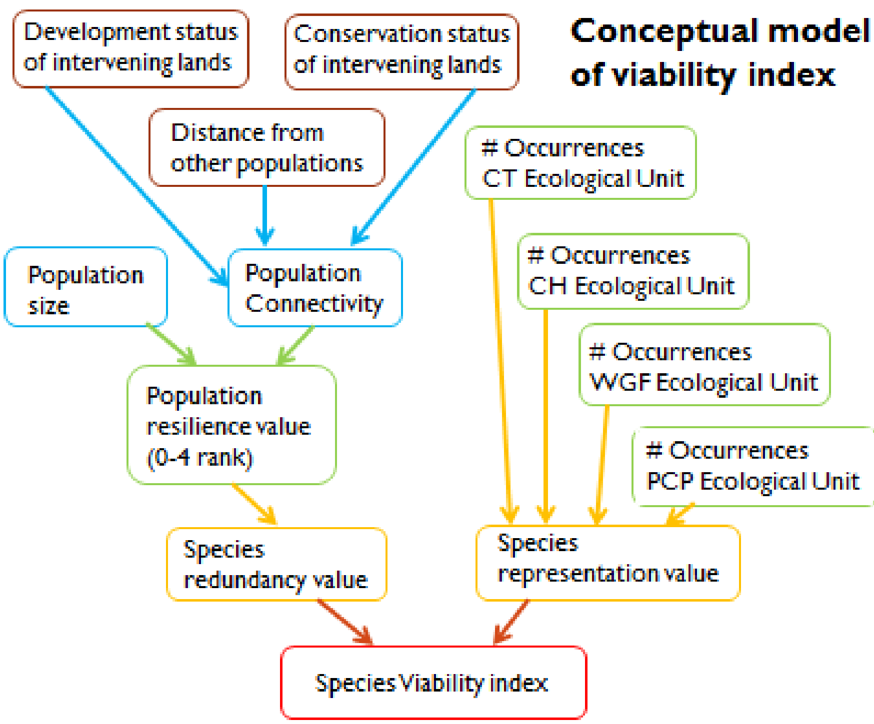

Figure 11. Hermes copper butterfly species viability index conceptual model.

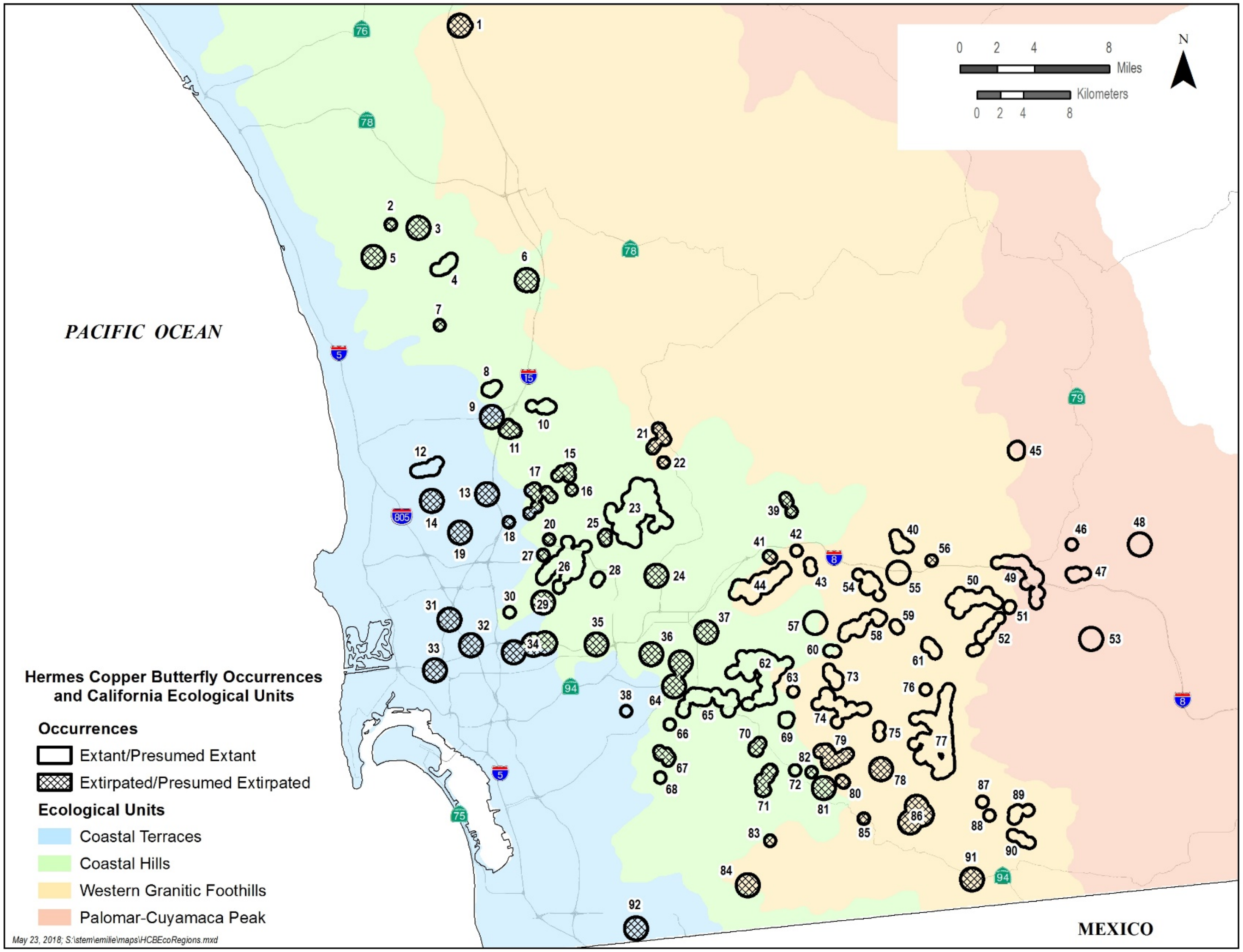

Figure 12. Hermes copper butterfly occurrences and California Ecological Units (Goudey and Smith 1994 [2007]).

4.3 Possible Future Conditions

Given climate change predictions of more extreme weather, less precipitation, and warmer temperatures, and the recent trend of relatively frequent megafires, we can assume the primary stressors of drought and wildfire will continue to increase in magnitude. If land managers work to conserve and manage all occupied and temporarily unoccupied habitat and maintain habitat patch contiguity/connectivity, this should prevent further habitat loss. Although fire and drought are difficult to control and manage for, natural recolonization and assisted recolonization through translocation in higher abundance years (e.g., Marschalek and Deutschman 2016b) could allow recolonization of extirpated occurrences. All scenarios described below incorporate some change in environmental conditions. It is important to keep in mind, however, that even if environmental conditions remain unchanged, the species may continue to lose populations so that viability declines by virtue of maintaining the current trend.

Below we present four potential future scenarios and associated modeled viability measure under four simple sets of possible future conditions. We assume the species' extinction risk was minimal under baseline known historical conditions, and that under current conditions it is relatively high (Service 2011, p. 20918).

<u>Conditions worsen throughout the range, resulting in increased extinction risk</u>

One potential future scenario would be a continued warming, drying trend, and an inability to minimize wildfire impacts or assist recolonization. Due to a combination of increased wildfire and drought frequency and severity, no habitat patches are recolonized, and all Hermes copper butterfly occurrences with a resilience score of less than 4 are extirpated (without reducing the redundancy weight of remaining occurrences based on changed size or isolation status). These losses would reduce the species redundancy value from 109 to 52. Based on the resulting redundancy value ratio of 52/368, the species would retain 14% of its historical baseline population redundancy. There would be no occupancy remaining in the CT ecological unit (0%), CH ecological unit occupancy would be reduced from 40% to 8% (3/40 not extirpated), WGF unit from 63% to 26% (9/35 not extirpated), and PC unit from 100% to 17% (1/6 not extirpated). Based on these proportional values, the species would retain approximately 13%

(0+7+26+17/400) of its historical representation. Resulting changes to the population redundancy and representation values would cause an approximate drop from 43% to 14% (14+13/200) species viability relative to historical conditions. We judge that this scenario is about as likely as not to occur in the next 30 years.

A megafire comparable to the 1970 Laguna Fire increases extinction risk

If there was a megafire comparable to the 1970 Laguna Fire, many occurrences would likely be extirpated, and due to the number of occurrences already lost, the likelihood of any being recolonized would be low. This scenario assumes extirpation of occurrences where the majority of the polygon within the 1970 Laguna Fire footprint.

This would result in a loss of 6 occurrences with a resilience rank of 1, 7 with a rank of 3, and 10 with a rank of 4. These losses would result in the species total redundancy value being reduced from 109 to 67, and based on the resulting redundancy value ratio of 67/368; the species would retain 18% of its historical baseline redundancy.

Six occurrences would be lost in the CH ecological unit, 14 in the WGF, and 3 in the PC. Occupancy in the CT ecological unit would remain at 18% (2/11 occurrences not extirpated), in the CH unit it would be reduced from 40% to 25% (10/40 not extirpated), in the WGF unit reduced from 63% to 23% (8/35 not extirpated), and in the PC unit reduced from 100% to 50% (3/6 not extirpated). Based on these proportional values, the species would retain 29% (18+25+23+50/400) of its historical representation.

These changes to population redundancy and representation values would result in an approximate drop in species viability relative to historical conditions from the current 43% to 24% (18+29/200). We judge this scenario more likely than not to occur in the next 30 years.

Conditions stay the same, resulting in extinction risk staying the same.

While environmental conditions never stay the same, changes that negatively affect populations may be offset by positive ones, including continued habitat conservation, and management actions such as translocations to recolonize burned habitats. In this scenario, the risk of wildfire remains high, population sizes fluctuate but they persist, and enough recolonizations occur to balance losses.

Occurrence extirpations and decreased resilience of some populations in this scenario are balanced by habitat recolonizations and increased resilience in others. Species viability would thus remain at approximately 43% relative to historical conditions. We judge this scenario about as likely as not to occur in the next 30 years.

<u>Conditions improve, resulting in decreased extinction risk</u>

One potential future scenario would be environmental stressors such as fire and drought decrease in frequency and magnitude relative to the past 30 years, and management actions such as continued conservation and translocation efforts are successful. Due to favorable climate conditions and proactive management and conservation, half of the presumed-extirpated occurrence habitats (36 with resilience rank of 0 increased to 2, 3, or 4 for a rank sum of 57) are known to be extant, no further occurrences are extirpated, and all the presumed extant occurrences are known to be extant (18 with rank of 1 increased to 2, 3, or 4 for a rank sum of 53; 53-18=35 more). This would increase the total redundancy value from 109 to 201 (109+57+35=201), and based on the resulting redundancy value ratio of 201/368, the species would rebound to 55% of its historical baseline redundancy. Occupancy in the CT California Ecological Unit would increase by 1 (3/11; 27%), in the CH by 11 (27/40; 68%), in the WGF by 6 (28/35; 80%), and PC occupancy would remain unchanged (100%). Based on these proportional values, the species would rebound to 69% (27+68+80+100/400) of its historical species representation.

These changes to population redundancy and representation values would result in an approximate increase in species viability relative to historical conditions from the current 43% to 62% (55+69/200). We judge that this scenario unlikely to occur in the next 30 years.

Chapter 5. Synthesis

We have determined that most recent Hermes copper butterfly habitat and population losses are attributable to population extirpation due to megafires over the past 15 years, and to a lesser but still significant extent, ongoing habitat loss and isolation resulting from land use change. Hermes copper butterflies occupy scattered areas of sage scrub and chaparral vegetation associations in an arid region susceptible to wildfires of increasing frequency and size. The likelihood populations will be burned by catastrophic megafires, combined with the isolation and small size of most extant populations and continued development of habitat, makes Hermes copper butterfly particularly vulnerable to population extirpation rangewide.

We estimate that the Hermes copper butterfly has lost approximately 57% of its known, historical species-level viability. This loss of historical viability is primarily due to a combination of development and megafires. Although climate and wildfire are difficult stressors to manage for, over half the known occupied or formerly occupied habitat is publicly-owned and managed, making range-wide management measures such as assisted recolonization possible. Furthermore, the majority of extant populations are on conserved lands and more habitat is planned for conservation in the future. Therefore, there is much potential for cooperative, collaborative planning, and decision making under conditions of environmental uncertainty. Still, the most likely future scenarios raise concern for the viability of this species over the next 30 years.

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APPENDIX I

Conceptual Model Narrative

In February 2012, the Institute for Ecological Monitoring and Management convened a workshop to help local managers and experts develop conceptual models for five topics of regional importance, including the Hermes copper. The following information is from Strahm *et al.* (2012, pp. 8 –13).

Hermes Copper Butterfly Working Group

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2. Douglas Deutschman, Professor of Biology, IEMM, San Diego State University
3. Mark Dodero, Restoration Biologist, RECON
4. David Faulkner, Entomologist, Forensic Entomology Service
5. Keith Greer, Senior Regional Planner, San Diego Association of Governments
6. Daniel Marschalek, Entomologist, California Department of Fish and Game
7. John Martin, Refuge Biologist, United States Fish and Wildlife Service
8. Dave Mayer, Senior Environmental Scientist, California Department of Fish and Game
9. Eric Porter, Biologist, United States Fish and Wildlife Service
10. Jennifer Price, Land Use/Environmental Planner, San Diego County Department of Parks and Recreation
11. Joyce Schlachter, Wildlife Biologist, Bureau of Land Management
12. Susan Wynn, Biologist, United States Fish and Wildlife Service

Anthropogenic Drivers (referred to stressors in this SSA)

<u>Development/Fragmentation</u> A large portion of the historical Hermes copper range is now developed, diminishing available habitat and increasing fragmentation (USFWS 2011). Hermes copper males do not disperse long distances and generally do not cross large patches of unsuitable habitat. Although females may have the capacity for long distance dispersal, habitat fragmentation may limit dispersal (including fragmentation caused by conversion of shrub lands into grasslands) (Marschalek and Klein 2010; Marschalek and Deutschman 2008; Deutschman *et al.* 2010).

Fire Wildfires cause direct mortality of Hermes copper. Frequent "megafires" (fires of unusually large extent) are especially problematic due to Hermes copper dispersal limitation and the low rate at which the species recolonizes areas (USFWS 2011; Marschalek and Klein 2010).

Road Kill It is unclear if road kill is a substantial issue for Hermes copper. Given their short dispersal distances and relatively low-flying habit it could potentially be a problem. Marschalek (2004) has observed at least one individual that appeared to have been killed in a collision; however, the relative importance of this threat is unknown and at this time seems to be far less important than that of fire (Marschalek and Klein 2010**).**

Invasive Plants Invasive plants, particularly non-native grasses, add significant flash fuel to the environment and increase the probability of accidental fires. As a result, these plants may alter the fire regime which can influence Hermes copper distribution by causing local extirpations and changing the population structure.

Recreation Recreation involving motorized equipment increases the number of possible ignition sources in Hermes copper habitat, and as a result could impact populations by altering the fire regime.

Argentine Ants Argentine ants (*Linepithema humile*) could potentially prey on immature stages of Hermes copper, and as a result could represent an artificially high predator population.

Natural Drivers

Habitat/Vegetation Community Hermes copper occurs in coastal sage scrub and southern mixed chaparral, utilizing spiny redberry as a host plant for oviposition, larvae, and pupation. Adult Hermes copper show a strong preference for nectaring on California buckwheat, however may utilize other plants occasionally, including chamise (*Adenostoma fasciculatum*) and tarplants (*Deinandra* sp.) (Marschalek and Deutschman 2009; Marschalek and Deutschman 2008; Klein pers. comm.; USFWS 2011; Thorne 1963; Marschalek pers. obs.).

Predators/Parasitoids It is unclear if predators or parasitoids on adult butterflies play a significant role in Hermes copper population dynamics. A single observation of a jumping spider feeding on an adult was made by Marschalek in 2010. Other potential predators or parasitoids are unknown.

Climatic Conditions Timing of emergence (beginning of the flight season) of Hermes copper appears to be influenced by temperature, precipitation, and elevation, although the specifics of this relationship are unknown. In addition, activity on a given day in the flight season is strongly influenced by temperature and cloud cover, with Hermes copper remaining inactive and generally unseen until a temperature of 22°C. Furthermore, Hermes copper tends to prefer the north and west sides of roads and trails for what seem to be purposes of thermoregulation (Marschalek and Deutschman 2008; Marschalek and Klein 2010; Deutschman et al. 2010).

Species Variables

Population Structure Genetic analysis indicates that Hermes copper dispersal is complex. Individuals at the same site do not always poses the most similar genetic composition. At this time genetic analysis suggests that populations at the center of the distribution in the southeast part of the county may be mixing at higher rates, but that there is genetic differentiation of small peripheral sites (Deutschman *et al.* 2010; 2011).

Adult Female Behavior Hermes copper females may be found in the same open spaces occupied by males; however, upon flushing they fly quickly away and do not generally return. Based on genetic information, some long-distance dispersal events do occur; however, field studies suggest that Hermes copper males typically do not exhibit such movements. Other *Lycaena* show different behavior between the sexes, with females dispersing longer distances than males (Deutschman et al. 2010; USFWS 2011).

Reproduction and Oviposition Most of the Hermes copper life cycle is achieved on spiny redberry, including oviposition, larval feeding, and pupation. Eggs are approximately one millimeter in diameter, generally positioned on the underside of relatively new growth, often near an intersection with another branch or leaf. It is unclear what degree of habitat selection is occurring by females, prior to oviposition (Thorne 1963; Marschalek and Deutschman 2009).

Dispersal and Gene Flow Hermes copper males appear to move only short distances (Marschalek and Deutschman 2008; Marschalek and Klein 2010), but females may engage in long-distance dispersal (Deutschman *et al.* 2010, 2011). Evidence suggests that long-distance dispersal occurs within the central region of their distribution in the southeastern portion of San Diego County, but that peripheral populations are more isolated (Deutschman *et al.* 2010, 2011).

Male Behavior Hermes copper males only make small movements in the process of defending territory. Even when spooked they usually return to the same area after a few minutes. Males are much more frequently encountered compared to females (Thorne 1963).

Eggs The location that females choose to oviposit could be crucial for understanding what constitutes high quality habitat. This information could be used to determine if unoccupied sites with spiny redberry are simply unoccupied, or if there is some crucial factor that makes them unsuitable. In addition reproductive success is critical for maintaining the species. It is unclear if eggs are subject to predation or other stressors.

Larvae Very little is known about the biology of Hermes copper larvae. This stage could be sensitive to a number of environmental stressors, predation, and parasitism. The transition from egg to larvae is the part of the lifecycle limiting our ability to rear Hermes copper in a laboratory setting.

Pupae Very little is known about the placement and phenology of Hermes copper pupae other than that pupation occurs on spiny redberry plants.

Adults Hermes copper adults are small but boldly colored butterflies. Although they are easy to spot, much remains unknown about their biology.

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APPENDIX II

Existing Regulatory Mechanisms and Voluntary Conservation Measures

Federal Mechanisms

National Forest Management Act

Under the National Forest Management Act of 1976 (16 U.S.C. 1600 *et seq*.), the U.S. Forest Service (USFS) is required to prepare a comprehensive land and natural resource management plan for each unit of the Forest Service, in accordance with the National Environmental Policy Act's (NEPA's) procedural requirements, to guide the maintenance and use of resources within national forests. The plans require an interdisciplinary approach, including a provision providing for diversity for plant and animal communities (16 U.S.C. 1604(g)(3)(B)). The USFS is currently operating under the transition provisions of the 2000 Planning Rule (USFS 2000, p. 67514) as an interim measure until a new planning rule is issued (USFS 2009, p. 67059). The 2000 rule allows forests to develop, revise, and amend forest plans using the procedures of the 1982 Rule (USFS 1982, p. 43037). All existing forest plans have been developed using the 1982 Planning Rule procedures, including the Cleveland National Forest Plan.

In preparing the Cleveland National Forest (CNF) Plan, USFS evaluated and identified the Hermes copper butterfly as a species of concern and then evaluated this species relative to its potential of risk from Forest Service activities and plan decisions in its 2005 Final Environmental Impact Statement (USFS 2005). The Hermes copper butterfly, along with 148 other species, was defined as a "species-at-risk" (USFS 2005, Appendix B, p. 36), requiring a further individual viability assessment. The subsequent threat category identified for the Hermes copper butterfly was 5 or "Uncommon, narrow endemic, disjunct, or peripheral in the plan area with substantial threats to persistence or distribution from [U.S.] Forest Service activities" (USFS 2005, Appendix B, p. 43). The specific threat associated with Hermes copper butterfly and Forest Service management activities is described as "Prescribed fire or fuel reduction projects in habitat (affecting host plant, *Rhamnus crocea*)" (USFS 2005, Appendix B, p. 52). There are approximately 3,181 ha (7,860 ac) of extant Hermes copper butterfly habitat (encompassing 7 populations) within the CNF and approximately 850 ha (2,100 ac) of Hermes copper butterfly habitat that has been extirpated or is of unknown status. The USFS incorporates measures into its planning efforts to address identified threats as it implements specific activities on forest lands. As an example, in 2007, measures were included to protect Hermes copper butterfly habitat ahead of the Horsethief Fuels Reduction Project (Jennings 2007, pers. comm.).

The Service has an extensive consultation history with the USFS. Most recently, the USFS submitted a biological assessment to review the effects of ongoing management activities of CNF (USFS 2012, p. 1). This assessment is intended to tier to and update the Service's consultation on the 2005 revision of the Land and Resource Management Plans for the Four Southern California Forests, including the CNF Plan. The biological assessment provides updated site-specific information on existing conditions and effects of USFS management within the CNF on Hermes copper butterfly and its habitat, specifically: 1) recreation activities, and 2) construction, use, and maintenance of roads and motorized trails. It also outlines conservation measures such as road use monitoring and, if necessary, installation of barricades or fencing to minimize effects to the species (USFS 2012, pp. 15–16).

Federal Land Policy and Management Act

The Federal Land Policy and Management Act of 1976 (FLPMA) governs the management of public lands under the jurisdiction of the BLM. The legislative goals of FLPMA are to establish public land policy; to establish guidelines for its [BLM's] administration; and to provide for the management, protection, development, and enhancement of the public lands. While FLPMA generally directs that public lands be managed on the basis of multiple use, the statute also directs that such lands be managed to "protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; …[to] preserve and protect certain public lands in their natural condition; [and to] provide food and habitat for fish and wildlife..." (43 U.S.C. 1701(a)(8)). Although the BLM has a multiple-use mandate under the FLPMA which allows for grazing, mining, and off-road vehicle use, the BLM also has the ability under the FLPMA to establish and implement special management areas such as Areas of Critical Environmental Concern, wilderness areas, research areas, etc. BLM's South

Coast Resource Management Plan covers the San Diego County area. Hermes copper butterfly was a species considered but not addressed in the BLM's South Coast Resource Management Plan (SCRMP; BLM 1994, p. 76) but many components of Hermes copper butterfly habitat (coastal sage scrub and chaparral) are contained within the SCRMP planning area, and receive some regulatory protection under the plan.

Wilderness Act

Portions of multiple Hermes copper butterfly occurrences fall within the Pine Creek and Otay Mountain Wilderness Areas and therefore are managed in accordance with the provisions of the Wilderness Act of 1964 (16 U.S.C. 1131 *et seq*.). The Wilderness Act of 1964 strictly limits use of wilderness areas, imposing restrictions on use of vehicles, new developments, chainsaw use, mountain bike use, leasing, and mining, in order to protect the natural habitats of the areas, maintain species diversity, and enhance biological values. Lands acquired by BLM within wilderness area boundaries become part of the designated wilderness area and are managed in accordance with all provisions of the Wilderness Act and applicable laws.

Sikes Act

The Sikes Act as amended (16 U.S.C. 670a *et seq*.) requires the Department of Defense to develop and implement integrated natural resources management plans (INRMPs) for military installations across the United States. There are historical Hermes copper butterfly observation locations and habitat on Marine Corps Air Station, Miramar (MCAS Miramar) and the adjacent Mission Gorge Recreational Facility (also known as Admiral Baker Field) owned by the U.S. Navy (Navy).

The INRMPs are reviewed every year by military installations and modified as needed, and are reviewed at least every 5 years with the Service and States. Through its 2011 INRMP, the U.S. Marine Corps manages natural resources on MCAS Miramar following principles of ecosystem management. In general, the MCAS Miramar strategy for conservation and management is to: (1) limit activities, minimize development, and mitigate actions in areas supporting high densities of vernal pool habitat, threatened or endangered species, and other wetlands; and (2) manage activities and development in areas of low densities, or no regulated resources, with site-specific measures and programmatic instructions. Management Areas (MAs) were identified primarily to support the conservation and management of Special Status Species (species listed by the federal government as threatened, endangered, proposed for listing as threatened or endangered, or are candidates for such listings), wetlands, and other areas warranting special attention (USMC 2011, Executive Summary, p. 4 and chapter 4, p. 16). For the Hermes copper butterfly, all sites identified as supporting the species prior to the 2003 Cedar Fire remain undeveloped, and most of these sites and other areas of potential habitat are within MAs identified to conserve other threatened and endangered species. No recent surveys have been conducted on MCAS Miramar to our knowledge; however, the INRMP specifies that if Hermes copper butterfly is listed as threatened or endangered, focused surveys for the species must be completed prior to actions that would remove stands of spiny redberry (USMC 2011, chapter 7, p. 19).

Through the 2002 Naval Base San Diego INRMP, which is currently under revision, the Navy manages its open space areas, including those on Mission Gorge Recreational Facility, using an ecosystem-level approach that includes invasive species removal, habitat restoration and enhancement, and natural resource inventories. In the 2002 INRMP, the Navy identified the following focus areas for management actions: wildlife conservation and management, rare wildlife species, exotic vegetation control, habitat restoration, and fire management (Navy 2002, section 3, pp. 37–40 and 45–47). The Hermes copper butterfly is not identified as a rare species in the INRMP; however, some existing management recommendations and actions may also be beneficial to Hermes copper butterfly.

Healthy Forests Restoration Act

The Healthy Forests Restoration Act of 2003 (16 U.S.C. 6501 *et seq*.) includes the first meaningful statutory incentive for USFS and BLM to give consideration to prioritized fuel reduction projects identified by local communities. In order for a community to take advantage of this opportunity, a Community Wildfire Protection Plan (CWPP) must be prepared. The process of developing a CWPP can help a community identify and clarify priorities for the protection of life, property, and critical infrastructure in the wildland-urban interface (WUI) (Fire Safe Council of San Diego County 2011). See our discussion of CWPPs below under the State and Local Regulations subsection. Combined, the Healthy Forests Restoration Act and the Community Wildfire Protection Plan emphasize the need for Federal, State and local agencies to work collaboratively with communities in developing hazardous fuel reduction projects, and place priority on treatment areas identified by the communities themselves in a CWPP (Fire Safe Council of San Diego County 2011). While these regulations reduce the impact of wildfire to some extent, especially with regard to human property and safety, the impact of megafires on wildlands is not a threat that is susceptible to elimination by such regulatory mechanisms.

National Environmental Policy Act

All Federal agencies are required to adhere to the National Environmental Policy Act of 1970 (42 U.S.C. 4321 et seq.) for projects they fund, authorize, or carry out. Prior to implementation of such projects with a Federal nexus, NEPA requires the agency to analyze the project for potential impacts to the human environment, including natural resources. The Council on Environmental Quality's regulations for implementing NEPA state that agencies shall include a discussion on the environmental impacts of the various project alternatives (including the proposed action), any adverse environmental effects that cannot be avoided, and any irreversible or irretrievable commitments of resources involved (40 CFR part 1502). The public notice provisions of NEPA provide an opportunity for the Service and other interested parties to review proposed actions and provide recommendations to the implementing agency. NEPA does not impose substantive environmental obligations on Federal agencies—it merely prohibits an uninformed agency action. However, if an Environmental Impact Statement is prepared for an agency action, the agency must take a "hard look" at the consequences of this action and must consider all potentially significant environmental impacts. Federal agencies may include mitigation measures in the final Environmental Impact Statement as a result of the NEPA process that may help to conserve the Hermes copper butterfly and its habitat.

Although NEPA requires full evaluation and disclosure of information regarding the effects of contemplated Federal actions on sensitive species and their habitats, it does not by itself regulate activities that might affect the Hermes copper butterfly; that is, effects to the species and its habitat would receive the same scrutiny as other plant and wildlife resources during the NEPA process and associated analyses of a project's potential impacts to the human environment. We receive notification letters for Draft and Final Environmental Impact Reports prepared by BLM pursuant to NEPA.

State Mechanisms

California Department of Fish and Wildlife Status

The California Endangered Species Act does not protect invertebrates. Therefore, the Hermes copper butterfly is not identified as a Species of Special Concern by CDFW, nor could it be listed as endangered or threatened under the California Endangered Species Act (CDFW 2016, entire). It is also not included on the agency's Special Animals List (CDFW 2016b, entire).

California Environmental Quality Act (CEQA)

CEQA (California Public Resources Code 21000–21177) is the principal statute mandating environmental assessment of projects in California. The purpose of CEQA is to evaluate whether a proposed project may have an adverse effect on the environment and, if so, to determine whether that effect can be reduced or eliminated by pursuing an alternative course of action, or through mitigation. CEQA applies to certain activities of State and local public agencies; a public agency must comply with CEQA when it undertakes an activity defined under CEQA as a "project." A project is defined as an activity undertaken by a public agency or a private activity that requires some discretionary approval (i.e., the agency has the authority to deny or approve the requested permit) from a government agency, and which may cause either a direct physical change in the environment or a reasonably foreseeable indirect change in the environment. Most proposals for physical development in California are subject to the provisions of CEQA, as are many governmental decisions such as adoption of a general or community plan. Development projects that require a discretionary governmental approval require some level of environmental review under CEQA, unless an exemption applies (California Environmental Resources Evaluation System (CERES) 2014). If significant effects are identified, the lead agency has the option of requiring mitigation through changes in the project or deciding that overriding considerations make mitigation infeasible (Public Resources Code 21000; CEQA Guidelines at California Code of Regulations, Title 14, Division 6, Chapter 3, sections 15000–15387).

As with NEPA, CEQA does not provide a direct regulatory role for the CDFW relative to activities that may affect the Hermes copper butterfly. However, CEQA requires a complete assessment of the potential for a proposed project to have a significant adverse effect on the environment. Among the conditions outlined in the CEQA Guidelines that may lead to mandatory findings of significance are where the project "has the potential to … substantially reduce the habitat of a fish or wildlife species; cause a fish or wildlife population to drop below self-sustaining levels; threaten to eliminate a plant or animal community; substantially reduce the number or restrict the range of an endangered, rare or threatened species" (14 CCR § 15065(a)(1)). The CEQA Guidelines further state that a species "not included in any listing [as threatened or endangered] shall nevertheless be considered to be endangered, rare, or threatened, if the species can be shown to meet the criteria" for such listing (14 CCR § 15380(d)).

Local Mechanisms

The County of San Diego has developed the *Guidelines for Determining Significance and Report Format and Content Requirements – Biological Resources* (Guidelines) (County of San Diego 2010) to review discretionary projects and environmental documents pursuant to the CEQA. The Guidelines provide guidance for evaluating adverse environmental effects that a proposed project may have on biological resources and are consulted during the evaluation of any biological resource pursuant to CEQA. Included in the specific guidelines, under Special Species Status, is a determination as to whether a project will impact occupied Hermes copper butterfly habitat. Section 4.1 K (p. 14) of the guidelines states: "Though not state or federally listed, the Hermes copper meets the definition of endangered under CEQA Sec. 15380 because its "survival and reproduction in the wild are in immediate jeopardy from one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, disease, or other factors." The County's determination that the Hermes copper meets the definition of endangered under CEQA is based on the loss of Hermes copper populations by development and wildfire, and the review of published and unpublished literature. Interim guidelines for surveying, assessing impacts, and designing mitigation for Hermes copper are provided in Attachment C of the Report Format and Content Requirements – Biological Resources" (County of San Diego 2010, p. 14). The newly added Hermes copper butterfly section of the guidelines offers a proactive requirement for project review under CEQA that can provide a specific protective measure to the species and its habitat.

San Diego Multiple Species Conservation Program

The San Diego Multiple Species Conservation Program (MSCP) is a subregional habitat conservation plan (HCP) and Natural Community Conservation Plan (NCCP) made up of several subarea plans that have been in place for more than a decade. Under the umbrella of the MSCP, each of the 12 participating jurisdictions is required to prepare a subarea plan that implements the goals of the MSCP within that particular jurisdiction. The MSCP covers 235,625 ha (582,243 ac) and the County of San Diego Subarea Plan covers 102,035 ha (252,132 ac) of unincorporated county lands in the southwestern portion of the MSCP plan area. The County subarea plan is implemented in part by the Biological Mitigation Ordinance (BMO), which outlines specific project design criteria and species and habitat protection and mitigation requirements for projects within subarea boundaries (see MSCP Subarea Plan, County of San Diego 2007, and Biological Mitigation Ordinance (Ord. Nos. 8845, 9246), County of San Diego 1998). All projects within the County's subarea plan boundaries must comply with both the MSCP requirements and the County's policies under CEQA. Hermes copper butterfly is not a covered species under any MSCP subarea plans; however, the protections afforded by the BMO indirectly benefit the species by establishing mitigation ratios and project development conditions that restrict development within coastal sage scrub and mixed chaparral habitats. BMO affords some indirect protection to Hermes copper butterfly occurrences that fall all or partially within the County's subarea plan boundaries.

County of San Diego Resource Protection Ordinance

The County of San Diego Resource Protection Ordinance (RPO) (County of San Diego 2007) applies to all non-federal lands within the County located within and outside of the County of San Diego subarea plan boundaries. The RPO imposes restrictions on development to reduce impacts to natural resources including sensitive habitat lands. Sensitive habitat lands are those that support unique vegetation communities or those that are either necessary to support a viable population of sensitive species, are critical to the proper functioning of a balanced natural ecosystem, or which serve as a functioning wildlife corridor (County of San Diego 2007, p. 3). They can include areas that contain maritime succulent scrub, southern coastal bluff scrub, coastal and desert dunes, calcicolous scrub, and maritime chaparral, among others. Impacts to RPO sensitive habitat lands, which include lands with potential host and nectar plant habitat for Hermes copper butterfly (i.e., scrub and chaparral), are only allowed when all feasible measures have been applied to reduce impacts and when mitigation provides an equal or greater benefit to the affected species (County of San Diego 2007, p. 13).

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APPENDIX III

Information Used for Species Viability Index calculation

California ecological units (see Figure 9 above) were polygons from Goudey and Smith 1994 [2007]**: "**Ecological types are classified and ecological units are mapped based on associations of those biotic and environmental factors that directly affect or indirectly express energy, moisture, and nutrient gradients which regulate the structure and function of ecosystems. These factors include climate, physiography, water, soils, air, hydrology, and potential natural communities." Occurrences mapped in more than one ecological unit were categorized as occurring in the unit encompassing the majority of the occurrence polygon. To calculate percent species representation, percent populations extant within each Ecological Unit are converted to unitless values, summed, and divided by 400 (% representation = CT + CH + WGF + PC / 400). To calculate percent species viability, percent remaining representation and redundancy are converted to unitless values, summed, and divided by 200 (viability = representation + redundancy / 200).

As described in the text above, we rated population-level resilience based on a occurrence's size and movement corridor connectivity to other occurrences (as measures of contribution to species-level redundancy). Larger (core occurrence) populations are also likely to be more genetically diverse and therefore resilient. Movement corridor connectivity of habitat patches to extant populations increases the likelihood of immigration and habitat recolonization, therefore effectively increasing population-level redundancy.