Laguna Mountains Skipper
(Pyrgus ruralis lagunae)

5-Year Review:
Summary and Evaluation

Occupied habitat in Mendenhall Valley (Photo credit: A. Williams-Anderson/USFWS)
Laguna Mountains skipper (photo courtesy of Tom Mendenhall).

U.S. Fish and Wildlife Service
Carlsbad Fish and Wildlife Office
Carlsbad, California

April 29, 2019

5-YEAR REVIEW
Laguna Mountains skipper
(*Pyrgus ruralis lagunae*)

I. GENERAL INFORMATION

Purpose of 5-year Reviews:

The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing of a species as endangered or threatened is based on the existence of threats attributable to one or more of the five threat factors described in section 4(a)(1) of the Act, and we must consider these same five factors in any subsequent consideration of reclassification or delisting of a species. In the 5-year review, we consider the best available scientific and commercial data on the species, and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process defined in the Act that includes public review and comment.

Subspecies Overview:

The Laguna Mountains skipper (*Pyrgus ruralis lagunae*) is a small butterfly that was historically collected in the Laguna Mountains and on Palomar Mountain in San Diego County, California. It is a subspecies of the two-banded checkered skipper, a western North American species distributed from southwestern Canada almost to the Mexican border. The Laguna Mountains skipper is physically differentiated from the only other subspecies (rural skipper; *Pyrgus ruralis ruralis*) primarily through host plant use and wing pattern. The 1997 listing rule described the Laguna Mountains as supporting fewer than 100 individuals at a single location in 1995. Laguna Mountains skippers were last observed in the Laguna Mountains in 1999, and we subsequently determined it is extirpated from that mountain range. In the listing rule, Laguna Mountains skippers on Palomar Mountain were described as being "currently found at four sites," but the rule did not provide site descriptions. Today, the Laguna Mountains skipper is known from four occurrences (putative populations encompassing multiple meadows and clearings) on Palomar Mountain: Mendenhall Valley, French Valley, Doane Valley, and Pine Hills.

The Laguna Mountains skipper was listed as endangered under the Act based primarily on habitat destruction and degradation from razing and trampling of its host plant by cattle, as well as incidental consumption of immature life stages. Restricted range, localized distribution, and small population size were also considered threats, making the subspecies vulnerable to effects of habitat fragmentation and naturally occurring events such as fire and drought. The 2007 5-year review further identified catastrophic climate events as a vulnerability to the subspecies because of its small population size. The Act remains the primary regulatory mechanism protecting the species from habitat loss and direct causes of mortality. Ongoing research, monitoring, habitat protection, and grazing management are also being implemented to reduce impacts to the skipper and its habitat. Based on our assessment of the current threats to the Laguna Mountains skipper, we recommend no change in the listing status.

Methodology Used to Complete This Review:

This review was prepared by Alison Williams-Anderson and Bradd Baskerville-Bridges of the Carlsbad Fish and Wildlife Office (CFWO), following the Region 8 guidance issued in March 2013. Current and former CFWO staff that contributed to preparation or provided information used for development of this review include: Jesse Bennett, Kelly Goocher, Tyler Grant, Marci Koski, Emilie Luciani, Cara McGary, Joel Pagel, Eric Porter, Kurt Roblek, Peter Sorensen, Mary Beth Woulfe, and Susan Wynn. We used status and survey information obtained through coordination with stakeholders and species experts, and from unpublished and peer-reviewed published research. In particular, we relied on information from David and Tom Mendenhall; David Faulkner (Forensic Entomology Services); Daniel Marschalek and Douglas Deutschman (San Diego State University); Jana Johnson (Moorpark College); Travis Longcore (Urban Wildlands Group and University of Southern California); Ken Osborne (Osborne Biological Consulting); Jack Levy (independent consultant); Robert McElderry (University of California, Los Angeles); Gordon Pratt (University of California, Riverside, retired); Arthur Shapiro (University of California, Davis); Kirsten Winter, Lance Criley, and Jeffrey Wells (U.S. Forest Service); Lisa Fields and Larry Hendrickson (California State Parks), and Kathy Bates-Lande. This 5-year review contains updated information on the subspecies' biology and threats, and an assessment of information compared to that described in the 2007 5-year review. We focus on current threats to the subspecies pursuant to the Act's five listing factors. This review synthesizes information to evaluate the listing status of the subspecies and provides an indication of progress towards recovery. Finally, based on this synthesis and the threats identified, we herein recommend a prioritized list of conservation actions to be completed or initiated within the next 5 years.

Contact Information:

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Federal Register Notice Citation Announcing Initiation of This Review:

A notice announcing initiation of the 5-year review of this taxon and the opening of a 60-day period to receive information from the public was published in the *Federal Register* (FR) on June 18, 2018. Information relative to the Laguna Mountains skipper was incorporated. A notice was previously published on May 25, 2011 (Service 2011, p. 30378) and no information relevant to Laguna Mountains skipper was received.

Listing History:

<u>Federal Listing</u>
FR Notice: 62 FR 2313 (Service 1997)
Date of Final Rule: January 16, 1997
Entity Listed: Laguna Mountains skipper (*Pyrgus ruralis lagunae*), an insect subspecies
Classification: Endangered

<u>State Listing</u>
The Laguna Mountains skipper is not listed by the State of California as endangered or threatened. Insects are not covered under the California Endangered Species Act.

Associated Rulemakings:

Critical habitat was designated for the Laguna Mountains skipper on December 12, 2006 (Service 2006). Designated critical habitat consisted of two units encompassing approximately 6,242 acres (ac) [2,525 hectares (ha)] on lands under Federal [3,516 ac (1,423 ha)], State [381 ac (154 ha)], and private [2,345 ac (948 ha)] ownership within San Diego County.

Review History:

The most recent 5-year review for Laguna Mountains skipper was initiated in 2006 and signed in 2007 (Service 2007a). We recommended no change in status.

Subspecies' Recovery Priority Number at Start of 5-year Review:

The recovery priority number for Laguna Mountains skipper is 3C, based on a 1–18 ranking system where 1 is the highest-ranked recovery priority and 18 is the lowest (Service 1983a, pp. 43098–43105; Service 1983b, p. 51985). This number indicates that the taxon is a subspecies that faces a high degree of threat, a high potential for recovery, and conflict with economic activities.

Recovery Plan or Outline:

The notice of availability of the draft Recovery Plan for Laguna Mountains skipper published in the *Federal Register* January 26, 2016.

II. REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) Policy:

The Endangered Species Act defines "species" as including any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition of species under the Act limits listing as distinct population segments to species of vertebrate fish and wildlife. Because the subspecies under review is an invertebrate, the DPS policy is not applicable, and the application of the DPS policy to the subspecies' listing is not addressed further in this review.

Information on the Subspecies and its Status:

Taxonomic Status

The Laguna Mountains skipper (*Pyrgus ruralis lagunae*) is one of two subspecies of the two-banded checkered skipper (*Pyrgus ruralis*), a small butterfly in the skipper family (Hesperiidae). The Laguna Mountains skipper was first described by Scott (1981, p. 7), based on population isolation and color differentiation. The Laguna Mountains skipper is taxonomically differentiated from the nominate subspecies (rural skipper; *Pyrgus ruralis ruralis*) primarily through host plant use and wing pattern. The genus *Pyrgus* has three other species in San Diego County that are similar in appearance, including the common checkered skipper (*P. communis*), small checkered skipper (*P. scriptura*), and western checkered skipper (*P. albescens*). The taxonomic classification of the Laguna Mountains skipper has not changed since it was listed.

Description and Life History

The Laguna Mountains skipper has a wingspan of about 1.0 inch (in) (2.5 centimeters (cm)) and is distinguished from the nominate rural skipper (*Pyrgus ruralis ruralis*) by extensive white wing markings that give adults, particularly males, an overall appearance of more white than dark brown, and by the banding patterns on the hind wings (Scott 1981, p. 7; Levy 1994, p. 5). Osborne (2008, pp. 17 and 18) described the immature life stages of the rural skipper in detail, summarized here:

1. Whitish-green egg approximately 0.02 in (0.05 cm) in height;

2. Yellow to green first instar larva approximately 0.06 to 0.09 in (0.15 to 0.22 cm) in length;

3. Green second through fifth instar larvae up to approximately 0.8 in (2 cm) in length;

4. Dark brown pupae covered with powdery wax, approximately 0.47 in (1.2 cm) in length.

Adult females in captivity produced up to 184 eggs (Johnson *et al.* 2010, p.15), although based on other similar butterfly taxa, a total of 100 eggs may be more representative (Tashiro and Mitchell 1985, pp. 136 and 137; The Butterfly Farm 2015). Percent hatch for the few Laguna Mountains skippers brought into captivity was variable, ranging from 14 to 79 percent (Johnson *et al*. 2010, p.15; Longcore *et al*. 2014, p. 9), however captive conditions may have affected hatching rates (e.g. Tashiro and Mitchell 1985, pp. 136–138), as could diseases such as *Wolbachia* spp. (Longcore *et al*. 2014, p. 10). Larval survival rates in the field for Laguna Mountains skipper are unknown, however they are assumed to be very low. In a study conducted in 2016, 20 Laguna mountains skipper eggs deposited by spring flight females were monitored in the field for development; only three larvae hatched and formed shelters, and it appeared none survived to pupate (Osborne *et al.* 2016, p. 1). The study was expanded in 2017, and out of 132 individuals monitored, it was estimated fewer than 10 survived to pupation (approximately 7 percent survival; Osborne and Anderson 2018, p 1).

Pratt (1999, p. 15) estimated that it takes approximately 49 days for an egg to develop into a pupae, although the rate of insect development typically depends on ambient temperature and other environmental factors. Pratt (2014, pers. comm., p. 1.) also explained that based on their life cycle, Laguna Mountains skippers may spend most of the summer, fall, and winter as otherwise fully-formed adults within the pupal casing awaiting spring eclosion (emergence). See the *Population Ecology* section below for more information on the life cycle.

Host Plants

Laguna Mountains skipper is associated with its primary host plant *Horkelia clevelandii* (Cleveland's horkelia), on which adults deposit eggs, and larvae feed and sometimes pupate (Service 1997, p. 2314). *Horkelia clevelandii* is a rare species restricted to the Peninsular Range, specifically Palomar Mountain and the Cuyamaca, Laguna, and San Jacinto mountains of southwestern California (Osborne 2003, pp. 12 and 13; Baldwin *et al.* 2012, pp. 46 and 1182; Calflora 2014; San Diego Natural History Museum 2014), and the Sierra de San Pedro Mártir in northwestern Baja California, Mexico (Thorne *et al*. 2010, p. 30; Encyclopedia of Life 2014). Eggs are typically deposited on the underside of mature or moderately mature leaves (Osborne

2008, p. 5). Larvae, and sometimes pupae, are located in silken shelters wrapped in upper host plant leaves at heights of 3 to 5 in (8 to 13 cm) above the ground (Osborne 2008, p. 35).

Since listing, Laguna Mountains skippers have also been documented using *Drymocallis glandulosa*, (formerly *Potentilla glandulosa*; common cinquefoil) as a host in the wild (Pratt 1999, p. 10; Pratt 2006, pers. comm.; Osborne 2008, p. 5), although captive early instar rural skipper (*Pyrgus ruralis ruralis)* larvae did not survive as well on common cinquefoil as on *Horkelia* spp. (Osborne 2008, pp. 16 and 36). Osborne (2008, p. 16) found captive rural skipper larvae freely accepted and completed development on a number of related host plants: *H. fusca* (dusky horkelia); *H. cuneata* (wedge leaf horkelia); *H. clevelandii*; and *D. glandulosa*. Despite these results for its close relative, no Laguna Mountains skipper larvae survived when rearing was attempted using *H. truncata* (Ramona horkelia; Johnson *et al*. 2010, p. 22). Some captive Laguna Mountains skipper larvae have been successfully reared to pupation on *H. clevelandii* (Longcore *et al.* 2014, p. 9) and *D. glandulosa* (Mattoni and Longcore 1998, p. 6). It is possible, however, past mortality of early instars during Laguna Mountains skipper rearing stemmed primarily from minute pirate bug predation (Anthochoride: *Orius sp.*; Osborne and Anderson 2018, p. 1). Considering all the information on host plant use, it is likely Laguna Mountains skipper populations specifically require *H. clevelandii* for persistence, but the presence of alternate host plants increases habitat quality and allows for some additional development.

Appropriate ground cover is a significant habitat component of habitat suitability for Laguna Mountains skipper. Bare or “open” ground associated with host plants (Levy 1994, p. 6; Levy 1997, pp. 9 and 30; Mattoni and Longcore 1998, p. 10; Osborne 2008, p. 4; Marschalek and Deutschman 2014, pp. 2 and 3; Marschalek 2015a, pers. comm., p. 17), and disturbance to maintain it (Levy 1994, pp. 6, 7, 19; 1997, p. 9 and 10; Pratt 1999, pp. 17–19; Grant *et al.* 2009, p. 10), are thought to contribute to habitat suitability by increasing microclimate temperature and development rates of immature life stages. Marschalek (2015a, pers. comm., p. 17) also noted a significant correlation of Laguna Mountains skipper adult occupancy with “shrub cover” in the Doane Valley occurrence, where rushes (classified as shrubs) were common in occupied ravines. *Horkelia clevelandii* is a mid-successional species that is neither believed to support Laguna Mountains skipper development when largely shaded by other plant species, nor to persist when late-successional plant species colonize a habitat area. Therefore, elimination of fire and cattle grazing, in the absence of other sources of disturbance, is likely disadvantageous to the Laguna Mountains skipper and its host plant (Levy 1994, p. 76; Mattoni and Longcore 1998, p. 12).

Water and Moisture Associations

Researchers have for many years noted a strong association of Laguna Mountains skipper adults with moist soils and standing surface water (e.g. Faulkner 2015, entire). Levy (1997, pp. 22 and 23) concluded the subspecies is dependent on a localized perennial host plant that is less affected by annual fluctuations in precipitation. Mattoni and Longcore (1998, p. 10) hypothesized hydrologic change due to groundwater removal was a threat to the subspecies, and Osborne (2002, pp. 9 and 13) first suggested the potential importance of surface water as a resource for adult skippers. Osborne’s initial impression was reinforced by observations during the drought year of 2002, including host plant die-off (Osborne 2003, pp. 13, 14 and 16), leading him to conclude "Proximity of water—vernal conditions at Mendenhall Valley and Laguna campground, or seeps and springs at Iron Springs or [Observatory] campground—appears to be a common element to [Laguna Mountains skipper] habitat." Seeps and moist patches of ground, as with other mountain butterfly species, can provide a valuable source of sodium and other minerals for Laguna Mountains skippers, especially for males (Osborne 2003, p. 13; 2008, p. 33).

A Service study in 2007 and 2008 found probability of habitat use was strongly correlated with distance to surface water sources (USGS mapped "blue-line" streams) during low rainfall years (Grant *et al*. 2009). Analysis of habitat covariates in plots used by adults both years indicated Laguna Mountains skippers are primarily found in two types of areas: (1) far from water, close to the forest edge, on northeast slope aspects; and (2) close to water, far from the forest edge, on southwest slope aspects (Grant *et al.* 2009, pp. 14–22). This habitat use pattern likely reflects high host plant availability combined with relatively high water availability from sources such as dew (close to forest edge), and standing water availability where a warmer climate increases butterfly metabolic rates (far from forest edge). Additional survey results indicate Laguna Mountains skippers spend most of their time on or near host plants, and near water sources when away from host plants (Grant *et al.* 2009, p. 56). Marschalek (2015a, pers. comm., p. 20; 2015b, pers. comm.) found that in the Doane Valley occurrence, many adults were observed near ravines and creeks, even where host plants may be absent, but soil moisture levels are high. Marschalek (2015a, pers. comm., p. 20) attributed the correlation of adult occupancy with drainages and creeks to a possible preference for low-lying, less windy, and therefore warmer, more humid micro climates. Therefore, it is likely Laguna Mountains skippers depend on adequate soil moisture and surface water for population survival.

Nectar Sources

Osborne (2008, pp. 32–33) described nectar resource use and importance: "As with most butterfly species, nectaring is common and appears to be both facultative and opportunistic in nature." He goes on to say, "…nectaring is likely not a requirement for successful reproduction… Any nectar source observed to be used by butterflies generally, especially by other [skippers], should be considered as a potential [Laguna Mountains skipper] nectar source." While some nectar sources may be preferred, butterflies commonly use a variety of flowers they can cling to and get nectar from (Levy 1997, pp. 24 and 25; Pratt 1999, pp. 3 and 11; Grant *et al.* 2009, pp. 40–55; Marschalek and Deutschman 2014, p. 4; Marschalek 2015b, pers. comm., p. 19). During the summer flight season, however, experts believe the host plant *Horkelia clevelandii* is heavily relied upon for nectar and moisture by adults when other nectar sources are scarce (Levy 1994, pp. 7 and 24; 1997, p. 25; Mattoni and Longcore 1998, p. 4; Osborne 2002, p. 12; Williams and Bailey 2004, p. 26). Therefore, the primary host plant *H. clevelandii* is important not only as a larval food source during development, but also as an adult food source in the summer.

<u>Distribution and Abundance</u>

Distribution

The Laguna Mountains skipper was historically found in meadows in the Laguna Mountains and on Palomar Mountain in San Diego County (Figures 1, 2, and 3; Table 1). The listing rule (Service 1997, p. 2314) described the subspecies as extant at the El Prado [Meadow and] Campground in the Laguna Mountains, and stated the subspecies was “currently found at four sites in the [Palomar Mountain] region of San Diego County,” citing Levy (1994). Although the listing rule did not name or describe these sites, a review of Levy (1994, pp. 10 and 11) indicates they were: Mendenhall Valley, the Observatory Campground, Observatory Trail (at easternmost end of Upper French Valley), and Lower French Valley (Figure 2). The four Palomar Mountain sites referenced at listing are incorporated in three of the four extant occurrences identified as: Mendenhall Valley (which incorporates Observatory Campground), French Valley (which incorporates Observatory Trail), and Doane Valley (which includes Lower French Valley) (Table 1). The fourth occurrence believed to be extant is Pine Hills, which was documented after listing (most recent observation in Jeff Valley; Figure 2). We also identify two former occurrences in the Laguna Mountains: Laguna Meadow (incorporates El Prado Meadow considered extant at listing) and Crouch Valley (documented after listing) (Figure 3). While all adults in the 1990s were observed at the El Prado Meadow site, one empty Laguna Mountains skipper larval shelter and characteristic feeding damage were also reported from the small meadow above Crouch Valley (“Meadow Kiosk” site; Pratt 1999, p. 27; Mattoni and Longcore 1998, p. 6; for description of feeding damage see also Mattoni and Longcore 1998, p. 4, and Pratt 1999, p. 12). Extensive survey efforts in skipper habitat across the Laguna Mountains have not detected the subspecies over the past 20 years (Faulkner 2000, p. 2; 2001, p. 2; 2002, p. 2; 2003 p. 2; 2004, p. 2; 2005, p. 3; 2006, p. 2; Osborne 2002, p. 9; 2003, p. 2; Grant *et al*. 2009, p. 24; Marschalek 2014, pp. 3–14). Therefore, we consider the Laguna Mountains populations to be extirpated at this location.

In 2007, after the last 5-year review, one relatively comprehensive plot-based habitat usage survey was conducted in the Doane and Mendenhall Valley occurrences, and accessible publicly-owned portions of the French Valley occurrence (Grant *et al.* 2009, p. 63). Laguna Mountains skipper occupancy was most recently confirmed in the Doane Valley and Pine Hills occurrences in 2016 (Marschalek 2016, p. 1; Osborne 2016, p. 1; Osborne *et al.* 2016, p. 1) in the French Valley occurrence in 2007 (Grant *et al.* 2009, p. 63), and Mendenhall Valley in 2018 (Osborne 2018, pers. comm.) (Figure 2; Table 1).

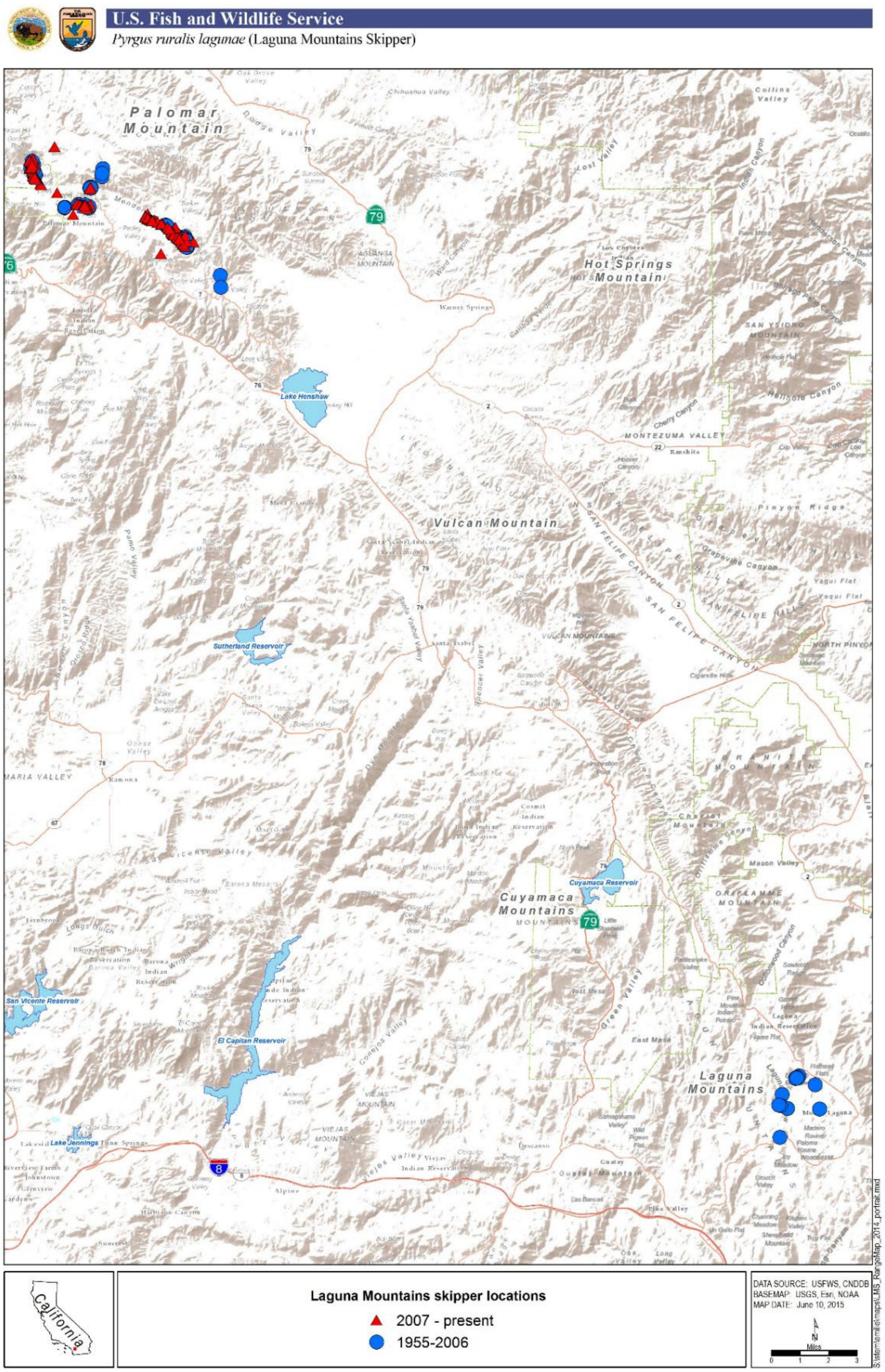

Figure 1. Laguna Mountains skipper historical range map and observations since the 2007 status review.

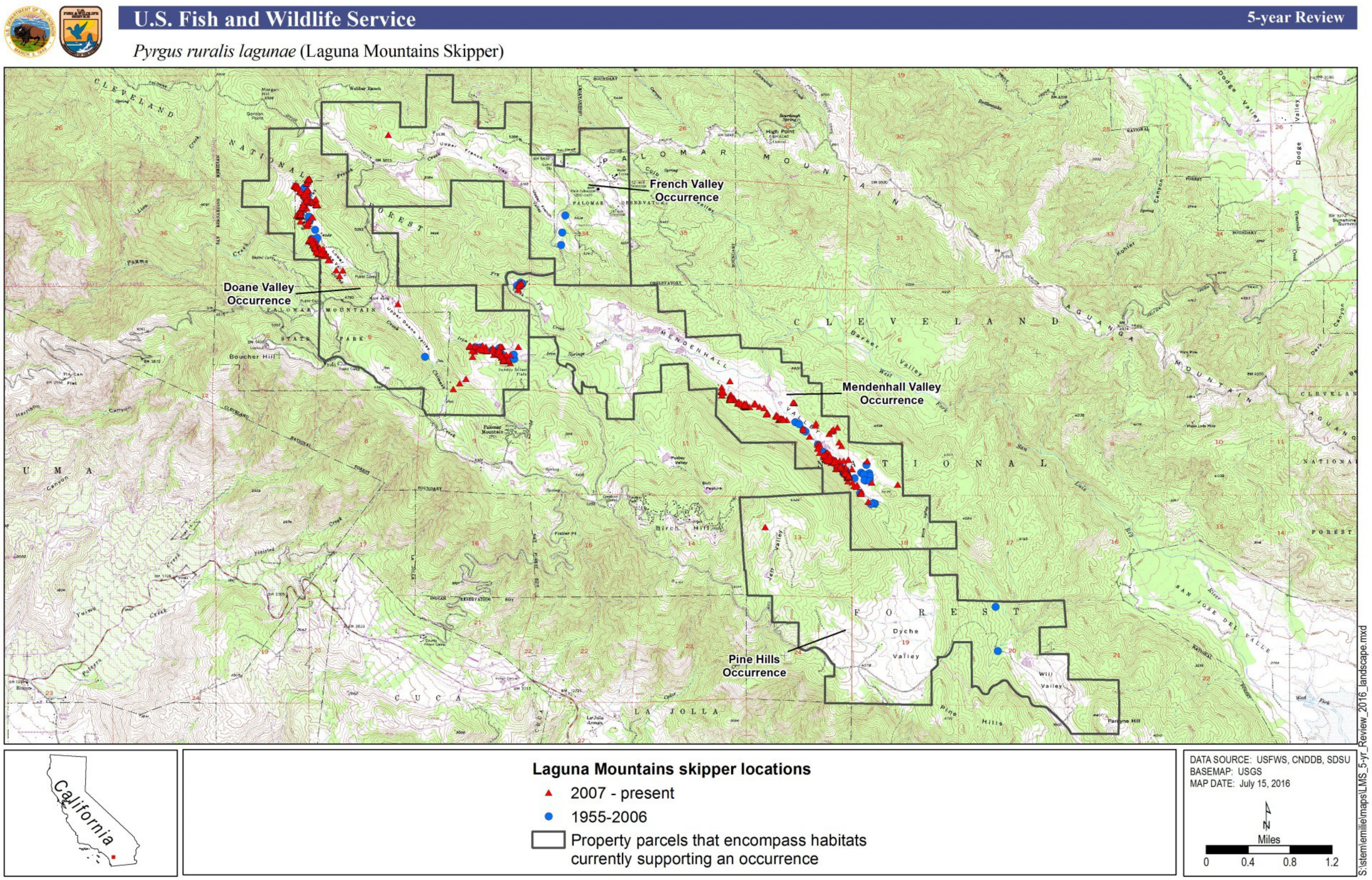

Figure 2. Laguna Mountains skipper (*Pyrgus ruralis lagunae*) occurrences on Palomar Mountain and property boundaries encompassing occupied habitat.

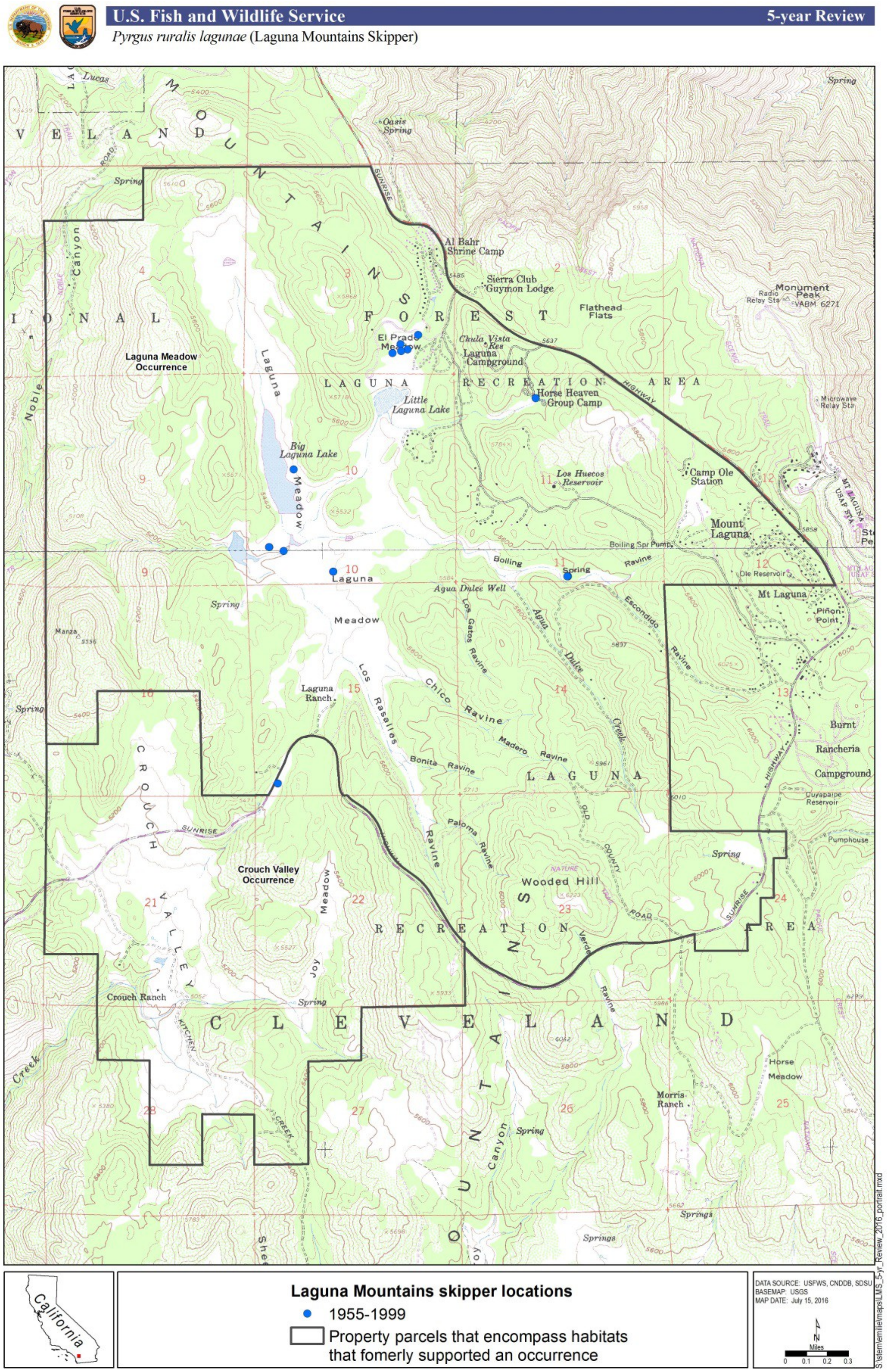

Figure 3. Historical distribution of Laguna Mountains skipper in the Laguna Mountains and property boundaries encompassing habitat.

Table 1. Laguna Mountains skipper occurrence information. Data from reports cited in text. Hypothesized occupancy status is based on the most recently available information. Majority landowner listed first.

Occurrences **(Associated location names)**	**Status at Listing**	**Current Status**	**Last year observed**	**Ownership**
Palomar Mountain				
Doane Valley (Lower French Valley, Lower Doane Valley, Upper Doane Valley, and Iron Springs)	Extant	Extant	2018[1]	Private, State, and USFS
French Valley (Upper French Valley, Palomar Observatory Trail, and Palomar Observatory Meadows)	Extant	Extant	2007[2]	Private and USFS
Mendenhall Valley* (Mendenhall Valley and Observatory Campground)	Extant	Extant	2018[3]	Private and USFS
Pine Hills (Jeff Valley, Dyche Valley, and Will Valley)	No records	Extant	2016[4]	Private and USFS
Laguna Mountains				
Laguna Meadow (Big Laguna Lake, El Prado Meadow, Laguna Campground, Horse Heaven Group Camp, Boiling Spring Ravine, and Agua Dulce Campground)	Extant	Extirpated	1999[5]	USFS and private
Crouch Valley (Meadows Kiosk and Joy Meadow)	No records	Extirpated	1999[5]	USFS and private

Abbreviations: State of California (State); United States Forest Service (USFS).
*Includes two "sites" from the listing rule.
Sources: [1]Faulkner 2018, pers. comm.; [2]Grant *et al.* 2009; [3]Faulkner 2018, pers. comm., pers. comm.; [4]Marschalek 2016; [5]Pratt 1999.

Doane Valley Occurrence

The majority of the Doane Valley occurrence is within Palomar Mountain State Park. State Park lands (including Lower French and Upper and Lower Doane Valleys) contain typical Laguna Mountains skipper habitat consisting of relatively large, wet meadows surrounded by pine forest. Occupancy in the privately-owned Iron Springs area of this occurrence was first documented in 2003, in habitat described as "open [smaller] meadows with tall grasses… open vehicle paths with low vegetative stature, and the cloistered confines of both wet and dry gully bottoms with mixed architecture of grasses, riparian vegetation… and steep, fern-covered-slopes" (Osborne 2003, p. 15). Although historical surveys indicated the Doane Valley occurrence consisted of a significantly smaller population than the Mendenhall Valley occurrence (Levy 1994, p. 11; Mattoni and Longcore 1998, p. 7), surveys indicated it supported a relatively large population in 2014 with a widespread distribution (Marschalek 2014, p. 10; Marschalek 2015, p. 5; Osborne 2016, p. 1).

French Valley Occurrence

The majority of the French Valley occurrence is a privately owned, large, wet meadow surrounded by pine forest. This meadow has not yet been surveyed, though recent surveys of accessible areas on the periphery of the Upper French Valley meadow have mostly been negative; the one exception was an adult reported in 2007 on the Brawn Meadow property at the western extreme of the valley (Grant *et al*. 2009, pp. 15, 23, 63 Map 3; Faulkner 2010b, pp. 2 and 4, "Palomar Station" site; Table 1). Prior to 2007, Laguna Mountains skippers (in this case, larvae) were last observed in 1999 on the eastern periphery of the meadow, east of South Grade Road near the Observatory Trail (Pratt 1999, p. 10). Extensive surveys of the higher elevation Palomar Observatory meadow complex have all been negative (Osborne 2003, p. 4; Grant *et al*. 2009, pp. 15, 63 Map 3), despite documentation of relatively dense patches of *Horkelia clevelandii* (Grant *et al*. 2009, pp. 23, 61, Map1). Therefore, the French Valley Laguna Mountains skipper occurrence is presumed extant, but the subspecies' historical distribution and population status in this area remains uncertain.

Mendenhall Valley Occurrence

Portions of habitat within Mendenhall Valley are privately owned and managed, and one parcel is Federally owned and managed by the U.S. Forest Service (USFS). The majority of habitat in this area consists of typical large, wet meadow surrounded by pine forest. Occupancy by Laguna Mountains skipper was first recorded in this area by Levy in 1994 (p. 11). The Observatory campground is a smaller, more isolated meadow where a few individuals of the subspecies are typically recorded every year. Experts have long considered Mendenhall Valley to support the largest and most robust population within the subspecies' range (for example, Mattoni and Longcore 1998, p. 7).

Pine Hills Occurrence

The Pine Hills occurrence observation sites were surveyed twice since the last 5-year review (Faulkner 2007, p. 3; 2010b, pp. 1 and 2, "East Grade" site), but Laguna Mountains skipper occupancy has not been confirmed there since 2001 (Osborne 2002, p. 7; Figure 1; Table 1). Habitat in the Pine Hills occurrence where Laguna Mountains skippers were last observed consists of oak woodland with small openings, contains no *Horkelia clevelandii,* and was determined to be insufficient to support a stand-alone population (Osborne 2002, pp. 7 and 13; Faulkner 2007, p. 7; Faulkner 2010b, p. 4). One observation in the Pine Hill occurrence was reported in a sunny opening near a creek, proximal to the northern end of Will Valley; a second observation occurred approximately a half mile northwest of the first in a forested opening (Osborne 2002, pp. 13; Figure 1). Will Valley is privately owned and has not been surveyed; therefore, it is likely skippers observed in the area were part of a population associated with this meadow and near Dyche Valley. Dyche Valley, approximately 540 feet (ft) (165 m) higher in elevation and only a half mile (1.6 km) from the Pine Hills observations (Figures 2 and 6), also appears climatically suitable, but has not been surveyed. Jeff Valley is slightly above and west of Dyche Valley and is a smaller, but relatively wet meadow. One Laguna Mountains skipper adult was observed in Jeff Valley in 2016 (Marschalek 2016, p. 1). The Pine Hills occurrence is confirmed extant, but the subspecies' historical distribution and population status in this area remains uncertain.

Other potential suitable habitat

When all mountain areas thought to otherwise contain potential habitat were reviewed using topographic relief and satellite imagery, only Palomar Mountain, the Laguna, and Cuyamaca Mountains in the United States, and the Sierra San Pedro Mártir and Sierra de Juarez in Mexico appeared to contain large, relatively wet meadows comparable to those that were historically occupied by Laguna Mountains skipper. Though a number of areas other than Palomar Mountain and the Laguna Mountains support *Horkelia clevelandii*, investigations over the past 14 years have not detected Laguna Mountains skipper. For more information on this topic see Appendix A.

Abundance Estimates

Estimating abundance of Laguna Mountains skippers is difficult because adult observations are statistically rare, and there have been no surveys conducted specifically to estimate abundance. Even historical information on which to base a qualitative comparison of Palomar Mountain to Laguna Mountains population abundance is sparse. Most experts believed Laguna Mountains skipper abundance in the Laguna Mountains was greater than on Palomar Mountain, due to the number of specimens that were collected historically (Wright 1930, p. 32, Levy 1994, pp. 9 and 10; Appendix B). However, Faulkner (2014a, pers. comm.) noted this difference in the number of collected specimens may instead reflect a bias based on a difference in habitat accessibility. In sum, there is insufficient information available to indicate how Laguna Mountains skipper historical population abundance might have differed on Palomar Mountain compared to the Laguna Mountains.

The few estimates of population size that have been reported are all from Mendenhall Valley on Palomar Mountain. Levy (1994, pp. 11 and 12) estimated the total spring adult population size in Mendenhall Valley in 1994 to be approximately 240 individuals, which he characterized as a crude estimate and likely inflated. Mattoni and Longcore (1998, p. 9) calculated there were approximately 1,470 adult skippers in 1997 during the spring flight season, using the number of eggs per host-plant leaf and estimates of host plant abundance. There are no recent estimates of Laguna Mountains skipper population size for Palomar Mountain.

Only qualitative subspecies abundance estimates from the Laguna Mountains are available, and reflect the decline of Laguna Mountains skipper in the region. While Pratt (1999, p. 7) described Laguna Mountains skippers as being “common” in April of 1986 at the protected El Prado Meadow site, Brown (1991, p. 5) described them as having “…become increasingly less common over the past 25 years” (a trend also indicated by collections from the Laguna Mountains; Appendix B), and surviving “…only along the edge of a fence where cattle are inhibited from grazing [at El Prado Meadow]…”. Levy (1994, p. 10) could not find any Laguna Mountains skippers in the Laguna Mountains, and concluded the subspecies was extirpated “very possibly from the entire Laguna Mountains range.” Levy stated the last recorded observations he was aware of in the Laguna Mountains were made by Charles Sekerman in 1986 (Levy 1994, p. 10). In the 1990s, only four adult skipper observations were recorded in the Laguna Mountains (Levy 1997, pp. 4, 26, and 53; Pratt 1999, p. 7; Table 1); the last was in 1999 when one observation of a male was made on two separate days (Pratt 1999, p. 7). The Laguna Mountains skipper appears to have experienced a long-term decline, resulting in functional extirpation by the early 1990s (the “extinction vortex” discussed by Grant et al. 2009, p. 10).

Dispersal and Movement within Habitat Patches

Laguna Mountains skippers are believed to occasionally disperse through forested areas between meadows, effectively maintaining a metapopulation structure, although evidence remains indirect (Mattoni and Longcore 1998, p. 9; Pratt 1999, p. 19; Pratt 2006, pers. comm., pp. 2 and 3; Osborne 2002, pp. 13 and 14). In 2007, host plant and skipper survey results implied that 23 percent of the meadows and forest margins on Palomar Mountain are used by the subspecies (Grant *et al.* 2009, p. 4). Also, as mentioned previously, in the 2007 study, proximity to “blue line” streams (streams recorded on USGS topographic maps) was strongly correlated with Laguna Mountains skipper observations during a dry year, but not in a relatively wet year (i.e. 2008). Grant *et al.* (2009, p. 4) found that during the wetter year, skippers appeared more dispersed (used a larger proportion of the area surveyed). These dry year results agree with Marschalek’s (2015a, pers. comm., p. 20) observations from 2014 and 2015 in lower French Valley and Osborne’s observations of two-banded checkered skipper (2008, p. 15). Therefore adult Laguna Mountains skipper within-habitat distribution likely expands and becomes more diffuse with increased water availability (puddles and moisture from rain collecting on vegetation), while contracting and clustering near streams and drainages when conditions are dry.

Population Ecology and Trends

Consistent monitoring for Laguna Mountains skipper was conducted in Mendenhall Valley for more than 6 years (Faulkner 2006; 2007; 2008; 2009; 2010a; 2011; 2012a; 2013; Table 2) at the "hot spot" monitoring site described by Mattoni and Longcore (1998, p. 8) and Pratt (1999, pp. 6, 17, and 33). While we are able to look at changes in the annual index of peak abundance from specific areas, we do not have data of sufficient scope or sample size to estimate changes in total population size over time. Surveys designed to mimic Faulkner's earlier ones were also conducted in 2015 (Marshalek 2015a, pers. comm.; Faulkner 2015, pers. comm.). Values for 2015 in Table 2 reflect counts only within the monitoring site. We are using the maximum number of adults observed per day (one count per visit; Table 2) as an abundance indicator for surveys. A number of studies have suggested methods for long-term monitoring and detection of population trends (Levy 1997, p.4; Mattoni and Longcore 1998, p. 13; Grant *et al*. 2009, p. 5; Marschalek 2014, p. 6); however, estimating abundance of Laguna Mountains skippers has proven difficult because population densities are relatively low and adults are challenging to identify.

Table 2. Laguna Mountains skipper adult survey data from Mendenhall Valley
Data include an approximate date and index of peak abundance for the spring and summer flight seasons, duration between peaks, annual summer to spring peak abundance ratios, and Palomar Observatory weather station rainfall data.

Year	Spring Peak (Date; peak abundance*)		Summer Peak (Date; peak abundance)		Days between peaks	Summer to spring Peak abundance ratio	Total precipitation Oct- April (mm)
2015	April 9	**14**[1]	July 2	**10**	84	0.71	331
2013	May 2	**4**	July 21	**2**	80	0.50	220
2012	May 10	**12**	July 16	**1**	67	0.08	235
2011	May 5	**10**	July 24	**4**	80	0.40	701
2010	May 2**	**7**	July 22	**2**	81	0.29	690
2009	April 26	**9**	June 27	**7**	62	0.78	375
2008	April 27	**8**	June 29	**5**	63	0.63	798
1997	Apr 15**	14[2]	June 30	9[2]	76	0.64	216
1994	May 20	4[3]	July 21	6[3]	62	1.50	535

Bold values are from surveys that used the same methods.
* Peak abundance is defined as the day when the maximum number of Laguna Mountains skippers was recorded per observer per season.
**Surveys may have started after the peak.
Surveyors: [1]Marschalek and Faulkner (count only within monitoring site during 2015); [2]Pratt; [3]Levy; all others Faulkner. Precipitation data source: http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?caCPAL.

Adult survey values, such as those collected by Faulkner (meandering but complete coverage of a reference site), or more intensive counts, such as Pollard Walks used by Marschalek (2015a pers. comm., pp. 10–13; coverage by transects of all areas likely to be occupied in an area of inference), are not sufficient to estimate population size. These survey values can, however, provide evidence of how Laguna Mountains skipper abundance changes over time and how populations are affected by environmental factors. We used monitoring data to look for evidence supporting hypotheses drawn from natural history and a conceptual population dynamics model. For example, the positive correlation of population growth with total October-April precipitation supports the hypothesis that Laguna Mountains skippers require surface water availability and sufficient soil moisture for population growth and survival (Appendix C; see also *Water and Moisture Associations* section above). Subspecies abundance in Lower French and Lower Doane Valleys was apparently lower than in the Mendenhall Valley monitored site prior to the 2007 fire (Levy 1994, p. 11; Grant *et al*. 2009, p. 69), but based on an index value (the maximum number of Laguna Mountains skippers recorded per observer per season in a single day), appears to have increased in size since then (Grant *et al*. 2009, p. 69; Marschalek 2014, p. 8; 2015, p. 5; Marschalek 2015a, pers. comm., p. 10; see further discussion in Succession and Nonnative Plants under Factor A below; Table 4).

Population Dynamics

Adults emerge from the overwintering pupal case in early spring, mate during the spring flight season, produce eggs (the spring brood), then die. Based on past adult abundance data (Table 2), it is assumed a portion of pupae from the spring brood emerge as adults in the summer, while the remainder of the pupae enter diapause (a period of dormancy with a low metabolic rate) and do not emerge as adults until the following spring (as do the summer offspring eventually). Laguna Mountains skippers are not believed to diapause for more than one fall/winter season (Pratt 1999, p. 8; Osborne, unpublished data). This life cycle is called "partially bivoltine" because reproduction occurs more than once per year, but not all first generation offspring complete development to participate in the second reproductive cycle (Figure 4; Pratt 1999, p. 32; Osborne 2008, pp. 16 and 17; Grant *et al.* 2009, pp. 15 and 21). Partial bivoltinism is a common life history strategy among insects. Individual Laguna Mountains skippers are believed to diapause (as pupae) in protected microhabitats within strong protective webbing shelters (Williams-Anderson video recording 2017) on or not far from the host plant where larval development took place (Pratt 2014, pers. comm.; Osborne 2015, pers. comm.).

Laguna Mountains skipper population dynamics are affected by a number of key life history factors. As is common with life stage development of other insects (Iowa State University 2015), timing of spring adult emergence of the Laguna Mountains skipper appears to be related to total "growth degree-days" (GDD; a measure of how warm it has been for how long). There is a relatively strong positive correlation of total January-to-mid-April GDD with the peak adult abundance index date; that is, higher total GDD is correlated with earlier spring adult abundance peaks (Appendix C). Studying the relationship between winter and spring temperatures and other environmental factors and the timing of diapause termination should help us predict population dynamics. For example, the longer it takes to reach the critical GDD for spring adult emergence, the drier the conditions are likely to be, the less suitable the habitat is likely to be for potential summer brood larvae, the lower population growth rate. Predicting spring adult emergence timing could therefore inform and assist monitoring of populations for resilience. While photoperiod (day length) is the most commonly supported environmental cue that triggers diapause initiation (Danks 2002, p. 129), if this is the case for Laguna Mountains skipper, it is also significantly reinforced by increasing temperature (McElderry 2016, pers. comm.), because there is considerable variability in peak abundance dates (Table 2). Whether individual spring brood pupae complete development or enter diapause likely depends on environmental conditions such as total GDD, host plant moisture levels, humidity, and genetic variability (termed “bet hedging”; Pratt 1999, p. 3; Pratt 2014, pers. comm.).

Whatever factors determine spring larval development rates and initiation of diapause, the later in the season a spring larva pupates, the less suitable habitat is likely to be for potential summer brood development. The hypothesis that later spring adult emergence decreases the number of spring brood larvae completing development (increases the number entering diapause) is supported by a relatively strong negative correlation of estimated peak spring adult abundance date with the index of relative summer adult population size (Appendix C). That is, it appears more adults emerging later in the spring results in a smaller summer adult population, because fewer spring brood offspring (caterpillars) mature to become summer adults (butterflies). On Palomar Mountain, adult abundance peaks first in April or May (the spring flight), followed by a second, typically smaller peak of spring brood adults approximately 60 to 80 days later, in June or July (the summer flight) (Table 2; Scott 1981, p. 7; Levy 1994, p. 11; Mattoni and Longcore 1998, p. 3; Pratt 1999, p. 11; Goocher 2006, p. 3; Osborne 2008, p. 5; Faulkner 2008, p. 2; 2009, pp. 2 and 3; 2010a, p. 2; 2011, p. 2; 2012a, p. 2; 2013, p. 2; Grant *et al*. 2009, pp. 15 and 19).

Experts have generally assumed adult Laguna Mountains skipper population sizes on Palomar Mountain have historically been smaller in summer than in the spring. This assumption is based on: (1) historical Laguna Mountains collection records (Appendix A); (2) typical population dynamics of rural skipper in the Sierra Nevada Mountains (Osborne 2015, pers. comm.); and (3) data from monitoring Laguna Mountains skippers (Table 2). However, collectors tend to visit sites more often in the spring because butterfly diversity is higher, so collection records may reflect that bias. The Laguna Mountains (where most historical collections occurred) are also typically drier than Palomar Mountain. This means that the typical seasonal window of weather conditions suitable for skipper growth and reproduction may be shorter in the Laguna Mountains, therefore, the typical population ratio of summer to spring adults may have been smaller.

Conceptual Population Ecology Model for the Laguna Mountains skipper

A conceptual population ecology model for the Laguna Mountains skipper is illustrated in Figure 4. This was developed to represent the life cycle and population dynamics (potential contribution of life stages to population growth rates and resilience). Figure 4 uses one set of example values based on captive rearing observations (egg production and hatch rate), information in Table 2 (summer to spring peak abundance ratio), surrogate species values for larval survival, and discussions with experts. The conceptual model identifies likely drivers of productivity (Figure 4, surrounding text). Multivoltine life cycles, including partially bivoltine, have potential thresholds of exponential growth, but also of catastrophic decline, depending on how subsequent generations fluctuate in size and contribute to annual population growth (Iwasa *et al.* 1992, entire). Successful reproduction by first brood individuals in the same year can contribute significantly to the following year’s total population size in bivoltine populations, even exponentially if conditions are favorable (Altermatt 2009, p. 6; Figure 4). All realistic variations of values used in the model illustrate the significance of summer brood production to annual population growth potential.

The Laguna Mountains skipper life cycle, characteristic of a partially bivoltine species, is depicted in Figure 4 with two flight seasons (spring and summer). Figure 4 uses an example starting with a population size of 200 adults (conservative value based on a Levy 1994 estimate) with approximately 100 eggs per female, and 70 percent hatch (Tashiro and Mitchell 1985, pp. 136–138; Johnson *et al.* 2010, p. 9; The Butterfly Farm 2015; Longcore *et al.* 2014, pp. 8 and 9). Example spring and summer brood survival rates used are 16 and 14 percent, respectively, because survival may be slightly lower in the summer depending on larval size and availability of host plants. These larval survival values are optimistic, based on data for the shoulder-streaked firetip skipper (*Pyrrhopyge papius*) (Greeney *et al*. 2010), and Laguna Mountains skipper field data (Osborne and Anderson 2018, p. 1). Pupal survival rates are based on Laguna Mountains skipper field data (Osborne and Anderson 2018, p. 1).

Using these plausible example values in Figure 4, the spring adult population (200 adults) produces a spring brood of 1,120 pupae. The majority of the spring brood (91 percent) undergo diapause and approximately 107 emerge as adults the following spring (based on a summer diapause survival of 0.5 and fall-winter diapause survival of 0.21; value rounded for model). In this example, a small percentage of pupae (9 percent) develop into approximately 101 adults during the summer the same year, undergo a second flight season, and produce a summer brood (445 pupae). These enter diapause and 93 emerge as adults in the spring with 107 of the spring brood individuals that went directly into diapause the previous year.

In the summer of 2017 researchers collected data in the field on immature Laguna Mountains skipper life stage survival (Osborne and Anderson 2018, p. 1). Following eggs in the field through pupation they estimated fewer than 10 out of 132 larvae developed to pupation (approximately 0.07 survival rate). They also placed diapausing pupa in the field in cages that excluded vertebrate predators, and recorded 85 percent survival during winter diapause. The former is likely an underestimate, as some larvae considered dead may in fact have wandered away and were not detected. The diapause survival rate is probably significantly higher than was realized by the wild population, as they were relatively protected from parasitism during larval development, and from vertebrate predation during diapause, both likely significant mortality factors for wild individuals. Based on this information we ran the model using 0.08 larval survival rates, and a 45 percent pupal diapause survival rate; other values used were those in figure 4, with summer pupal eclosion rate adjusted to maintain the 1:2 summer to spring adult abundance ratio. This model iteration resulted in a 31 percent contribution of the summer brood to the following spring adult population size, and 29 percent population growth rate.

Based on these and other plausible iterations of the model, general principles of population dynamics, the highest Laguna Mountains skipper population growth should be realized when the ratio of the summer to spring adult population size is largest, limited only by quality of summer habitat compared to that available in spring. Therefore, this model illustrates the potential magnitude of summer brood contribution to population growth overall, and that summer brood survival is critical for maintaining population resilience in a bivoltine species (see also Faccoli and Stergulc 2006, pp. 62 and 63).

The conceptual model (Figure 4) identifies several drivers that likely influence population abundance, such as host plant suitability, nectar and surface water availability, predation, temperature, mate availability, and development time. Because insect populations typically exhibit large fluctuations in size, "stability" is not a term typically used to characterize healthy, resilient population dynamics; rather, resilient populations are those that can reach extreme lows without risking permanent extirpation (in metapopulations—a population comprising multiple sub-populations—some sub-populations may be extirpated and then subsequently recolonized). Currently, the best measureable indicator of population resilience for the Laguna Mountains skipper is the summer adult population size. The inability to detect adults during the summer would indicate the summer adult population is so small that mates would have difficulty finding each other. A low summer-to-spring abundance ratio (approaching zero) is a strong indicator that abundance will decrease the subsequent year.

This latter hypothesis, that reduced summer adult abundance indicates population decline, is supported by long-term monitoring of other butterfly species in California. For example, Arthur Shapiro (2014, pers. comm.) described a "striking" pattern of recent multivoltine butterfly population losses in the Sacramento area, where the large marble butterfly (*Euchloe ausonides*) was regionally extirpated between 2000 and 2005, despite being previously common and using common nonnative host plants. In every case he noted, the summer adult flight season "disappeared" first, 1–4 years before the spring adults. It is not clear if loss of the second flight season was a cause or symptom of population decline, but it seems to at least be an indicator. Shapiro (2014, pers. comm.) also described a similar phenomenon in populations of the Laguna Mountains skipper's relative, the small checkered skipper (*Pyrgus scriptura*). Shapiro said in the 1970-80s it was multivoltine and common at all sites, but since 2005, its numbers have declined rapidly everywhere. The small checkered skipper is now extirpated at Shapiro's two primary long-term monitoring sites, and in both cases only the spring flight season was recorded the last few years. He further reports that in west Sacramento, small checkered skippers continue to be multivoltine, but in 2013 and 2014 adults were scarce during the fall, when they were normally most common. This pattern strongly suggests that summer adult monitoring of Laguna Mountains skipper would be a simple and affordable way to inform population status assessments.

One model reviewer with expertise in the field provided a particularly salient discussion of model implications. Robert McElderry (2016, pers. comm.) explained;

> "Theoretically, the summer brood has great reproductive value, so it is likely necessary for population resilience. However, if the summer brood were [always] beneficial, natural selection would select against the 'optional' nature of this life history pathway, and all individuals would participate in the summer brood. There must therefore be some long-term resilience the population achieves in having two competing life history pathways. The pathway of direct development and summer breeding is expected to have a greater per capita pay off (>90:1) compared with the pathway in which individuals diapause during the summer, waiting until the following spring to breed. There are a number of reasons to expect that summer is not usually this productive."

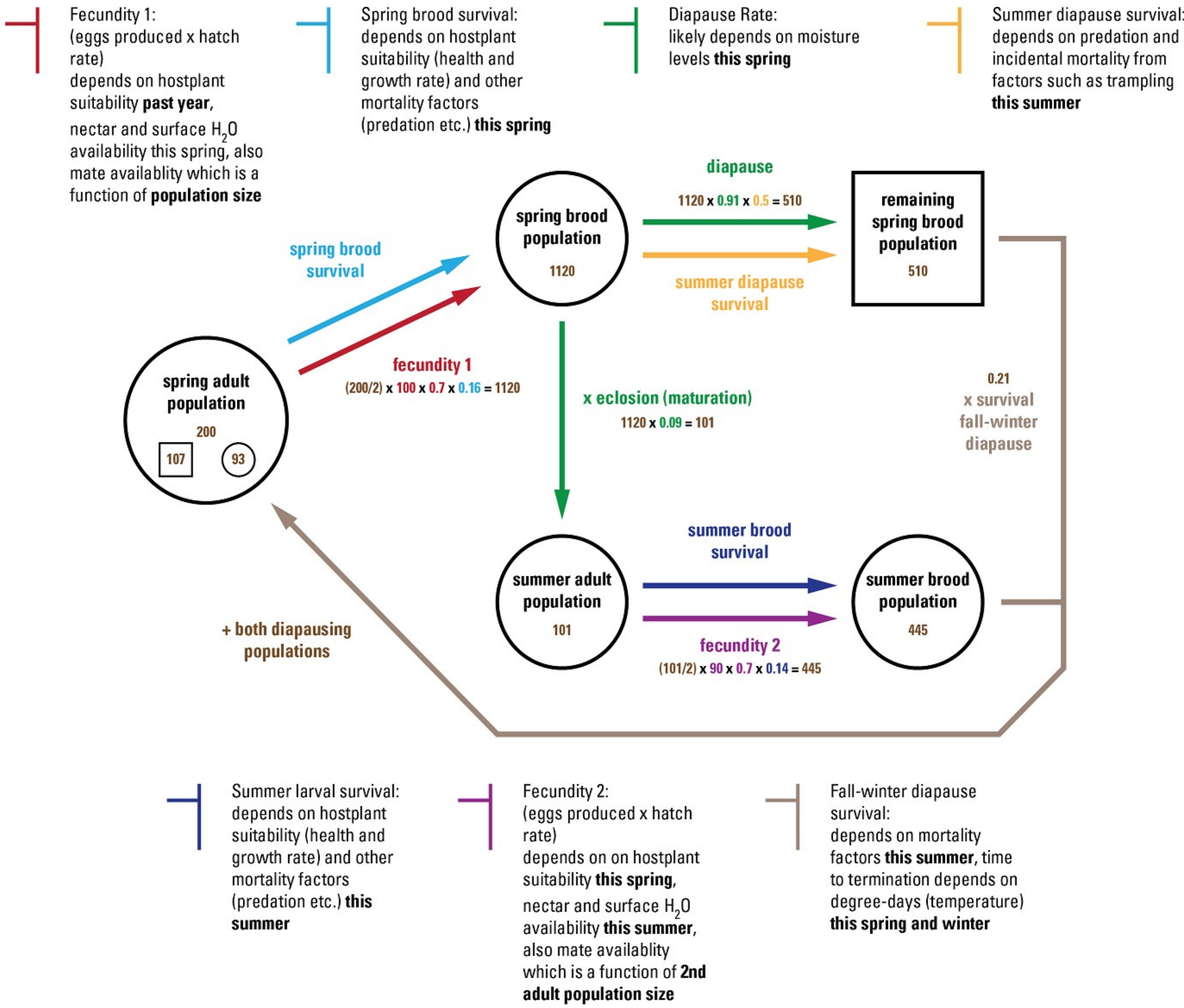

Figure 4. Life cycle and conceptual population ecology model for the Laguna Mountains skipper. A portion of the spring brood enter diapause, while the remainder complete development to become the summer adult population. The population dynamic values illustrated here as plausible examples are based on values from the literature, expert opinion, and monitoring data that indicates a typical summer to spring peak adult abundance ratio of 0.5. These example values illustrate "replacement" population growth rate with no net loss or gain of individuals. Factors that may affect productivity throughout the season are illustrated on top and to the right with colored markers. Sources: Tashiro and Mitchell 1985; Levy 1994; Faulkner 2008; 2009; 2010a; 2011; 2013; Johnson *et al.* 2010; Greeney *et al.* 2010; The Butterfly Farm 2015; Longcore *et al.* 2014. Developed by A. Williams-Anderson, U.S. Fish and Wildlife Service

What McElderry's explanation means is that while the importance of the summer brood to population growth is clear, if too high a percentage of the population underwent a second flight season, it could put the entire population at risk when environmental conditions are not suitable. A similar argument was made by Shapiro (2015, pers. comm.), that an excessively large summer brood would make the entire population vulnerable to summer weather stochasticity, and could lead to population crash.

Further analysis and refinement of this Laguna Mountains skipper population ecology model using additional field and captive population data will help predict population growth. This information will in turn inform monitoring needs and management action thresholds. Model reviewers agreed that sensitivity analysis, ongoing monitoring of phenology, and feedback between life history data and the model will be key to understanding subspecies' recovery needs and inform management action thresholds (Appendix E) (Forister 2016, pers. comm.; McElderry 2016, pers. comm.; Marschalek 2016, pers. comm.; Osborne 2016, pers. comm.; Shapiro, 2016, pers. comm.).

<u>Subspecies-specific Research and/or Grant-supported Activities</u>

Several research projects and grant-supported activities have been undertaken or funded since the last 5-year review was completed. These included four research projects, two captive rearing programs, and one conservation easement acquisition.

U.S. Forest Service Funded Recovery Activities

All Laguna Mountains skipper monitoring activities undertaken since publication of the last 5-year review in 2006 (summarized in Table 2) were funded wholly or partially by the USFS. The USFS also conducted a 2014–2015 study examining fire effects on *Horkelia clevelandii*. There was an average increase in host plant abundance where habitat was burned, with the greatest increases reported in plots that were dominated by native deergrass (*Muhlenbergia rigens*). Grass cover was also greatly reduced post-fire (Miller 2015, p. 2). Table 3 provides a complete list of Forest Service- funded recovery activities since the last 5-year review.

Service-funded Recovery Activities

We have learned much about the subspecies from research conducted over the past decade. In 2007 and 2008, CFWO staff conducted a Laguna Mountains skipper study to determine: (1) host plant distribution and abundance on Palomar Mountain; (2) subspecies distribution on Palomar Mountain; (3) status of Laguna Mountains skipper in the Laguna Mountains; and (4) subspecies habitat needs. In 2007, Ken Osborne conducted research along three independent, but interrelated, lines of study. The first study investigated microhabitat conditions associated with hostplants selected for oviposition, the second explored methods for captive rearing, and the third tested the feasibility of hostplant transplantation and propagation. The findings of the CFWO study (Grant *et al.* 2009) and Osborne (2008) have been incorporated in the appropriate sections of this review.

Table 3. Examples of conservation efforts illustrating the studies and activities that have been funded and implemented since listing to benefit the Laguna Mountains skipper.

Year	Title	Reference and/or funding Agency
1994- 2015	Annual surveys to monitor the status of LMS populations	Levy 1997; Mattoni and Longcore 1998; Pratt 1999; Faulkner 2000-2013 & 2015 /USFS, Cleveland National Forest
1997-ongoing	Grazing management	USFS, Cleveland National Forest
1999-ongoing	Multiple grazing exclosures on Palomar and Laguna Mountains	USFS, Cleveland National Forest
2014	Rebuilt and expanded the exclosure at Observatory Campground (installed 1997) to protect skipper habitat	USFS, Cleveland National Forest
2014-2015	Effect of prescribed fire on habitat (experiment)	Miller 2015/USFS, Cleveland National Forest funding

A study to measure Laguna Mountains skipper larval survival rates in the field and under captive "ranching" conditions in Mendenhall Valley was funded by the Service in 2015. The research was initiated by Osborne Biological Consulting in the spring of 2016, and remains ongoing. This funding also paid for a reintroduction and captive rearing plan for the Laguna Mountains skipper (Longcore, in prep), and coordination among stakeholders and agencies to initiate reintroduction to the Laguna Mountains (or the Cuyamaca Mountains if deemed appropriate).

In 2007, the Service funded a Laguna Mountains skipper habitat restoration project with the Anza Borrego Foundation (Service 2007b). This project resulted in 1300 individual *Horkelia clevelandii* being planted in Upper Doane Valley in 2009. Deer consumed most of the plants, and 13 percent survival was recorded in 2010 [California Department of Parks and Recreation (CDPR) 2012, p. 2]. The remaining funds paid for additional Laguna Mountains skipper surveys (in the Laguna Mountains, with negative results) (CDPR 2012, p. 2).

Captive Rearing of the Laguna Mountain skipper

Two captive rearing projects have been funded since 2007. In 2010, The Urban Wildlands Group, Inc., was contracted to evaluate the feasibility of, and initiate, a Laguna Mountains skipper captive rearing program. This was a collaborative effort between The Urban Wildlands Group and Moorpark College, located at America's Teaching Zoo at Moorpark College in Moorpark, California. Initial investigations provided important rearing information, though no progeny of captured females survived to pupation (Johnson *et al.* 2010, p. 20). Additional funds were provided in 2012 to help with captive rearing (Longcore *et. al.* 2014). Initial stages of a Laguna Mountains skipper butterfly "ranching" project were funded in the amount of $18,000 as part of the 2016 at-risk butterfly conservation initiative cycle by the Walt Disney Company (Daniels 2015, pers. comm.), additional funding was provided by this source for fieldwork in 2017 and 2019 totaling $77,000. One of the primary and most valuable lessons learned from this research was the role minute pirate bugs (*Orius* sp.) play as a significant early larval mortality factor (Osborne and Anderson 2018, p. 1).

Section 6 funding – Land Acquisition Grant for Easement on Portions of the Mendenhall Property on Palomar Mountain

In 2007, the California Department of Fish and Wildlife (CDFW), in coordination with the Service, prepared a Nontraditional Section 6 Recovery Land Acquisition Grant (Cooperative Endangered Species Conservation Fund) for the purchase of a conservation easement on portions of the Mendenhall property located on Palomar Mountain (Mendenhall Valley). The Service and CDFW worked closely for many years with the landowner to develop a conservation easement protecting habitat from impacts from grazing and future development. The 280 ac (113.3 ha) conservation easement was appraised for $1,252,000. The landowner agreed to sell the conservation easement for $948,000 and make a donation of $304,000 that constituted the required non-Federal match for the grant. This section 6 grant resulted in purchase of the conservation easement in 2011, promoting Laguna Mountains skipper recovery through partnerships and voluntary actions. The Service is initiating coordination in 2019 with all parties involved with Laguna Mountains skipper recovery in Mendenhall Valley, including the Mendenhalls, USFS, and researchers to develop a formal grazing management plan for pasture land covered by the easement.

Section 6 funding – Studying Populations of Laguna Mountains skipper on Palomar Mountain

In 2012, the CDFW, in coordination with the Service, prepared a Traditional Section 6 grant titled "Monitoring Populations of the Endangered Laguna Mountains Skipper on Palomar and Laguna Mountains in San Diego County." The grant totaled $64,800. San Diego State University investigators initiated surveys in 2014 and continued in 2015 (Marschalek and Deutschman 2014, p. 1). The study goal was to conduct surveys throughout suitable habitat on Palomar and Laguna Mountains to evaluate the subspecies' status, provide future site management recommendations, inform possible acquisition opportunities (CDFW 2012, p. 3), and to quantify potentially important microhabitat covariates (Marschalek 2015a, pers. comm., p. 1). The methodology was similar to the CFWO 2007/2008 study (Grant *et al.* 2009, p. 13), but modified based on recommendations from the CFWO 2007/2008 study to more efficiently address the objectives (Marschalek 2014, pers. comm.; 2015a, pers. comm., p. 9). The earlier study restricted surveys to 164 ft (50 m) radius circle plots (Grant *et al.* 2009, p. 13), while the current study uses "wandering" transects to cover the entire meadows (CDFW 2012, pp. 3 and 4). Both studies surveyed for Laguna Mountains skipper adults and recorded microhabitat data. Another objective of this 2-year grant was to establish transects so counts can be used for population size indices (Marschalek 2014, p. 6; Marschalek 2015a, pers. comm., p. 10).

FIVE-FACTOR ANALYSIS

The following five-factor analysis describes and evaluates current threats to Laguna Mountains skipper relative to the five listing factors outlined in section 4(a)(1) of the Act.
Threats identified in the final listing rule (Service 1997, pp. 2317–2320) under Factor A were range reduction and habitat destruction and degradation from grazing and trampling of *Horkelia*

clevelandii by domestic cattle. These were considered the primary factors responsible for the Laguna Mountains skipper decline. Over-collection and incidental predation by cattle as well as potential but undocumented predation by wild turkeys, were discussed as threats under factor C. Existing protections described under Factor D were not considered adequate, absent listing under the Act. Under Factor E, localized distribution and small population size were listed as factors that make the subspecies more vulnerable to the effects of other threats above, as well as stochastic events such as drought and wildfire. The 2007 5-year review added parasitism as a potential threat, but dismissed ingestion by wild turkey and cattle as unsubstantiated threats under factor C (Service 2007a, pp. 8–13). .

FACTOR A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Factor A threats identified in the final listing rule were range reduction and habitat degradation by domestic cattle. The 2007 5-year review summarized threats under Factor A by stating "a majority of remaining suitable habitat has been and continues to be negatively impacted due to fragmentation, continued overgrazing, and human recreational presence" (Service 2007a, p. 9). Additional threats not identified in the previous 5-year review are also considered here, including ground and surface water loss, and nonnative plant invasion and succession. We now consider fragmentation and recreational activities as likely stressors but not population-level threats. This is because the available information indicates that the impacts associated with fragmentation or recreation are limited in scope and we are not aware of any current or planned activities that would be considered a threat to the species. Therefore, we do not address fragmentation and recreational activities at this time. Though habitat loss due to land use has not been identified as a threat, conversion of even relatively small host plant patches for land use (i.e. agriculture, structure development, or water storage) could severely impact a small population of Laguna Mountains skipper. Current and potential Factor A threats impacting the Laguna Mountains skipper are discussed below: habitat modification due to grazing; spring, ground, and surface water loss; succession and nonnative plants; and climate change and drought (Table 4).

<u>Habitat Modification Due to Grazing</u>

Although grazing can be used as a positive management tool to improve habitat quality (see the <u>Succession and Nonnative Plants</u> section below), adverse impacts to Laguna Mountains skipper habitat may result from inappropriate grazing management. The primary impact from excessive cattle grazing on Laguna Mountains skipper habitat is erosion of meadow structure that may cause drying and loss of soil (Osborne 2002, pp. 12 and 14; Osborne 2003, p. 16). Erosion caused by grazing has been observed in Laguna Mountains skipper meadow habitats resulting in deep gullies, which can lower the water table and dry surrounding soils (Osborne 2002, pp. 12 and 14). Soil moisture is important to *Horkelia* growth and surface water is important for the nutritional needs of the Laguna Mountains skipper. Therefore, livestock-related erosion and the concomitant lowering of the water table likely modifies (degrades) Laguna Mountains skipper habitat. Grazing may be negatively impacting two of the four occurrences on Palomar Mountain; impacts are of low magnitude but without management, it could be an issue the future.

Table 4. Laguna Mountains skipper threats table.

Occurrences **(Other associated locations in the literature and on maps)**	**Ownership**	**Current threats to extant occurrences, and factors that could negatively affect a reintroduced population**
Palomar Mountain, extant		
Doane Valley (Lower French Valley, Lower Doane Valley, Upper Doane Valley, and Iron Springs)	Private, State, and USFS	Succession (State); land use change (private); climate change, small population size, water withdrawal, drought, wildfire (all)
French Valley (Upper French Valley, Palomar Observatory Trail, and Palomar Observatory Meadows)	Private and USFS	Habitat modification and incidental mortality due to grazing, land use change (private); succession; climate change, water withdrawal, small population size, drought, wildfire (all)
Mendenhall Valley (Observatory Campground)	Private and USFS	Succession, land use change (west valley); climate change, small population size, water withdrawal, drought, wildfire (all)
Pine Hills (Jeff Valley, Dyche Valley, and Will Valley)	Private and USFS	Habitat modification due to grazing, land use change, (Dyche and Will Valleys); climate change, water withdrawal, incidental mortality due to grazing, small population size, drought, wildfire (all)
Laguna Mountains, extirpated		
Laguna Meadow (Big Laguna Lake, El Prado Meadow, Laguna Campground, Horse Heaven Group Camp, Boiling Spring Ravine, and Agua Dulce Campground)	Private and USFS	Climate change, small population size, drought, wildfire (all)
Crouch Valley (Meadows Kiosk and Joy Meadow)	Private and USFS	Habitat modification and incidental mortality due to grazing, land use change, climate change, small population size, water withdrawal, drought, wildfire (all)

Grazing impacts to habitat are currently relatively light and managed in the Laguna Meadow and Mendenhall Valley occurrences, and as discussed in the Succession section below, grazing has the potential to benefit Laguna Mountains skipper habitat. To our knowledge, grazing is not being managed to minimize impacts to Laguna Mountains skipper habitat at the French Valley (Upper French Valley) or Pine Hills (Dyche Valley and Will Valley) occurrences on Palomar Mountain. Faulkner (2007, p. 7) described the Pine Hills Laguna Mountains skipper observation area as "impacted by cattle during most of the [Laguna Mountains skipper] survey season." We reviewed satellite imagery (USGS 2015) and, where possible, made visual inspections of meadows from roads (Williams-Anderson 2014, pers. obs.; Figure 6); it appeared to us that the level of grazing was relatively intense in Dyche Valley. We conclude that habitat damage due to grazing may be a threat to Laguna Mountains skipper in at least two occurrences on Palomar Mountain (French Valley and Pine Hills). While we believe the grazing in these areas may be high enough to impact Laguna Mountains skipper habitat, we recognize that there are a number of variables that influence stock density and range management choices. We believe there are opportunities for partnering and hope to work with all private landowners and managers of grazed lands that contain Laguna Mountains skipper habitat in the near future, to determine the optimal grazing regime for both Laguna Mountain Skipper conservation and cattle ranching.

Spring, Ground, and Surface Water Loss

Surface water, spring water, and groundwater removal can all affect the water table and soil moisture levels in meadow habitats. Established meadow hydrology is very important to the quality of Laguna Mountains skipper habitat, therefore, removal of groundwater (Mattoni and Longcore 1998, p. 10) poses a potential threat. Unregulated removal of water for commercially bottled water from artesian springs and wells (sometimes labeled "spring" water) is of particular concern at all four occurrences on Palomar Mountain where the subspecies occurs (Appendix D) (Faulkner 2014b and c, pers. comm.). Determining the effects of gravity spring and artesian well water removal on meadow water table and soil moisture levels is a complex process. This is because these methods of groundwater removal intercept underground flows temporarily forced to the surface by impermeable rock, or removal of water stored in the deeper, discontinuous fractured granite (FAO 2015). The hydrology of these meadows has not been documented to our knowledge. Thus, it is difficult for us to assess the effects of groundwater removal on Laguna Mountains skipper habitat. Nevertheless, groundwater removal has the potential to exacerbate effects of drought, such that the two in combination could reduce the amount of surface water and soil moisture and thereby result in a threat to Laguna Mountains skippers. We cannot fully determine the magnitude of impacts at this time, and it is uncertain whether groundwater removal currently poses a threat to the subspecies. An assessment of groundwater hydrology and removal in Laguna Mountains skipper-occupied meadows is an informational need.

Succession and Nonnative Plants

Succession in meadow habitats results in perennial herbaceous and woody vegetation shading, and eventually replacing, the more open canopy, herb-dominated habitat typically used by

Laguna Mountains skippers. Succession can impact Laguna Mountains skipper habitat in locations where disturbances, such as fire and grazing, do not occur.

Grazing has been excluded for decades in Upper Doane Valley and western Mendenhall Valley, resulting in apparent displacement of skipper host plants, primarily by later successional native species (Marschalek 2014, p. 4). Late-successional native plant species can reduce host plant suitability by shading and displace host plants through competition (Figure 5). Observations of succession in Mendenhall Valley cattle exclosures (Marschalek and Deutschman 2014, p. 3) and Laguna Meadow (Williams-Anderson 2015, pers. obs.; Figure 5) indicate host plants can be overgrown by other native plants. Impacts from nonnative plant invasion appear to be less of a threat than succession (Criley 2015, pers. comm.), but will likely require management to protect Laguna Mountains skipper habitat (Williams and Bailey 2004, pp. 21 and 30; Grant *et al*. 2009, p. 10). Early intervention in nonnative invasions may be advantageous.

Luiseño Native Americans historically used lands on Palomar Mountain ("Paauw" in the Luiseño language, which translates to "mountain") in tribal territories and villages such as "Malava" in Mendenhall Valley, and "Paisvi" at Iron Springs (Sparkman 1908, p. 192; Wood and Bruggeman 2014, p. 10). Levy's (1994, pp. 13–15) analysis of historical tribal land management practices led him to believe mountain meadow habitats where the Laguna Mountains Skipper is found may have been "actively and extensively managed" by burning to reduce succession until late in the nineteenth century. He concluded "…early fire management may have favored, and the current policies mitigate against, growth of plants such as *Horkelia clevelandii*" (Levy 1994, p. 16). Levy (1994, p. 23) further noted the Palomar Fire in 1987 "appears to have transiently created favorable habitat for *H. clevelandii* in Lower French Valley...", and he believed habitat management by fire, and in some cases grazing (Levy 1994, p. 20), might be needed to prevent succession. Data collected since the last 5-year review (discussed below) further supports Levy's hypothesis.

Succession appears to be the cause for low host plant abundance in western Mendenhall Valley and Upper Doane Valley, where the disturbance regime has changed: cattle have not grazed for decades and wildfire has been absent for even longer. In contrast, Lower French Valley and much of Lower Doane Valley burned in 1987 and 2007 (Grant *et al*. 2009, pp. 61–69), where Laguna Mountains skippers are currently relatively abundant (Marschalek 2014, p. 8). Although host plant cover was at least temporarily reduced after the 2007 fire, Laguna Mountains skippers were observed in twice as many plots in 2008 than in 2007 (Grant *et al.* 2009, pp. 9, 10, 58). Similar results were obtained in a 2014-2015 study examining fire effects on *Horkelia clevelandii*. There was an average increase in host plant abundance where habitat was burned, with the greatest increases reported in plots that were previously dominated by *Muhlenbergia rigens* (deergrass). Grass cover was also greatly reduced post-fire (Miller 2015, p. 2).

Figure 5. *Horkelia clevelandii* in the Agua Dulce Meadow on Laguna Mountain (at the headwaters of Agua Dulce creek) showing succession more than 10 years after cattle grazing was practically eliminated. *Horkelia clevelandii* is being overgrown by California wild rose (*Rosa californica*), native grasses, and other competing plant species (right picture is close-up illustrating how *H. clevelandii* is being overgrown). When this area was regularly grazed, *H. clevelandii* was abundant and exposed; however, this area also suffered from extensive erosion due to excessive cattle use (Williams-Anderson 2001, pers. obs.) Photo credits: A. Williams-Anderson/USFWS.

Annual monitoring data to examine changes in pre-and post-2007 Poomacha Fire Laguna Mountains skipper abundance is unavailable; however, some pre- and post-fire data is available that supports the hypothesis that fire can beneficially reverse succession. Grant *et al.*'s (2009, entire) pre-fire and 1 year post-fire data, and Marschalek's (2014, entire; 2015, entire; Marschalek 2015a, pers. comm., pp. 5–8) 7- and 8-year post-fire surveys covered similar portions of Lower French, Lower Doane, and Mendenhall Valleys in the spring. Grant *et al.*'s and Marschalek's survey methods were also relatively consistent within years, so the ratios of their abundance and occupancy index values (Lower French and Doane/Mendenhall) should be comparable among years (Table 4). Lower French and Doane Valleys had not burned since 1987 (records since approximately 1900), and cattle had not grazed there for over 20 years. Although the number of Laguna Mountain skipper adults observed per host plant (a density index) was higher in undisturbed Lower French and Doane Valleys, compared to grazed Mendenhall Valley, the maximum adults observed/person/day (an abundance index) was 3 to 6 times higher in Mendenhall Valley (Table 4). In contrast, 7 years after the fire, the abundance index for Lower French and Doane Valleys (30) was similar to the Mendenhall Valley index (31); 8 years after fire the Lower French and Doane Valleys abundance index (60) increased to almost double that of Mendenhall Valley (31) indicating the Poomacha Fire improved habitat quality in Lower French and Doane Valleys, and supporting the a-priori hypothesis that fire reduces succession and improves habitat quality. A similar pattern of abundance ratios (Lower French and

Doane/Mendehall) was recorded for Grant *et al.'s* survey plots: the occupancy ratio in 2007 was 3/12 (0.25), and slightly higher in 2008 at 6/20 (0.30), while in both 2014 and 2015 it was double the earliest value at 7/14 (0.50) (Marschalek 2015a, pers. comm., p. 10), indicating abundance in the Doane Valley occurrence had increased after the fire relative to abundance in the Mendenhall Valley occurrence. Occupied portions of Lower French and Doane Valleys and the southwestern portion of Mendenhall Valley contained a similar number of plots (27 and 30, respectively).

None of these data are conclusive with regard to the threat of succession or the effects of disturbance, but they support the hypotheses that succession is a threat, and fire and grazing can be valuable habitat-management tools to reduce impacts and promote Laguna Mountains skipper recovery.

Table 5. Comparison of abundance index of adult Laguna Mountains skippers (LMS) and the number of LMS observed per plant in Mendenhall Valley (MV) and Lower French and Doane Valleys (FDV). "No fire" means only record since 1900 except a minimal partial burn in 1987 (Palomar Fire; Grant *et al.* 2009, p. 69). "Some grazing" means surveys were conducted in a cattle grazing exclosure, but surrounding occupied habitat was grazed. Values include counts outside the monitoring site.

	LMS per plant	LMS		**Ratios MV/FDV:**	
2007				LMS per plant	LMS
FDV	0.0097	7	(no grazing, no fire)	0.3726	3.57
MV	0.0036	25	(some grazing, no fire)		
2008					
FDV	0.0124	9	(no grazing, 1st year post-fire)	0.6491	6.22
MV	0.0081	56	(some grazing, no fire)		
2014					
FDV		30	(no grazing, 7 years post-fire)		1.03
MV		31	(some grazing, no fire)		
2015					
FDV		60	(no grazing, 8 years post-fire)		0.52
MV		31	(some grazing, no fire)		

Drought and Climate Change

Drought is detrimental to butterfly populations because it can reduce host plant availability and quality, reduce nectar source availability, and reduce other sources of moisture utilized by adults to maintain hydration and mineral salts. While future climate scenarios predicted by models do not always predict reduced rainfall, they often do. As discussed in greater detail below, this likely results in longer or more severe droughts. Alternatively, even when total annual rainfall increases, if rainfall becomes more concentrated in extreme events, and/or temperatures also increase, habitats will still become drier, effectively mimicking the effects of drought. This is reflected in increased climatic water deficit values (CWD), which is the potential evapotranspiration minus actual evapotranspiration, an indicator of soil moisture level and plant drought stress (see below discussion and Appendix F). Therefore, as we discuss below, prolonged drought, or changed climate conditions that produce similar effects, could be detrimental to Laguna Mountains skipper habitat.

Drought

Periodic drought was described as a threat to the Laguna Mountains skipper in the listing rule (Service 1997, p. 2319) and 2007 5-year review (Service 2007a, p. 12). As Laguna Mountains skipper population size trends appear to generally follow precipitation (Appendix C), it is likely Laguna Mountains skipper populations reached historically low and vulnerable levels during the 1980s, and drought is a logical contributing factor to extirpation in the Laguna Mountains (see *Population Ecology* and *Abundance Estimates* sections above). Laguna Mountains skipper habitats are drier in the Laguna Mountains, and have received approximately 6-8 in (152-203 mm) less rain per year on average from 1971 to 2001 than on Palomar Mountain. This was also a period of weather extremes, including four drought years in a row starting with 1998 and ending in 2001, with the driest year of the period (County of San Diego 2010, figures 2-2 and 2-3, pp. 113–114; Grant *et al.* 2009, p. 47). Therefore, the phenomenon of weather-related population decline (Figure 4) likely contributed to extirpation of Laguna Mountains skipper from the southern portion of its range. Not only did Laguna Mountains skippers experience drought years in the Laguna Mountains during their decline, they experienced high temperatures that dried soils even more. Information reviewed and analyzed in this report further supports Grant *et al.*'s (2009, pp. 4 and 5) hypothesis based on the surface water relationship they found; that is, the extended drought conditions in the Laguna Mountains likely contributed to the Laguna Mountains skipper's extirpation at that location. We consider drought to be a significant threat to Laguna Mountains skipper because of the subspecies' dependence on the availability of moist soils and surface water, which in turn are dependent on groundwater levels. While we believe prolonged or severe drought can be a severe threat on its own, it is likely that greatest impact to Laguna Mountains skipper is the combination of drought with other stressors, such as vulnerability to grazing during periods of dry forage (see Factor C discussion below).

Moreover, the likelihood of drought may be increasing. The trends have been for increased temperatures and decreased precipitation since the Laguna Mountains skipper was extirpated from its namesake region. Average January-September temperatures California in 2014 were the highest on record since 1895, continuing a steady upward trend since the late 1970s; only 4 years since 1977 have been below the hundred year mean [National Oceanic and Atmospheric Administration (NOAA) 2014, p. 4; Figure 7]. Average temperature (January to October) on Palomar Mountain in 2014 was the warmest on record, and the 4 year precipitation deficit was the greatest on record, equivalent to the loss of an entire average year of rainfall (NOAA 2014, pp. 1 and 7). In 2015, record high temperatures continued, as did below-average rainfall (CDWR 2015, p. 1; NCEI 2015).

Climate Change

Our analyses under the Act include consideration of ongoing and projected changes in climate. 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 statistics (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, or both (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, and substantial increases in precipitation in some regions of the world and decreases in others (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 percent 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). IPCC likelihood estimates provide a probabilistically quantified measure of uncertainty in a finding based on statistical analysis of observations, or model results, or expert judgment, or a combination of these (as we have done throughout this document). 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 percent 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; 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 about 2030, 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; Prinn *et al*. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23). For a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation see IPCC 2013b (entire).

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 fragmentation) (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 has been and is currently 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 for us to use. 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). To assess the vulnerability of Laguna Mountains skipper to the effects of climate change, we relied primarily on the high-resolution downscaled California Basin Characterization Model (Appendix F) to evaluate past and projected changes in climate factors that affect Laguna Mountains skipper habitat suitability. The primary environmental variables affecting Laguna Mountains skipper populations are soil moisture levels and surface water availability, influenced by temperature, precipitation, and habitat substrate, and reflected in the calculation of climatic water deficit.

Generally temperature and precipitation affect Laguna Mountains skipper development and survival, as exothermic metabolism increases with increasing temperature, and precipitation increases host plant quality and nectar availability. We expect that temperature (GDD) also determines when pupae break diapause in the spring. California’s climate has been getting progressively warmer since the 1970s, with record high temperature and low precipitation statistics in 2014, including those for Palomar Mountain (NOAA 2014, pp. 1, 4, and 7). Average downscaled climate model projections for change in the Laguna Mountains skipper watershed mean annual maximum temperature are +3.2º F (1.8º C) for 1950-2005 vs. 2025-2049, and +5.4º F (3.3º C) for 2050-2075 (USGS 2014; Figure 9). Therefore, Laguna Mountains skipper development rates should increase and they should break diapause earlier on average. The related small checkered skipper (*Pyrgus scriptura*) demonstrated a shift toward earlier emergence in the Sacramento area from 1972– 2003 by almost 3 weeks, a trend found for all butterflies that diapause as pupae (Forister and Shapiro 2003, pp. 1132–1134). If habitat conditions do not get drier, this could be advantageous, resulting in a larger summer brood and increased population growth (Figure 4).

Laguna Mountains skippers are also sensitive to a warming, drying climate because of their dependence on soil moisture levels and surface water availability, the effect temperature has on growth and development of immature stages and adult phenology (see *Population Ecology* section above and Appendix C), and because they currently inhabit a single mountaintop at maximum elevation, with no opportunity for unassisted range shift northward or upward in elevation. Comparison of the average annual CWD between two 30 year intervals (1951-1980 mean compared to 1981-2009 mean) using the California Basin Characterization Model (Appendix F), other climate data sources, and subspecies-specific information support that habitat drying due to climate change was a contributing factor to the subspecies' extirpation on the Laguna Mountains.

If summer adult and brood population sizes decline significantly (a trend of lower and lower summer to spring flight adult population size ratios), because the climate is warming and drying (higher CWD) causing spring brood individuals to break diapause earlier and fewer individuals complete their development, populations could decline to extirpation. If the number of spring brood individuals that enter diapause increases, the contribution of those individuals to population growth would not likely compensate for the contribution they would have made had they completed development and reproduced the same year. In other words, the spring adults that complete development can contribute exponentially more to population growth compared to those that enter diapause in the spring (Figure 4). This phenomenon would explain what has been occurring with small checkered skippers near Sacramento (Shapiro 2014, pers. comm.; see above). Shapiro (2015, pers. comm.) hypothesized that alternatively, if the CWD decreased (as in the wettest model scenarios; Appendix F), this could lead to an excessive increase in the proportion of the population participating in the summer brood. Everything then depends on second brood survivorship and with increased climate variability, could increase the risk of a population crash.

The California Basin Characterization Model indicates historical CWD values were higher in the Laguna Mountains during the 30-year period when Laguna Mountains skipper populations declined to extirpation than it had been for the prior 30 years (Appendix C). There was likely a synergistic effect between increased drying of the habitat and increased grazing at the time, because as drought conditions reduce preferred annual forage plants, cattle are more likely to impact larvae when feeding on the tops of the greener perennial host plants. (Levy 1994, pp. 20 and 46; Pratt 1999, p. 27; Mattoni and Longcore 1998, p. 4). There were also more cattle grazing (Brown 1991, p. 5; K. Osborne 2015, pers. comm.; Criley 2016, pp. 5 and 6) and the climate was drier in Laguna Meadow (Grant *et al*. 2009, p. 47; County of San Diego 2010, p. 113) than on Palomar Mountain in the years leading up to the extirpation of Laguna Mountains skipper from Laguna Mountain. Currently, grazing pressure in Laguna Meadow has since been reduced, so drought in that area would not likely have as detrimental an impact on the habitat.

Climate change model projections indicate climate will change habitat conditions on Palomar Mountain and the Laguna Mountains in a similar fashion (equal magnitude in each mountain area) over the next 60 years (Appendix C). Given the Laguna Mountains skipper's dependence on soil moisture and surface water availability, "driest" case CWD projections indicate drying may detrimentally affect habitat suitability. However, "wettest" case projections suggest that CWD levels could improve over the next 30 years, then return to near current levels over the following 30 years (60 years of projections, two 30 year means). It is also possible that increased and more severe storm events could exacerbate meadow erosion where it is already impacted by grazing (see Habitat Modification Due to Grazing under **Factor A** above), and cause Laguna Mountains skipper population (e.g. Service 2003, p. 30). Near-term habitat climate conditions are projected to change very little, or even improve (Appendix F). While there are opportunities for adaptation, and a possibility of minimum effect, climate change is a potential long-term threat to the Laguna Mountains skipper due to the possibility of habitat drying (Appendix F).

Summary of Factor A

The threat of Laguna Mountains skipper habitat modification due to grazing has been reduced in portions of its range since listing by ongoing management. We believe that grazing remains a threat in the French Valley and Pine Hills occurrences, and it could impact our ability to reintroduce the Laguna Mountains skipper to Crouch Valley because grazing intensities in those areas have not been reduced since the last 5-year review. Grazing can also be used as a management tool where succession impacts the habitat quality for the Laguna Mountains skipper. We hope to work with private landowners to balance their needs for grazing while maintaining Laguna Mountains skipper habitat. Ground and surface water reduction due to water exportation and climate change are potential rangewide threats that require further investigation. Drought is a significant threat and succession is a threat where no natural or artificial disturbance occurs. Near-term habitat conditions are not projected to change, or to possibly improve and return to historical conditions. Climate change is a potential threat due to the possibility of long-term habitat drying, especially where grazing is not managed to minimize impacts to Laguna Mountains skipper habitat.

FACTOR B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Collection and vandalism were considered as potential threats to the Laguna Mountains skipper at the time of listing. These were both briefly discussed in the previous 5-year review, though the impacts were not well known and were considered speculative (Service 2007a, p. 9). At the current time, there is no information to support that collection or vandalism are threats to the Laguna Mountains skipper or its habitat.

FACTOR C: Disease or Predation

Disease

Disease was not identified as a threat to the Laguna Mountains skipper at the time of listing or in the previous 5-year review (Service 1997; Service 2007a). More recently, Longcore *et al.* (2014,

p. 11) expressed concern that the proteobacteria *Wolbachia* may be responsible for the infertility of a wild caught adult female captured for captive rearing. Bacteria in the genus *Wolbachia* are cytoplasmically inherited in reproductive tissues (ovaries and testes) of a wide range of arthropods (Werren 1997, p. 587). *Wolbachia* has been reported to interfere with reproduction in a range of ways, including cytoplasmic incompatibility among infected and non-infected individuals (Werren 1997, p. 593; Nice *et al.* 2009, p. 3137) and was confirmed to be present in the Laguna Mountains skipper population on Palomar Mountain (Hamm *et al.* 2014, p. 4). *Wolbachia* infection can be expected to cause significant problems for rare butterfly species conservation, because it can: (1) promote the spread of undesirable maternal genetic elements through "hitchhiking;" (2) reduce population size by effectively altering the sex ratio; and (3) reduce genetic variation (Nice *et al*. 2009, p. 3138). *Wolbachia* may also have offsetting beneficial effects, such as protection against viral infection (Unckless 2011, pp. 111–138). While impacts from disease are not known to impact the Laguna Mountains skipper, additional investigation is required.

<u>Predation and Parasitism</u>

Predation was not identified as a threat to the Laguna Mountains skipper at the time of listing. New information we received since the completion of the 2007 5-year review indicates one predator that could potentially impact Laguna Mountains skipper populations is the nonnative seven-spotted ladybird beetle (*Coccinella septempunctata*), which has been observed in increasing numbers within the range of Laguna Mountains skipper. This species, originally from Eurasia, was introduced into the eastern United States from 1956 to 1971, but it was not known to have established residency until 1973 when a population was observed in New Jersey (Faulkner 2009, pers. comm.). Faulkner (2009, pers. comm.) started noticing the species in large numbers in the Laguna Mountains about 10 years ago. In 2008, he found them to be common in the Lower French Valley on Palomar Mountain, along with the native convergent ladybird beetle (*Hippodamia convergens*). Although the literature states the seven-spotted ladybird beetle eats aphids, Faulkner believes that like many ladybird species, they feed on a wider variety of small, soft-bodied insects, including butterfly eggs and early instar larvae. The Asian ladybird beetle (*Harmonia axyridis*), another introduced nonnative species, has been shown to prey on butterfly larvae (Sheppard *et al.* 2004, p. 2077). While predation on Laguna Mountains skippers has not been reported, Faulkner (2009, pers. comm.) has observed en masse aggregations, often in bunch grasses during the winter, much as convergent ladybird beetles aggregate. During the 2007 and 2008 surveys, Service biologists observed large swarms ("tens of thousands of individuals") in meadows in the Laguna Mountains (Grant *et al*. 2009, p. 25). Large numbers of seven spotted ladybird beetles were also observed in Mendenhall Valley and Pine Valley occurrences during the spring Laguna Mountains skipper flight season in 2015 (Williams-Anderson 2015, pers. obs.). he restricted range and apparent low population numbers of Laguna Mountains skipper make the recent establishment of the seven-spotted ladybird beetle on Palomar Mountain a potential threat that needs to be further investigated.

In 2017-2018 Osborne and Anderson (2018, p. 1) discovered that minute pirate bugs (*Anthochoride: Orius sp.*) were a major early instar mortality factor during rearing and apparently in the wild field population (these were commonly observed while searching for larvae). While this predator is likely native and not therefore a threat influenced by human activity, any ecological habitat changes that might increase the abundance of this predator could negatively impact Laguna Mountains skipper population growth.

Parasitism was mentioned in the previous 5-year review (Service 2007a, pp. 9 and 10), as Laguna Mountain skipper eggs have been heavily parasitized by *Trichograma brevacapalum*, a parasitic wasp (Mattoni and Longcore 1998, p. 4). Tachinid flies were also mentioned as a potential source of larval mortality (Osborne 2002 p. 12 and 15; 2003 p. 10 and 16). We do not have any additional information to determine the impacts of parasitoids on Laguna Mountains skippers. Because the Laguna Mountains skipper evolved with these parasites, and we have no information suggesting that the level of parasitism has changed, we do not currently consider parasitism a threat.

<u>Incidental Ingestion and Trampling</u>

Incidental ingestion and trampling of immature life stages by cattle was considered a threat to Laguna Mountains skipper at the time of listing, and has been a concern of researchers for some time (Brown 1991, p. 5; Mattoni and Longcore 1998, pp. 4 and 6; Osborne 2003, pp. 14, 36–38; 2008, p. 35; Pratt 2006, pers. comm.; Longcore and Osborne 2015, p. 164). Despite concerns, the last 5-year review dismissed ingestion and trampling as threats. During this review, in part due to discussions with USFWS staff, it came to our attention that grazing by deer has been historically overlooked as another potentially source of larval mortality. Osborne's (2008, p. 35) rearing and field observations demonstrated larvae and pupae are located in silken shelters made from upper host plant leaves at heights of 3 to 5 in (8 to 13 cm), parts commonly consumed by grazing ungulates. *Horkelia clevelandii* is reportedly grazed more heavily during the summer (Levy 1994, pp. 20 and 46; Mattoni and Longcore 1998, p. 4; Pratt 1999, p. 27) when other preferred forage has been consumed, or when annual forage is more desiccated and no longer preferred (see Figure 6 for illustration of winter grazing impacts in 2014). Late-season grazing also apparently removes significant amounts of flowers, where eggs are sometimes deposited during the second flight season (Levy 1994, p. 20; Mattoni and Longcore 1998, p. 4). Mattoni and Longcore (1998, p. 4) provided a description of direct Laguna Mountains skipper mortality caused by apparent grazing in Mendenhall Valley:

> "Over 30 locations for eggs found in the field were flagged for key factor determination. However, most of the flags were knocked over by cattle. Of the two eggs actually seen oviposited on April 29, both hatched on May 8 (12 days for development in the field). On May 14 both had woven shelters, one by joining two large leafs and the second by joining several small leaves. When next observed on May 21, the first had presumably been eaten and the plant trampled, the second was in its second instar. Prior to the June 3 visit, the second larva, and flag, also disappeared… By the time of the second generation flight, drought and grazing substantially reduced optimal [*Horkelia clevelandii*] tissue. Few large green marginal leafs were available in July. The goldfields had largely senesced and the only nectar source now was [*H. clevelandii*] itself. Some second generation eggs were found on flowerheads as well as the few acceptable leafs. Grazing removed substantial *Horkelia* flowerheads… "

Although the issue has not been explicitly studied in the field, it can be assumed that grazing by deer and cattle that commonly occur in Laguna Mountains skipper habitat impacts populations through incidental ingestion and possibly trampling. A review of the literature indicates deer and cattle are equally likely to graze on *Horkelia clevelandii* during the summer. Deer primarily browse woody forage, and cattle prefer grass, but both types of ungulate consume significant, and typically similar, amounts of forbs (Thill and Martin 1988, p. 542; Ortega 1991, p. 56; Martinez *et al* 1997, p. 253; Scasta *et al.* 2016, p. 213). Data indicates consumption of forbs is highest, and diets overlap the most in pastures grazed regularly by cattle (Findholt *et al.* 2005, pp. 5, 11, and 13) during summer and fall (Ockenfels and Lewis 1997, p. 89; Hosten *et al.* 2007, p. 13). Cattle are also known to consume *Potentilla* (also used by Laguna Mountains skipper as a host plant) and *Frageria sp*., plants related to *H. clevelandii* (Pacific Rural Press 1904, p. 1; Hosten *et al.* 2007, pp. 11 and 27). However, when *H. clevelandii* was planted in Upper Doane Valley in the winter of 2009, the majority of the young green plants appeared to have been consumed by deer that destroyed frost covers protecting the plants (California State Parks 2011, p. 2; Bates-Lande 2016, pers. comm.). Impacts at this location were not likely additive however, as deer apparently avoid upland areas where cattle actively graze (Hosten *et al.* 2007, p. 1). Therefore, grazing by deer should be considered a significant factor in incidental consumption of Laguna Mountains skipper larvae, while cattle may additively increase the otherwise natural grazing intensity of ungulates in occupied habitat where their grazing activities overlap.

One way to investigate grazing impacts is to compare grazing and butterfly history among meadows. We considered information from the Forest Service (Criley 2016; Winter and Criley 2018, pers. comm.), additional information from the Mendenhall family on grazing practices (Mendenhall 2018, pers. comm.), and historical butterfly information, and conducted additional analysis to understand the factors contributing to species extirpation. The USFS submitted a report (Criley 2016, pp. 1 and 6) in response to "inferences to a higher grazing pressure in Laguna Meadow possibly leading to the extirpation of Laguna Mountain …," to help inform the draft recovery plan and "…efforts attempting to correlate grazing use with Laguna Mountain skipper population trends and distribution." It concluded Laguna Meadow and Mendenhall Valley had similar grazing histories through the apparent period when the Laguna Mountains skipper declined in the Mount Laguna area.

We examined the assumptions required to compare grazing effects between the two mountain areas and relate them to butterfly population persistence. First of all such an analysis may not be robust enough to violate the assumption of no difference between habitat areas and remain valid. Habitat differences could affect resilience of Laguna Mountains skipper populations to drought and grazing impacts. For example, the Laguna Mountains typically receive less rainfall than Palomar Mountain (County of San Diego 2010, p. 113), thus Laguna Mountains skipper populations may be more vulnerable in the southern mountains to grazing impacts, especially during summer larval development. Furthermore, such an analysis may not be robust enough to violate the assumption of identical management and remain valid. While cattle have always been moved to different parts of Mendenhall Valley during the summer and winter, they are not moved to a different meadow entirely in the winter as in Laguna Meadow. Criley (2016) did not analyze grazing intensity on the private portion of Mendenhall Valley, which is part of the same skipper population distribution as the Forest Service pasture. Finally, the analysis may not be robust enough to violate the assumption of population independence within a mountain area and remain valid. There were no other Laguna Mountains skipper populations in ungrazed meadows in the Laguna Mountains to potentially provide immigrants to Laguna Meadow, compared to Palomar Mountain (such as the Doane Valley Occurrence; Figure 2) for Mendenhall Valley. Violation of those assumptions makes it difficult to infer butterfly population effects from grazing intensity data comparisons among meadows.

Figure 6. Localized grazing impacts to meadow vegetation in Dyche Valley on Palomar Mountain, winter 2014. Winter is a time when forage is most scarce, and maximum impact effects, including ground disturbance from trampling, are evident: (1) photograph from the highway, including vegetation outside the fence, (2) disturbed meadow soil and cropped vegetation inside the fence, (3) wider view of meadow inside the fence, and (4) cattle and cattle feces inside the fence. Photo credits: A. Williams-Anderson/USFWS.

We estimated and compared differences in grazing intensity between Laguna Meadow and Mendenhall Valley during the period of species decline. The Laguna Mountains skipper appears to have experienced a long-term decline in the Laguna Mountains, and likely crossed a threshold of irreversible decline by the early 1990s (see *Abundance Estimates* section above). Using information provided in Criley (2016 pp. 8 and 10) and Mendenhall (2018 pers. comm.), and combining the total acreage of the currently occupied meadow area/grazing allotment in Mendenhall Valley, we calculated average annual grazing intensity (head months per acre) for Laguna Meadow and Mendenhall Valley. We found that from 1977 through 1989 (after which grazing intensity was reduced due to ongoing drought) estimated grazing intensity in Laguna Meadow was almost double that in Mendenhall Valley (1.12 vs. 0.65 head months per ac.). From 1990 through 1999 (when the last Laguna Mountains skipper was observed in Laguna Meadow), grazing intensity was similar in the two meadow areas as alluded to by Criley (2016, p. 6), even slightly lower in Laguna Meadow than in Mendenhall Valley (0.46 vs. 0.6 head months per ac.). By 1990 however, in Brown’s (1991, p. 5) opinion, the species was already in decline for more than 20 years. We found that during the extreme drought years from 1987 to 1991, when Faulkner (*in* USFS 2016, p. 2) noted the species was in clear decline, average grazing intensity was still significantly higher in Laguna Meadow (0.8 vs. 0.6 head months per ac.), compared to Mendenhall Valley. Therefore, analysis of grazing intensity in Mendenhall Valley and Laguna Meadow supports the hypothesis that grazing pressure during drought years contributed to extirpation of the Laguna Mountains skipper from the Laguna Mountains.

Several pre- and post-cattle grazing event observations by experts in the field also support the hypothesis that grazing can result in Laguna mountains skipper mortality. Inspection of host plants prior to and after movement of cattle (“trespassing” from lower-elevation private lands) through USFS pasture in the southeastern portion of Mendenhall Valley revealed apparent cropping by grazing (Osborne 2018, pers. comm.). Qualitative observation of host plant conditions during field studies in Mendenhall Valley also support this hypothesis (Osborne and Anderson 2016 and 2017, pers. obs.). *Horkelia clevelandii* in the study area (infrequently visited by cattle compared to the primary meadow) appeared to have few grazing impacts, while many plants in the primary meadow where cattle were frequently observed appeared to be close-cropped to the ground. Plants most accessible and exposed to cattle in the primary meadow resembled prostrate “mats” of vegetation, in contrast with the more erect “bushy” appearance of plants in the study area. The appearance of host plants inside the grazing exclosure (not in the area that is getting overgrown with deer grass) in the primary meadow, which does not exclude deer and other grazers, compared to those outside was also more “bushy.” These observations suggest cattle grazing is the cause of the mat-like appearance of plants in the active pasture.

It is clear the USFS has invested substantial effort into conserving Laguna Mountains skippers throughout the species historical range, and minimizing grazing impacts to the species (Table 4). It is not clear what more the USFS could have done, considering the information available on Laguna Mountains skipper during the years leading up to extirpation in the Laguna Mountains. It may also be true the subspecies was experiencing irreversible decline due to a combination of climate change and land management practices before the Forest Service started managing the land. Nevertheless, all the information considered above supports the hypothesis that direct impacts of grazing (incidental ingestion and trampling) contributed to the decline and extirpation of the subspecies in the Laguna Mountains (last observed in 1999), and pose a threat to Laguna Mountain skipper at high enough densities, especially during drought conditions.

Summary of Factor C

Disease, *Wolbachia* in particular, is a new potential threat to Laguna Mountains skipper not previously considered. Predation and parasitism are also considered potential threats since listing, and the last 5-year review expressed concern that a nonnative ladybird beetle abundant in the Laguna Mountains might pose a particular threat. This species of ladybird beetle is now found in occupied habitat on Palomar Mountain. The potential threats of predation and disease are considered greater since the last 5-year review, but require further investigation to determine the extent of impacts to Laguna Mountains skipper populations. Incidental ingestion and trampling by cattle was considered a threat at the time of listing, but was not clearly described as such in the last 5-year review. Following an in-depth literature review and analysis of their population ecology, we believe incidental ingestion and trampling of immature life stages can have moderate impacts, having a population level effect. This threat continues to threaten the Laguna Mountains skipper where grazing is not managed to reduce impacts, especially during dry summer conditions.

FACTOR D: Inadequacy of Existing Regulatory Mechanisms

At the time of listing existing regulatory protections were not considered adequate to prevent extinction. The 2007 5-year review stated "…regulatory mechanisms in the absence of listing are inadequate to address the threats to the Laguna Mountains skipper to such an extent that it is no longer in need of the protections of the Act." Below we review the current state of Laguna Mountains skipper regulatory protection.

Federal Protections

<u>Organic Administration Act of 1897 and the Multiple–Use, Sustained–Yield Act of 1960</u>

The USFS Organic Act of 1897 (16 U.S.C. § 475–482) established general guidelines for administration of timber on USFS lands, which was followed by the Multiple–Use, Sustained–Yield Act (MUSY) of 1960 (16 U.S.C. § 528–531), which broadened the management of USFS lands to include outdoor recreation, range, watershed, and wildlife and fish purposes.

<u>The National Forest Management Act</u>

The National Forest Management Act (NFMA) (16 U.S.C. § 1600 *et seq*.) requires the USFS to develop a planning rule under the principles of the MUSY of 1960 (16 U.S.C. § 528–531). The NFMA outlines the process for the development and revision of the land management plans and their guidelines and standards (16 U.S.C. § 1604(g)).

A new National Forest System (NFS) land management planning rule was adopted by the USFS in 2012 (entire). The new planning rule guides the development, amendment, and revision of land management plans for all units of the NFS to maintain and restore NFS land and water ecosystems while providing for ecosystem services and multiple uses. Land management plans (also called Forest Plans) are designed to: (1) Provide for the sustainability of ecosystems and resources; (2) meet the need for forest restoration and conservation, watershed protection, and species diversity and conservation; and (3) assist the USFS in providing a sustainable flow of benefits, services, and uses of NFS lands that provide jobs and contribute to the economic and social sustainability of communities. A land management plan does not authorize projects or activities, but projects and activities must be consistent with the plan. The plan must provide for the diversity of plant and animal communities including species-specific plan components in which a determination is made as to whether the plan provides the "ecological conditions necessary to…contribute to the recovery of federally listed threatened and endangered species…". In addition, the NFMA requires land management plans to be developed in accordance with the procedural requirements of NEPA, with a similar effect as zoning requirements or regulations as these plans control activities on the national forests and are judicially enforceable until properly revised.

Under the NFMA, the Cleveland National Forest (2005, entire) completed a Land and Resource Management Plan (LRMP) to provide for multiple use and sustained yield of the products and services obtained from National Forests, including wildlife. Within this plan, the USFS identified habitat management strategies and tactics to move listed species toward recovery and delisting and achieve desired area-specific goals.

National Environmental Policy Act

All Federal agencies are required to adhere to the National Environmental Policy Act (NEPA) 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 Laguna Mountains skipper 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 Laguna Mountains skipper; that is, effects to the subspecies 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 Statements prepared pursuant to NEPA, including Land Management Plans.

Endangered Species Act of 1973, as amended

The Endangered Species Act of 1973, as amended (Act), is the primary Federal law providing protection for Laguna Mountains skipper. The Service is responsible for administering the Act, including sections 4, 7, 9, and 10.

Section 7(a)(1) of the Act requires all Federal agencies to utilize their authorities in furtherance of the purposes of the Act by carrying out programs for the conservation of endangered and threatened species. Since listing, the Service has analyzed the potential effects of Federal projects under section 7(a)(2) of the Act, which requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect listed species. A jeopardy determination is made for a project that is reasonably expected, either directly or indirectly, to appreciably reduce the likelihood of both the survival and recovery of a listed species in the wild by reducing its reproduction, numbers, or distribution (50 CFR 402.02). A non-jeopardy determination may include reasonable and prudent measures that minimize the amount or extent of incidental take of listed species associated with a project. Under the terms of section 7(b)(4) and section 7(o)(2) of the Act, taking that is incidental to and not intended as part of a Federal agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of an incidental take statement (50 CFR 402.02). Since the 2007 5-year review, we conducted two formal consultations under section 7 of the Act that anticipated incidental take of Laguna Mountains skipper. These formal consultations addressed project impacts to Laguna Mountains skipper as a result of USFS operations such as grazing leases.

Section 9 of the Act prohibits the taking of any federally listed endangered or threatened species. Section 3(18) defines “take” to mean “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.” Service regulations (50 CFR 17.3) define “harm” to include significant habitat modification or degradation which actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harassment is defined by the Service as an intentional or negligent action that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. The Act provides for civil and criminal penalties for the unlawful taking of listed species.

The Service may issue incidental take permits to applicants pursuant to section 10(a)(1)(B) of the Act for projects without a Federal nexus that would likely result in incidental take of listed species. To qualify for an incidental take permit, applicants must develop, fund, and implement a Service-approved Habitat Conservation Plans (HCP) that details measures to minimize and mitigate the project’s adverse impacts to listed species. Regional HCPs in some areas now provide an additional layer of regulatory protection for covered species, and many of these HCPs are coordinated with California's related Natural Community Conservation Planning (NCCP) program. There are currently no HCPs that cover Laguna Mountains skipper.

State Protections in California

The State's authority to conserve rare invertebrate wildlife is contained within two major statutes: the California Environmental Quality Act (CEQA), and the Natural Community Conservation Plan Act (NCCP).

California Environmental Quality Act (CEQA)

As a federally listed subspecies, Laguna Mountains skipper is considered a rare species under CEQA (Section 15380, Public Resources Code), which 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 projects proposed to be undertaken or requiring approval by State and local public agencies (*http://www.ceres.ca.gov/topic/env_law/ceqa/summary.html*). CEQA requires disclosure of potential environmental impacts and a determination of "significant" if a project has the potential to reduce the number or restrict the range of a rare or endangered plant or animal; however, projects may move forward if there is a statement of overriding consideration. If significant effects are identified, the lead agency has the option of requiring mitigation through changes in the project or to decide that overriding considerations make mitigation infeasible (CEQA section 21002). Protection of listed species through CEQA is, therefore, dependent upon the discretion of the lead agency involved.

Natural Community Conservation Planning Act

In 1991, the State of California passed the NCCP Act to address the conservation needs of natural ecosystems throughout the State (Fish and Game Code 28002835). The NCCP program is a cooperative effort involving the State of California and numerous private and public partners to protect regional habitats and species. The primary objective of NCCPs is to conserve natural communities at the ecosystem scale while accommodating compatible land uses. NCCPs help identify, and provide for, the regional- or area-wide protection of plants, animals, and their habitats while allowing compatible and appropriate economic activity. Many NCCPs are developed in conjunction with HCPs prepared pursuant to the Act. Regional NCCPs may provide protection to federally listed species by conserving native habitats upon which the species depend. There are currently no NCCPs that cover Laguna Mountains skipper.

Sustainable Groundwater Management Act

On September 16, 2014, the Governor of California signed a package of bills that established a California groundwater regulation framework for the first time. Together Senate Bill (SB) 1168, Assembly Bill (AB) 1739, and SB 1319 (which amends AB 1739) of the 2013-2014 legislative session, form the Sustainable Groundwater Management Act. The Legislature intends that AB 1739 (in part) provide groundwater sustainability to agencies (as created by SB 1168) with authority to regulate groundwater extraction through measures such as well spacing rules, extraction allocation transfers within the watershed, and accounting rules (Abbott and Kindermann, LLP 2014, pp. 1 and 4). This legislation should require regulation of spring and ground water removal from Laguna Mountains skipper habitats.

Local Protections in San Diego County

Subregional plans, adopted as an integral part of the County of San Diego's General Plan, are policy plans specifically created to address the issues, characteristics, and visions of communities within the County (County of San Diego 2011a, p. 1). The North Mountain Subregional Plan (NMSP) was adopted in 2011, and includes the Palomar Mountain/Aqua Tibia Wilderness Resource Conservation Area (County of San Diego 2011a, p. 1; RCA). Land Use Policy 5 mandates the County "Encourage preservation of areas with rare, unique, or endangered wildlife and plants" (p. 6). Land Use Policy 7 mandates the County "Encourage a groundwater study for the Palomar Mountain area directed by the County Groundwater Hydrologist that shall be completed after the study is authorized and funding approved by the Board of Supervisors (p. 7)." Under the category of General Conservation the NMSP states that although existing companies export spring water from Palomar Mountain, local regulations do not apply to private extract of spring water, and its effect on groundwater supply is unknown. It states that export of groundwater would require a Major Use Permit and analysis of its impact on groundwater supplies, and to protect this groundwater resource, it is important to ensure that the total amount of extraction does not exceed the amount of average annual groundwater recharge (County of San Diego 2011a, p. 14). NMSP General Conservation policy 1 states "Groundwater levels should be monitored," and policy 2 states "Cumulative effects of new development should be carefully regulated and the quality of groundwater constantly monitored" (County of San Diego 2011a, p.15).

The Central Mountain Subregional Plan (CMSP) was adopted in 2011 and includes the Crouch Valley, Mount Laguna, and Mount Laguna Coniferous Forest RCAs (County of San Diego 2011b, p. 147). Private Inholdings in or Lands Adjacent to U.S. Forest Service Lands and California State Parks Policy 1 mandates "all development on private inholdings or adjacent properties shall aim to minimize impacts on adjacent public lands, especially with regard to visual, biological, noise, and dark sky resources" (County of San Diego 2011b, p. 78). Policy 8 states that groundwater recharge basins may need to be preserved through the use of open space easements. Policy 11 discourages commercial establishments of high water, and Policy 12 prohibits groundwater mining (County of San Diego 2011b, p. 104). Under the category of General Conservation the CMSP states that communities must be able to function on whatever groundwater resources they have, plus any recharge that occurs. It further defines conservation as the foresighted utilization, preservation, and/or renewal of natural or biological resources, for the greatest good of the greatest number, on a sustainable basis. In the Central Mountain Subregion, RCAs are identified to protect wildlife habitat, native plants and animals, scenic slopes, and landmarks (County of San Diego 2011b, pp. 120 and 121). Land use Policy 1 mandates application of "appropriate Rural and Semi-Rural land use designations to areas identified as containing rare and endangered plant and animal species…" Land Use Policy 2 states the County and other public or non-profit agencies should consider purchasing the RCAs identified in Appendix B as funds become available (County of San Diego 2011b, p. 129). Vegetation and Wildlife Policy 11 states that biological studies specifically addressing endangered, threatened, and sensitive species identification are required for discretionary permits when deemed necessary by County environmental review staff, and Policy 12 requires spring surveys in areas where sensitive species are known to exist (County of San Diego 2011b, pp. 128 and 129).

Summary of Factor D

Federal and State regulatory mechanisms provide discretionary protections for the subspecies based on current management direction, but do not guarantee protection for the subspecies absent its status under the Act. Listing of Laguna Mountains skipper under the Act in 1997 resulted in increased awareness of the importance of protecting and managing habitat for this subspecies in San Diego County. It is unlikely that existing regulatory mechanisms in place at the time of listing would have sufficiently addressed the threats faced by Laguna Mountains skipper and achieved the same results. The Act is still the primary regulatory mechanism mandating Laguna Mountains skipper conservation, and it is through the Act that we continue to work with private landowners and State and Federal agencies to implement actions to reduce ongoing threats and recover this subspecies. Therefore, in absence of the Act, other laws and regulations have limited ability to protect Laguna Mountains skipper throughout a substantial portion of the subspecies' range.

FACTOR E: Other Natural or Manmade Factors Affecting Its Continued Existence

The listing rule indicated that the restricted range, localized distribution, and small population size of the Laguna Mountains skipper "make them vulnerable to the effects of habitat loss, degradation and fragmentation, especially with regard to naturally occurring events" (Service 1997, p. 2318). The 2007 5-year review again identified small population size as a threat. It stated that because of the concentration of individuals on Palomar Mountain, the Laguna Mountains skipper is vulnerable to threats such as wildfire, drought, and climate change (the latter two factors are discussed above under factor A). An assessment of Factor E threats currently impacting Laguna Mountains skipper is provided below.

<u>Small and Declining Populations</u>

The threat to the Laguna Mountains skipper posed by small population size and isolation has increased since the time of listing due to loss of the Laguna Meadow and Crouch Valley occurrences. The remaining Laguna Mountains skipper populations located on Palomar Mountain are relatively small and susceptible to stochastic events, which may result in extirpation of additional populations. Small population size also increases the probability of extinction of the subspecies due to difficulty of finding mates, loss of genetic diversity, and lack of colonists to repopulate habitat patches (Allee 1931, pp. 246 and 247). Low genetic diversity may decrease a species' ability to adapt to changing environmental conditions. Genetically homogenous populations may therefore be more at risk and less able to recover from environmental or demographic variability (such as drought and fire events) compared to large diverse populations. Therefore, the extremely restricted range and localized distribution make the Laguna Mountains skipper more vulnerable to extirpation by environmental events.

Wildfire

At the time of listing the Laguna Mountains skipper was thought to occur in fire-adapted ecosystems, but it was noted that a large fire could eliminate affected populations (Service 1997, p. 2319). This characterization has not changed, although we know more now about positive effects from fire activity, including reduced fuel loads and maintenance of an early succession stage. Grant *et al*. (2009, p. 10) expressed concern that "a single high intensity conflagration fueled by Santa Ana katabatic winds [carries high density air from a higher elevation down a slope under the force of gravity] could potentially drive the species to extinction..." Other fire-adapted species that typically survive burns have been extirpated from portions of their range (for example, Quino checkerspot butterfly (*Euphydryas editha quino*); Service 2003, p. 30), and catastrophic wildfire is known to be a threat to small, isolated butterfly populations (Healy and Wassens 2008, p. 13). Therefore, wildfire poses a rangewide threat with potential to extirpate small populations.

Summary of Factor E

The threat posed by small population size has increased since listing with the loss of the Laguna Mountains occurrences. Catastrophic wildfire is a threat to smaller, more isolated populations and the remaining Laguna Mountains skipper populations are not secure, because of vulnerability to stochastic processes such as wildfire and drought.

Cumulative Effects of Threats Under all Factors

The primary threats that currently impact the Laguna Mountains skipper include habitat modification through succession, incidental ingestion by cattle or deer during drought periods, erosion where grazing is not managed appropriately, population isolation, and small population size. Small population size and isolation in particular makes this subspecies susceptible to impacts of stochastic events such as severe weather, drought, and wildfire. There may also be a synergistic effect between drying of habitat during drought conditions and increased Horkelia grazing by deer and cattle, because as available forage is reduced, grazers may focus feeding on the tops of the green perennial host plants where larvae occur. Additionally, where high levels of grazing have resulted in erosion, the change in drainage patterns can result in lowered groundwater tables, which reduces habitat quality by decreasing the availability of moisture soil and surface water. Water extraction, through pumping and capture of water at gravity and artesian springs, also lowers the groundwater table. The effects of drought may further exacerbate all the other conditions that result in lowered groundwater tables. Climate change may also increase the severity of current threats with potential for increased drying, erosion, and changes to CWD.

III. SYNTHESIS

The Laguna Mountains skipper is currently restricted to Palomar Mountain where there are four extant occurrences. They inhabit large wet mountain meadows and adult occupancy is generally associated with surface water such as streams and wet seeps. The primary threats to survival of the Laguna Mountains skipper are: habitat modification through succession and cattle grazing, incidental ingestion of immature life stages by cattle or deer, climate change, and small isolated populations susceptible to events such as drought and fire.

Habitat degradation due to grazing is managed in the Mendenhall Valley occurrence, but remains a likely threat on private land in at least one occurrence on Palomar Mountain. Incidental ingestion and trampling of immature life stages can have moderate impacts having a population level affect, and is considered a threat wherever grazing occurs without management to minimize impacts to the species. Succession appears to be reducing habitat quality within western Mendenhall Valley and upper Doane Valley (Mendenhall Valley and Doane Valley occurrences), though disturbance (managed grazing and controlled burns) can be utilized to restore and maintain habitat. The remaining Laguna Mountains skipper populations on a single mountain are relatively small, and therefore especially susceptible to impacts such as drought and wildfire. Climate projections are conflicting and suggest habitat may experience extreme drying in the future, or improve over the next 30 years and then return to moisture levels consistent with current levels over the next 60 years. It is also possible more extreme and more frequent storm events could negatively impact populations. Grazing has been greatly reduced and is now well-managed in the Laguna Meadow occurrence since it began the decline resulting in extirpation.

With extirpation of the Laguna Mountains occurrences, the subspecies lost crucial population redundancy and quite possibly also genetic diversity. Any further reduction in distribution may affect our ability to reestablish Laguna Mountain skippers in the formerly occupied southern portion of their range. Steps to establish a captive rearing program are being taken to learn more about the biology of the Laguna Mountain skipper and develop the methodology necessary to restore populations at locations other than Palomar Mountain. While the subspecies' extinction vulnerability has increased since the last 5-year review, and the Laguna Mountains skipper remains in danger of extinction throughout its range, this has been partially mitigated through ongoing partnerships among stakeholders, regulators, and scientists who continue working together to improve our understanding of what is needed for subspecies recovery. While there are ongoing efforts to improve management and reintroduce the species to historical habitats, threats have not been ameliorated, and there is no indication the status of remaining populations on Palomar Mountain has improved since listing. The Laguna Mountains skipper remains in danger of becoming extinct throughout its range and no status change is recommended at this time.

IV. RESULTS

Recommended Listing Action:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (indicate reason for delisting according to 50 CFR 424.11):
    ____ *Extinction*
    ____ *Recovery*
    ____ *Original data for classification in error*
__X No Change

V. New Recovery Priority Number and Brief Rationale:

No change.

VI. RECOMMENDATIONS FOR ACTIONS OVER THE NEXT 5 YEARS

The actions listed below are recommendations to be completed over the next 5 years. These will help guide continuing recovery of the Laguna Mountains skipper by providing information to better manage each of the populations. We will continue to work with partners (i.e., Federal and State agencies, and private landowners). We will work with Service programs, such as the Service's Partners for Fish and Wildlife Program, to identify opportunities for conservation or preservation of potential Laguna Mountains skipper habitat on private land. Conservation of this taxon is dependent on continued cooperation with our partners (e.g., USFS, CDFW, California State Parks, and private landowners) to minimize impacts from current threats and stressors and aid future restoration. It is important to work with all our partners to identify funding sources for all the actions listed below.

1. Continue captive rearing efforts to inform and supply stock for augmentation and reintroduction efforts.

2. Assess feasibility and recovery benefits of releases of captive-reared individuals into managed habitat on Palomar Mountain and in the Laguna Mountains, and conduct releases as deemed appropriate.

3. Continue life history research to, improve population growth modeling using the population ecology model, and inform monitoring and other recovery actions.

4. Determine survey methods for monitoring and estimating population size and detecting presence of Laguna Mountains skippers. Initiate monitoring and determine a course of action if critical decline is indicated in the future.

5. Conduct a study to quantify impacts of incidental ingestion and trampling of immature life stages by cattle.

6. Investigate the likelihood of seven-spotted ladybird beetle predation on Laguna Mountains skipper larvae.

7. Work with hydrologists and other partners to investigate impacts of ongoing groundwater removal on Palomar Mountain and Laguna Mountains meadow aquifers.

8. Develop new partnerships with private landowners that graze cattle in French Valley, Pine Hills, and Crouch Valley occurrences; also with community members and public land managers from Palomar Mountain, the Cuyamaca Mountains, and Laguna Mountains.

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Shapiro, A. 2015. Arthur Shapiro, University of California, Davis**.** Electronic document review (draft 5 year review) sent to Alison Williams-Anderson (Service). October 19, 2015.

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Winter, K. and L. Criley. 2018. Email chain with Alison Williams-Anderson (Service). Subject: "LMS Recovery Plan comments." Initiated Oct 26, 2018 at 7:58 PM.

APPENDIX A

Historical Laguna Mountains Skipper Distribution

A number of areas have potential to support the Laguna Mountains skipper other than Palomar Mountain and the Laguna Mountains, but investigations over the past 14 years have not detected occupancy. Although habitat appears suitable in the Cuyamaca Mountains (Williams and Bailey 2004, p. 30), the subspecies has never been collected or observed there (Brown 1991, p. 5 erroneously stated it had been collected near the community of Julian based on a collection label that referenced distance to Julian; Levy 1994, p. 10; Faulkner 2012b, p. 1). Surveys by Osborne (2003, pp. 10 and 12) and Faulkner (2015, p. 5) in the San Jacinto Mountains during drought were negative, although host plants were found in a number of meadows and especially in gullies and drainages. Faulkner (2015, p. 5) noted that "The primary factor excluding Laguna Mountains skipper from the San Jacinto Mountains and Hot Springs Mountain is the limited number of open wet meadows which are more common on Palomar Mountain and in the Laguna Mountains of San Diego County." Host plant presence, elevation, and other parameters also identify mountainous areas east of Palomar Mountain in San Diego County as containing potential habitat: the Hot Springs Mountain complex; (Bucksnort Mountain/Rocky Mountain/Pine Mountain/Indian Flats/Chihuahua Valley/Lost Valley/Los Coyotes Indian Reservation); and Volcan Mountain (Pratt 2006, pers. comm.). Levy (1997, p. 26) surveyed Indian Flats Campground near Hot Springs Mountain once in July of 1997, but found no Laguna Mountains skippers. More recently Faulkner (2015, p. 3) surveyed two drainages on Hot Springs Mountain during a drought year, and detected no Laguna Mountains skippers either. Faulkner (2015, p. 4) stated he believed that even during drought, Laguna Mountains skippers should have been detectable if they were present. Finally, *Horkelia clevelandii* has been reported from the Sierra San Pedro Mártir in Baja California, Mexico (Thorne *et al.* 2010, p. 30). No surveys have been conducted on Volcan Mountain or in Mexico that we are aware of.

All mountain areas thought to otherwise contain potential habitat for the Laguna Mountains skipper were reviewed using topographic relief and satellite imagery. Only Palomar Mountain, the Laguna Mountains, and the Cuyamaca Mountains in the United States, the Sierra San Pedro Mártir, and the Sierra de Juarez in Mexico, were found to contain large relatively wet meadows comparable to Mendenhall Valley and Laguna Meadow. The highest precipitation in San Diego county occurs on Palomar Mountain (followed by the Cuyamaca Mountains), with precipitation in the wettest years exceeding 70 in (178 cm) (County of San Diego 2010, p. 5). Wet meadows are generally distinguished by their hydrologic regime, landscape context, and soils. As commonly defined, wet meadows have mineral, seasonally saturated soils with little or no peat accumulation (Rains-Jones 2011, p. 3). These meadows are surrounded by large ridges and mountains, forming true valley "basins" over 2 mi (3.2 km) long. If Mattoni and Longcore's (1998, p. 9) hypothesis that a large reservoir population in Mendenhall Valley supplies periodic colonists to adjacent forest patches accurately describes Laguna Mountains skipper population structure (such as a mainland-island metapopulation), this key landscape feature may explain the subspecies' known historical distribution.

The unique shape of the mountains that support large wet meadows and Laguna Mountains skipper host plants in southern California, especially the geographic location and topography of Palomar Mountain that makes it so wet, was even noted historically: "Palomar is one of the few higher mountains of Southern California that does not border the desert… Lacking the conventional cone shape expected of a mountain, Palomar rises abruptly from the San Luis Rey river valley on the south for about three thousand feet, only to spread out on top in an area of something like eight square miles, including wooded hills, grassy spring-fed valleys, and trickling canyons" (Wood and Bruggeman 2014, p. 5). Given what we know about historical occupancy, mountains occupied by Laguna Mountains skippers under modern climate conditions can be assumed to fit the relatively rare "hourglass shape" described by Elsen and Tingley (2015, pp. 1 and 2), characterized by a mid-elevation decrease in availability of elevational surface area (concentration of flatter habitat at mid-elevations, below higher peaks or ridges). The majority of what used to be the large wet meadow in the Cuyamaca Mountains is now at least periodically inundated due to dam construction, so given this altered hydrology it is unclear whether the area could support a Laguna Mountains skipper population. The Sierra San Pedro Mártir (also "hourglass shaped") supports four relatively large wet meadows. The lowest elevation and most similar in appearance to historically occupied Laguna Mountains skipper habitat is Santa Rosa Meadow, but it is still approximately 1000 ft (305 m) higher in elevation than Laguna Meadow, 2000 ft (610 m) higher than Mendenhall Valley, and the only one of the four where the host plant has not been recorded (Thorne *et al.* 2010, p. 30). Therefore, although a number of other mountain areas contain habitat elements as discussed above, it is not likely any new Laguna Mountains skipper populations will be discovered (see also Grant *et al.* 2009, p. 4; Faulkner 2015, entire).

APPENDIX B

Laguna Mountains Skipper Specimens and Label Information from Collections.

Most historical Laguna Mountains skipper collections were from the Laguna Mountains (Table B1), where the species was first taxonomically described (type specimen). There is a pattern of reduced specimen collection over the years leading up to extirpation, indicating population decline (Figure B1), however collections are not very reliable indicators of abundance. Most specimens were collected in the spring, when collectors commonly look for butterflies, but a significant number were also collected in the summer on both mountains (Table B1 and Figure B2), indicating there has always been a substantial second flight season and summer brood throughout the subspecies range.

Table B1. Laguna Mountains skipper collected specimens. Sources: Levy 1994, Scott 1981, Faulkner 2014c, pers. comm. (M= male, F=female)

Place Name on Label	Date	Total	M	F	Collector	Notes
Big Laguna Meadow	4/24/1962	1				Mapped middle of big meadow
Big Laguna Meadow	5/15/1967	3				"
Boiling Springs	4/24/1962	1				
Boiling Springs	4/30/1966	1	1		O. Shields	
East Laguna	5/5/1956	2				
East Laguna	5/5/1957	9	4	6	F. Thorne	Number of individuals differ in papers
East Laguna	7/14/1957	17	15	2	F. Thorne	
East Laguna	5/9/1958	2				
East Laguna	5/20/1962	3				
East Laguna (North end of)	5/5/1956	4			F. Thorne	1 male holotypes, 1 female allotype, 2 m, 4 f paratypes
El Prado Campground	4/22/1986	unk				Mapped middle of EP Campground
Horse Haven Springs	4/5/1972	3				Mapped middle of Horse "Heaven" Campgrouund
Laguna Lake	6/5/1955	1		1	O. Seite	Mapped near Big Laguna Lake
Laguna Lakes	5/25/1958	3	2	1	O. Shields	Not in Levy paper mapped between lakes in big meadow
Laguna Mountain	August (?)	1			F. Thorne	Faulkner pers. comm., private collection
Laguna Mts	4/13/1947	7	5	2	J. Creelman	
Laguna Mts	4/13/1947	13				
Laguna Mts	4/13/1947	2				

Place Name on Label	**Date**	**Total**	**M**	**F**	**Collector**	**Notes**
Laguna Mts	4/19/1947	3				
Laguna Mts	4/20/1947	11	7	4	J. Creelman	
Laguna Mts	4/20/1947	2				
Laguna Mts	4/25/1948	1	1		J. Creelman	
Laguna Mts	5/2/1948	1		1	J. Creelman	
Laguna Mts	5/2/1948	2				
Laguna Mts	5/9/1948	3	2	1	J. Creelman	
Laguna Mts	5/9/1948	1				
Laguna Mts	5/16/1948	1	1		J. Creelman	
Laguna Mts	6/6/1956	1		1	E. Hulbirt	
Laguna Mts	6/5/1957	2	1	1	E. Hulbirt	
Laguna Mts	5/30/1960	1				
Laguna Mts	4/15/1961	1				
Laguna Mts	4/29/1961	4				
Laguna Mts	5/29/1964	1				
Laguna Mts	4/8/1972	2				
Last sm meadow before **Palomar** Observatory	6/2/1991	2				
Little Laguna	5/9/1958	2	3	1	F. Thorne	Mapped in meadow next to Little Laguna Lake
Little Laguna	4/8/1972	3				"
Little Laguna (Meadow)	7/19/1975	1				"
Little Laguna (Meadow)	7/17/1979	1				"
Palomar	7/17/1927	1				
San Diego Co	6/28/1936	2	1	1	F. Thorne	Assumed Laguna Mountain
San Diego Co	4/24/1949	1				
San Diego Co	5/1/1949	4				
San Diego Co	5/9/1958	1				
San Diego Co	unk	7				

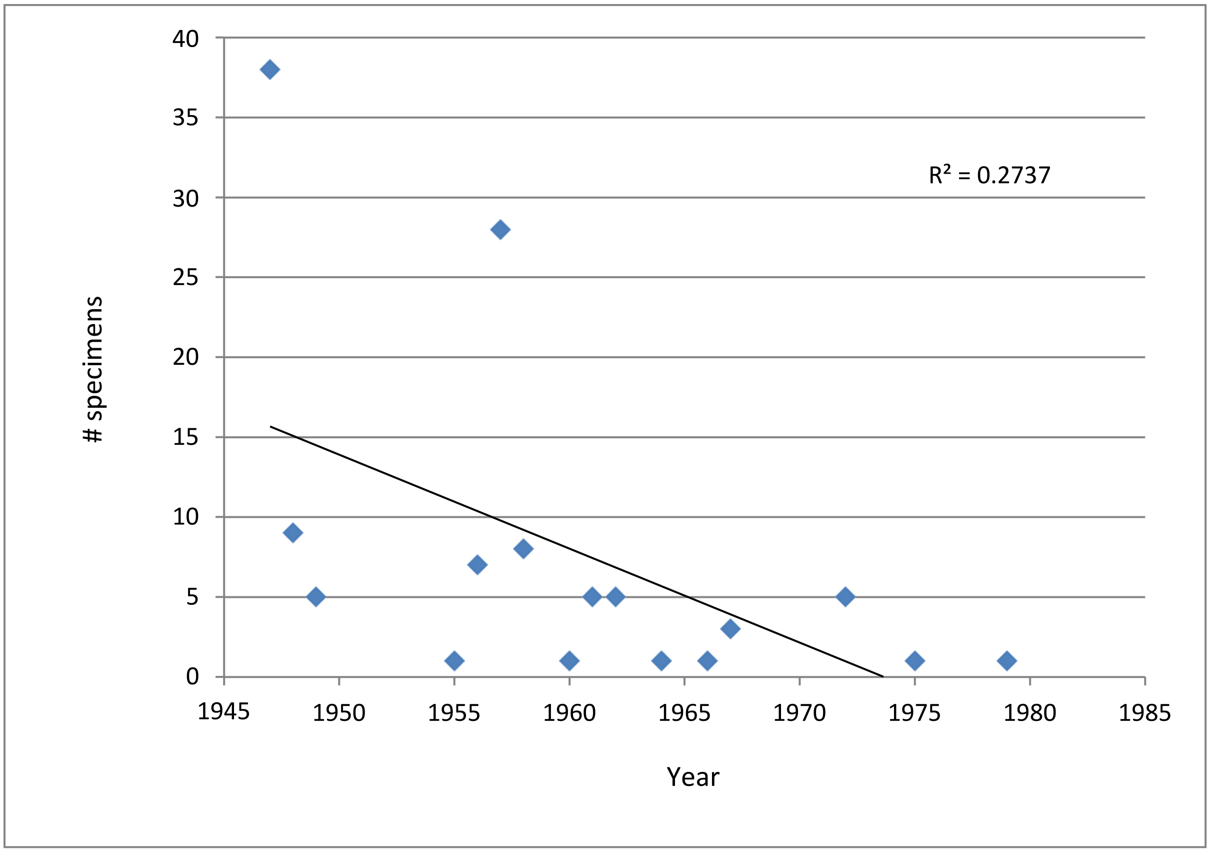

Figure B1. Laguna Mountains skipper specimens by collection date from the Laguna Mountains only.

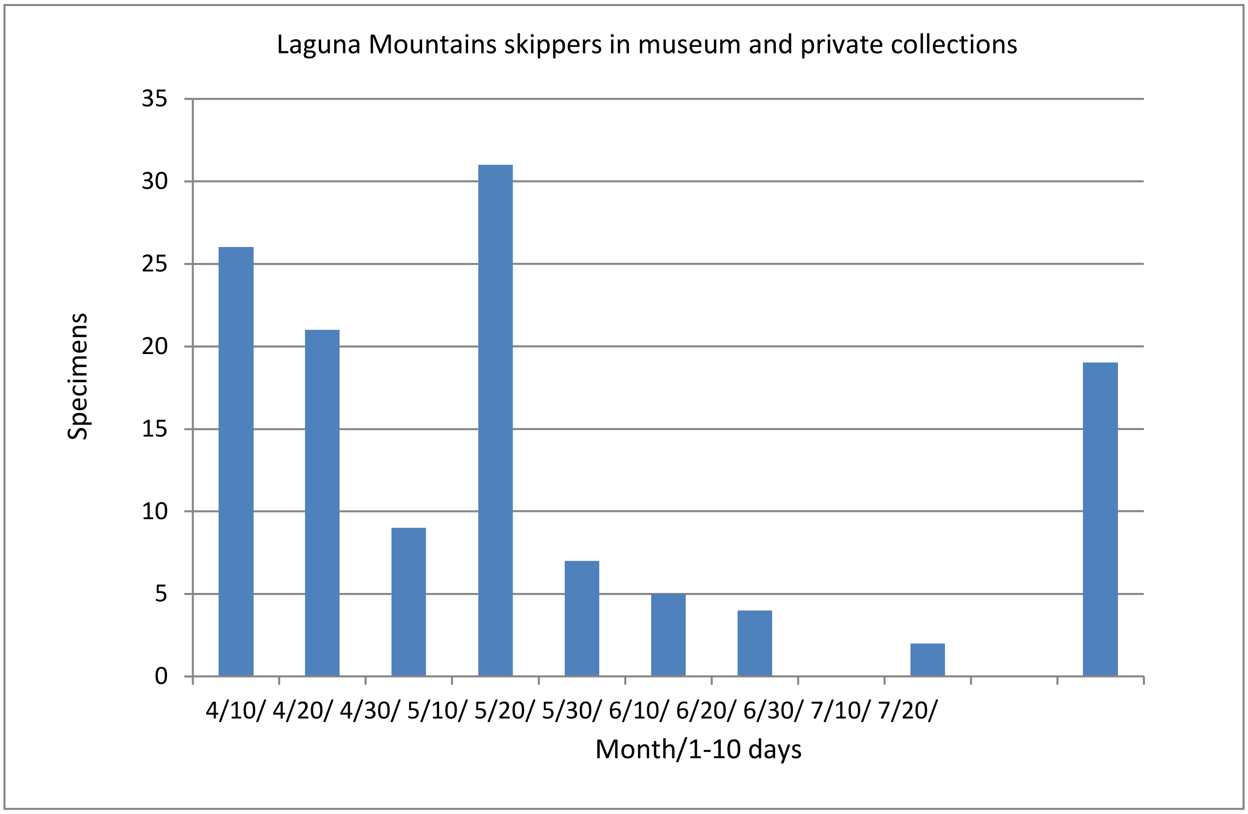

Figure B2. Laguna Mountains skipper specimens by 10 day collection period from the Laguna Mountains only.

APPENDIX C

Laguna Mountains Skipper Population Growth Analyses

Correlation of adult abundance index with environmental variables support the hypotheses that rainfall totals affect population size (Figure C1), higher fall and winter temperatures result in earlier emergence from diapause (Figure C2), and the relative size of the summer adult population (the number of spring brood individuals that mature the same year) is reduced the later emergence from diapause occurs (Figure C3).

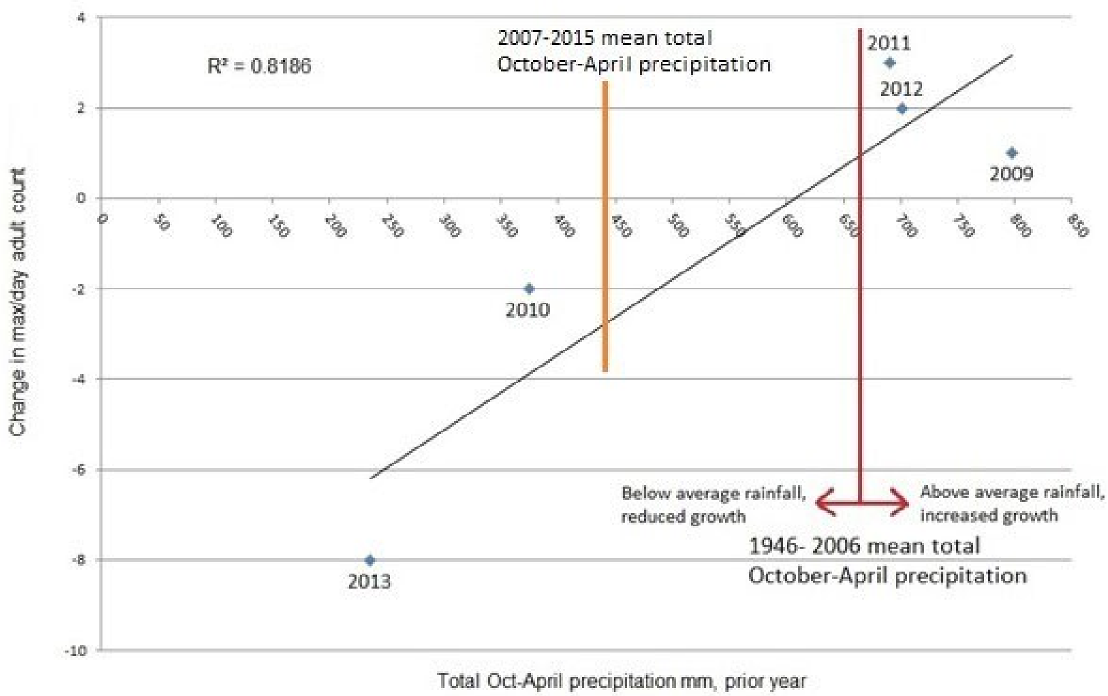

Figure C1. Monitoring data from Mendenhall Valley from 2009–2013 (Faulkner 2008, p. 2; 2009, pp. 2 and 3; 2010, p. 2; 2011, p. 2; 2012a, p. 2; 2013, p. 2) support the hypothesis that population growth increases when rainfall totals (October through April) from the previous year are above average and decreases when rainfall totals are below average (relationship illustrated by trendline). When rainfall totals approach the historical average (441 to 660 mm), population growth should occur at a replacement rate, that is no increase or decrease in size (approximate x-axis intercept of best-fit line). The y-axis represents the change in spring peak abundance (maximum number of Laguna Mountains skippers recorded per observer in a single day each year) during the spring flight season from one year to the next. The red line represents the average precipitation (October – April) level between 1946 and 2006 (660 mm); the brown line represents average precipitation from recent years (2007 to 2015).

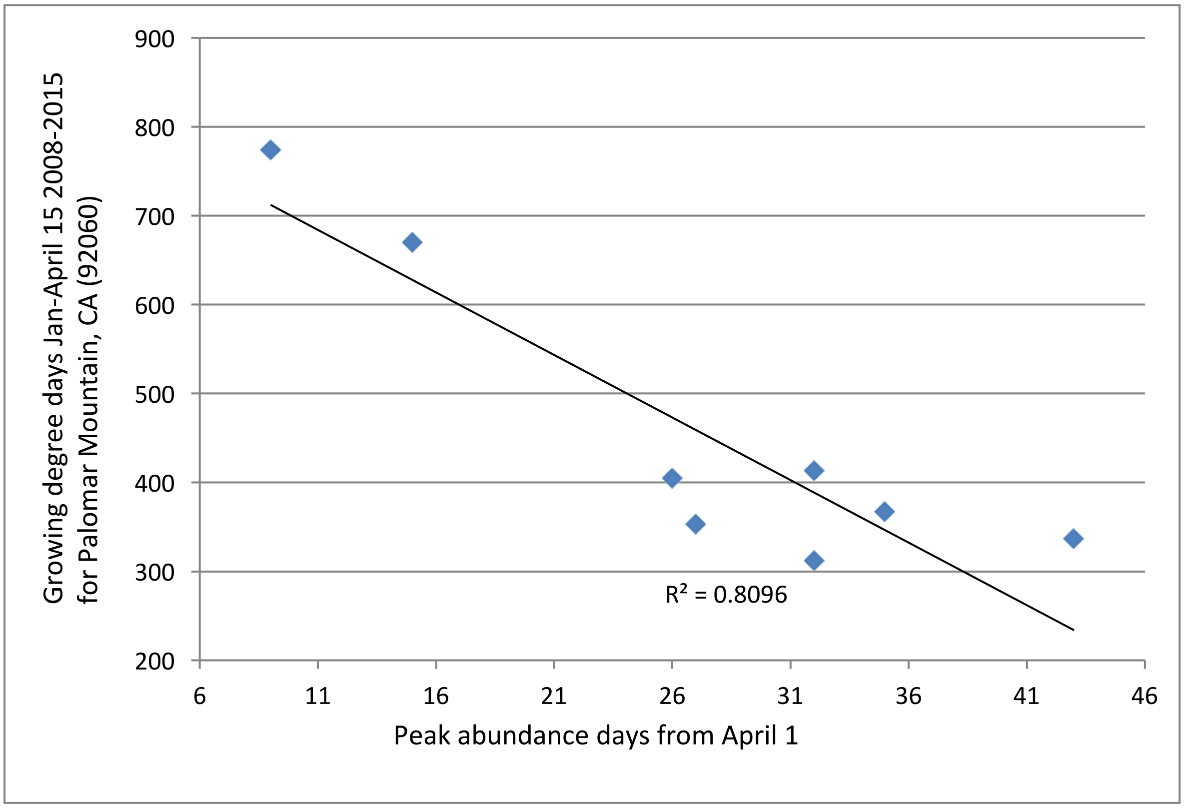

Figure C2. There is a strong correlation of total growing degree days (GDD; how warm it has been for how long) January through mid–April for Palomar Mountain with the peak spring adult abundance. This supports the hypothesis that pupal emergence (from diapause) in Laguna Mountains skipper is related to total GDD, because a higher total GDD for that period is correlated with earlier emergence. Data sources: Faulkner 2008–2015, Marschalek 2015b, pers. comm. and 2014, and The Weather Channel, http://adstest.climate.weather.com/outlook/agriculture/growing-degree-days/92060.

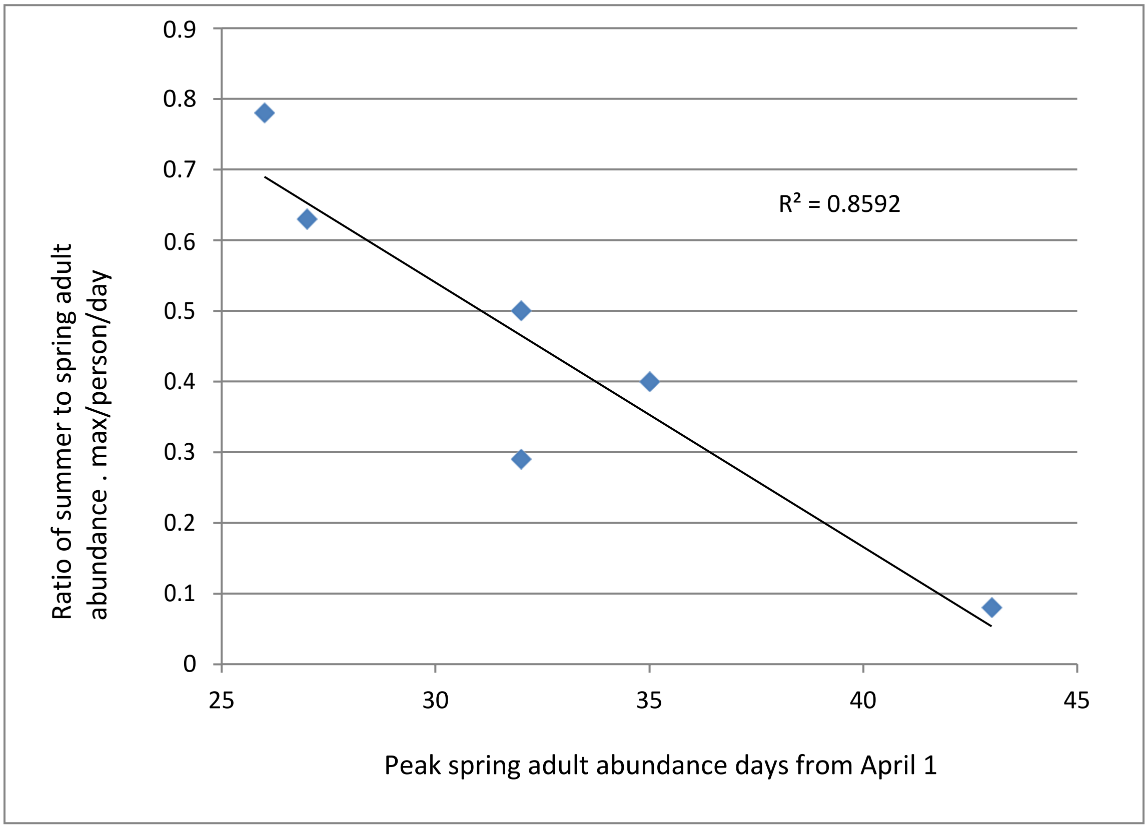

Figure C3. Correlation of adult abundance index ratio with the date peak spring adult abundance was estimated. This suggests that the later the peak is observed in the spring, the lower the number of summer adults and the resulting ratio of summer to spring adults. Data collected by Faulkner only, representing the most consistent methods with no possible surveyor affect/bias. Data sources: Faulkner 2008–2013.

APPENDIX D

Ground and Spring Water removal

Surface water, groundwater, and soil moisture levels are all affected by the water table in meadow habitats. When the water table is higher than adjacent streams, groundwater will discharge and increase stream flow, when groundwater levels are lower, water leaves the stream and recharges groundwater (Greenwood and Homier 2013, p. 10). Therefore, removal of groundwater via wells (Mattoni and Longcore 1998, p. 10), diversion and storage of surface water for livestock (Grant *et al.* 2009, pp. 24 and 26), and soil drying from erosion (Osborne 2002, p. 14) are potential threats to Laguna Mountains skipper, considering the dependence of the subspecies on established meadow hydrology (see *Water and Moisture Associations* subsection above).

On Palomar Mountain and in the Laguna Mountains, precipitation recharge water tables are either tapped by wells, or flow naturally out of local "artesian" springs. Although Palomar Mountain and Laguna Mountains communities rely on groundwater, local use levels are relatively low. Of greater concern than local water use are the additional impacts of extended drought and commercial water export on Laguna Mountains skipper habitat (Table D1). The crystalline fractured rock aquifers of Palomar Mountain and the Laguna Mountains (County of San Diego 2010, p. 124, Figure 2-13) supply desirable "spring" water for drinking, and there are several private water companies who bottle and sell water from both mountain aquifers (County of San Diego 2011a, p. 33 and 34; Table 3). The springs on the southern edge of Palomar Mountain were acquired from the Mendenhalls in 1978 by the Palomar Artesian Springs Partnership (Palomar Spring Water Company 2016). The Palomar Spring Water Company was subsequently incorporated in 1982, and claims responsibility for creation and operation of five springs on Palomar Mountain and the Laguna Mountains (Palomar Spring Water Company 2014). While it is unknown how much well and spring water is being removed, Faulkner (2014d, pers. comm.; 2014e, pers. comm.) commented on observations made on Palomar Mountain and stated "Water is the big issue for Palomar Mountain. Seeps that were wet into August in most years were dry in April [2014]. The lower ponds in Mendenhall Valley were dry by May. [I observed] at least five [Famous Ramona Water Inc.] tanker trucks per day haul water from the property across the street …from the entrance to the road leading to Mendenhall Valley. The actual number of visits may be higher. I believe there is another location that also pumps water to the west of the junction toward the State Park and have seen trucks go back and forth while at the Palomar Store." The former location is in a drainage just above western Mendenhall Valley and the water likely comes from wells, the latter is the Palomar Spring Water Company property, artesian springs commonly labeled on historical maps (Figure 2 in *Distribution* subsection above). One of the photographs Faulkner (2014e, pers. comm.) sent showed a truck labeled as 6,500 gallons (gal) (24,605 liters (l)) of spring water. That indicates up to 32,500 gal (123,026 l) of water per day exported that would probably have otherwise entered the Mendenhall Valley water table.

Table D1. Drinking water companies that obtain water from Palomar Mountain or the Laguna Mountains.

Company/brand	Described water source	Type of sales
Famous Ramona Water Inc.	Palomar Mountain west of Mendenhall Valley	Bulk
Palomar Spring Water	Five springs on Palomar and Laguna Mountains	Bulk
Palomar Granite Springs Spring Water	32479 South Grade Rd., Palomar Mountain	Bulk
Nestle Waters (Arrowhead Mountain Water)	Palomar Mountain Granite Springs	Bottled
Albertsons A+	Palomar Mountain Spring	Bottled
Palomar Mountain Premium Spring Water	Free-flowing springs on Palomar Mountain	Bottled
Borrego Springs Bottled Water	Pristine mountains in San Diego County like Laguna and Palomar	Bottled
Beechnut (bottled by Famous Ramona Water Inc.)	Palomar Mountain	Bottled
Paradise Drinking Water	Palomar Mountain Range	Bottled
Horizon Water	Private source on Palomar Mountain	Bottled

Sources: Environmental Working Group 2014; Faulkner pers. comm. 2014c; Loopnet.com 2016**;** James 2015; Borrego Springs Mountain Water 2016; Olson 1999; Palomar Mountain Premium Spring Water 2016; Palomar Spring Water Company 2014; Palomar Spring Water Company 2016; Paradise Drinking Water 2019.

Throughout the United States, ecosystems have been affected by water diversions and spring and seep developments that decrease the quantity of instream flows and lower water tables (Greenwood and Homier 2013, Appendix G; Castelli *et al.* 2000, p. 251). Water extraction is especially damaging in arid regions where the presence of instream and groundwater flows are crucial to meadow vegetation. Mountain spring and well water export for commercial bottled drinking water is not regulated or monitored in San Diego County (County of San Diego 2010, p. 67), therefore effects on meadow habitat groundwater levels are unknown (County of San Diego 2011a, p. 14). While groundwater export should require a Major Use Permit and analysis of impact on groundwater supplies (County of San Diego 2011a, p. 14), there is not always a clear difference between spring and groundwater removal. For example, the County of San Diego (2011b, pp. 39 and 40) described this situation, "The Laguna Meadow Aquifer was historically bounded with overflow occurring only at natural springs along the lower exposure of the aquifer. However, one of these natural springs above Crouch Valley has been intercepted by a commercial water mining operation that draws its water via a horizontal bore from the lower end of the aquifer." From 1998 to 2004 water levels dropped steadily at monitored wells on Palomar Mountain, the water table rose only during periods of above-average rainfall in 1994–1995, 1997–1998, and 2004–2005. Groundwater levels recovered in 2005, but not to the 1998 high (County of San Diego 2010, p. 28). County documents state "If groundwater mining were to become common practice [on Palomar Mountain], …the sensitive montane ecosystem [would be] threatened" (County of San Diego 2011a, pp. 33 and 34), and also that the Laguna Mountains and Crouch Valley resource conservation areas must be protected from private exploitation, and the export of groundwater resources for commercial sale and individual benefit should be prohibited to protect the public aquifer resource (County of San Diego 2011b, pp. 36 and 37).

APPENDIX E

Population Ecology Model Manipulation

One model reviewer (Osborne 2016, pers. comm.) performed a limited sensitivity analysis (Table E1). He altered example values to see what was necessary for population persistence without a summer brood. Osborne found that without a summer brood it was necessary to unrealistically increase spring brood survival rates (from 0.16 to 0.25), or significantly increase spring adult fecundity (from 100 to 140) and slightly increase spring brood survival (from 0.16 to 0.18) to prevent population decline. Given that limited field data in 2016 indicate spring brood survival was lower than the original example value of 0.16 (Osborne *et al.* 2016, p. 1), and monitoring data indicate summer reproduction is a predictable occurrence, Osborne's analysis supports the hypothesis that a summer brood is essential to prevent population decline.

Anderson's further manipulation of example model values was undertaken to explore the magnitude of summer brood contribution to population size (Table E1). In all cases spring brood survival rates were reduced to reflect recent 2016 data (Osborne *et al*. 2016, p. 1; 0.16 to 0.1). With no other adjustments, this resulted in a 60 percent population decline. Based on historical data, a summer to spring adult population ratio was maintained at 1:2. Furthermore, in order to estimate average population parameters required for population resilience, it is necessary to hold constant the replacement growth rate (subsequent spring adult population size equal to the starting value). Additional example value adjustments by Anderson with these objectives in mind resulted in 42-47 percent contribution of the summer brood to the subsequent spring adult population size.

These limited sensitivity exercises support the hypothesis that summer reproduction is needed to maintain population resilience. They also indicate that in some years, summer brood individuals could comprise the majority of the next spring adult population.

Subsequent to publication of the draft Laguna Mountains skipper recovery plan, we noticed the model and example values used did not account for adult sex ratio (Figure E1). In order to incorporate an assumed 1:1 sex ratio, while maintaining the 1:2 summer to spring adult population size ratio and maintain spring adult population size (replacement population growth rate), it was necessary to increase summer eclosion rate (decreasing spring brood diapause rate) and increase fall and winter diapause survival rate. The earlier model and example values were reviewed by peer reviewers and used in the sensitivity analyses. While the above described changes were made to address the sex ratio, the sensitivity analysis results (effect magnitude) should not be affected, therefore we did not undertake additional sensitivity analysis for this document.

Table E1. Laguna Mountains skipper population ecology model sensitivity analyses results. Manipulations listed below were changes in values compared to those given in Figure 4 in the text above.

Name	Model manipulations	Subsequent spring adult population	Proportion of spring adult population made up from summer brood (percent)	Effect of manipulation relative to model run*
Model	No manipulation	200	45	
Osborne	Spring pupal survival value of 0.075 added to formula (formula change applied to all subsequent Osborne manipulations)	200	45	Adjusting spring pupal survival to 0.075 did not affect subsequent spring population
Osborne	All spring pupae subjected to a flat monthly mortality rate of 0.849	200	37	Increasing spring pupal mortality from 0.750 to 0.849 resulted in a reduced contribution to spring adult population; did not affect subsequent size of spring adult population
Osborne	All spring pupae subjected to a flat monthly mortality rate of 0.849 and increased spring larval survival rate from 0.16 to 0.25 Eliminated summer brood (all spring brood enter diapause)	200	0	Increased larval survival countered increased pupal mortality and loss of summer brood; no effect in spring adult population
Osborne	Increased spring fecundity from 100 to 140, increased larval survival rate from 0.16 to 0.18.	202	0	Increased fecundity and increased larval survival compensated for

Name	Model manipulations	Subsequent spring adult population	Proportion of spring adult population made up from summer brood (percent)	Effect of manipulation relative to model run*
	Eliminated summer brood (all spring brood enter diapause)			loss of summer brood; no effect in spring adult population
Osborne	All spring pupae subjected to a flat monthly mortality rate of 0.848 (less than above by 0.001). Eliminated summer brood (all spring brood enter diapause)	120	0	Loss of summer brood resulted in decrease of spring population
Anderson	Decrease summer brood survival rate from 0.16 to 0.10. Maintain ratio of summer to spring adult population size (1:2) by increase summer eclosion rate from 0.045 to 0.071	121	46	Decrease in summer brood survival while maintaining summer to spring adult population ratio of 0.5 resulted in decreased spring adult population
Anderson	Decrease summer brood survival rate from 0.16 to 0.10. Maintain ratio of summer to spring adult population size (1:2) and replacement population growth rate by increase spring fecundity from 100 to 160, and summer fecundity from 90 to 140	200	45	Increased fecundity countered decrease in summer brood survival resulting in no change to summer population size

Name	Model manipulations	Subsequent spring adult population	Proportion of spring adult population made up from summer brood (percent)	Effect of manipulation relative to model run*
Anderson	Decrease summer brood survival rate from 0.16 to 0.10. Maintain ratio of summer to spring adult population size (1:2) and maximize both hatch rates (100 percent) to maintain replacement population growth rate (impossible).	172	42	Even with 100% hatch, the summer population size decreased with decrease in summer brood survival
Anderson	Decrease summer brood survival rate from 0.16 to 0.10. Maintain ratio of summer to spring adult population size (1:2) and replacement population growth rate by increasing summer eclosion rate from 0.045 to 0.071 and increasing summer diapause survival rate from 0.100 to 0.165	200	47	Increased summer eclosion and increased summer diapause countered effect of decreased summer brood survival to result in no change to spring adult population size

* Example values from model: starting number of spring adults (200), spring fecundity (100), spring hatch (0.7), spring diapause survival (0.1), summer diapause survival (0.5), summer eclosion (0.045), summer adults (100), summer fecundity (90), summer hatch (0.7), and summer larval survival (0.14).

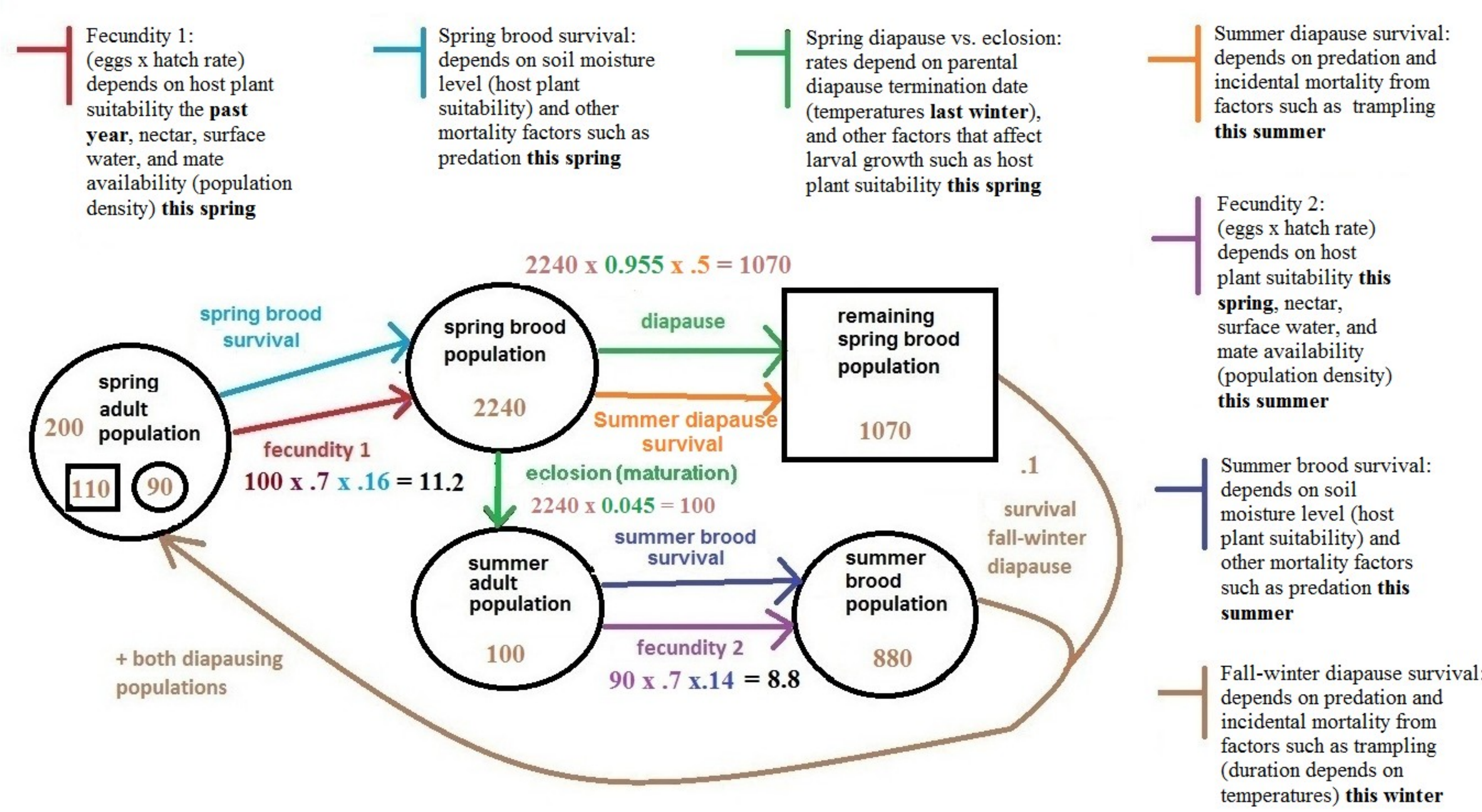

Figure E1. Draft Recovery Plan model and example values.

APPENDIX F

Basin Characterization Model Information

The California Basin Characterization Model 2014 (CA-BCM 2014) dataset provides historical and projected climate and hydrologic surfaces for the region that encompasses the state of California and all the streams that flow into it (California hydrologic region). The CA-BCM 2014 applies a monthly regional water-balance model to simulate hydrologic responses to climate at the spatial resolution of a 270-meter (m) grid.

Model outputs are intended for watershed-scale evaluation. Use of the data for analyses at a scale smaller than the planning watershed could yield misleading results.

Creator: Lorraine and Alan Flint, USGS
Contributor: Jim Thorne, Ryan Boynton, UC Davis
Publisher: California Climate Commons
Spatial Resolution: 270m
Temporal Coverage: 1921-2099
Date Issued: July, 2014

Source of above and for more information: http://climate.calcommons.org/dataset/2014-CA-BCM. We reviewed future scenarios from six different General Circulation models for three future time periods (30 year averages) and two historical time periods for climatic water deficit (CWD: potential minus actual evapotranspiration; a measure of soil moisture level or plant drought stress). We examined future scenarios from four different General Circulation models for three future time periods (30 year averages) and two historical time periods for total annual precipitation. We examined data sets from Palomar Mountain and Laguna Mountains areas separately, and found the "wettest" or "driest" projections were not always from the same models for both mountains. "Wettest" means the maps with the greatest area of maximum projected precipitation or lowest CWD, "driest" means the opposite; these extremes represent the range of California Basin Characterization Model future projections produced by all GCM models used.

Laguna Mountains skippers are sensitive to climate change because of their dependence on soil moisture levels and surface water availability, and because they currently inhabit a single mountaintop at maximum elevation, with no opportunity for range shift northward or upward in elevation. Comparison of the average CWD between two 30 year intervals (1951–1980 mean compared to 1981–2009 mean) using the California Basin Characterization Model indicates CWD was higher in the Laguna Mountains during the 30 year period when Laguna Mountains skippers declined and were extirpated, than it had been for the prior 30 years (Figure 1).

Climate change model projections indicate climate will similarly affect habitat on Palomar Mountain and the Laguna Mountains over the next 60 years (Figures F1 and F2). Given their dependence on soil moisture and surface water availability, "driest" case CWD projections indicate drying may detrimentally affect habitat suitability for Laguna Mountains skipper. However, "wettest" case projections suggest that conditions could improve over the next 30 years and then return to CWD levels consistent with current levels by the next 60 years.

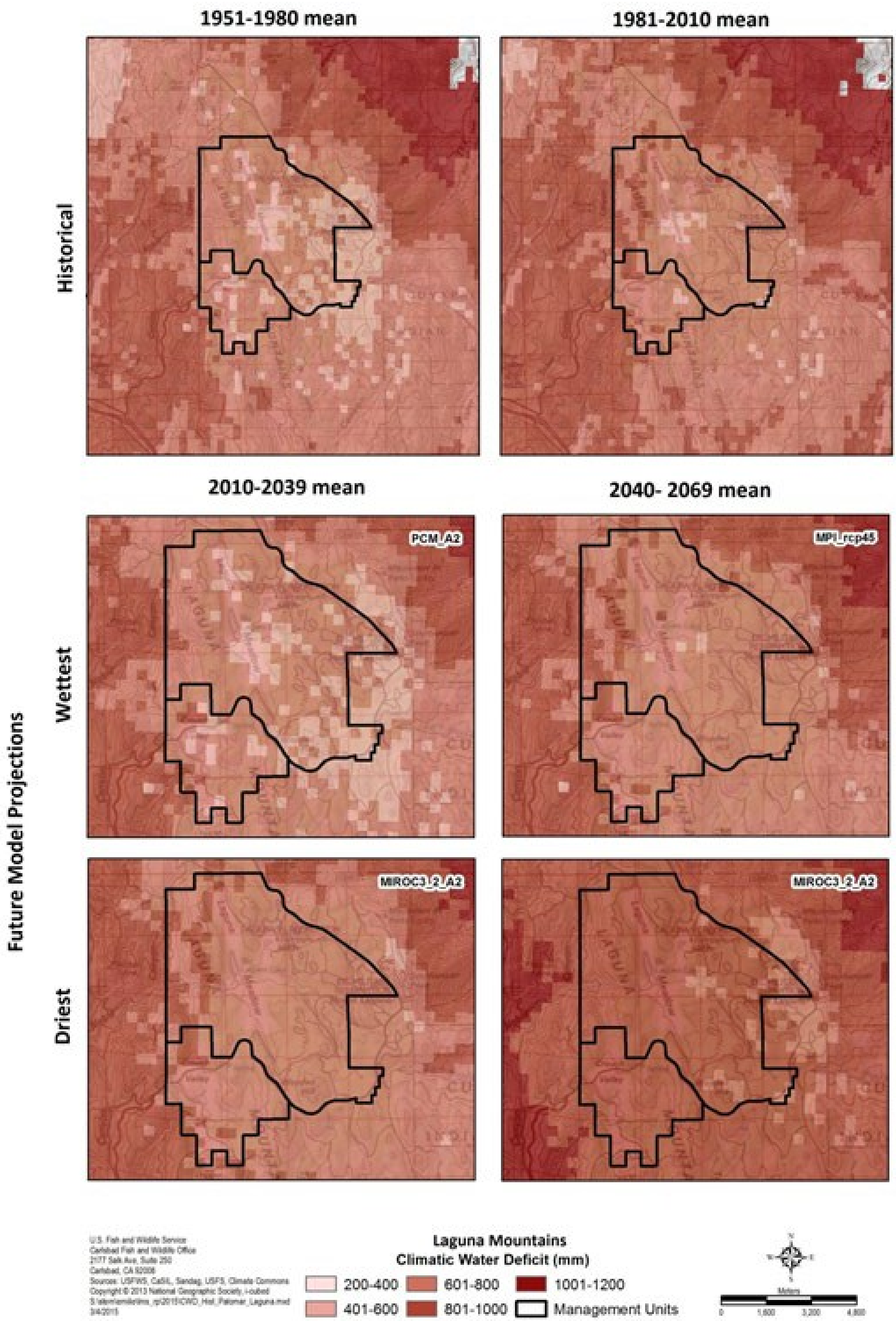

Figure F1. Historical 30 year mean modeled climatic water deficit (CWD) and future CWD projections for the Laguna Mountains, formerly occupied by Laguna Mountains skippers. Lower CWD values indicate higher soil moisture levels. Climatic water deficit can serve as an indicator of plant drought stress and soil moisture levels.

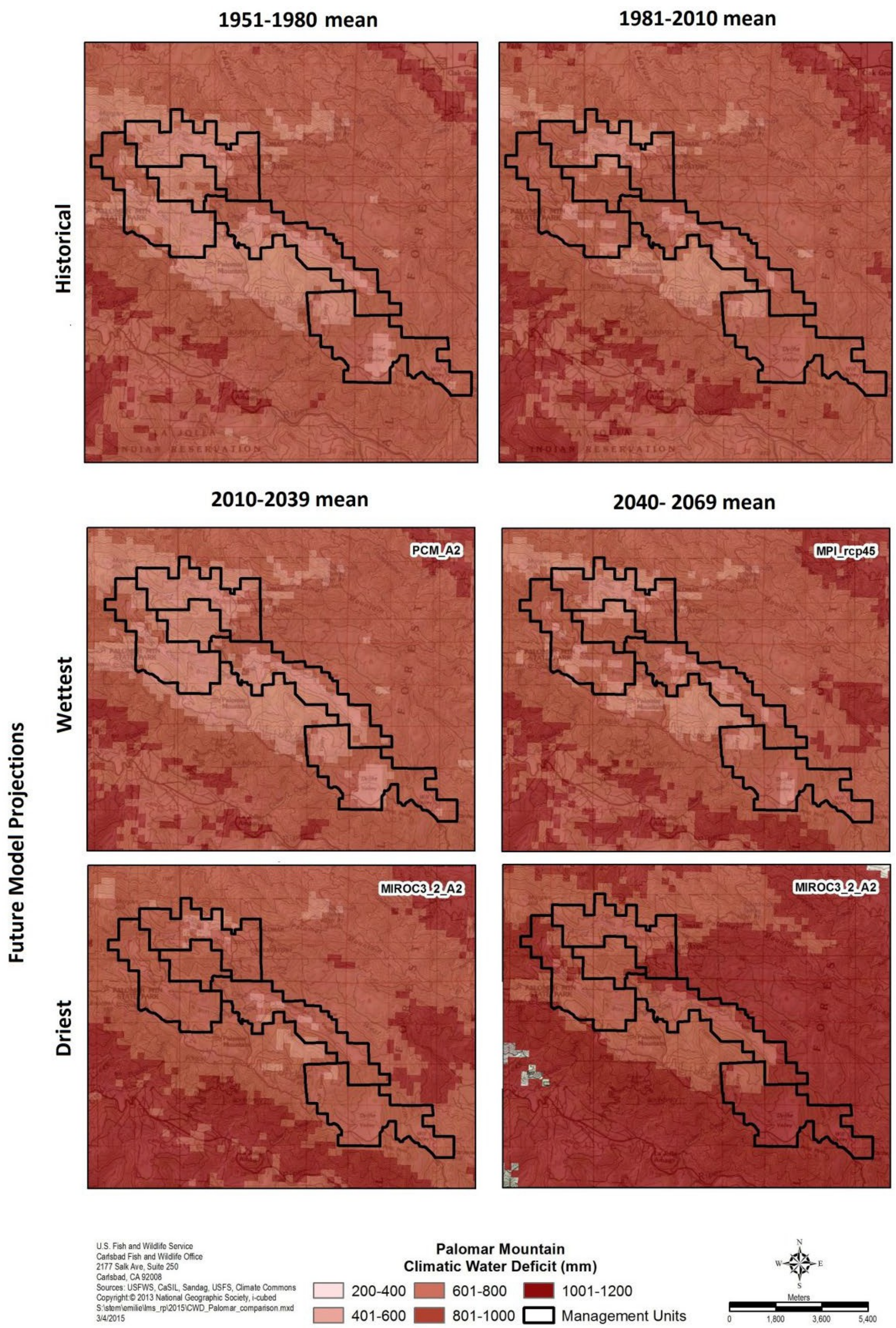

Figure F2. Historical 30 year mean modeled climatic water deficit (CWD) and future CWD projections for Palomar Mountain occupied by Laguna Mountains skippers. Lower CWD values indicate higher soil moisture levels. Climatic water deficit can serve as an indicator of plant drought stress and soil moisture levels.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW

Laguna Mountains skipper
(*Pyrgus ruralis lagunae*)

Current Classification: Endangered

Recommendation Resulting from the 5-year Review:

_____ Downlist to Threatened
_____ Uplist to Endangered
_____ Delist
__X__ No change needed

Review Conducted By: Carlsbad Fish and Wildlife Office

FIELD OFFICE APPROVAL:

Acting Field Supervisor, U.S. Fish and Wildlife Service

SCOTT SOBIECH Digitally signed by SCOTT SOBIECH Date: 2019.04.29 06:20:19 -07'00'

Approve____Date __________