

5-YEAR REVIEW

Lange's metalmark butterfly (*Apodemia mormo langei*)

GENERAL INFORMATION:

Subspecies: [*Apodemia mormo, langei*; as currently listed in 50 CFR 17.11 or 17.22]

Date listed: [June 1, 1976]

FR citation(s): [41 FR 22041]

Classification: [endangered subspecies]

BACKGROUND:

Most recent status review:

U.S. Fish and Wildlife Service. 2008. Five-Year Review for the Lange's metalmark butterfly (*Apodemia mormo langei*), Antioch Dunes evening-primrose (*Oenothera deltoides* subsp. *howellii*), and Contra Costa wallflower (*Erysimum capitatum* var. *angustatum*). Sacramento Fish and Wildlife Field Office. Sacramento, California. June 2008. 42 pp.

FR Notice citation announcing this status review:

83 FR 28251, Initiation of 5-Year Status Reviews of 50 Species in California, Nevada, and the Klamath Basin of Oregon; June 18, 2018

ASSESSMENT:

Subspecies Overview:

Lange's metalmark butterfly (*Apodemia mormo langei*), hereafter referred to as Lange's metalmark, is a member of the Riodinidae family (Pelham, 2014) and is a subspecies of the *Apodemia mormo* (Comstock, 1939; ITIS, 2019). The species *Apodemia mormo* (commonly referred to as "Mormon metalmark") occurs in scattered, often isolated, populations throughout western North America (Powell and Parker, 1993) and is found in a variety of habitat types, from canyons and valleys to sandy dunes. All populations are closely associated with wild buckwheat species in the *Eriogonum* genus (Opler and Powell, 1961). Populations in the southern portion of the range can have two to three overlapping generations per year, but in the northern portion of the range, populations tend to have only one generation per year (Opler and Powell, 1961). Due to the localized activity patterns of the Mormon metalmark and the distribution where *Eriogonum* flowering overlaps with the Mormon metalmark flight period, the species occurs in scattered populations with little interbreeding (Opler and Powell, 1961).

The Lange's metalmark is a relatively small butterfly, with a wing expanse from 18-27 millimeters [mm.] (0.06 -0.71-inches [in.]), mostly black and orange colored with white spotting, and primarily identified by orange scaling of the discal spot (Comstock, 1939). It is a univoltine subspecies (producing one brood per year) that lays eggs in small clusters on the larval host plant in late summer. The first larval instar emerges from these eggs following the first rain events of the fall, and



the leaves of the larval host plant provide both food and shelter throughout the larval instar phases (Arnold, 1978; Arnold, 1980). Adult butterflies begin emerging from pupation in early August, and may be observed until mid- or late-September, with females laying eggs throughout this adult flight period (Service, 1984). Adult butterflies may live on average a week, and though little is known about the duration of the larval stages in the wild, pupation is thought to last 6-18 days (Arnold, 1980).

All life stages of Lange's metalmark are closely tied to *Eriogonum nudum* var. *psychicola* (formerly var. *auriculatum*), hereafter referred to as Antioch Dunes buckwheat. This host plant, also endemic to the Antioch Dunes, serves as the primary nectar source for adult butterflies, as sites for oviposition, and as the larval foodplant (Arnold, 1978). However, Antioch Dunes buckwheat may not be utilized by the Lange's metalmark until plants are about three years old, when it is able to produce robust flowers (Arnold, 1983). Antioch Dunes buckwheat is a perennial forb that requires sandy, well-drained soils and some form of disturbance, preferably by natural processes such as wind or erosion, to shift the sand for seedling establishment (Arnold, 1978). Flowering of Antioch Dunes buckwheat begins in July or August, depending on the climate, and just prior to the emergence of Lange's metalmarks.

Currently, Lange's metalmark can only be found within the Antioch Dunes National Wildlife Refuge (ADNWR), the last remnants of the Antioch Dunes following commercial mining and land development. The ADNWR boundary encompasses 67 acres; the 41-acre Stamm Unit, owned by the Service, and the 26-acre Sardis Unit, of which 14 acres are owned by the Service and 12 acres are owned by Pacific Gas and Electric (Service, 2002) (Figure 1). Lange's metalmark is associated with Antioch Dunes, a riverbank dune system that historically reached heights of over 100 feet, but specimens collected from Oakley suggest the subspecies may not have been confined to the Antioch Dunes (Howard and Arnold, 1980; Stanford *et al.*, 2011).

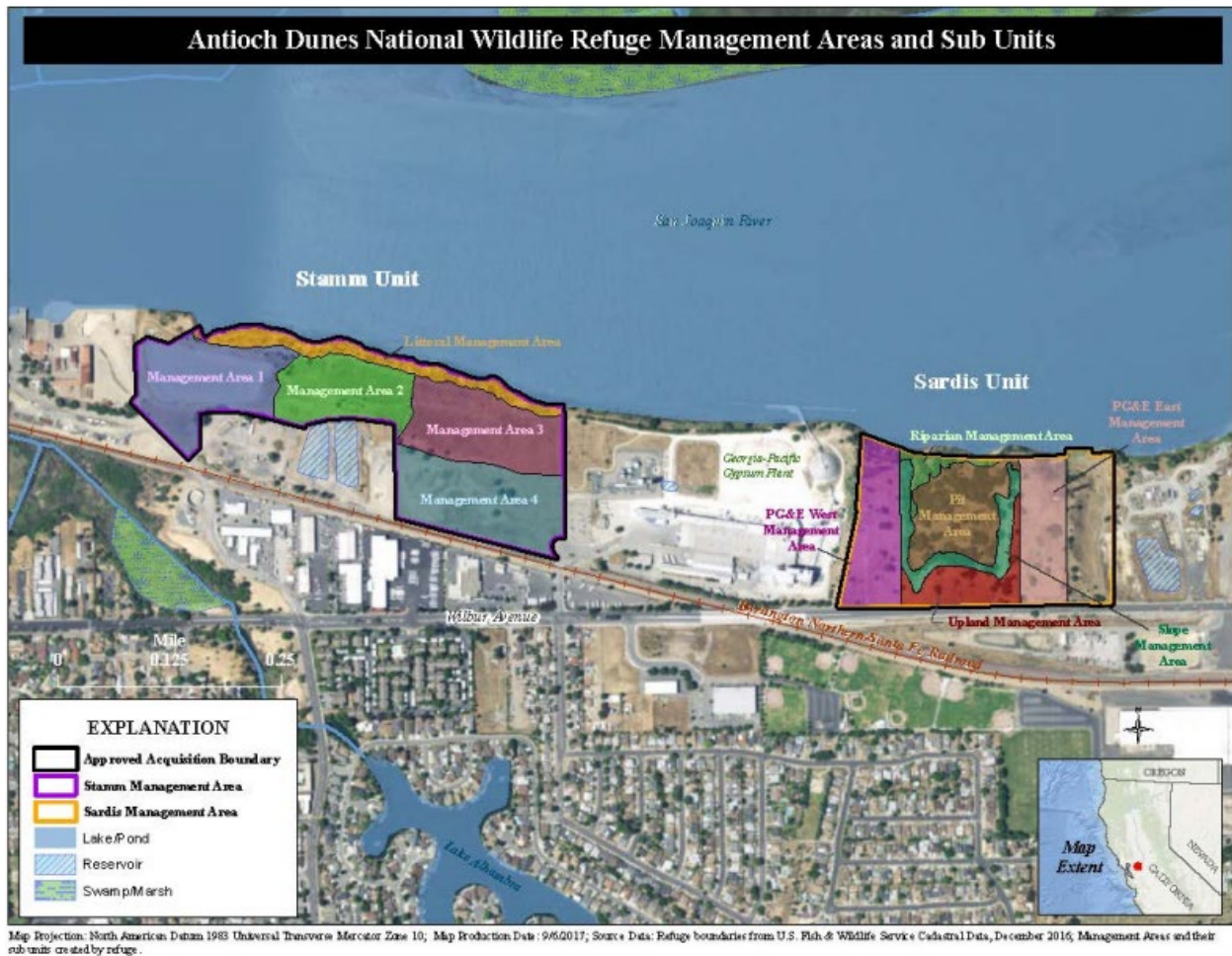


Figure 1. Antioch Dunes National Wildlife Refuge (Service, 2019c).

Information on the Subspecies and its Status

Population Status and Trends:

The only extant population of Lange's metalmark is located at ADNWR, a very limited geographic area representing the entirety of the known range-wide native population. The refuge itself is bifurcated by the Georgia Pacific Gypsum Plant, separating the Sardis and Stamm Units by greater than 600 meters. Annual surveys have been conducted in at least some portion of the Stamm and Sardis Units since about 1986. Prior to this, Arnold and Powell conducted ecological studies of the Lange's metalmark and its habitat from 1977 to 1985 (Arnold, 1978; Arnold, 1980; Arnold, 1983; Arnold and Powell, 1983; Arnold 1986; Powell, 1983). During this time, Arnold used capture-mark-recapture methods to estimate the population of Lange's metalmark, and studied the flight patterns of individuals (Arnold, 1978; Arnold, 1986). These studies estimated that the population size was approximately 2,100 in 1976, but declined rapidly to an estimate of 560 in 1982, before partially rebounding to an estimate of 1,286 in 1985 (Arnold, 1983; Arnold, 1986). These studies were discontinued due to a determination by the Service that capture-mark-recapture methods adversely affected the species (Service, 1986).

Surveys for Lange's metalmark have been conducted annually by refuge biologists since 1986. The current method is referred to as a "Pollard walk." The Pollard walk is conducted by walking along transects, which are segmented by management unit or habitat type, while looking for and counting butterflies along the transect (UWG, 2017). For Lange's metalmark, the standard approach to conducting Pollard walks has been modified by using a stick to gently tap vegetation along the transect, to help flush butterflies and increase detectability (UWG, 2017). This survey method is conducted once per week during the flight phase and yields weekly counts for each management unit. Group surveys have also been conducted about once per week using a variable number of refuge biologists and volunteers; this group survey data has usually resulted in the peak butterfly count in a given year (the highest single-day count from the flight phase) (Service, 2008). Based on surveys conducted since 1986, peak counts have ranged from as high as 2,342 adult butterflies in 1999, to below 50 adult butterflies in every year since 2009 (Service, 2018c). In 2018, Pollard walk surveys resulted in a total count of nine individuals and group surveys resulted in a total of 20 observations (Service, 2019a). In 2019, Pollard walk surveys resulted in a total count of only five butterflies, and the group surveys resulted in a total of 10 observations (Service, 2019a).

Recovery criteria for Lange's metalmark were established in Service (2019b) and use a 15-year moving median of butterfly abundance to help make downlisting and delisting decisions. We considered deriving an abundance estimator for Lange's metalmark in two ways: by using only the peak daily count for a given year, typically derived from the group surveys; and by using the counts from all weekly surveys in a given year derived from Pollard walk surveys. We concluded that the Pollard walk surveys, which are a commonly used approach to estimate butterfly abundance, were most likely to result in relatively unbiased abundance estimates. We were also concerned that the group surveys, with their highly variable number of people participating each week and year, were not as likely to result in unbiased abundance estimates, especially when compared to the standardized Pollard walk approach. Thus, for this 5-year review we used an abundance estimator that incorporates survey data from all Pollard walk surveys conducted in a given year; this approach is described in more detail in Appendix C of Service (2019b), and follows the approach described by Schultz and Dlugosch (1999).

The approach of additive models when applied to the Pollard walk, such as Schultz and Dlugosch (1999), assumes that the survey period begins before the first butterfly of the flight phase is available for detection and ends after the last butterfly of the flight phase is available for detection. In some cases, one or more butterflies were documented on the first and/or last survey of the year, and thus did not result in a count of zero for these surveys. In these situations, we added a zero count for the week before and/or the week after the survey period, as needed so that no data was sacrificed. The fact that butterflies have sometimes been observed on the first or last survey of the year suggests that, in some years, the flight phase might begin slightly before and/or end slightly after our scheduled survey period. In future years, we will consider extending the survey period to ensure that we are capturing the full flight phase during the scheduled survey.

The abundance estimator described in Schultz and Dlugosch (1999), and the population index for Lange's metalmark described in Service (2019b), do not incorporate information about the

probability of detecting the target species in the study area being considered (also referred to as “detection probability” or “detectability”). The probability of detection using the Pollard walk survey method for Lange’s metalmark at ADNWR is not currently known. Based on our experience conducting Pollard walk surveys, we believe that gently tapping vegetation while looking for Lange’s metalmark is likely to increase the detectability of this butterfly. However, we do not yet know whether detectability changes under other conditions, such as: whether this probability changes as the flight season progresses; whether there is a difference in detectability between male and female butterflies; and how detectability varies with survey personnel, environmental conditions, and other factors. The detectability of Lange’s metalmark might also change with habitat structure, population density, and as butterflies employ various mating and courtship behaviors and flight patterns (e.g., Pellet *et al.*, 2012).

To derive a detection probability estimate for Lange’s metalmark, we compiled detection probability estimates published for other butterfly species in North America, and elsewhere. Detection probability estimates reported in the literature we reviewed (Winarni, 2007; Kery and Schaub, 2011; Pellet *et al.*, 2012; Puntteney and Schorr, 2016; Riva *et al.*, 2020) ranged from 0.04 to 1.0. The average detection probability reported by these publications is ~0.47. These results suggest that if 100 small, cryptic and very elusive butterflies were available for detection in the survey area, the number of butterflies observed during a survey could be expected to be as low as 4 ($100 \times 0.04 = 4$). On the other hand, for a large, colorful, and gregarious butterfly, all 100 might be documented ($100 \times 1.0 = 100$). Lange’s metalmark is a small butterfly that can be difficult to detect if perching in vegetation, but is readily observable when in flight. We believe that the Pollard walk surveys conducted by well-trained biologists at Antioch Dunes, in combination with gently tapping vegetation, likely results in a detection probability of 0.5 or greater. This is approximately equal to the average detection probability derived from our literature search on detectability in butterflies. We consider a detection probability of 0.5 to be a conservative estimate for Lange’s metalmark using our current Pollard walk survey approach. When factored in, a detection probability of 0.5 brings the current estimate of the Lange’s metalmark population to 8 individuals ($4/0.5 = 8$).

Figure 2 displays the trend in abundance through the past approximately three decades, and also exhibits Lange’s metalmark’s potential for dramatic inter-annual increases and declines in

abundance. For the period from 1986-2019, the abundance estimate has ranged as high as 7,488 individuals in 1997, to below 100 individuals in all but one year since 2009 (Figure 2).

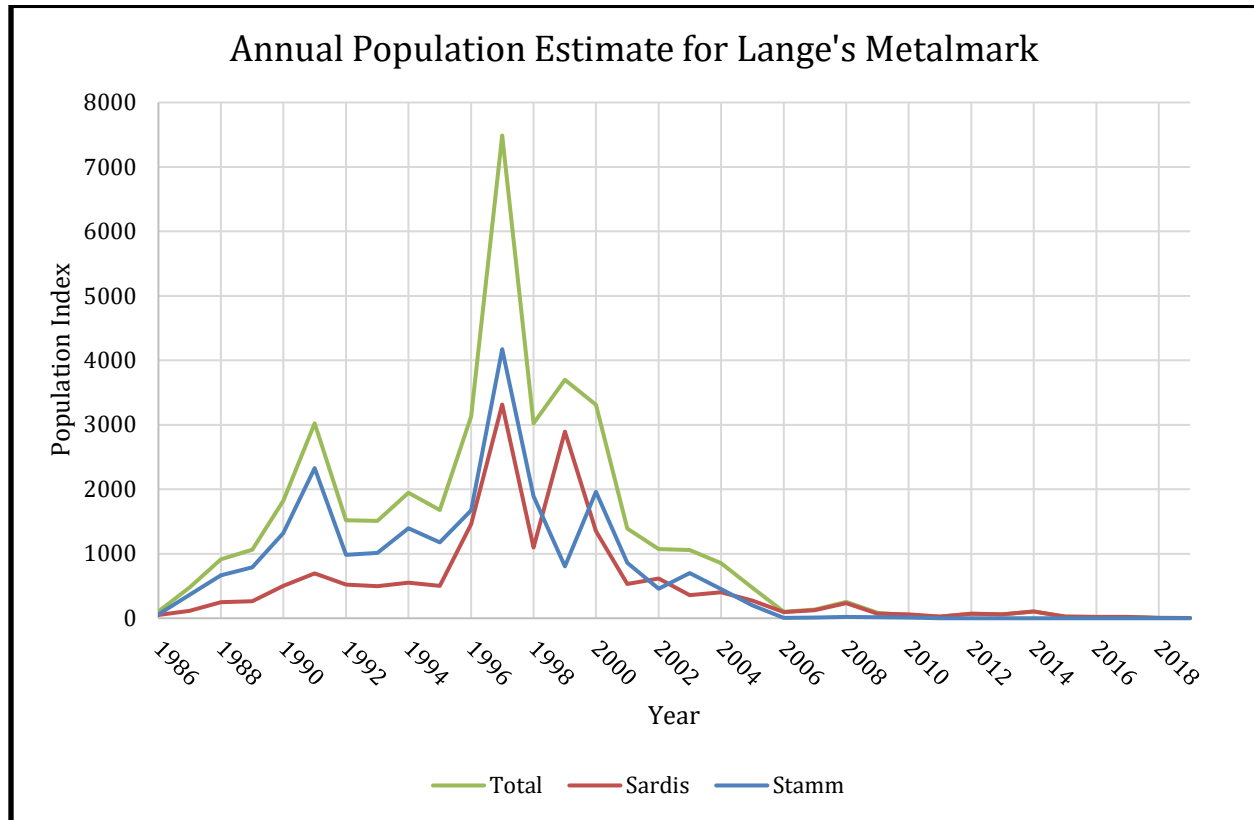


Figure 2. Abundance estimates for Lange's metalmark from 1986 to 2019 for the Sardis unit, Stamm unit, and the total (both units) at the Antioch Dunes National Wildlife Refuge.

Threats and Stressors Under the Five Factors:

A. Present or threatened destruction, modification, or curtailment of habitat or range.

1. Habitat loss from land conversion:

The primary threat affecting Lange's metalmark at the time of listing was habitat loss from industrial and agricultural development (Service, 2008). Beginning in the late 1800's, a part of the Antioch Dunes was converted to a vineyard and the sand was mined for brickmaking (Service, 2002a). Further development and mining in the area continued until the refuge was established in 1980 (Service, 2002a). Though this threat has been ameliorated, historical habitat loss has severely constrained the area of occupied dune habitat and degraded the quality of what little remains at Antioch Dunes—with attendant changes to the dune topography and loss of ecosystem function.

2. Habitat degradation due to loss of natural disturbance regime:

Historically, unimpaired erosion and sediment transport to the Sacramento/San Joaquin River delta built a large riverine dune system where wind-driven dispersal of sand and disturbance of dunes provided the ecological context sustaining the native plant and insect community of the region. The construction of an extensive water supply and delivery system (dams, levees, etc.) in the Central Valley of California has reduced overall size and connectedness of the natural dune community (Powell, 1983; McNally, 2014).

3. Habitat degradation due to establishment and expansion of invasive vegetation:

There are many non-native plants found at the ADNWR. The refuge's 2002 Comprehensive Conservation Plan (CCP) recently identified *Centaurea solstitialis* (yellow-star thistle) as a non-native weed significantly degrading habitat (Service, 2002a). It was also noted that *Erodium* sp. and *Vicia villosa* spp. quickly recolonized areas following a prescribed burn treatment (Service, 2002a). Service (2008) reported that the spread of non-native vegetation had reached every part of the refuge; with *Bromus diandrus*, *Vicia villosa* ssp. *varia*, and *Centaurea solstitialis* being the most common species. The most recent plant inventory revealed annual grasses, all of which are non-native species, covered about 50% of each unit (14 acres of the Sardis unit, and 22 acres of the Stamm unit), and the most prevalent non-native species were *Vicia villosa* ssp. *varia*, *Centaurea solstitialis*, *Erodium cicutarium*, *Brassica nigra*, and *Hirschfeldia incana* (Mathers and the Service, 2018).

Although not identified as a primary threat to the subspecies when first listed, the threat of non-native vegetation was identified in the revised recovery plan as well as the CCP because of the effects to the host plant, Antioch Dunes buckwheat (Service, 1984; Service, 2002a). The CCP identified non-native weeds as a major threat due to their ability to outcompete native plants for resources, and their capacity to stabilize soils (Service, 2002a). Annual grasses and brush, as highly flammable vegetation, present an additional fire threat, further described below (Service, 2002b). Certain non-native plants can enrich the soil, primarily through nitrogen fixation (e.g., *Vicia villosa*), and as a result, create an environment that promotes the establishment of other non-native species (i.e., disfavoring native species that have evolved in nutrient-poor soils) (Owsley, 2011). *Vicia villosa* also grows on top of, and around, the host plant of Lange's metalmark and are very difficult to remove without damaging the host plant and potentially harming Lange's metalmark (Terrazas, 2012). While these effects are all indirect, invasive vegetation currently constitutes the most pervasive and persistent threat currently affecting the very small, isolated and fragmented remnant population of this subspecies.

4. Habitat degradation due to air particulate deposition from industrial operations:

Air pollution from industrial operations was first identified as a threat in the 2002 CCP and specifically, concerns were focused on the emissions of the Georgia-Pacific

gypsum plant and nearby power plants (Service, 2002a). However, until recently, there has not been research into the magnitude and severity of this threat.

In conducting an assessment for industrial contaminant contribution to refuge soils, McNally (2014) concluded that there were notably high inputs for several airborne particulates (see Appendix A). Through air quality analysis, high calcium and sulfur concentrations were found in both units, but levels were higher at Sardis (downwind of the plant). These findings could be directly attributed to the gypsum plant, because gypsum, predominantly composed of water-soluble calcium sulfate, readily dissolves into calcium and sulfur (McNally, 2014). As there were relatively higher levels of calcium, it is likely that there are other sources depositing calcium, such as fuel combustion (McNally, 2014). Magnesium and sodium were also notably high, and higher in the Sardis unit than in the Stamm unit, which suggests the source to be emissions from the gypsum plant and other nearby industrial uses (McNally, 2014). Soil analysis of ADNWR showed significant levels of nitrate, and the levels of ammonia were high even for agricultural soil (McNally, 2014). The likely sources of these particles are the natural gas fired power plants west of the Antioch Dunes emitting nitrogen oxides and that use ammonia to control these emissions. These analyses suggest that air particulate deposition is enriching ADNWR soils with nutrients, which can provide additional competitive advantages to invasive weeds, thereby reducing the ability of native dune species to colonize, persist, and support Lange's metalmark in the degraded ecosystem.

Due to the proximity of the gypsum plant to the refuge, the gypsum deposition has long been a concern. Gypsum deposition was documented as early as 1988 and, as noted in the 2002 CCP, the plants and soil of the Sardis unit were regularly coated in gypsum dust. This prompted concerns for plant health and detrimental changes in soil chemistry, but the direct effects on the Lange's metalmark were uncertain (Service, 2002a). At the time of the last 5-year review, the refuge staff were working with Georgia-Pacific to reduce gypsum dust by keeping the gypsum wetted down (Service, 2008). This review cited a study demonstrating that chemically inert dust may adversely increase transpiration through the cuticle of insect larvae and cause desiccation and abrasion of the cuticle (Wigglesworth, 1945 in Service, 2008). Past research has suggested that gypsum and other mineral dust are known to cause desiccation and abrasion of the cuticle, or exoskeleton, of insects and may also block normal transpiration rates including water retention (Alexander *et al.*, 1943; Fleschner, 1958). A pilot study was conducted to investigate the effects of gypsum dust on a surrogate species, and though initial findings may have indicated effects, the results were inconclusive (UWG, 2015, see Appendix A). Further investigation is required to assess the distribution and impact of the gypsum dust, and follow-up efforts are underway through a cooperative agreement with Urban Wildlands Group (UWG), California State University (CSU) Stanislaus, and University of California (UC) Davis.

The Service continues to work with Georgia-Pacific to reduce the amount of gypsum dust drifting into the Sardis unit. Currently, the Georgia-Pacific gypsum plant is

implementing a dust control plan (GP, 2016). Aside from regular meetings with the refuge biologists and management, the gypsum facility has committed to preventative and control measures to reduce dust emissions (GP, 2016). In the last year, the plant has also been planning and developing two additional gypsum housing structures (Louis Terrazas pers. comm., 2020). It is expected that these structures will significantly reduce the amount of gypsum exposed to wind conditions and available to drift onto the refuge. Additionally, funds have been allocated to conduct baseline gypsum monitoring in the next few years.

5. Habitat degradation due to trespassing:

When the refuge was first established, it was open to public use, but this resulted in foot, bike, and motorcycle traffic, and public use sparked many wildfires (see below). These activities also trampled host and nectar plants. Such stressors were significantly reduced when ADNWR was fenced in 1986. The prior 5-year review (Service, 2008) no longer considered recreational and pedestrian traffic to be a significant threat. However, there are still many trespassers who inadvertently trample plants and illegally start campfires (Service, 2008). Trespassing and other illegal human activity is also identified as a factor that continues to contribute to wildfires in the refuge complex' natural resource management plan (Service, 2019c). Though it is not known to what degree trespassing occurs, the effects of trespassers remain a threat to the Lange's metalmark, its host plant, and its habitat.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

The previous 5-year review recognized the past illegal collection and poaching of female butterflies as a potential source of substantial population depletion. It is unlikely that Lange's metalmark individuals are still being collected illegally because there is limited access to the refuge and therefore, limited opportunity. However, if these activities are ongoing then they represent a threat to this subspecies from direct mortality of any individual(s) collected and a reduction in annual recruitment by the removal of potentially reproductive individuals.

C. Disease or predation.

Arnold (1980) found that larvae of the Lange's metalmark were parasitized by tachinid flies (family Tachinidae, order Diptera) and by parasitic wasps (families Braconidae and Encyrtidae, order Hymenoptera). In the absence of evidence that parasitism or predation is occurring at a rate that is significantly affecting the population, we cannot draw a conclusion regarding the extent of this threat to the current population. The magnitude of this stressor requires further investigation.

D. Inadequacy of existing regulatory mechanisms.

The 2008 5-year review (Service, 2008) reviewed Federal, State, and local regulatory protections. In summary, Lange's metalmark is protected by several federal regulations but there are currently no state and local protections.

E. Other natural or manmade factors affecting its continued existence.

1. Low Population Numbers and Stochasticity:

Extinctions and declines of Lepidoptera species have been widely observed, with growing evidence that the cause generally entails both environmental and genetic factors (New, 2014). Considering its current population size, the Lange's metalmark population is highly vulnerable to demographic and genetic stochasticity. Lange's metalmark is considered a protandrous subspecies (i.e., males tend to emerge before females), which at low populations may cause complete reproductive asynchrony and can lead to the Allee Effect (Calabrese and Fagan, 2004; Calabrese *et al.*, 2008; Larsen *et al.*, 2013).

Although there have been efforts to augment the Lange's metalmark population through head-starting (raising young in captivity), there is a possibility that the methods used have reduced genetic variability (see Appendix A). Only a few females (one to five) were collected each year, and therefore the offspring of just one to five gene lines were released into the declining population. In some years, it is likely that the released individuals contributed more to the breeding population than the wild gene lines (Figure 3). With no way to ensure that sibling mating is actively avoided, inbreeding is possible, and if there has been reduction in genetic representation and inbreeding suppression, extinction risk may have increased with potentially negative effects on egg hatching rates, larval survival, and adult longevity (Nieminen *et al.*, 2001; Saccheri *et al.*, 1998).

Another factor to be considered is domestication selection which may have resulted from female collection when females were selected based on their willingness to accept artificial nectar and confinement (UWG, 2017). If these behaviors were inherited genetically, it is possible that females were collected from recently released individuals thereby reinforcing certain gene lines. If we are to recover the subspecies, the population should be augmented in such a way that both preserves and enhances the genetic variability that remains in the population.

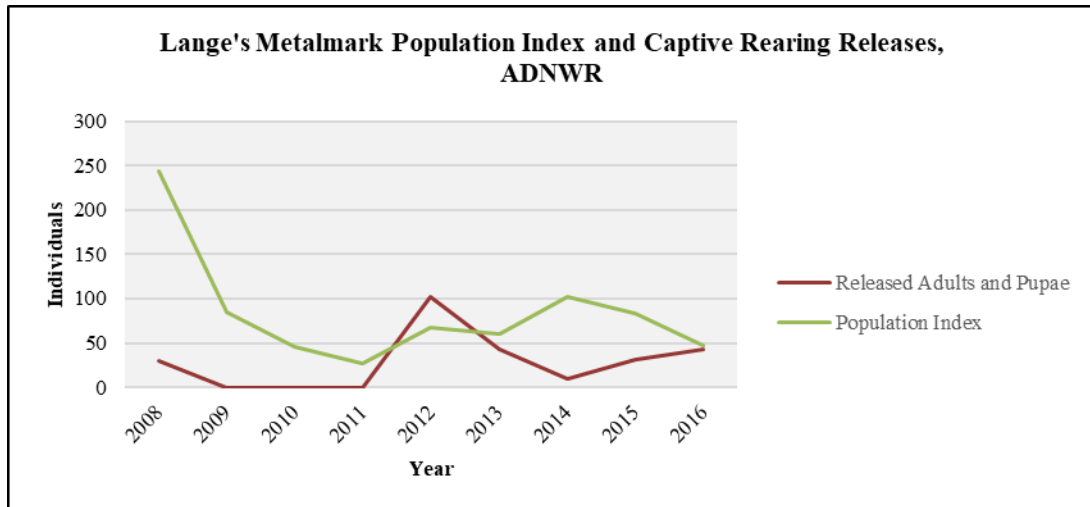


Figure 3. Comparison of Lange’s metalmark population index and number of pupae and/or adult butterflies released from the captive rearing program at the ADNWR* (Service, 2019b)

2. Wildfire:

Historically, it is unlikely that fire had a substantial influence on the ecology of the Antioch Dunes system, as it was sparsely vegetated (Service, 2002b). However, since the establishment of the refuge in 1980, there have been 27 wildfires (uncontrolled fires) recorded (Service, 2002b; Service, 2018a). More than half of these wildfires occurred in the 80’s, and most occurred on the Sardis and PG&E units. In the 1990’s, the frequency of wildfires declined and, with the exception of one wildfire, all occurred on the Stamm unit. The last recorded wildfire at ADNWR was in 2013, and that was one of only two wildfires that occurred in the past decade (Service, 2018a). Despite the decline in frequency, the recent wildfires have burned larger areas. In the 1980’s, the average area burned was 1.73 acres (ac), and by the 2000’s, this average increased to 11.72 ac (Service, 2018a). The increase in fire severity is likely due to the widespread abundance of annual non-native grasses.

Wildfires can have both direct and indirect effects to the Lange’s metalmark. If a wildfire ignites unoccupied habitat, it can harm the Lange’s metalmark host plant, as well as other nectar plants—indirectly affecting the Lange’s metalmark through habitat destruction. As noted in the previous 5-year review, past observations indicate that buckwheat can recover from a wildfire but it is more likely that non-native species like *Erodium cicutarium* will quickly recolonize the area (Service, 2002; Service, 2008). If a wildfire ignites occupied habitat, it is very likely that the sessile (immobile) Lange’s metalmark will directly perish (all life stages remains present on the host plant throughout their life cycle). When individuals transition into imagoes (mature, adult stage), they may be able to escape a wildfire, but eggs already laid at utilized oviposition sites are all directly destroyed. These direct and indirect effects to

* For 2009-2011, larvae were released but for that life stage, there is no certainty that those individuals matured in the wild. Pupal casings can be collected to measure success of eclosion for pupae released but there is only one year, in 2016, when all pupal casings could be recovered and which indicated that all released had eclosed.

Lange's metalmark and its habitat render wildfire to be a particularly lethal stressor, its relative contribution over time to population decline being a function of the frequency and nature of the artificial fire regime. Wildfires were identified as one of the highest threats to Lange's metalmarks in the refuge complex' natural resource management plan (Service 2019c).

3. Pesticide Application:

Pesticides (both herbicides and insecticides) have the potential to affect the Lange's metalmark. Specialized herbicides are used at the ADNWR to manage non-native plants. Three herbicides used at ADNWR have been tested on a surrogate species, and all had a detrimental effect on larval survival to pupation (Stark *et al.*, 2012; see Appendix A). However, this study only assessed the effects of the direct application to the surrogate species and the indirect effects from consuming host plants undergoing herbicide application, and so it is unclear if herbicide drift would have the same effects. It is also possible that herbicide mixtures (i.e., adjuvants included during application) may have detrimental effects to the butterfly (see Mullin *et al.*, 2016) if similar ecotoxic modes of action exist for Lange's metalmark as exist for honeybees. As herbicides are not currently applied to the Refuge where the butterfly is located (Service, 2008), it is unlikely that this is a threat to the butterfly or its habitat (in fact, the purpose of the applications is invasive control, and therefore beneficial to habitat).

It is possible that insecticides targeting mosquitos could affect the Lange's metalmark population. The Contra Costa Mosquito and Vector Control District (CCMVCD) uses both adulticides and larvicides in their efforts to reduce the mosquito population and mosquito-borne diseases. Larvicides are specific to mosquitos, and so are unlikely to affect Lange's metalmark, but there is increasing evidence that adulticides can affect butterflies (Boyce *et al.*, 2007; Oberhauser *et al.*, 2009; Zhong *et al.*, 2010; Hoang *et al.*, 2011; Bargar *et al.*, 2012). However, CCMVCD has primarily applied Pyroicide by a truck-mounted ultra-low volume sprayer in the region (CCMVCD, 2019a) (not aerial spraying). The active ingredients of Pyroicide is Pyrethrin, a naturally-occurring insecticide, and piperonyl butoxide (PBO), a chemical which makes the pesticide more effective by inhibiting an insect's natural defense against it (EPA, 2006a; EPA 2006b). No known study has analyzed the effects of Pyroicide/PBO on butterflies. Further, both active ingredients break down quickly when in the environment, so there is less of a chance that impacts will reach uncommon species. Lastly, application has never been on the refuge, and only in the year 2007 did CCMVCD spray directly next to the refuge (CCMVCD, 2019b). Therefore, insecticides can pose a threat under certain circumstances, but more data is needed to determine the relative impact of this potential stressor.

Emerging Threats

Climate Change

Although it is difficult to isolate the impacts of climate change due to confounding factors, climate change has been a primary cause of several observed effects on multiple members of the Lepidoptera order (Parmesan and Yohe, 2003). Studies have focused on the major effects, which include changes to abundance, distribution, and phenology (Kocsis and Hufnagel, 2011). Evidence of direct impacts by climate change to the abundance of butterflies have been difficult to infer, but one study shows strong associations between weather data and population trends of 28 British butterflies analyzed over 20 years (Roy *et al.*, 2001). While this study showed an increase in the 28 populations, many more studies have shown stable and declining populations over a similar or longer time interval (Kocsis and Hufnagel, 2011).

Changes in distribution have been observed, with substantial evidence of elevation shifts, latitudinal shifts (migration poleward), and extended migration distances (Parmesan, 1999; Parmesan and Yohe, 2003; Sparks *et al.*, 2007). Phenological changes could be the direct effect of climate change: with first appearances in the flight season occurring earlier, leading to peak detections occurring earlier, and for multivoltine species (i.e., producing many broods a year), a longer flight duration (Roy and Sparks, 2000; Sparks *et al.*, 2006; Parmesan and Yohe, 2003; Parmesan, 2007).

Current climate data for California, and more specifically, Antioch, indicates a changing environment with a shift from historical climate conditions (Cayan *et al.*, 2009; CLCC and the Service, 2018; Esralew, 2016). Based on this data, by 2050, California is projected to have an increase in average annual temperature by 2.7 degrees Fahrenheit, and while projected patterns in precipitation vary, assessments indicate that California will generally trend towards a drier climate (Cayan *et al.*, 2009; CLCC and the Service, 2018). Further, the intensity and frequency of both extreme heat and winter storms are projected to increase (CLCC and the Service, 2018). Temperature trends at both the regional and local scales, show an increase in annual average temperatures for Antioch (Esralew, 2016). Precipitation trends vary between models, with potential for both increases and decreases in average precipitation, and so predicting this variable is difficult at this time (Esralew, 2016).

Considering the literature, we might anticipate that climate change will have a negative impact on Lange's metalmark. When populations increase in response to climate change or variation, these species tend to be highly mobile, tolerant of a wide range of conditions, and within reach of available suitable habitat (Warren *et al.*, 2001). The Lange's metalmark as a relatively sedentary subspecies, endemic to a fragmented habitat, surrounded by developed lands, and highly dependent on an endemic plant, will likely be unable to relocate to suitable habitat or conditions elsewhere. Without further research, we cannot project the response of the Antioch Dunes buckwheat to climate change. However, the shift in temperature, precipitation, and frequency of extreme conditions

may be better tolerated by non-natives than native plants (CLCC and the Service, 2018). Hotter, drier conditions may increase the frequency, and would increase the severity of wildfires. This will come at a cost to both the survival and reproduction efforts of the Lange's metalmark.

Information acquired since the last status review:

This 5-year review was conducted by the U.S. Fish and Wildlife Service's (USFWS) San Francisco Bay-Delta Fish and Wildlife Office. Data for this review were solicited from interested parties through a Federal Register notice announcing this review on June 18, 2018. We also contacted staff from the ADNWR, species experts, and researchers to request any data or information we should consider in our review. Additionally, we conducted a literature search and a review of information in our files. New information that was relevant to this search is described in further detail in Appendix A.

Lange's metalmark exhibits extremely limited ecological representation and population redundancy—only remaining in one subsection of the Sardis Unit at ADNWR. The subspecies has not been observed at the Stamm Unit since 2010, and the overall ADNWR population has continued to decline from a peak count of 46 in 2009 to a peak count of four in 2019* (Service, 2008; Service, 2013a; Service, 2019a). Hence, the remaining population exhibits extremely low resilience, and active habitat management is essential to protect what persists. New information is consistent with the trend over the last decade-plus--a precipitous decline in the subspecies continues (Figure 2). As the Lange's metalmark is only known to persist at the Sardis Unit of the ADNWR at record low numbers, the species is likely at imminent risk of extinction.

RECOVERY CRITERIA:

Recovery criteria are used to measure the progress towards a biological state where the threats to the species has been greatly reduced or removed altogether. Recovery criteria are not binding when determining to downlist or delist but do provide guidance for this determination (*Friends of Blackwater v. Salazar*, 2012). In 2019, the *Revised recovery plan for three endangered species endemic to Antioch Dunes, California* (Service, 1984), was amended to include objective, measurable criteria as required by section 4(f)(1)(B)(ii) of the Endangered Species Act (Act) and as directed by the Department of Interior's Strategic Plan for Fiscal Years 2018-2022 (Service, 2018b). Please refer to the recovery plan revision for all downlisting and delisting recovery criteria for Lange's metalmark (Service, 2019b). To be considered for downlisting to threatened, the subspecies would need three populations at separate, managed locations with a 15-year moving median of 2,600 individuals and a minimum effective population size of 50. Currently, there is one extremely small population at risk of extirpation (the moving 15-year median is 123 at the time of this writing). As this fundamental metric has not been met, we have not further evaluated progress towards achieving other recovery objectives.

* This result is from the group survey as opposed to a Pollard walk conducted solely by a refuge biologist.

CONCLUSION:

After reviewing the best available scientific information, we conclude that the Lange’s metalmark remains an endangered subspecies. The evaluation of threats affecting the subspecies under the factors in 4(a)(1) of the Act and analysis of the status of the subspecies in our 2008 5-year review remains an accurate reflection of the subspecies current status.

RECOMMENDATIONS FOR FUTURE ACTIONS:

On December 4, 2019, staff of the Bay-Delta Fish and Wildlife Office met with the staff of the ADNWR and agreed on formally convening a recovery implementation team (RIT) for the listed species within the ADNWR. The primary purpose for convening this RIT is to have experts advise the Service on conservation priorities for the next five years, and how we will adaptively manage and monitor based on objective success criteria. Recommendations for future actions will be provided in the future via the recovery planning process, working with the internal team.

It may be useful to consider other approaches to Lange’s metalmark abundance estimation, in addition to those used in this 5-year review. It may also be useful, as time and resources allow, to conduct one or more detection probability trials to help clarify the detectability of Lange’s metalmark at ADNWR.

Kaylee Allen, Field Supervisor, Fish and Wildlife Service

Approve _____ Date _____

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Appendix A: New Information

Species-specific Research and/or Grant-supported Activities

New information has been provided by several research projects and grant supported activities directed at the Lange's metalmark or Antioch Dunes National Wildlife Refuge. This synopsis is appended to provide an update on new information since the last 5-year review. Information provided below did not materially influence the Five Factor assessment and conclusion regarding current status of the Lange's metalmark.

1. *Eriogonum nudum* Taxonomy (Reveal, 2007):

Reveal (2007) described a new variety of *Eriogonum nudum* based on samples collected from the ADNWR, and identified it as variety *psychicola*, closely related to variety *auriculatum*, but with the distinguishing characteristic of densely tomentose flowers (flowers covered in densely matted hair). The botanist claims the variety is endemic to the Antioch Dunes, and strongly associated with the Lange's metalmark. The Integrated Taxonomic Information System has accepted this taxonomic designation.

In August 2011, botanist Heath Bartosh sampled between 20 to 30 *Eriogonum nudum* plants in several management areas of the refuge, and all were identified as variety *psychicola* based on morphological characters (Service, 2011). Refuge management has since accepted the new taxonomic designation to be the correct name for the sole host plant for Lange's metalmark larvae and preferred nectar source for adult butterflies.

2. Captive Propagation of Lange's metalmark (UWG, 2007; UWG, 2008; UWG, 2011; UWG, 2016; UWG, 2018; Johnson, 2019):

Beginning in 2007, the Lange's metalmark population has been the focus of a captive rearing and release program. Initially, the program was intended for captive breeding of the subspecies, and efforts ensued at two facilities in its first year. One facility experienced early emergence of pupae, and discontinued their efforts. The remaining facility, America's Teaching Zoo in Moorpark, California continued efforts with Dr. Jana Johnson as the program lead. In 2008, the first captive breeding effort at Moorpark, 14 females successfully reproduced, which led to the release of 88 larvae in 2009 (Table 1). However, there has been no success with captive breeding since, so the program shifted towards captive rearing, or head starting.

The program methodology has changed slightly over the years, but generally followed the same protocol. One to five females were collected from the Sardis unit of the refuge during the flight season. Females were held in containers with buckwheat and other nectar sources, to test their behavior when in captivity. If captured females failed to feed or display other behaviors associated with stress, they were released. Those that remained were taken to the Moorpark facility where they were offered Antioch Dunes buckwheat to lay their eggs on, and both natural and artificial nectar. They were also force-fed several times daily and monitored closely until they died. Eggs were kept in double-layered multi-plant containers

with lighting controlled by tarps or nets, and if the temperature dropped below 50°F, containers were either covered by blankets or brought into a greenhouse. When larvae hatched from eggs, larvae were split into groups of about six per container and regularly kept outside. However, in recent years, it was discovered that herbicide and pesticide application on the nearby campus of Moorpark College occurred often, so the larval stock were frequently (about once a week) moved into the greenhouse or into an office on campus. Throughout egg and larval maintenance, individuals were moved to new, healthy buckwheat leaves when the leaves they occupied were in poor health. When pupation began, pupae and substrate were moved to an “eclosion cup,” with dividers between pupae, and dried buckwheat leaves or cardboard placed over the pupae to shield them from light. In previous years, if adult butterflies were not released, they were kept in order to attempt breeding (these attempts ended after 2014).

Intended to augment the wild population, the captive population’s realized contribution to the wild population over time is unknown. In the first three years of the program, releases occurred on the Stamm unit. When releases began, the Stamm Unit had a total count of ten butterflies (Service, 2008). Aside from the 30 adult butterflies released in this first year, all releases were in the larval stage and it was difficult to confirm if these individuals had pupated, eclosed, or mated with the wild population (see Table 1).

Year	Adults Captured	Eggs	Hatched	Released Larvae	Released Pupae	Released Adults
2007-2008	5	294		30	0	30
2008-2009	14*	828	354	88	0	0
2009-2010	4	544	184	119	0	0
2010-2011	5	285	97	2	0	0
2011-2012	5	624	362	0	79	23
2012-2013	3	215		0	28	15
2013-2014	3	140	64	1	7	2
2014-2015	4	159		0	30	1
2015-2016	5	448	108	1	43	0
2016-2017	4	532	144	0	0	0
2017-2018	3	175	58	7	0	0
2018-2019	1	75	43	0	0	0

Table 1. Number of adult females captured and offspring produced and released for the duration of the captive rearing program

Despite these releases, Lange’s metalmark no longer occupies the Stamm unit. When releases first occurred on the Sardis unit in 2010, only two larvae were released, and these may have eclosed prior to the wild population, as the captive stock was slightly more advanced than the wild population. Every year after, releases mostly consisted of pupae and adult butterflies. However, pupae were not successfully tracked to eclosion until the release in 2016, when

* These females were not captured but reared offspring of the females collected in the previous year and were the only individuals successfully mated in captivity thereby producing the only captive-bred individuals released into the wild.

pupae were released on a mesh cone attached to Antioch Dunes buckwheat plants using a twist tie. The mesh cones allowed refuge biologists to easily find the plant chosen for the released pupae and recover pupal casings after eclosion. Overall, other than the released adult butterflies and the 2016 release, the fate of released individuals can not be confirmed. Further, the reproductive performance of captive reared releases was not estimated, so it is unknown how many of these individuals were able to contribute to the next generation. In 2019, Dr. Johnson concluded that the loss of larvae in the past two years could probably be attributed to weather and advised that captive rearing be moved to a location with a similar climate to the refuge (Johnson, 2019).

3. Grazing Management Study (Larson, 2008; Larson, 2009):

In 2008 and 2009, Stephanie Larson conducted a study to test the efficacy of cattle grazing for controlling non-native vegetation on ADNWR. Two fenced-in plots within the Stamm unit were treated with either a “light” or “heavy” grazing intensity as determined by the residual dry matter (herbaceous biomass), and comparative yield following each grazing period. Management objectives included: achieving a reduction in the density of non-native vegetation, an increase in area of bare ground, maintaining or increasing Antioch Dunes buckwheat density, and establishing a baseline of impact by the two grazing intensities. In both years, only the “heavy grazing regime” met predetermined targets and it was determined that there was no physical impact to the Antioch Dunes buckwheat present. These results indicated that cattle grazing could be a management tool for controlling non-native vegetation.

4. Effects of Herbicides (Stark *et al.*, 2012):

The Service, in conjunction with Washington State University Puyallup Research and Extension Center, investigated the potential effects of herbicides on the Lange’s metalmark population (Stark *et al.*, 2012). Herbicides tested were those most frequently applied to non-native vegetation at ADNWR, which included triclopyr, sethoxydim, and imazapyr. First instars of *Apodemia virgulti*, a surrogate species for Lange’s metalmark, were exposed indirectly through application to *Erigonum siskiyouense*, at recommended field rates. Researchers measured survival and morphology as effect endpoints. Findings indicated that all three herbicides reduced the number of larvae that reached the pupal stage. The mechanism by which these herbicides reduce larval survival is not yet known, because the herbicides tested have different modes of action. Therefore, not only do the three herbicides tested have the potential to reduce the Lange’s metalmark population but other herbicides could as well, if applied on the population or its host plant.

5. Microclimate Relationships (Chin, 2012):

Chin (2012) focused on the microclimate patterns of Antioch Dunes buckwheat and how those patterns relate to the Lange’s metalmark population. Specifically, the parameters measured were the temperature and relative humidity. Measurements were recorded at different points, base and canopy, on the Antioch Dunes buckwheat plant. Comparisons were also made between plants clear of vetch (*Vicia villosa varia* and *Vicia sativa nigra*), and

covered in vetch, as well as between the Stamm and Sardis unit. Differences in temperature and relative humidity were more significant between parcels and the points on the plant, but not as significant between overgrown and clear stands. Also, variation was found to be most significant during what is thought to be the active hours (1100-1700) for Lange's metalmark adults. Results of this study suggest that the Lange's metalmark population may continue to experience microclimate variation even if ADNWR is cleared of non-native vegetation.

6. Historical Geography of Antioch Dunes (McNally, 2014):

McNally (2014) is a culmination of research on the historical geography of the ADNWR, the seasonal averages of temperature and precipitation, and deposition of atmospheric aerosols. The historical geography analysis describes how the aeolian (wind-driven) processes that had shaped the Antioch dunes has been interrupted by significant land development. Therefore, the dunes cannot naturally recover from degradation (i.e. mining), so any further restoration would require importing sediments. From the analysis of climate data, multiple regression models indicated that increased spring precipitation was associated with a negative growth rate in the Lange's metalmark population. This is thought to be an indirect stressor as spring precipitation benefits non-native vegetation over Antioch Dunes buckwheat and other natives. Lastly, analysis of air and surface soil samples indicate significant atmospheric inputs, which are likely to be enriching the soil of the Antioch Dunes and changing the ecosystem. As a result, ADNWR presently provides suitable habitat for non-natives, rendering a competitive disadvantage to natives of the relict dune system. This dissertation highlights the need for sediment imports to rebuild the dunes and restore the ecosystem to a nutrient-poor, aeolian dune system, and suggests that enhanced vegetation management is necessary following years of spring precipitation.

7. Effects of Gypsum (UWG, 2015):

In a pilot study, researchers investigated the potential impacts of gypsum dust on Lange's metalmark through investigation on a surrogate--Behr's metalmark (*Apodemia virgulti*). Gypsum powder was sprinkled onto metalmark adults, eggs, and larvae. As the gypsum did not disperse, frequency of application to the eggs and larvae were reduced. In contrast, the gypsum would typically fall off the adult butterflies. Due to a site evacuation of the facility, many adult butterflies had to be released and therefore, sample size limitations of the pilot study precluded statistical inference. Follow-up investigation is currently funded by the ongoing Central Valley Project Habitat Restoration Program grant to UWG.

8. Genetic Evaluation of Lange's metalmark (Proshek *et al.*, 2015; Dupuis *et al.*, 2018):

Two studies were published on the evolutionary significance and genetic distinction of the *Apodemia mormo* complex and specifically, Lange's metalmark.

In Proshek *et al.*, a few genetic markers were analyzed and comparisons were made between all members of the *Apodemia mormo* complex. Significant divergences in both mitochondrial and microsatellite DNA were found between populations in the Pacific Northwest, California, and east of the continental divide. Findings by both mitochondrial and

microsatellite DNA also indicated little overlap between taxonomic designations and genetic placement. Specific to Lange's metalmark, the study found that the population could be considered genetically distinct based on mitochondrial DNA. However, using microsatellite DNA, it was only genetically distinct when using regional, ordination-based methods (DAPC) and not individual-based Bayesian clustering methods (STRUCTURE).

Dupuis *et al.* conducted a genomic evaluation of Lange's metalmark to determine whether the population was genetically distinct and adaptively significant, and therefore an evolutionary significant unit. For comparisons, this study focused more on the populations west of the continental divide. Genetic divergence of these populations were strongest between *Apodemia virgulti* originating from southern California and *Apodemia mormo* originating from northern and central California but the *Apodemia mormo* population of Canada was more closely related to the southern California populations. Genomic analysis did confirm that Lange's metalmark is genetically distinct but no more so than what is expected from geographic isolation and therefore, no more distinct than the surrounding populations. Adaptive genetic variation could not be determined in the absence of ecological and fitness-related information and therefore, the authors could not determine whether the population is an evolutionary significant unit.

Antioch Dunes Restoration and Management Activities

Consistent with the previous status review, ADNWR staff continue to collect and maintain nursery stock of Antioch Dunes buckwheat to be planted in newly cleared habitat, or stored for future out-plantings (Service, 2008). In addition to out-plantings, the refuge began coordinating sand imports onto the Stamm Unit with the Army Corps of Engineers and Port of Stockton in 2013 (Service, 2013b). Sand is dredged out of the Stockton Deep Water Shipping Channel regularly by the U.S. Army Corps of Engineers as routine maintenance of channels used for commercial shipping (Service, 2017). ADNWR has been and will continue to be a dredging material placement site when dredging occurs offshore (Service, 2017). As a way to re-create dunes within the refuge, dredge spoils are pumped into the Stamm unit after sections of the unit have been cleared of vegetation (Service, 2019c). The first import brought 40,310 cubic yards of sand and has since accumulated to a total of 87,810 cubic yards since 2013 (Service, 2013b; Louis Terrazas pers. comm., 2019). Imports can be expected every two years as dredging is fairly constant. The goal is to not only re-create dunes but re-create the suitable dune habitat that once supported the Lange's metalmark and the listed plants (Service, 2019c).

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