

**Recovery Plan for Three Endangered Species Endemic to Antioch Dunes, California:
Lange's metalmark butterfly (*Apodemia mormo langei*), *Oenothera deltoides* subsp. *howellii*
(Antioch Dunes evening-primrose), and *Erysimum capitatum* var. *angustatum* (Contra
Costa wallflower)**

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Original Approved: March 21, 1980; Revised, April 25, 1984

Original Prepared by: USFWS, Portland, Oregon

RECOVERY PLAN AMENDMENT

The U.S. Fish and Wildlife Service (Service, USFWS) has identified that best available information indicates the need to amend the *Revised recovery plan for three endangered species endemic to Antioch Dunes, California* (Recovery Plan; Service 1984) by adding recovery criteria for Lange's metalmark butterfly (*Apodemia mormo langei*), *Oenothera deltoides* subsp. *howellii* (Antioch Dunes evening-primrose), and *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower). Because the Recovery Plan does not include recovery criteria, the modification is shown as an addendum, not superseding any portion of the plan, but instead being inserted following *Part II. Recovery Objective, Plan Outline, Objective 3* (page 38) and preceding *Plan Narrative* (page 39). In this modification, we review the need for recovery criteria, show proposed criteria, and describe the justification and rationale supporting this Recovery Plan modification.

**For
U.S. Fish and Wildlife Service
Region 8, Pacific Southwest
San Francisco Bay-Delta Fish and Wildlife Office
Sacramento, California**

September 2019

Approved: _____


Regional Director, U.S. Fish and Wildlife Service
Pacific Southwest Region

Date: _____

9/26/19

INTRODUCTION

The purpose of this document is to incorporate recovery criteria for the Lange’s metalmark butterfly (*Apodemia mormo langei*), *Oenothera deltooides* subsp. *howellii* (Antioch Dunes evening-primrose), and *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower) as an amendment to the Recovery Plan. This current document provides a brief overview and synthesis of information related to the recovery criteria; it is not intended as a comprehensive review of the Recovery Plan or a five-year review of species’ status. Refer to the Recovery Plan ([here](#)) and the *Five-Year Review for the Lange’s metalmark butterfly (Apodemia mormo langei), Antioch Dunes evening-primrose (Oenothera deltooides subsp. howellii), and Contra Costa wallflower (Erysimum capitatum var. angustatum)* (2008 Five-Year Review; Service 2008) ([here](#)) for detailed descriptions of each species biology, previous population status and trends, and threats assessments. Updates to these five-year reviews are also in progress or scheduled within the near future.

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METHODOLOGY USED TO COMPLETE THE RECOVERY PLAN AMENDMENT

The San Francisco Bay-Delta Fish and Wildlife Office (BDFWO), with assistance from Antioch Dunes National Wildlife Refuge (ADNWR), assembled technical workgroups of subject matter experts (Appendix A) to assist in the development of these recovery criteria. Experts were selected to represent a diversity of technical knowledge (e.g., taxonomy, ecology, habitat management) and affiliation, including Federal, State, and local governmental agencies, academic institutions, and non-governmental organizations.

Input from the workgroup was gained via video-conference meetings and email distribution of materials and work products, and some experts were further engaged individually via email and telephone communication. This input was solicited during development of the criteria. Also, the experts provided further technical assistance when the proposed criteria were published in the *Federal Register* and the Service responded to public comments, peer review, and workgroup member feedback (see peer review description below). Using information from the various references, BDFWO staff developed iterative work items and draft documents for review by the workgroup experts and led them through the review.

Primary references in this review included: the Recovery Plan; the 2008 Five-Year Review; ADNWR annual survey results for Lange’s metalmark butterfly (Service 2018e), *Oenothera deltooides* subsp. *howellii*, and *Erysimum capitatum* var. *angustatum* 2015-2017 (Service 2018a); the ADNWR annual management activity summary 2003-2018 (Service 2018b); the Service Inventory and Monitoring Program’s summary of ADNWR survey data for Lange’s metalmark, *O.d.* subsp. *howellii*, and *E.c.* var. *angustatum* 1985-2014 (Service No Date); California Natural Diversity Database (CNDDDB) element occurrence data (CNDDDB 2018); and published and gray literature.

Population viability analysis (PVA) was attempted for each species; however, due to various data constraints, the underlying data was insufficient to derive confident estimates of minimum viable populations at this time. Additionally, due to the lack of species-specific biological, ecological, and genetic information, recovery criteria for other narrow endemic species were considered as surrogate or proxy references. No single available example sufficiently replicated the various

ecological characteristics and current status to translate specifically as a stand-in for the Antioch Dunes species. Therefore, combined minimum viable population (MVP) sizes from the most suitable surrogate references were used to estimate threshold population sizes until more robust species-specific data and other information allow for more refined calculations.

Peer review of the proposed criteria was conducted in accordance with the Service's 1994 Peer Review Policy (59 FR 34270; July 1, 1994) and guidelines of the 2004 Office of Management and Budget (OMB) Information Quality Act Guidelines (<https://www.whitehouse.gov/sites/default/files/omb/memoranda/fy2005/m05-03.pdf>). Peer review and public comments were taken into consideration when finalizing the criteria and a summary of the comments received is included as an appendix to this final document.

ADEQUACY OF RECOVERY CRITERIA

Section 4(f)(1)(B)(ii) of the Endangered Species Act (Act) requires that each recovery plan shall incorporate, to the maximum extent practicable, "objective, measurable criteria which, when met, would result in a determination...that the species be removed from the list." Legal challenges to recovery plans (see *Fund for Animals v. Babbitt*, 903 F. Supp. 96 (D.D.C. 1995)) cited in Government Accountability Audit (GAO 2006) also have affirmed the need to frame recovery criteria in terms of threats assessed under the five threat factors (five factors; ESA 4(a)(1)).

The Recovery Plan was first approved March 21, 1980 and revised April 25, 1984. It does not identify recovery criteria because at the time it was written there was insufficient information regarding the species' population trends and stability to develop criteria. Because the Recovery Plan does not include objective, measurable criteria, it is considered out of compliance with statutory requirements. This current document amends the Recovery Plan by establishing fundamental, quantitative downlisting and delisting recovery criteria for each of the three species to meet these requirements.

Current Recovery Criteria

As indicated above, the Recovery Plan does not identify recovery criteria. In place of criteria, a prime objective was determined: "to prevent the further loss of the Lange's metalmark butterfly, Contra Costa wallflower, and Antioch Dunes evening-primrose; to protect introduced populations and their habitats; and to determine the number of populations which are necessary to reclassify each species to threatened and to delist." (Service 1984).

Three primary actions and several supporting actions for each primary action were established as practical means to reach the objective and these actions are outlined in the Recovery Plan (Service 1984). As of the writing of the 2008 Five-Year Review, at least 80 percent of the supporting recovery actions were considered as either completed or ongoing in implementation (Service 2008). However, despite those activities, the population trends for all three species at the time were declining (Service 2008). A cross-reference of relevance and integration of the

recovery criteria to the primary objective and primary actions from the Recovery Plan and the five factors for each species is provided below in the *Rationale for Amended Criteria* section.

Synthesis: Habitat and Species Descriptions, Population Status, Threats and Stressors

A brief synthesis with habitat and species descriptions, population status, and threats and stressors under the five factors for each species is provided below. Refer to the Recovery Plan and 2008 Five-Year Review for more detailed descriptions. Additionally, although not directly related to the scope of this recovery criteria development, a question arose about taxonomic status for one of the species (*Erysimum capitatum* var. *angustatum*; Contra Costa wallflower) during development of the criteria; this question is addressed in Appendix B. A more thorough review of taxonomic status may be included in the next five-year review for a given species, as appropriate.

Habitat Description

The Lange's metalmark butterfly (*Apodemia mormo langei*) (hereafter referred to as Lange's metalmark), *Oenothera deltoides* subsp. *howellii*, and *Erysimum capitatum* var. *angustatum* are endemics of a relatively narrow habitat association known as the "Antioch Dunes" along the shore of the San Joaquin River in Contra Costa County, California. Based on historical information, the geographic area that once comprised the tall, open, sand dunes characterized as the Antioch Dunes, is estimated at between approximately 120 acres (Stanford *et al* 2011) and approximately 500 acres (Service 1978b); estimates differ relative to interpretations of the degree of topographic relief (e.g., what constitutes "tall dunes") and the distinction of other natural community features from the rest of the interior dune habitat.

The Antioch Dunes were part of a larger habitat association typified by sandy soils, remnant of eolian (wind-blown) processes, which covered approximately 6,800-8,400 acres (Stanford *et al* 2011). This interior dune habitat was classified as approximately 5,600 acres of "interior dune – vegetation undefined", which was sparsely vegetated and included the Antioch Dunes, and approximately 2,800 acres "interior dune scrub", which was densely vegetated (Figure 1). Both habitat types included oaks, scrub oaks, and other vegetation; the density of vegetation is what distinguished the two (Stanford *et al* 2011).

There is limited information about the historical distribution of the Lange's metalmark butterfly, *O.d.* subsp. *howellii*, and *E.c.* var. *angustatum* beyond the Antioch Dunes and across the broader, interior dune habitat. Relative to the suitability of soils and overall habitat descriptions, these listed species may have also occurred in the "interior dune – vegetation undefined" habitat and within any relatively open interface of the "interior dune – vegetation undefined" and "interior dune scrub" habitats.

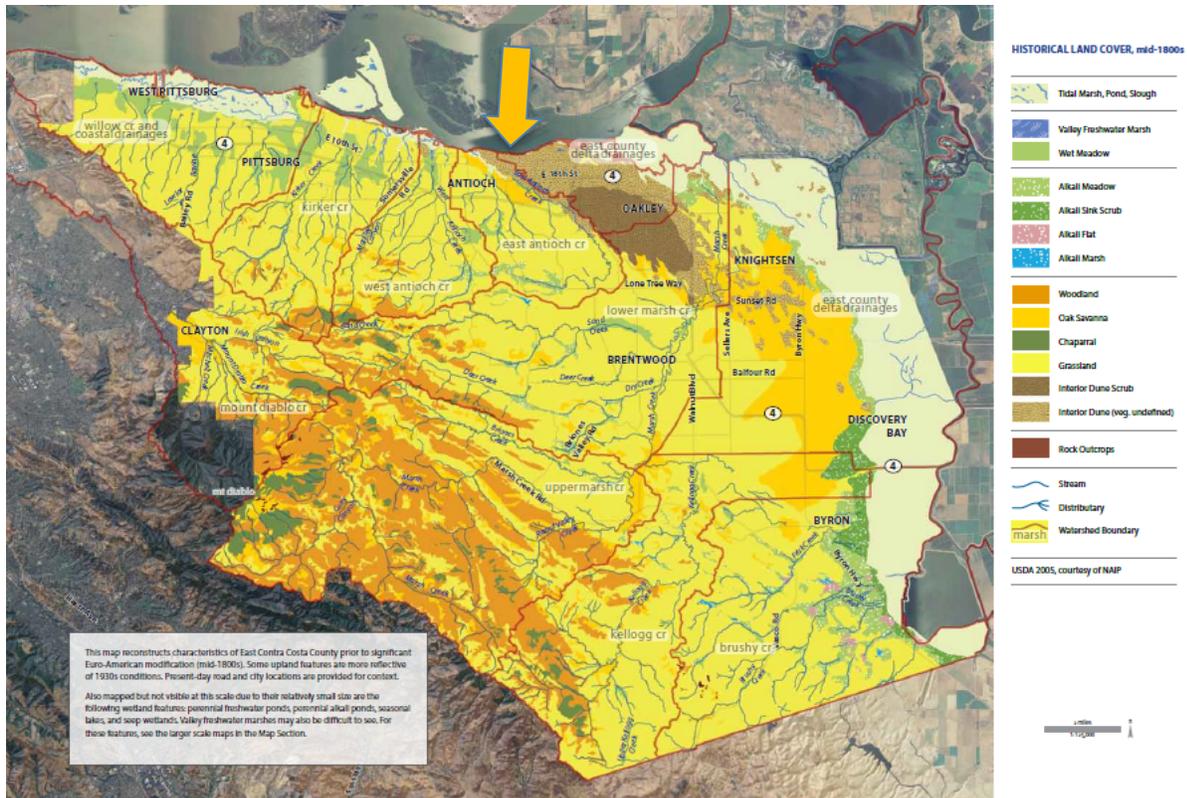


Figure 1. East Contra Costa County mid-1800s land cover showing the estimated distribution of the interior dune habitat (interior dunes scrub [dark brown]; interior dunes – vegetation undefined [light brown]) (figure from Stanford *et al* 2011) with arrow pointing to the location of the Antioch Dunes.

Since the mid- to late-1800s, the Antioch Dunes habitat has been mostly destroyed and degraded by sand mining for various commercial uses, conversion to other land uses, invasion by non-native vegetation, and recreational uses (Service 1984). These habitat alterations have also largely eliminated the wind-blown disturbance regime that helps maintain the openness of the dunes in the remaining small and fragmented habitat units. The remaining Antioch Dunes habitat is found almost completely within the two management units of the ADNWR; the approved 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 2). The Lange’s metalmark is now considered entirely restricted to the remaining Antioch Dunes habitat at the ADNWR (currently only the Sardis Unit), and *O.d.* subsp. *howellii* and *E.c.* var. *angustatum* are now considered almost entirely restricted to the remaining Antioch Dunes habitat at the ADNWR.

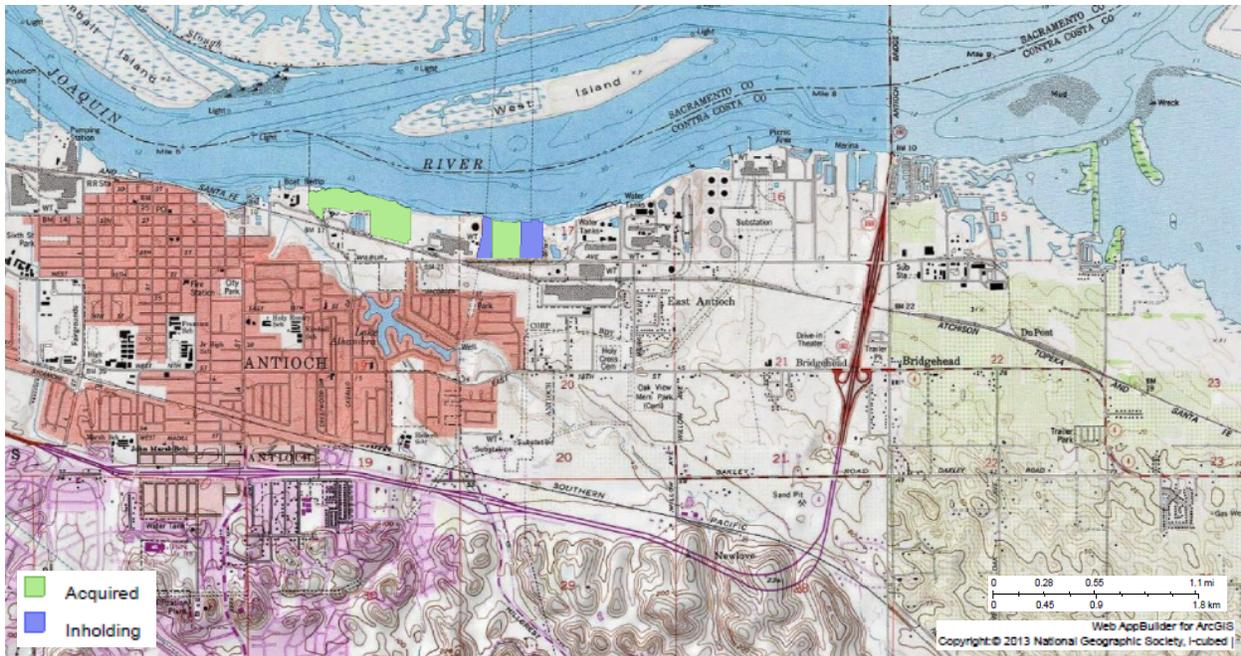


Figure 2. Location of the Antioch Dunes National Wildlife Refuge. The approved 67-acre refuge boundary includes Service-owned (green polygons) and privately-owned (blue polygons) property.

Species Descriptions

Lange's Metalmark

Lange's metalmark is a recognized subspecies of the Mormon metalmark (*Apodemia mormo*) according to the Integrated Taxonomic Information System (ITIS; 2018) and is isolated from all other occurrences of the *A. mormo* complex. It is a univoltine subspecies, producing one brood a year. Adults emerge (eclose) in early August and may be observed until mid- or late-September, with egg laying throughout this adult flight period (Service 1984). All life stages of Lange's metalmark are closely tied to *Eriogonum nudum* var. *psychicola* (Antioch Dunes naked-stem buckwheat, hereafter referred to as naked-stem buckwheat), as the primary nectar source for adults, for oviposition sites, and as the larval foodplant. However, naked-stem buckwheat may not be utilized by the Lange's metalmark until it is about three years old, when the plant is able to produce robust flowers (Arnold 1983). Naked-stem 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 naked-stem buckwheat begins in July or August, depending on the climate, and just prior to the emergence of Lange's metalmarks.

Oenothera deltoides subsp. *howellii*

Oenothera deltoides subsp. *howellii* is a short-lived perennial in the primrose family (Onagraceae). It is self-incompatible, requiring cross-pollination for viable seed (Klein 1970 in Service 1984). It is regarded as a psammophyte, occurring in nearly pure and shifting sand (Service 1984) and research by Thomson (2005a) affirmed this requirement by demonstrating that a lack of soil disturbance inhibited seed germination. It is vespertine (flowers open in early

evening and close by mid-morning) and blooming occurs from March to September (Service 1984; Service 2008). Blooming may occur in the first year, but it blooms more profusely in the second or later year. It produces seed capsules with smooth buff- to black-colored seeds that require stratification for germination (Service 1984). Arnold (pers. comm. 1982 in Service 1984) believed that bees were the primary pollinating agents for the species. Gregory (1963 in Service 1984) noted that while hawk-moths are pollinators of other *Oenothera*, they were not known from Antioch Dunes until 1983 and at that time their role as pollinators of *O.d.* subsp. *howellii* had not been documented. The 2008 Five-Year Review explained that at the time of that review, no studies had been conducted to identify if *O.d.* subsp. *howellii* requires specialized pollinators (Service 2008).

Erysimum capitatum var. *angustatum*

Erysimum capitatum var. *angustatum* is one of many varieties of the western wallflower (*Erysimum capitatum*). It is a short-lived perennial and monocarpic (individuals die after setting seed) (Service 1984). Pollination is by bees that nest in open banks and may also be by a variety of other unspecified insects (Service 2002). A study in 1987 by Pavlik *et al* (1998a) determined that seed production for *E.c.* var. *angustatum* was not a limiting factor and germination of new seeds was considered relatively high, with 40-60% typical, comparable to germination rates in non-endangered relatives. Additional work by Pavlik *et al* (1988b) determined that, at that time, the growth of *E.c.* var. *angustatum* populations was not genetically constrained, but was environmentally constrained due to limited habitat, interspecific vegetation competition, and possibly pollination limitations. Seedling emergence (and presumably, germination) was significantly higher in dune soils than unbroken clay soil, and higher (but not significantly) in dune soil than in broken clay soil (Pavlik *et al* 1988b). The reproductive phenology encompasses germination in October, leafing from October through December, budding in February, flowering in March (peaking in April or May), and fruiting beginning in April and peaking in July (Service 2008).

Population Status

The California Natural Diversity Database (CNDDDB) tracks reported species locations (i.e., element occurrences, EOs), recording observations over time and a species' presence or abundance at a given reported locality. The CNDDDB is a member of the nationwide NatureServe network, which gathers, manages, and represents data for species and ecological systems using the NatureServe Core Methodology. While these abundance data generally are in the form of coarse estimates and sometimes may only represent observation of a few individuals, more precise data are sometimes included as part of monitoring programs for rare species. NatureServe data may be used to illustrate and track site-specific and range-wide status and distribution of listed species. It is used here to identify the range-wide distribution based on EOs. Where available, site-specific survey data is referenced below to illustrate population status and trends. Because, currently, the Lange's metalmark occurs exclusively at ADNWR and *Oenothera deltoides* subsp. *howellii* and *Erysimum capitatum* var. *angustatum* occur almost exclusively at ADNWR, the ADNWR data essentially represents the entire respective population statuses.

Lange's Metalmark

According to the CNDDDB (2019), Lange's metalmark is known from only a single EO (Table 1). It is associated with ADNWR and is considered a natural occurrence, representing the entirety of the known range-wide natural/native population. Nearly annual surveys have been conducted in at least some of the subunits of the Stamm and Sardis Units since about 1986.

Table 1. California Natural Diversity Database (CNDDDB) element occurrence (EO) information for Lange's metalmark butterfly and most recent survey counts.

EO# (a)	County (a)	Presence (a)	Occurrence Type (a)	Ownership (a)	Most Recent Observation (b)	Most Recent Peak Count and Index (year) (b)
1	Contra Costa	Presumed Extant	Natural/Native	USFWS, Private (includes ADNWR)	2018	Peak count = 30 adults, Index = 53 individuals (2017); Peak count = 5 adults, no Index calculated (2018)

Notes: (a) CNDDDB 2019; (b) Service 2018e

Surveys for Lange's metalmark are currently carried out using the basic Pollard walk method with modifications. This method yields weekly counts per habitat/management unit. Based on surveys conducted since 1986, peak counts (the highest single-day count from the flight period) have been as high as 2,342 adults in 1999, but have been below 50 adults in every year since 2009 (Service 2018e, Service No Date). Surveys in 2018, although not conducted across the entire refuge, yielded a peak count of only five adults, the lowest on record (Susan Euing pers. comm. December 12, 2018).

A population index could be derived based on maximum count. However, this approach does not yield an accurate abundance estimate at higher densities and with unequal survey effort across space and time, and these biases limit the inferential power of our existing dataset. Instead, we used count data to produce a population index by using an additive model to calculate the sum of weekly counts over the number of survey days completed during the flight phase. We opted for this methodology to get a better understanding of the population trend for Lange's metalmark, and present a relative abundance index (Figure 3; following the methodology of Schultz and Dlugosch 1999, see Appendix C). Still, due to lack of consistent implementation of the Pollard walk throughout the monitoring period, our index is expected to underestimate the population, but it does display the relative 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 1986-2017, this calculated index has been as high as 6,980 individuals in 1997, but has been below 100 individuals in all but one year since 2009 (Figure 3).

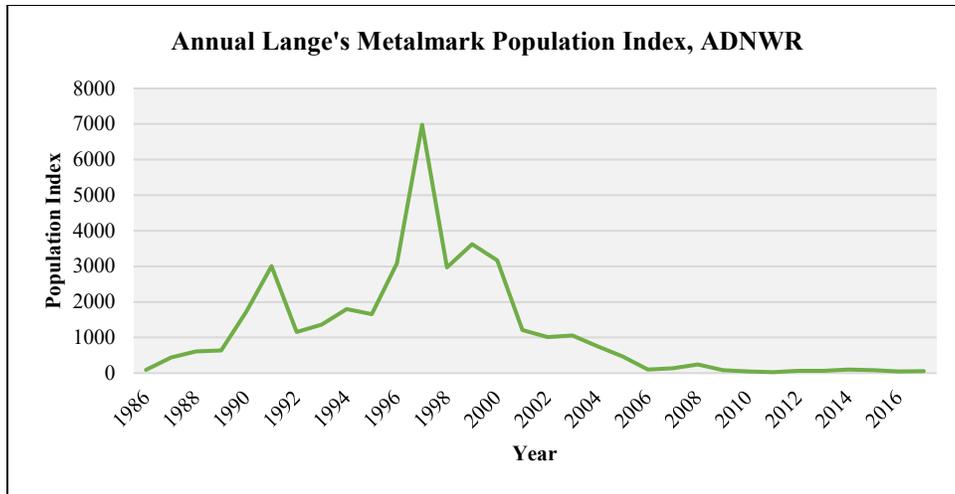


Figure 3. Calculated population index of Lange’s metalmark from 1986 to 2017 at the Antioch Dunes National Wildlife Refuge (ADNWR).

In 2007, a captive breeding program was established for Lange’s metalmark. However, breeding in captivity has been generally unsuccessful and the program has shifted to a head starting approach--annually collecting three to five females and rearing their offspring in captivity to later be released back into the wild. Unfortunately, only seven larvae were released in 2018 due to an unexplained die-out in the captive population, and none were released in 2017 due to early eclosion of the captive population, putting them out of sync with the mating period of the wild population. As the wild population continues to decline, captive-reared individuals begin to account for a greater percentage of the population (Figure 4).

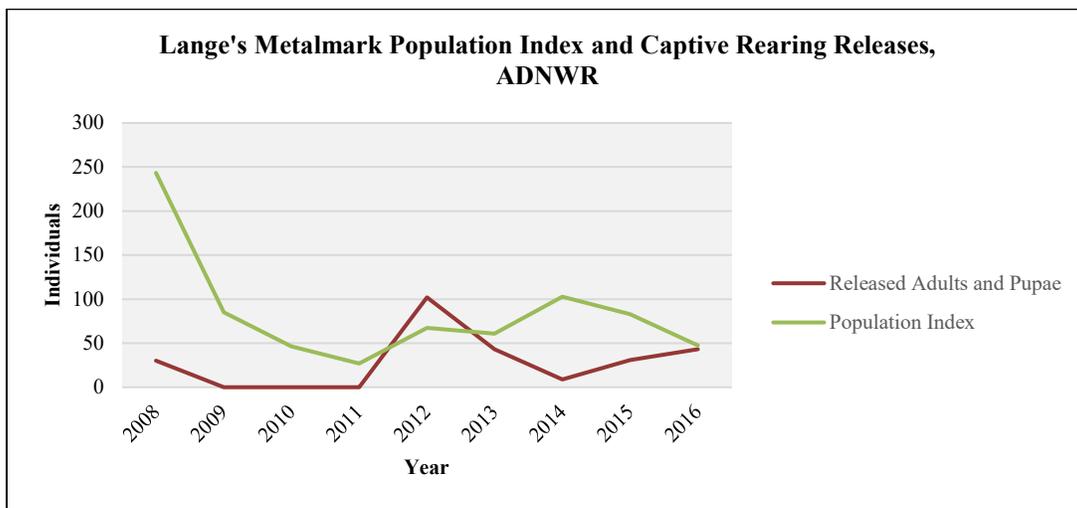


Figure 4. Comparison of Lange’s metalmark population index and the number of pupae and/or adults released from the captive rearing program at the Antioch Dunes National Wildlife Refuge (ADNWR).¹

¹ 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.

Oenothera deltooides subsp. howellii

According to the CNDDDB (2018a), *Oenothera deltooides subsp. howellii* is known from 10 EOs, nine of which are presumed extant and one of which is considered likely extirpated (Table 2). Of the nine presumed extant EOs, six are considered natural occurrences and three are considered transplanted outside of native habitat and/or range. The two CNDDDB EOs that occur at the ADNWR (EO #1, which includes the Stamm Unit and EO #4, which includes the Sardis Unit) represent the majority of the known range-wide natural/native population. Nearly annual plant counts have been conducted in at least some of the subunits of the Stamm and Sardis Units since about 1985.

Table 2. California Natural Diversity Database (CNDDDB) element occurrence (EO) information for *Oenothera deltooides subsp. howellii* (Antioch Dunes evening-primrose) and most recent survey counts.

EO# (a)	County (a)	Presence (a)	Occurrence Type (a)	Ownership (a)	Most Recent Observation	Most Recent Survey Plant Count (year)
1	Contra Costa	Presumed Extant	Natural/Native	USFWS (ADNWR - roughly Stamm)	2017 (c)	2,008 total; 1,472 flowering (2017; c)
3	Contra Costa	Possibly Extirpated	Natural/Native	Private	1978 (a)	unknown
4	Contra Costa	Presumed Extant	Natural/Native	USFWS, Private (ADNWR - roughly Sardis)	2017 (c)	326 total; 263 flowering (2017; c)
5	Sacramento	Presumed Extant	Transplant outside of native habitat/range	California Department of Parks and Recreation (Brannan Island)	2007 (b)	84 total (2007; b)
7	Contra Costa	Presumed Extant	Transplant outside of native habitat/range	East Bay Regional Park District (southern edge Browns Island)	2018 (d)	34 total; 5 flowering (2018; d)
8	Contra Costa	Presumed Extant	Transplant outside of native habitat/range	Private, Regional Parks, State? (west end Browns Island)	1984 (a)	unknown
9	Contra Costa	Presumed Extant	Natural/Native	City of Oakley	2011 (a)	unknown
10	Contra Costa	Presumed Extant	Natural/Native	Private	2012 (a)	unknown
11	Contra Costa	Presumed Extant	Natural/Native	Unknown	1996 (a)	unknown
12	Contra Costa	Presumed Extant	Natural/Native	Unknown	2000 (a)	unknown

Notes: (a) CNDDDB 2018a; (b) Service 2008; (c) Service 2018a; (d) Michele Hammond pers. comm. October 9, 2018).

The 2008 Five-Year Review (Service 2008) summarized that when the subspecies was listed in 1978, only 15 acres of the original 500-acre dune habitat was remaining and there was a population of 872 flowering plants and 376 small plants just within the single EO at the Sardis Unit. The populations of other EOs at the Stamm Unit, and introduced colonies at Brannan and Brown Island, were not counted at that time. A total population of just over 500 plants was counted in 2007 from what were considered to be the three major known EOs (about 400 plants at the Stamm and Sardis Units combined; fewer than 50 plants at the Kemwater Unit [adjacent to the Sardis Unit and part of EO#4]; and about 84 plants at the Brannan Island transplanted location; Service 2008). The 2008 Five-Year Review described the population as unstable and not self-sustaining and that the trend in population dynamics had been declining since listing (Service 2008).

The total population in 2017 was estimated at 2,368 individuals, with 2,334 plants counted at the ADNWR (2,008 at the Stamm Unit and 326 at the Sardis Unit) and 34 plants at one of the transplanted locations at Browns Island (Table 2). Population numbers have shown some

improvement since the 2008 Five-Year Review, as illustrated by plant count numbers from ADNWR (Figure 5; Service 2018a, Service No Date). However, despite the improvement, the overall population is still not considered stable or self-sustaining due to the overall low population numbers, low redundancy of populations, and continuing and increasing threats.

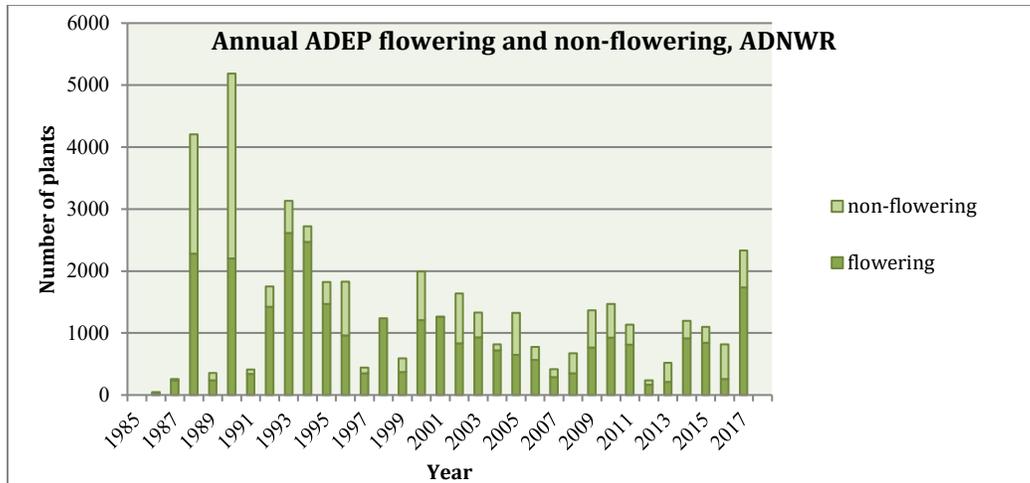


Figure 5. Annual counts of flowering and non-flowering *Oenothera deltoides* subsp. *howellii* (Antioch Dunes evening-primrose; ADEP) at the Antioch Dunes National Wildlife Refuge (ADNWR).

Erysimum capitatum var. *angustatum*

According to the CNDDDB (2018b), *Erysimum capitatum* var. *angustatum* is known from four EOs, all of which are presumed extant (Table 3). Of the four EOs, three are considered natural occurrences and one is considered transplanted outside of native habitat and/or range. The two CNDDDB EOs that occur at the ADNWR (EO #1, which includes the Stamm Unit and EO #3, which includes the Sardis Unit) represent the majority of, and possibly the entire, known range-wide natural/native population. Nearly annual plant counts have been conducted in at least some of the subunits of the Stamm and Sardis Units since about 1985.

Table 3. California Natural Diversity Database (CNDDDB) element occurrence (EO) information for *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower) and most recent survey counts.

EO# (a)	County (a)	Presence (a)	Occurrence Type (a)	Ownership (a)	Most Recent Observation	Most Recent Survey Plant Count (year)
1	Contra Costa	Presumed Extant	Natural/Native	USFWS (ADNWR - roughly Stamm)	2017 (b)	726 total; 609 flowering (2017; b)
2	Contra Costa	Presumed Extant	Natural/Native	Private	2001 (a)	unknown
3	Contra Costa	Presumed Extant	Natural/Native	USFWS, Private (ADNWR - roughly Sardis)	2017 (b)	8,561 total; 3,602 flowering (2017; b)
4	Contra Costa	Presumed Extant	Transplant outside of native habitat/range	Unknown (Browns Island)	1979 (a)	unknown

Notes: (a) CNDDDB 2018b; (b) Service 2018a.

The 2008 Five-Year Review (Service 2008) summarized that when the variety was listed in 1978, only 15 acres of the original 500-acre dune habitat was remaining and there was a population of 174 fruiting plants and 60 rosettes or seedlings just within the single EO at the Sardis Unit. The populations of other EOs at the Stamm Unit and introduced colony at Brown’s Island were not counted at that time. A total population of approximately 3,200 plants was

counted in 2007 from what were considered to be the two major known EOs, the Stamm and Sardis Units combined (Service No Date).

The total population in 2017 was estimated at 9,287 individuals at the ADNWR (726 at the Stamm Unit and 8,561 at the Sardis Unit) (Table 3). Population numbers have shown some improvement since the 2008 Five-Year Review, as illustrated by plant count numbers from ADNWR (Figure 6; Service 2018a, Service No Date). However, despite the improvement, the overall population is still not considered stable or self-sustaining due to the overall low population numbers, low redundancy of populations, and continuing and increasing threats.

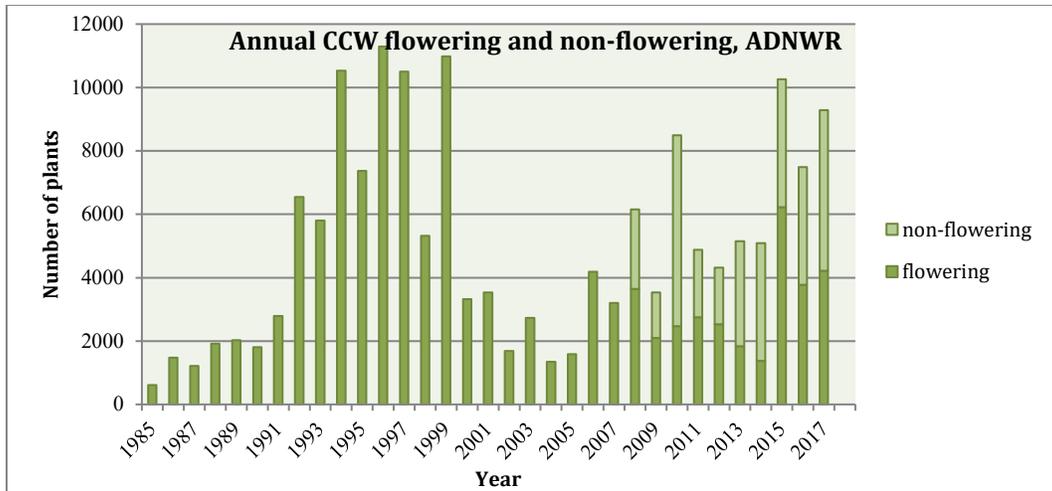


Figure 6. Annual counts of flowering and non-flowering *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower; CCW) at the Antioch Dunes National Wildlife Refuge (ADNWR) (non-flowering plants were not counted until 2008).

Threats and Stressors Under the Five Factors

A brief review of the five factors and underlying threats and stressors to the Lange’s metalmark, *Oenothera deltoides* subsp. *howellii*, and *Erysimum capitatum* var. *angustatum* follows. This review synthesizes information from the Recovery Plan, 2008 Five-Year Review, the *Lange’s Metalmark Butterfly Threat Assessment and Ranking of Potential Management Alternatives* (Richmond *et al* 2015), additional references (as cited), and the 2018 development of recovery criteria. Refer to the documents listed above for more detailed discussion of threats and stressors. A more detailed treatment of current threats and stressors will be discussed in the next five-year review for each species.

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

1. Habitat destruction from sand mining, industrial and urban/suburban development, and/or conversion to agriculture

Habitat for the Lange’s metalmark, *O.d.* subsp. *howellii*, *E.c.* var. *angustatum*, and pollinators, and area available for habitat restoration is threatened by destruction and conversion to other uses. This threat is largely ameliorated on the ADNWR

and other properties with protection/management agreements in place, but not on properties without such agreements.

2. Habitat degradation due to loss of natural disturbance regime

The reduction in sand deposition in Antioch Dunes habitat as a result of water management/use (dams, levees, etc.) in the Sacramento/San Joaquin River Delta system and reduced effectiveness of wind-driven dispersal of sand and disturbance of dunes has and continues to reduce overall size and connectedness of the dune natural community.

3. Habitat degradation due to non-native and native invasive vegetation

Invasive vegetation colonizes open sand habitat, reducing available suitable Lange's metalmark, *O.d.* subsp. *howellii*, *E.c.* var. *angustatum*, and pollinator, habitat. Invasive plants out-compete native species, including Lange's metalmark host and food plants, and *O.d.* subsp. *howellii* and *E.c.* var. *angustatum*, for sunlight, space, nutrients, and moisture. They also stabilize the sand/soil, eliminating the natural disturbance regime and may cause soils to become more eutrophic (Thomson 2005a, Thomson 2005b, Chin 2012, McNally 2014). The 2008 Five-Year Review notes that the proliferation of non-native invasive plants has been increasing rapidly since 1998 (Service 2008) and these conditions continue (Chin 2012, McNally 2014, Service 2018a, Service 2018b, Service 2018c, Service 2018d).

The use of herbicides to control non-native and native invasive vegetation may also present potential threat to Lange's metalmark host and food plants, *O.d.* subsp. *howellii*, and *E.c.* var. *angustatum* occurring in the same vicinity. Applying herbicides selected for the target species and using appropriate rates and technique should minimize effects to non-target Lange's metalmark host and food plants, *O.d.* subsp. *howellii*, and *E.c.* var. *angustatum*. These practices have been instituted at the ADNWR, so this threat is considered largely ameliorated there (Service 2008), but it may pose a risk to current and future occurrences of these listed species elsewhere. Additionally, some herbicides may pose threat directly to Lange's metalmark. In a study of Behr's metalmark, a close relative of Lange's metalmark butterfly, the herbicides triclopyr, sethoxydim, and imazapyr were found to reduce the number of adults that emerged from pupation by 24-36% after exposure to typical field application rates (Stark *et al* 2012 in Richmond *et al* 2015).

4. Habitat degradation due to gypsum dust deposition from neighboring plant (facility)

The 2008 Five-Year Review reported that gypsum dust building up on plants may reduce exposure to sunlight and decrease photosynthesis. It may also alter soil chemistry due to introduction of calcium and sulphates, which may affect the growth of Lange's metalmark host and food plants, *O.d.* subsp. *howellii* and *E.c.*

var. *angustatum* and promote colonization by invasive species. Deposition is noted as affecting mostly the Sardis Unit. The ADNWR staff have met with Georgia-Pacific (G-P) about concerns over the dust and G-P increased efforts to reduce airborne gypsum (beyond the standards for air pollution control) by keeping it wetted down when possible during production activities. At the time of the 2008 Five-Year Review, staff noted a reduction in dust from G-P efforts. The review noted that there was no evidence that gypsum dust was adversely affecting any of the three species (Service 2008). However, it also cited a study that demonstrated that dusts may adversely increase transpiration through the cuticle of insect larvae and cause desiccation and abrasion of the cuticle (Wigglesworth 1945 in Service 2008), which may affect Lange's metalmark and pollinators of *O.d.* subsp. *howellii* or *E.c.* var. *angustatum*.

The ADNWR staff reported an increase in gypsum dust deposition at ADNWR in 2017-2018 (Susan Euing pers. comm. December 12, 2018). In 2018, staff noted that gypsum was being deposited on the refuge at concentrations that coats plants, leading to cancellation of surveys for the Lange's metalmark in some parts of the refuge (Susan Euing pers. comm. August 17, 2018). In 2019, after several weeks into the Lange's metalmark survey season, ADNWR staff confirmed that no surveys had been canceled due to concerns about gypsum dust deposition (Louis Terrazas pers. comm. September 10, 2019). The magnitude of this potential stressor requires further investigation and Service partnership with G-P is ongoing.

5. Habitat degradation due to rogue hiking/trails

This activity may cause direct injury or mortality to the Lange's metalmark, to its host and food plants, and to *O.d.* subsp. *howellii* and *E.c.* var. *angustatum* from trampling while also increasing potential for accidental introduction of wildfire from hikers. These threats and stressors were significantly reduced when ADNWR was fenced in 1986 and the 2008 Five-Year Review (Service 2008) no longer considered recreational and pedestrian traffic to be a significant threat. However, ADNWR staff note that incidence of trespassing and human encampments at ADNWR has increased in the past several years (Susan Euing pers. comm. December 12, 2018).

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

These activities represent a threat to the Antioch Dunes species from direct mortality of any individual(s) collected and a reduction in annual recruitment by killing or injuring reproductive individuals.

C. Disease or predation

Arnold (1980 in Service 2008) 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). The magnitude of this stressor requires further investigation.

Evidence exists of *O.d.* subsp. *howellii* infestation by beetles (possibly family Chrysomelidae), which feed on petals, pollen, and seed pods. Also, in the early 1980s up to 50% of *O.d.* subsp. *howellii* was infested with small mirid bugs (family Miridae of the insect order Hemiptera) that prey upon *O.d.* subsp. *howellii*, and these insect predators remained an identified threat in 2008 (Service 2008). The magnitude of this stressor requires further investigation.

Three moth taxa are known to prey upon *E.c.* var. *angustatum*; a fairy moth (*Chalceopla simpliciealla*), an egg-eating moth (*Calculus* spp.), and the diamond back moth (*Plutella xylostella*) (Service 2008). Pavlik *et al* (1988b) determined that pre-dispersal predation of seeds significantly impacted reproduction during studies conducted in 1987 and 1988. The magnitude of this stressor requires further investigation.

D. Inadequacy of existing regulatory mechanisms

The 2008 Five-Year Review (Service 2008) reviewed Federal, State, and local regulatory protections and noted no specific inadequacies.

E. Other natural or manmade factors affecting its continued existence

1. Wildfire

Because the Lange's metalmark remains above ground, it is susceptible to injury or mortality from wildfire. Due to its currently limited distribution and small population size, a single wildfire could be catastrophic to the species. Wildfire may also cause direct mortality of Lange's metalmark's host and food plants.

Wildfire may cause direct mortality of *O.d.* subsp. *howellii* and *E.c.* var. *angustatum* plants during vulnerable life stages. These stages include the period from germination during the beginning of the wet season in December through the deposition of seeds in mid-summer. However, historical evidence indicates that the native plants may recover rather quickly from a wildfire (Service 2008). Any mortality would also result in reduced annual recruitment by killing or injuring reproductive individuals. The threat extends to pollinators and other pollinator plant species.

2. Fuelbreak discing

Fuelbreak discing may cause direct injury or mortality to Lange's metalmark, its host and food plants, and to *O.d.* subsp. *howellii*, and *E.c.* var. *angustatum*. However, it also creates open, disturbed, sand/soil that may be suitable for

colonization by *O.d.* subsp. *howellii* and *E.c.* var. *angustatum*, as well as invasive vegetation. The net impact of this activity to listed plant resilience is unquantified.

3. Loss of pollinators

Lange's metalmark is addressed as a pollinator for this discussion of the potential threat posed by possible insecticide drift from mosquito abatement spraying on neighboring properties (Richmond *et al* 2015). The Mosquito Abatement District allows for spraying of insecticides to reduce the incidence of West Nile Virus at a wetland adjacent to the Stamm Unit of the ADNWR. The spray could drift on to the refuge and affect pollinators, such as Lange's metalmark and those that pollinate *O.d.* subsp. *howellii* or *E.c.* var. *angustatum*. While ADNWR staff have worked with county mosquito control staff to minimize effects from this potential threat, the magnitude of this stressor requires further investigation.

As of the 2008 Five-Year Review, there was no evidence that lack or loss of pollinators has negatively impacted *O.d.* subsp. *howellii* or *E.c.* var. *angustatum* (Service 2008), but both species require cross-pollination, so an adequate pollinator population is necessary. Bees are suspected pollinators for both species and hawkmoths may also be pollinators for the primrose; however, actual pollinator taxa are unknown. This potential threat requires investigation.

4. Low population numbers

Extinctions and declines of Lepidoptera species have been widely observed nationwide with building evidence that the cause generally entails both environmental and genetic factors (New 2014). Considering its current 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 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, it is unknown whether genetic variability has been reduced by the release of offspring from just a few individuals into a declining population. A concern is that annual releases may lead to increased inbreeding, as very small numbers of source animals (with no control for possible sibling mating of the collected foundresses) may contribute large components of the actively breeding population after release of captive reared adults/larva. If there has been reduction in genetic representation and inbreeding suppression, extinction risk may have increased with negative effects on egg hatching rates, larval survival, and adult longevity (Nieminen *et al* 2001, Saccheri *et al* 1998). 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.

Oenothera deltooides subsp. *howellii* and *E.c.* var. *angustatum* are threatened by few and small populations that are limited to a small and localized distribution, which increases the risk of extirpation and extinction due to: (1) Reduced resiliency (the ability of a species to withstand stochastic disturbance; resiliency is positively related to population size and growth rate and may be influenced by connectivity among populations); (2) Low redundancy (spreading risk among multiple populations or a large area to minimize the potential loss of the species from catastrophic events); and (3) Low representation (the breadth of genetic and environmental diversity within and among populations that influences the ability of a species to adapt to changing environmental conditions over time).

5. Climate change

An emerging threat for the Lange's metalmark (as for many other butterfly species) is climate change. Distribution trends have been generally documented in many different taxa; but specifically, there is evidence of butterflies declining in the southern portions of their range as well as expanding their range northward, and it has been noted that the rate of host plant senescence may be increasing, causing asynchrony with butterfly hosts (Parmesan 2007, Forister *et al* 2010). Specific to the Mediterranean climate regime of California, greater frequency of extremely wet and dry events are projected (Swain *et al* 2018). Weather extremes and long-term shifts in climate at Antioch could further exacerbate current threats to the Lange's metalmark.

Oenothera deltooides subsp. *howellii* and *E.c.* var. *angustatum* are threatened by multiple environmental effects anticipated with climate change, which may result in loss of habitat, altered temperature and moisture regimes causing direct mortality and/or impaired reproduction, and altered temperature and moisture regimes causing indirect mortality and/or impaired reproduction via phenological mismatches with pollinators and between pollinators and their host and/or other nectar plants (Richmond *et al* 2015).

RECOVERY CRITERIA

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the Act are no longer necessary and a species may be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants. Downlisting is the reclassification of a species from an endangered species to a threatened species. The term "endangered species" means any species (species, sub-species, or Distinct Population Segment) which is in danger of extinction throughout all or a significant portion of its range. The term "threatened species" means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Revisions to the Lists, including delisting or downlisting a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered species or threatened species (or not) because of threats to the species. Section 4(b) of the Act requires that the determination be made “solely on the basis of the best scientific and commercial data available.” Thus, while recovery plans provide important guidance to the Service, States, and other partners on methods of minimizing threats to listed species and measurable objectives against which to measure progress towards recovery, they are guidance and not regulatory documents.

Recovery criteria should help indicate when we would anticipate that an analysis of the species’ status under section 4(a)(1) would result in a determination that the species is no longer an endangered species or threatened species. A decision to revise the status of or remove a species from the Federal Lists of Endangered and Threatened Wildlife and Plants, however, is ultimately based on an analysis of the best scientific and commercial data then available, regardless of whether that information differs from the recovery plan, which triggers rulemaking. When changing the status of a species, we first propose the action in the *Federal Register* to seek public comment and peer review, followed by a final decision announced in the *Federal Register*.

Recovery Criteria Amendment

As explained above, it is necessary that we frame recovery criteria in terms of threats assessed relative to the five threat factors under section (4(a)(1). The five factors are discussed in the *Justification for Criteria* and *Rationale for Criteria* sections, below. A summary of how the criteria fit into the existing framework of, and address, the five factors and recovery objective and actions is provided below in the *Rationale for Recovery Criteria* and cross-referenced in Tables 4-6.

Additionally, the Service uses the conservation biology principles of resiliency, redundancy, and representation (the 3 Rs) in various applications when describing species viability. The 3Rs were first described by Shaffer and Stein (2000) and relate to viability based on the concept that, in general, species extinction risk will decrease, or at least does not increase, with increases in resiliency, redundancy, and representation. In the Service’s use of the terms, they are defined as follows: Resiliency is the ability of a species to withstand stochastic disturbance and is positively related to population size and growth rate and may be influenced by connectivity among populations; Redundancy is spreading risk among multiple populations or a large area to minimize the potential loss of the species from catastrophic events; and Representation is the breadth of genetic and environmental diversity within and among populations that influences the ability of a species to adapt to changing environmental conditions over time. The 3 Rs are addressed in the *Justification for Recovery Criteria* section below. Justification for the Lange’s metalmark criteria is presented in the context of the 3 Rs and justifications for the *Oenothera deltooides* subsp. *howellii* and *Erysimum capitatum* var. *angustatum* criteria are presented in the context of population and habitat and metrics with reference to the 3 Rs.

We establish both downlisting and delisting criteria for Lange’s metalmark, *Oenothera deltooides* subsp. *howellii*, and *Erysimum capitatum* var. *angustatum* as follows:

Lange's Metalmark

Downlisting Recovery Criteria

The Lange's metalmark can be considered for downlisting when:

1. At least three populations are established at separate, managed locations².
2. All sites have implemented adaptive management plans to provide dune habitat that provides a disturbance regime that supports naked-stem buckwheat (with some degree of natural recruitment) and a diversity of nectar plants to provide adult food source throughout the flight period. Vegetation monitoring has been conducted over a 15-year period.
3. As determined by direct monitoring, each population must have a 15-year moving median of 2,600 individuals *and* minimum effective population size of 50 with a stable or increasing growth rate (λ).

Delisting Recovery Criteria

The Lange's metalmark can be considered for delisting when:

1. At least five populations are established at separate, managed locations².
2. All sites have implemented adaptive management plans to provide dune habitat that provides a natural disturbance regime that supports self-sustaining naked-stem buckwheat (all plants are naturally recruiting) and a diversity of nectar plants to provide adult food source throughout the flight period. Monitoring has been conducted over a 15-year period.
3. a) As determined by direct monitoring, each population must have a 15-year moving median of 2,600 individuals *and* minimum effective population size of 500 with a stable or increasing growth rate (λ); *OR*
b) population viability analysis determines that Lange's metalmark, range-wide, has a 95% probability of persistence over a 100-year period.

Oenothera deltoides subsp. howellii

Downlisting Recovery Criteria

Oenothera deltoides subsp. *howellii* will be considered for downlisting when:

1. There are at least five separate self-sustaining (all plants are naturally recruiting*) populations, including: at least three populations, each with a 15-year moving median of at least 4,800 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants.

² Sites should be separated at sufficient distance to provide for threat abatement from fires, and to provide some level of diversity in ecological setting, but may also benefit from some level of connectivity. It is not possible at this time to provide a reliable, one-size-fits-all quantitative metric for this variable, as the answer will be site and condition dependent.

- a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.
- b. Populations should be protected and have in place a long-term management plan for the conservation of *O.d.* subsp. *howellii* and commitment for implementation of the plan.

Delisting Recovery Criteria

Oenothera deltoides subsp. *howellii* will be considered for delisting when:

- 1. There are at least seven separate self-sustaining (all plants are naturally recruiting*) populations including: at least five populations, each with a 15-year moving median of at least 4,800 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants. *OR*, population viability analysis determines that *O.d.* subsp. *howellii* has a range-wide 95% probability of persistence over a 100-year period.
 - a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.
 - b. Populations should be protected and have in place a long-term management plan for the conservation of the *O.d.* subsp. *howellii* and commitment for implementation of the plan.
- 2. A post-delisting monitoring plan for the species has been developed.

*Any flowering individuals counted as naturally recruiting would have to be \geq two flowering seasons post-outplanting. This would indicate the individual has completed the life cycle in situ.

Erysimum capitatum* var. *angustatum

Downlisting Recovery Criteria

Erysimum capitatum var. *angustatum* will be considered for downlisting when:

- 1. There are at least five separate self-sustaining (all plants are naturally recruiting*) populations of: at least three populations, each with a 15-year moving median of at least 7,000 flowering plants; and at least two populations, each with a 15-year moving median of at least 4,000 flowering plants.
 - a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.
 - b. Populations should be protected and have in place a long-term management plan for the conservation of *E.c.* var. *angustatum* and commitment for implementation of the plan.

Delisting Recovery Criteria

Erysimum capitatum var. *angustatum* will be considered for delisting when:

1. There are at least seven separate self-sustaining (all plants are naturally recruiting*) populations of: at least five populations, each with a 15-year moving median of at least 7,000 flowering plants; and at least two populations, each with a 15-year moving median of at least 4,000 flowering plants. *OR*, population viability analysis determines that *E.c. var. angustatum* has a range-wide 95% probability of persistence over a 100-year period.
 - a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.
 - b. Populations should be protected and have in place a long-term management plan for the conservation of *E.c. var. angustatum* and commitment for implementation of the plan.
2. A post-delisting monitoring plan for the species has been developed.

*Any flowering individuals counted as naturally recruiting would have to be \geq two flowering seasons post-outplanting. This would indicate the individual has completed the life cycle in situ.

Justification for Recovery Criteria

Lange's Metalmark

Resiliency

In addressing resiliency, we sought to establish an individual population MVP size. We attempted a PVA (per Schultz and Hammond 2003) and found the underlying Lange's metalmark data insufficient to derive any confidence in an estimated MVP size. We then searched the literature to identify possible surrogates, looking for con-generics or even butterflies from the same or different families with similar ecology.

We reviewed 18 PVAs for 11 butterfly taxa (bog fritillary [*Procllossiana eunomia*, *Boloria eunomia*], cranberry fritillary [*Boloria aquilonaris*], checkered blue butterfly [*Scolitantides orion*], dingy skipper [*Erynnis tages*], false heath fritillary [*Melitaea diamine*], Fender's blue butterfly [*Icaricia icariodes fenderi*], Glanville fritillary [*Melitaea cinxia*], marsh fritillary [*Euphydryas aurinia*], silver-spotted skipper [*Hesperia comma*], silver-studded blue butterfly [*Plebejus argus*], woodland brown butterfly [*Lopinga achine*], from 13 publications (Bergman and Kindvall (2004), Bulman *et al* (2007), Gutiérrez (2005), Hanski (1994), Hanski and Thomas (1994), McIntire *et al* (2007), Sawchik *et al* (2002), Schtickzelle and Baguette (2004), Schtickzelle *et al* (2005a), Schtickzelle *et al* (2005b), Schultz and Hammond (2003), Wahlberg *et al* (1996), and Wahlberg *et al* (2002)). In evaluating their biology/ecology/life history, combined with the underlying MVP model for overall suitability, our qualitative assessment relied on evaluation of what we considered to be logical individual and combined criteria for each species and the respective MVP model.

Assessing Butterfly Biology/Ecology/Life History Surrogate Suitability for Lange's Metalmark

We compiled brief biological, ecological, and life history information for each of the 11 butterfly species from the following references: Baguette (2003); Bergman and Landin (2002); Bergman and Kindvall (2004); Fric *et al* (2010); Gutiérrez *et al* (1999); Hanski and Thomas (1994);

International Union for Conservation of Nature (No Date); Komonen *et al* (2008); McIntire *et al* (2007); NatureServe (2019); Ojanen *et al* (2013); Radchuck *et al* (2013); Schtickzelle and Baguette (2004); Schtickzelle *et al* (2005a); Schultz and Hammond (2003); Service (No Date); Wahlberg *et al* (2002b); Wikipedia (No Date a); Wikipedia (No Date b); Wikipedia (No Date c); and Wisconsin Department of Natural Resources (No Date).

In evaluating surrogate suitability based on the biology/ecology/life history of the 11 butterfly species, we gave primary attention to elements such as univoltine vs. multivoltine (producing one brood per year versus multiple broods per year), dispersal distances, and differences in specialized ecology (e.g., Myrmecophilism - dependence on support by certain ants). Based on Lange's metalmark biology/ecology/life history, we found the bog fritillary to be a good surrogate and we identified moderately good surrogates in the marsh fritillary and Fender's blue butterfly. Our evaluations for four of the other species indicated moderate suitability (woodland brown butterfly) or poor-moderate suitability (dingy skipper, false heath fritillary, and silver-spotted skipper). The remaining four species (checkered blue butterfly, cranberry fritillary, Glanville fritillary, and silver-studded blue butterfly) were considered not suitable as Lange's metalmark surrogates.

Assessing MVP Model Suitability

In evaluating MVP model suitability from the 13 publications, we looked at several parameters and considerations. We did not evaluate the suitability of MVP models (or similar metrics such as equilibrium densities) for the four species that were deemed unsuitable based on biological, ecological, and life history considerations. For the MVP models that we did evaluate, we considered the following:

- 1) Whether an individual population MVP size was specifically referenced and/or generated (e.g., some publications did not cite or generate an individual MVP size, some generated minimum viable metapopulation sizes, and some were habitat-based assessments).
- 2) Whether the PVA model relied on hypothetical data and/or scenarios that seemed inappropriate for surrogacy to LMB and MVP size (e.g., some models incorporated hypothetical data and some modeled hypothetical future scenarios such as combined effects of different climate change projections and grazing regimes to habitat).
- 3) Whether the PVA was too specific to its subject species (e.g., modeling effects to specific species-reliant habitat condition and connectivity from several proposed local habitat management scenarios).
- 4) Whether the model was density-dependent. We felt that density-dependent population dynamics (vs. density-independent) was a better fit for the sedentary Lange's metalmark.
- 5) If the date of publication preceded Traill *et al* (2007), whether or not its baseline data were used in the Traill *et al* (2007) meta-analysis. Traill *et al* (2007) covered 141 sources and 212 species (after filtering 529 sources and 2,202 species) in their analysis. Given their intensive screening, we considered it noteworthy if a publication date was prior to, but not used in Traill *et al* (2007).
- 6) We considered those with habitat area requirements (e.g., X hectare(s) with an equilibrium density of Y individuals) less suitable because we are not speaking to habitat area requirement in our recovery criteria for Lange's metalmark at this time.

- 7) We also considered those with undefined terms (e.g., “many” and “long-term”) to be less suitable.

Based on these criteria, we considered the MVP models in the Sawchik *et al* (2002) assessment for the bog fritillary and the Schtickzelle *et al* (2005a) assessment for the marsh fritillary to have the best suitability as Lange’s metalmark surrogates. We considered the suitability of the MVP model for the Schultz and Hammond (2003) assessment for the Fender’s blue butterfly to be moderately-poor. These three publications were used in Traill *et al* (2007) for the respective species. Six of the 13 publications we reviewed (Bergman and Kindvall (2004), Bulman *et al* (2007), Gutiérrez (2005), McIntire *et al* (2007), Wahlberg *et al* (1996), and Wahlberg *et al* (2002a)) did not cite or generate an individual population MVP size. Our evaluation of the MVP models in the remaining four publications assessed three (Hanski (1994), Hanski and Thomas (1994), and Schtickzelle and Baguette (2004)) as not very suitable, and we did not assess the model in Schtickzelle *et al* (2005b) because the species (cranberry fritillary) was considered unsuitable based on its biology/ecology/life history.

Assessing Combined Biology/Ecology/Life History and MVP Model Suitability

When combining the biology/ecology/life history and MVP model suitability into an overall surrogate suitability assessment, we made the following decisions: (1) if a species biology/ecology/life history was not suitable, it was considered unsuitable overall; (2) if an MVP model was not suitable, it was considered unsuitable overall; (3) evaluations that did not contain at least one good, moderately-good, or moderate rating were considered not very suitable; and (4) those with combined overall assessments of not very suitable or not suitable were not advanced for consideration as a potential surrogate MVP size for LMB.

Based on these criteria, we identified three MVP published estimates as having the best combined biology/ecology/life history and MVP model suitability for Lange’s metalmark. We considered the Sawchick *et al* (2002) MVP model and size for bog fritillary and the Schtickzelle *et al* (2005a) MVP model and size for marsh fritillary to have good overall suitability. These two publications were used in Traill *et al* (2007) for the respective species. The good suitability of the Sawchick *et al* (2002) MVP model combined with the good biology/ecology/life history suitability of the bog butterfly seemed to be a somewhat better fit overall, as compared to the good suitability of the Schtickzelle *et al* (2005a) MVP model combined with the moderately-good biology/ecology/life history suitability of the marsh fritillary. The other publication cited in Traill *et al* (2007) is the Schultz and Hammond (2003) MVP model for Fender’s blue butterfly, which we found to be a moderately-good fit based on biology/ecology/life history. However, we considered this MVP model poorly-moderately suitable, due to some degree of acknowledged arbitrariness by the authors in setting the initial population size and vital rate parameters in the model, so we considered the combined overall suitability moderately-poor.

We then met with our Lange’s metalmark technical workgroup and the peer reviewer who submitted a comment about the recovery criteria minimum population size proposed in our draft amendment, to discuss these three MVP sizes with the best combined suitability. Based on input from the technical workgroup and peer reviewer, we identified the importance of using more than one species and MVP model to buffer our uncertainty from the lack of a very robust

surrogate species. We also decided to round the resulting MVP size to the nearest hundred to avoid implied precision in MVP sizes given the lack of confidence intervals for our selected MVP sizes. Based on that, we combined the Sawchick *et al* (2002) MVP size for bog fritillary and the Scthickzelle *et al* (2005a) MVP size for marsh fritillary as follows:

- 1) We used the Sawchick *et al* (2002) MVP size of 2,000 females for bog fritillary, adjusted to 3,374 individuals using empirical Lange's metalmark female:male densities from ADNWR in 1977 (41.8 females/acre and 28.7 males/acre, or 1.456 females:1.0 male) reported by Arnold (1980 in USFWS 1984).
- 2) We used the Scthickzelle *et al* (2005a) MVP size of 1,740 individuals for marsh fritillary.
- 3) We averaged the two, yielding a value of 2,557 individuals, and rounded to the nearest hundred, resulting in 2,600 individuals.

We therefore conclude that our recovery criteria minimum population size of a 15-year moving median of 2,600 individuals is a reasonable estimate of an MVP for the Lange's metalmark until, and if, further research, and improved monitoring, defines some other figure with greater statistical certainty.

Effective Population Size in the Lange's metalmark Recovery Criterion

The effective population size (effective population size is explained in the description for the *Recovery Plan for the Lakeside Daisy* in the *Oenothera deltoides subsp. howellii* and *Erysimum capitatum var. angustatum*, *Population Metrics, Size and Number of Individual Populations* section below) for downlisting was chosen based on genetic considerations, namely the general 50/500 rule that argues that an effective population size of at least 50 is needed to avoid inbreeding depression and thereby reduce the likelihood of extinction in the short-term, and an effective population size of 500 to avoid loss of quantitative genetic variation which would reduce extinction risk in the long-term (Rieman and Allendorf 2001, Jamieson and Allendorf 2012, Franklin 1980, Soulé 1980, Nelson 1987). We recognize that this is a general rule, and an effective population size of 50 or 500 may not be the appropriate benchmarks for this particular subspecies. However, without additional information on the current and past effective population size, it is not possible to provide a more specific estimate of required effective population size for this subspecies.

Redundancy

It is expected that a single butterfly population can experience significant growth where there is suitable larval habitat (Thomas *et al* 2011). Research is required to better understand what can be considered suitable, and even optimal, habitat. It should be noted that Riodinidae, the family of butterflies to which Lange's metalmark belongs, are generally sedentary so there is no expectation of natural recolonization or significant gene flow between populations unless they are within close proximity (New 1993, ITIS 2019). Considering this, we do not treat Lange's metalmark populations as metapopulations and suitable habitat must be managed so that butterflies will persist within a representative unit as a single population. With sufficient abundance and stable population trend, we find three and five such units should provide sufficient population redundancy to denote reduced risk of extinction and recovery, respectively.

Representation

As there is no reliable record of the Lange's metalmark's historical distribution, we are suggesting that three and five units containing individual MVPs to enhance range wide persistence via population redundancy will also convey a side benefit of increasing representation. It is not possible at this time to characterize specific attributes of newly restored habitat required to broaden ecological representation, so these features of the units are areal estimates (i.e., acreage) for the present criteria. Considering the importance of the larval foodplant, naked-stem buckwheat, it is imperative that all representative units be managed as dune habitat. This should consist of natural successional and disturbance processes which promote the growth and recruitment of naked-stem buckwheat as well as other nectar sources.

Due to the Lange's metalmark's close relationship with the naked-stem buckwheat, and possibly other plant species, and the use of PVA results as an alternative recovery criterion threshold, we selected the 15-year moving median interval to evaluate population size for the same reasons it was selected for the Antioch Dunes listed plants (refer to the *Oenothera deltooides subsp. howellii* and *Erysimum capitatum* var. *angustatum*, *Population Metrics, Size and Number of Individual Populations, Population Monitoring Time Interval* section below for explanation). Also, as the response of the larval foodplant and the Lange's metalmark to climate change is not yet known, it is not addressed here, but will be discussed more in the upcoming five-year review.

Oenothera deltooides subsp. howellii* and *Erysimum capitatum* var. *angustatum

Population Metrics

Increasing the size of individual populations and the species' range-wide abundance improves a species' resiliency, or the ability to withstand stochastic disturbance. Because we lack information on species-specific biology, genetic information, and sufficient survey data, we believe using population numbers from the references described below reflect the current best available information to estimate desired population resiliency. Additionally, increasing the number of individual populations (redundancy) spreads the risk for potential loss of the species from catastrophic events. As narrow endemics, *Oenothera deltooides* subsp. *howellii* and *Erysimum capitatum* var. *angustatum* are restricted to relatively small ranges. Because the ranges are small, something like drought may impact most of or the entire range. This makes having multiple populations critical, since these may be able to withstand such events differently due to any site-specific microclimatic or ecological variances.

Size and Number of Individual Populations

We used a standardized MVP size for plants (per Traill *et al* 2007), existing recovery criteria from other narrow endemic plant taxa, and flowering count data in a relatively "good" year from the ADNWR populations, as comparative references in developing the recovery criteria. It is important to note that these references do not provide precisely translatable population size thresholds since they vary by taxon, availability of data, and the methods used to develop the criteria. Additionally, the other recovery plan examples may include additional criteria (other than population sizes and numbers) that may not be articulated in the descriptions below. We

also reviewed annual precipitation data and PVA minimum data time-series recommendations in considering an appropriate monitoring interval. We attempted PVA (per Morris *et al* 1999) for *O.d.* subsp. *howellii* and *E.c.* var. *angustatum*, but because of the high uncertainty associated with the results due to data limitations, we did not use them to estimate necessary population size relative to a probability of persistence (for example, a 95% probability of persistence for 100 years). However, because we believe that, when possible, use of PVA is an appropriate evaluation tool, we allowed for its use as an alternative when considering delisting. A brief description of these references and discussion follows:

Standardized MVP and Other Species Population Criteria Examples

Trail *et al* (2007) established a standardized MVP for plants of 4,824 individuals (with 95% confidence bounds of 2,512-15,992 individuals), based on analysis of published studies for 22 taxa of mosses, ferns, dicotyledons, monocotyledons and gymnosperms. They defined standardized viability as a persistence probability of 99% over 40 generations.

The *Recovery Plan for Clarkia imbricata (Vine Hill Clarkia)* (Service 2015) established downlisting criteria for *Clarkia imbricata*, a narrow endemic annual species in the same family (Onograceae) as *O.d.* subsp. *howellii*, to include three separate locations with a 10-year average of 4,000 plants or more. Delisting criteria were the same as downlisting criteria, except that 5 separate locations are required.

The *Seven Coastal Plants and the Myrtle's Silverspot Butterfly Recovery Plan* (Service 1998) established delisting criteria for three subspecies of *Erysimum menziesii* (Menzies' wallflower) that occur in coastal sand dunes covering several thousand acres across three counties. The criteria called for population sizes that included: three populations with 300 individuals and two populations with 5,000 or more individuals for *E.m.* subsp. *eurekaense*; four or more distinct sites, with five separate populations with an average of 300 plants and two populations with an average of 5,000 individuals for *E.m.* subsp. *menziesii*; and at least two populations averaging at least 5,000 individuals and three populations averaging at least 300 individuals for *E.m.* subsp. *yadonii*.

The *Recovery plan for the Lakeside Daisy (Hymenoxys acaulis var. glabra)* (Service 1990) established delisting criteria for the Lakeside daisy, which is self-incompatible (requires outcrossing for seed production), similar to *O.d.* subsp. *howellii* and possibly *E.c.* var. *angustatum*, for a minimum size for restored populations of at least 5,000 adult plants, maintained for 15 years (Service 1990). The population size was selected to buffer against high turnover rates (mortality and recruitment) and provide for adequate effective population size (N_e). The N_e is the number of individuals that an idealized population would need to have in order for some specified parameter of interest to be the same in the idealized population as in the real population. The specified parameter of interest with respect to minimally viable population size commonly relates to within-population/species genetic diversity. In most populations, the census population size (N) is usually larger, and in some case much larger, than the N_e . For *H.a.* var. *glabra*, the N_e was estimated as the number of compatible individual or mating groups within a population and DeMauro (1988 in Service 1990) found that among *H.a.* var. *glabra* used in initial breeding experiments, the N_e was 30% lower than the N .

Survey Data from Antioch Dunes National Wildlife Refuge

For the annual survey data from ADNWR (1985-2017) that we used, in any given year flowering plants may not occur in every subunit and do not occur with uniform density across units or years. The years of data we selected for use represented years with some of the higher flowering plant counts during the period of 1985-2017 and for which no management activities that might have affected count numbers (such as outplanting, which may inflate count numbers) were recorded for the subunits. Flowering plant numbers for all subunits with flowering plant surveys in the subject year (including zero counts) were summed and then divided by the sum of acreages for the same subunits to generate an average of flowering plants/acre (density). By using an average density instead of a maximum density, our approach here is intended to estimate potential population numbers that are both realistic and representative of “good” conditions for the species. Additionally, based on our analysis it appears *E.c. var. angustatum* occurred at ADNWR at higher densities than *O.d. subsp. howellii* and for this reason, we apply higher population size thresholds to *E.c. var. angustatum* than to *O.d. subsp. howellii* and higher necessary habitat area estimates to *O.d. subsp. howellii* than to *E.c. var. angustatum*.

Population Monitoring Time Interval

The 15-year moving median interval for evaluating population size for *O.d. subsp. howellii* and *E.c. var. angustatum* was selected as a minimum time interval to capture highly variable plant population fluctuations due to precipitation extremes, which have a clear proximate relationship with plant abundance. We validated this period for our data smoothing based on an empirical minimum time frame necessary to capture several periods of wet and dry years and a minimum annual data series time frame necessary for PVA (Morris *et al* 1999), as described below.

Plant survival and reproduction may be highly influenced by within- and across-year precipitation/drought cycles, especially for short-lived perennials such as *O.d. subsp. howellii* and *E.c. var. angustatum*. For this reason, monitoring vegetation across a sufficient spectrum of climate variability, including precipitation extrema, can yield a more comprehensive view of population status and trend than monitoring metrics within a narrower climatic scope. Based on historical data, annual precipitation across California is highly variable, especially as compared to the rest of the nation (Dettinger *et al* 2011). We looked at historical precipitation data from a variety of sources, but it was difficult to find a robust long-term data series. We therefore investigated known, aggregated water indices including the Sacramento River and Eight River Runoff Water Year Hydrologic Classification Indices that are not influenced by water management activities, such as reservoir storage (Craig Anderson pers. comm. February 8, 2018). We also reviewed available data from 110 years of the Sacramento Basin Precipitation Index (SBPI), which is influenced by water management activities, to try to determine the minimum time interval required to capture at least three “critical dry” and “wet” water year types. This analysis indicates an interval as short as 12 years, on average, may capture this representative range of wet and dry years (Derek Hilts pers comm. October 31, 2018). Finally, we considered that California is also subject to decadal shifts in precipitation patterns, which also contribute to a variable climatic regime (Mantua *et al* 1997) that would likely influence intermediate term plant population dynamics.

Together, the data clearly indicate that California inter-annual precipitation is highly variable. Therefore, a longer monitoring interval would better express fluctuations within this inter-decadal periodicity (i.e., 30 years may actually be necessary to more accurately represent local climatic variability as it impacts plant population dynamics on a macro-ecological scale). Additionally, since we include use of PVA results as an alternative recovery criterion threshold, using a 15-year interval should allow for more robust PVA results than the minimum 10-year data series recommended by Morris *et al* (1999). Presumably, the inherent climatic variability that is observed and expected in California's weather future has an attendant influence on plant populations that suggests a longer data smoothing interval is required to derive a more representative abundance benchmark. Based on this, we believe a 15-year timeframe is the minimum interval necessary to capture sufficient climatic variability and provide a reasonable quantitative benchmark indicating population viability.

Oenothera deltooides subsp. howellii

Flowering plant count data from subunits in 1988 for the Stamm Unit and from 1993 for the Sardis Unit were used to estimate an average density and then an average total number of flowering plants for the ADNWR. For the Stamm Unit, an average density of 106 flowering plants/acre was estimated from seven subunits (of 24 total subunits) with a total of 1,874 flowering plants on approximately 18 acres (of 41 total acres). Applying this average density to the entire 41-acre Stamm Unit approximates to 4,338 flowering plants. For the Sardis Unit, an average density of 61 flowering plants/acre was estimated from 20 subunits (of 29 total subunits [versus 34 total subunits for *Erysimum capitatum* var. *angustatum* survey information because subunits were split differently between *Oenothera deltooides* subsp. *howellii* and *E.c.* var. *angustatum* surveys]) with a total of 1,528 flowering plants on approximately 25 acres (of 26 total acres). Applying this average density to the entire 26-acre Sardis Unit approximates to 1,580 flowering plants. Adding the two units together brings the total to a “good year” average of 5,916 flowering plants on the 67 acres.

We used a combination of the Traill *et al* (2007) MVP and the approximated densities and population sizes outlined above, to describe population sizes necessary for large and medium self-sustaining populations in the criteria as follows: a large population is defined as a 15-year moving median of at least 4,824 naturally recruiting flowering plants, after the Traill *et al* (2007) standardized MVP, which we have rounded to the nearest hundred (4,800) to avoid implied precision in MVP size given the lack of confidence intervals for our estimated MVP size; and a medium population is defined as 15-year moving median of at least 1,500 naturally recruiting flowering plants, after the average density calculated from the Sardis Unit at ADNWR. By using these population sizes we expect that the large populations should have sufficient within-population resilience and the medium populations may support additional species (range-wide) resilience by supporting additional genetic diversity that may be shared with the other populations over time. Additionally, because the habitat area expected for each location may not be very big and the overall distribution of locations may be geographically restricted (see below), we felt that five and seven separate locations provide for necessary redundancy to buffer against catastrophic events. Overall, the size and number of populations is based on a resiliency and redundancy step-wise from a 15-year moving median of at least 17,400 naturally recruiting flowering plants across five locations for reclassification to threatened status and a 15-year

moving median of at least 27,000 naturally recruiting flowering plants across seven locations for delisting.

Erysimum capitatum var. *angustatum*

Flowering plant count data from subunits in 1997 for the Stamm and Sardis Units were used to estimate an average density and then an average total number of flowering plants for the ADNWR. For the Stamm Unit, an average density of 115 flowering plants/acre was estimated from 11 subunits (of 24 total subunits) with a total of 2,956 flowering plants on approximately 25.64 acres (of 41 total acres). Applying this average density to the entire 41-acre Stamm Unit approximates to 4,727 flowering plants. For the Sardis Unit, an average density of 481 flowering plants/acre was estimated from 19 subunits (of 34 total subunits [versus 29 total subunits for *Oenothera deltooides* subsp. *howellii* survey information because subunits were split differently between *O.d.* subsp. *howellii* and *Erysimum capitatum* var. *angustatum* surveys]) with a total of 7,547 flowering plants on approximately 15.69 acres (of 26 total acres). Applying this average density to the entire 26-acre Sardis Unit approximates to 12,506 flowering plants. Adding the two units together brings the total to a “good year” average of 17,223 flowering plants on the 67 acres.

We used the approximated densities and population sizes outlined above, to describe population sizes necessary for large and medium self-sustaining populations in the criteria as follows: a large population is defined as a 15-year moving median of at least 7,000 naturally recruiting flowering plants; and a medium population is defined as a 15-year moving median of at least 4,000 naturally recruiting flowering plants, after the average density calculated from the ADNWR. By using these population sizes we expect that the large populations should have sufficient within-population resilience and the medium populations may support additional (range-wide) species resilience by supporting additional genetic diversity that may be shared with the other populations over time. Additionally, because the habitat area expected for each location may not be very extensive and the overall distribution of locations may be geographically restricted (see below), we felt that five and seven separate locations provided for necessary redundancy to buffer against catastrophic events. Overall, the size and number of populations is based on a resiliency and redundancy step-wise from a 15-year moving median of at least 29,000 naturally recruiting flowering plants across five locations for reclassification to threatened status and a 15-year moving median of at least 43,000 naturally recruiting flowering plants across seven locations for delisting.

Separation Distance Between Individual Populations

We used a maximum distance travelled by pollinators to estimate a functional separation distance between individual populations. However, since species-specific pollinators are not known for *Oenothera deltooides* subsp. *howellii* or *Erysimum capitatum* var. *angustatum*, we looked at flight distances for several species of bees that may serve as pollinators, as reference. The Recovery Plan describes that Arnold (pers. comm. 1982 in Service 1984) believed that bees were the primary pollinating agents for *O.d.* subsp. *howellii*. Diane Thomson (pers. comm. October 31, 2018) observed bees regularly visiting *O.d.* subsp. *howellii* flowers during four years of field work during her research on the primrose at ADNWR. The 2002 *Antioch Dunes National*

Wildlife Refuge, Comprehensive Conservation Plan (Service 2002) noted that unlike other Brassicaceae the wallflower does not require a specific pollinator and *E.c. var. angustatum* is pollinated by bees that nest in the open banks. Bees in these references were not identified to genus or species. The Recovery Plan identifies several species of the bee genus *Andrena* (*Perdita*) and one “new” species of sweat bee, the Antioch evening-primrose sweat bee (*Evyllaes* [*Lasioglossum*] sp. nov.), in a list of unique flora and fauna of the Antioch Dunes (Service 1984). Gregory (1963 in Service 1984) also noted that hawk-moths may be pollinators of *O.d.* subsp. *howellii*. We did not find references with information about foraging distances for hawkmoths, so they were not included in this analysis.

The flight distances of different bee species vary. In general, larger bees fly greater distances than smaller bees. For some of the larger bees, such as species of the genus *Bombus*, Wolf and Moritz (2008) measured the flight distance of *Bombus terrestris* at 267.2 meters (877 feet) +/- 180.3 meters (592 feet), with a maximum distance of 800 meters (2,625 feet). Osborne *et al* (2008) measured a routine foraging distance for *Bombus terrestris* of at least 1.5 kilometers (4,921 feet) from their colonies in a landscape providing forage resources at all distances. An average foraging distance for *B. vosnesenskii* ranged from 2.9 to 8.8 kilometers (9,514 to 28,871 feet) based on foragers genotyped in 2007 (Rao and Strange 2012). Medium-sized bees such as mining bees (*Andrena* spp.) or leafcutter bees (*Megachile* spp.) can fly 350-450 meters (1,148-1,476 feet) from the nest, and small bees, such as sweat bees (*Halictus* spp.) and small carpenter bees (*Ceratina* spp.) generally fly no more than 200 meters (656 feet) from their nest (Agriculture and Agri-Foods Canada 2014).

Using the list of bee genera named in the Recovery Plan and the flight distances listed above, we selected a separation distance of at least 1,500 feet to separate individual locations based on pollinators and expected cross-pollination. This distance is greater than the maximum foraging distance from a nest travelled by medium-sized bees (1,476 feet), such as those of the genus *Andrena*, and small bees (665 feet), such as those of the genus *Ceratina*, several species of which are also known from the ADNWR and are suspected pollinators. It does not exclude distances travelled by the larger bees (*Bombus* spp.). This separation distance may be revised, as appropriate, at a time when we obtain better information about pollinators.

The added consideration is that a natural and/or man-made firebreak between locations should exist to minimize shared catastrophic risk from wildfire during vulnerable life stages. Additionally, since the genetic diversity within and among current populations is unknown, at a time when we obtain information about genetics, we may revise, as appropriate, the parameters for separation and connectivity between and among individual populations.

Habitat Metrics

Oenothera deltoides subsp. *howellii*

Habitat supporting populations of *Oenothera deltoides* subsp. *howellii* may currently be limited to approximately two small populations (on approximately 26 acres and 41 acres at ADNWR) and two very small populations (on unknown acreages on Brannan and Browns Islands), so an increase in the number of locations and area of occupied suitable habitat is critical to reduce the

risks to the species from potential catastrophic events. Because we do not have robust information regarding historical habitat condition and species density, we used ADNWR data to estimate the area of suitable habitat that may be necessary to support the population sizes articulated in the criteria; for this same reason, we have not included habitat area requirements in the criteria, but rather habitat area estimates. Based on our estimated species densities (see discussion in the *Population Metrics* section, above), we estimate that amount of suitable habitat necessary to support the population sizes of *O.d.* subsp. *howellii* required in the criteria including: at least 40 acres to support the large populations (4,800 flowering plants) and at least 25 acres to support the medium populations (1,500 flowering plants). A stable or growing *O.d.* subsp. *howellii* flowering population size, demonstrated by the 15-year moving median discussed above under *Sizes and Numbers of Individual Populations*, will serve as a proxy for suitability of habitat.

Overall, these estimated suitable habitat acreages represent a resiliency and redundancy stepwise from a total of at least 170 acres across five populations for reclassification to threatened status and at least 250 acres across seven populations for delisting. The occupied suitable habitat acreages represent a significant increase (from approximately 67 to 170 and then to 250 acres) and fall within the range of what is estimated as the possible historical extent of the Antioch Dunes habitat portion (120-500 acres) of the broader interior dunes habitat type (6,800-8,400 acres).

Erysimum capitatum var. *angustatum*

Habitat supporting populations of *Erysimum capitatum* var. *angustatum* may currently be limited to approximately two small populations (on approximately 26 acres and 41 acres at ADNWR), so an increase in the number of locations and area of occupied suitable habitat is critical to reduce the risks to the species from potential catastrophic events. Because we do not have robust information regarding historical habitat condition and species density, we used ADNWR data to estimate the area of suitable habitat that may be necessary to support the population sizes articulated in the criteria; for this same reason, we have not included habitat area requirements in the criteria, but rather habitat area estimates. Based on our calculated species densities (see discussion in the *Population Metrics* section, above), we estimate that amount of suitable habitat necessary to support the population sizes of *E.c.* var. *angustatum* required in the criteria includes: at least 25 acres to support either the large (7,000 flowering plants) or medium (4,000 flowering plants) populations. A stable or growing *E.c.* var. *angustatum* flowering population size, demonstrated by the 15-year moving median discussed above under *Sizes and Numbers of Individual Populations*, will serve as a proxy for suitability of habitat.

Overall, these estimated suitable habitat acreages represent a resiliency and redundancy stepwise from a total of at least 125 acres across five populations for reclassification to threatened status and at least 175 acres across seven populations for delisting. The occupied suitable habitat acreages represent a significant increase (from approximately 67 to 125 and then to 175 acres) and fall within the range of what is estimated as the possible historical extent of the Antioch Dunes habitat portion (120-500 acres) of the broader interior dunes habitat type (6,800-8,400 acres).

Justification Summary for *Oenothera deltooides* subsp. *howellii* and *Erysimum capitatum* var. *angustatum*

In defining criteria for delisting, we strive to attain a breadth of genetic and environmental diversity within and among populations that sufficiently influences the ability of a species to adapt to changing environmental conditions over time (representation) such that protection under the Act is no longer necessary. This is addressed through criteria that provide for adequate redundancy and resiliency in order to gain sufficient representation. We lack sufficient information to assess genetic and ecological representation across the current extant range of the species; however, we presume in recovery implementation as these criteria are met via new acquisitions and management actions, representation will inherently be encompassed opportunistically (i.e., new managed populations will by default be secured across a representative range of the species). Therefore, we believe the population and habitat metrics described above best address species representation based on the best available science, with the expectation that the criteria may be revised, as appropriate, at a time when we obtain better information.

Rationale for Recovery Criteria

Our rationale is that the recovery criteria can be achieved by successful implementation of the existing prime recovery objective and primary recovery actions and in doing so, the threats and stressors affecting each species will be ameliorated to an extent that downlisting or delisting may be warranted. To illustrate how and where the criteria reflect and integrate with the prime recovery objective, primary recovery actions, and five factors (threats/stressors), each are cross-referenced in Tables 4-6, below.

Table 4. Cross-reference of relevance and integration of criteria to existing primary recovery objective, primary recovery actions, and the five factors for Lange’s metalmark butterfly (LMB).

Recovery Criteria	Primary Recovery Objective that Addresses Criterion	Primary Recovery Action that Addresses Criterion	Five Factors (Threat/Stressor) Ameliorated
Downlisting will be considered when:			
1. At least three populations are established at separate, managed locations*.	1a, 1b, 1c	1, 2	A1,A2, A3, A4, A5, B, E1, E2, E3, E4, E5
2. All sites have implemented adaptive management plans to provide dune habitat that provides a disturbance regime that supports naked-stem buckwheat (with some degree of natural recruitment) and a diversity of nectar plants to provide adult food source throughout the flight period. Vegetation monitoring has been conducted over a 15-year period.	1a, 1b	1, 2, 3	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
3. As determined by direct monitoring, each population must have a 15-year moving median of 2,600 individuals and minimum effective population size of 50 with a stable or increasing growth rate (lambda).	1a, 1c	1, 2	C, E3, E4, E5
Delisting will be considered when:			
1. At least five populations are established at separate, managed locations*.	1a, 1b, 1c	1, 2,	A1,A2, A3, A4, A5, B, E1, E2, E3, E4, E5
2. All sites have implemented adaptive management plans to provide dune habitat that provides a natural disturbance regime that supports self-sustaining naked-stem buckwheat (all plants are naturally recruiting) and a diversity of nectar plants to provide adult food source throughout the flight period. Monitoring has been conducted over a 15-year period.	1a, 1b	1, 2, 3	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
3. a) As determined by direct monitoring, each population must have a 15-year moving median of 2,600 individuals and minimum effective population size of 500 with a stable or increasing growth rate (lambda); <i>OR</i>	1a, 1c	1, 2	C, E3, E4, E5
3. b) population viability analysis determines that Lange’s metalmark, range-wide, has a 95% probability of persistence over a 100-year period.	1a, 1c	1, 2	C, E3, E4, E5

(*Sites should be separated at sufficient distance to provide for threat abatement from fires, and to provide some level of diversity in ecological setting, but may also benefit from some level of connectivity. It is not possible at this time to provide a reliable, one-size-fits-all quantitative metric for this variable, as the answer will be site and condition dependent)

Recovery Plan Primary Objective (Service 1984, p. 33)

- 1a. To prevent the further loss of the LMB, CCW, and ADEP;
- 1b. to protect introduced populations and their habitats; and
- 1c. to determine the number of populations which are necessary to reclassify each species to threatened and to delist.

Recovery Plan Primary Recovery Actions (Service 1984, p. 34)

- 1. Protect Antioch Dunes ecosystem and essential habitat for LMB, CCW, ADEP
- 2. Restore Antioch Dunes ecosystem, and increase numbers and improve habitat for LMB, CCW, ADEP
- 3. Initiate information and education program

Five Factors and Underlying Threats and Stressors (see the Threats and Stressors Under the Five Factors section of this document for detailed description)

Note: *Factor D. Inadequacy of existing regulatory mechanisms* is not considered a threat/stressor for the Lange’s metalmark, so is not addressed in the Table.

- A. Present or threatened destruction, modification, or curtailment of its habitat or range
 - 1. Habitat destruction due to sand mining, industrial/urban/suburban development, conversion to agriculture
 - 2. Habitat degradation due to loss of natural disturbance regime
 - 3. Habitat degradation due to invasive non-native vegetation
 - 4. Habitat degradation due to gypsum dust deposition from neighboring plant (mostly Sardis Unit)
 - 5. Habitat degradation due to rogue hiking/trails
- B. Overutilization for commercial, recreational, scientific, or educational purposes
- C. Disease or predation
- E. Other natural or manmade factors affecting its continued existence
 - 1. Direct injury or mortality due to wildfire during vulnerable life stages
 - 2. Direct injury or mortality and promotion of invasive species due to fuel break discing
 - 3. Impaired reproduction and fitness due to loss of pollinators
 - 4. Reduced ability to withstand stochastic and catastrophic events and adapt to changing environmental conditions over time (increased risk of extirpation and extinction) due to low population numbers
 - 5. Loss of habitat, direct mortality, and/or impaired reproduction due to altered temperature and moisture regimes and phenological mismatches with pollinators and plants due to climate change

Table 5. Cross-reference of relevance and integration of criteria to existing primary recovery objective, primary recovery actions, and the five factors for *Oenothera deltooides* subsp. *howellii* (Antioch Dunes evening-primrose; ADEP).

Recovery Criteria	Primary Recovery Objective Addressing Criterion	Primary Recovery Action Addressing Criterion	Five Factor (Threat/Stressor) Ameliorated
Downlisting will be considered when:			
1. There are at least five separate self-sustaining (all plants are naturally recruiting) populations, including: at least three populations, each with a 15-year moving median of at least 4,800 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants.	1a, 1b, 1c	1, 2	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.	1a, 1b	1, 2	E1, E2, E4
b. Populations should be protected and have in place a long-term management plan for the conservation of <i>O.d.</i> subsp. <i>howellii</i> and commitment for implementation of the plan.	1a, 1b	1, 2, 3	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
Delisting will be considered when:			
1. There are at least seven separate self-sustaining (all plants are naturally recruiting) populations, including: at least five populations, each with a 15-year moving median of at least 4,800 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants. <i>OR</i> , population viability analysis determines that <i>O.d.</i> subsp. <i>howellii</i> has a range-wide 95% probability of persistence over a 100-year period.	1a, 1b, 1c	1, 2	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.	1a, 1b	1, 2	E1, E2, E4
b. Populations should be protected and have in place a long-term management plan for the conservation of <i>O.d.</i> subsp. <i>howellii</i> and commitment for implementation of the plan.	1a, 1b	1, 2, 3	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
2. A post-delisting monitoring plan for the species has been developed	1a, 1b	1	E4, E5

Recovery Plan Primary Objective (Service 1984, p. 33)

- 1a. To prevent the further loss of the LMB, CCW, and ADEP;
- 1b. to protect introduced populations and their habitats; and
- 1c. to determine the number of populations which are necessary to reclassify each species to threatened and to delist.

Recovery Plan Primary Recovery Actions (Service 1984, p. 34)

- 1. Protect Antioch Dunes ecosystem and essential habitat for LMB, CCW, ADEP
- 2. Restore Antioch Dunes ecosystem, and increase numbers and improve habitat for LMB, CCW, ADEP
- 3. Initiate information and education program

Five Factors and Underlying Threats and Stressors (see the Threats and Stressors Under the Five Factors section of this document for detailed description)

Note: *Factor D. Inadequacy of existing regulatory mechanisms* is not considered a threat/stressor for *Oenothera deltooides* subsp. *howellii*, so is not addressed in the Table.

- A. Present or threatened destruction, modification, or curtailment of its habitat or range
 - 1. Habitat destruction due to sand mining, industrial/urban/suburban development, conversion to agriculture
 - 2. Habitat degradation due to loss of natural disturbance regime
 - 3. Habitat degradation due to invasive non-native vegetation
 - 4. Habitat degradation due to gypsum dust deposition from neighboring plant (mostly Sardis Unit)
 - 5. Habitat degradation due to rogue hiking/trails
- B. Overutilization for commercial, recreational, scientific, or educational purposes
- C. Disease or predation
- E. Other natural or manmade factors affecting its continued existence
 - 1. Direct injury or mortality due to wildfire during vulnerable life stages
 - 2. Direct injury or mortality and promotion of invasive species due to fuel break discing
 - 3. Impaired reproduction and fitness due to loss of pollinators
 - 4. Reduced ability to withstand stochastic and catastrophic events and adapt to changing environmental conditions over time (increased risk of extirpation and extinction) due to low population numbers
 - 5. Loss of habitat, direct mortality, and/or impaired reproduction due to altered temperature and moisture regimes and phenological mismatches with pollinators and plants due to climate change

Table 6. Cross-reference of relevance and integration of criteria to existing primary recovery objective, primary recovery actions, and the five factors for *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower; CCW).

Recovery Criteria	Primary Recovery Objective Addressing Criterion	Primary Recovery Action Addressing Criterion	Five Factor (Threat/Stressor) Ameliorated
Downlisting will be considered when:			
1. There are at least five separate self-sustaining (all plants are naturally recruiting) populations, including: at least three populations, each with a 15-year moving median of at least 7,000 flowering plants; and least two populations, each with a 15-year moving median of at least 4,000 flowering plants.	1a, 1b, 1c	1, 2	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.	1a, 1b	1, 2	E1, E2, E4
b. Populations should be protected and have in place a long-term management plan for the conservation of <i>E.c.</i> var. <i>angustatum</i> and commitment for implementation of the plan.	1a, 1b	1, 2, 3	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
Delisting will be considered when:			
1. There are at least seven separate self-sustaining (all plants are naturally recruiting) populations, including: at least five populations, each with a 15-year moving median of at least 7,000 flowering plants; and at least two populations, each with a 15-year moving median of at least 4,000 flowering plants. <i>OR</i> , population viability analysis determines that <i>E.c.</i> var. <i>angustatum</i> has a range-wide 95% probability of persistence over a 100-year period.	1a, 1b, 1c	1, 2	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
a. A distance of at least 1,500 feet and a natural and/or man-made firebreak separates individual populations.	1a, 1b	1, 2	E1, E2, E4
b. Populations should be protected and have in place a long-term management plan for the conservation of <i>E.c.</i> var. <i>angustatum</i> and commitment for implementation of the plan.	1a, 1b	1, 2, 3	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
2. A post-delisting monitoring plan for the species has been developed	1a, 1b	1	E4, E5

Recovery Plan Primary Objective (Service 1984, p. 33)

- 1a. To prevent the further loss of the LMB, CCW, and ADEP;
- 1b. to protect introduced populations and their habitats; and
- 1c. to determine the number of populations which are necessary to reclassify each species to threatened and to delist.

Recovery Plan Primary Recovery Actions (Service 1984, p. 34)

- 1. Protect Antioch Dunes ecosystem and essential habitat for LMB, CCW, ADEP
- 2. Restore Antioch Dunes ecosystem, and increase numbers and improve habitat for LMB, CCW, ADEP
- 3. Initiate information and education program

Five Factors and Underlying Threats and Stressors (see the Threats and Stressors Under the Five Factors section of this document for detailed description)

Note: *Factor D. Inadequacy of existing regulatory mechanisms* is not considered a threat/stressor for the *Erysimum capitatum* var. *angustatum*, so is not addressed in the Table.

- A. Present or threatened destruction, modification, or curtailment of its habitat or range
 - 1. Habitat destruction due to sand mining, industrial/urban/suburban development, conversion to agriculture
 - 2. Habitat degradation due to loss of natural disturbance regime
 - 3. Habitat degradation due to invasive non-native vegetation
 - 4. Habitat degradation due to gypsum dust deposition from neighboring plant (mostly Sardis Unit)
 - 5. Habitat degradation due to rogue hiking/trails
- B. Overutilization for commercial, recreational, scientific, or educational purposes
- C. Disease or predation
- E. Other natural or manmade factors affecting its continued existence
 - 1. Direct injury or mortality due to wildfire during vulnerable life stages
 - 2. Direct injury or mortality and promotion of invasive species due to fuel break discing
 - 3. Impaired reproduction and fitness due to loss of pollinators
 - 4. Reduced ability to withstand stochastic and catastrophic events and adapt to changing environmental conditions over time (increased risk of extirpation and extinction) due to low population numbers
 - 5. Loss of habitat, direct mortality, and/or impaired reproduction due to altered temperature and moisture regimes and phenological mismatches with pollinators and plants due to climate change

ADDITIONAL SITE SPECIFIC RECOVERY ACTIONS

No additional site-specific recovery actions are identified at this time for Lange's metalmark, *Oenothera deltooides* subsp. *howellii*, or *Erysimum capitatum* var. *angustatum*.

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Susan Euing, USFWS San Francisco Bay National Wildlife Refuge Complex. December 12, 2018.

Michele Hammond, East Bay Regional Park District. October 9, 2018.

Derek Hilts, USFWS San Francisco Bay-Delta Fish and Wildlife Office. October 31, 2018.

Louis Terrazas, USFWS San Francisco Bay National Wildlife Refuge Complex. September 10, 2019.

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Personal Communication:

Craig Anderson, USFWS San Francisco Bay-Delta Fish and Wildlife Office. February 8, 2019.

Susan Euing, USFWS San Francisco Bay National Wildlife Refuge Complex. December 12, 2018.

Derek Hilts, USFWS San Francisco Bay-Delta Fish and Wildlife Office. October 31, 2018.

Louis Terrazas, USFWS San Francisco Bay National Wildlife Refuge Complex. September 10, 2019.

APPENDIX A:

2018 Lange's Metalmark Butterfly Recovery Criteria Workgroup Members

Last	First	Title	Expertise	Affiliation
Albertson	Joy	Supervisory Wildlife Biologist	LMB and ADNWR	USFWS San Francisco Bay NWR Complex
Arnold	Richard	Entomologist	LMB	Entomological Consulting Services
Brubaker	Don	Manager, Antioch Dunes, Marin Islands, San Pablo Bay NWRs	LMB and ADNWR	USFWS San Francisco Bay NWR Complex
Carson	Evan	Population Geneticist	genetics	USFWS San Francisco Bay-Delta Fish and Wildlife Office
Euing	Susan	Refuge Biologist, ADNWR	LMB and ADNWR	USFWS San Francisco Bay NWR Complex
Galarreta	Angela	Fish and Wildlife Biologist	LMB recovery criteria coordinator	USFWS San Francisco Bay-Delta Fish and Wildlife Office
Johnson	Jana	Principal Investigator of the Butterfly Project	LMB	Moorpark College
Longcore	Travis	Science Director	LMB	Urban Wildlands Group
McNally	Alison	Assistant Professor of Geography	ADNWR	California State University, Stanislaus
Osborne	Ken	Entomologist	LMB and California butterflies	Osborne Biological Consulting
Terrazas	Louis	Wildlife Refuge Specialist, ADNWR	LMB and ADNWR	USFWS San Francisco Bay NWR Complex

Notes: ADNWR = Antioch Dunes National Wildlife Refuge; LMB = Lange's metalmark butterfly; NWR = National Wildlife Refuge; USFWS = U.S. Fish and Wildlife Service

2018 *Oenothera deltooides* subsp. *howellii* (Antioch Dunes Evening-Primrose) and *Erysimum capitatum* var. *angustatum* (Contra Costa Wallflower) Recovery Criteria Workgroup Members

Last	First	Title	Expertise	Affiliation
Albertson	Joy	Supervisory Wildlife Biologist	ADEP, CCW, and ADNWR	USFWS San Francisco Bay NWR Complex
Bartosh	Heath	Senior Botanist	ADEP, CCW, rare plant specialist	Nomad Ecology
Brubaker	Don	Manager, Antioch Dunes, Marin Islands, San Pablo Bay NWRs	ADEP, CCW, and ADNWR	USFWS San Francisco Bay NWR Complex
Chen	Ernest	Fish and Wildlife Biologist	ADEP and CCW recovery criteria coordinator (moved to another assignment, Sept 2018)	USFWS San Francisco Bay-Delta Fish and Wildlife Office
Euing	Susan	Refuge Biologist, ADNWR	ADEP, CCW, and ADNWR	USFWS San Francisco Bay NWR Complex
Ferrell	Molly	Senior Environmental Scientist	delta ecosystem	California Department of Water Resources
Kelch	Dean	Supervisor of Environmental Compliance, Permits and Regulation	botanist, statewide species and ecosystem	California Department of Food and Agriculture
Mankowski	Anne	Fish and Wildlife Biologist	ADEP and CCW recovery criteria coordinator (assigned lead, Sept 2018)	USFWS San Francisco Bay-Delta Fish and Wildlife Office
O'Brien	Bart	Botanic Garden Manager	ADEP and CCW	East Bay Regional Parks District
Pickart	Andrea	Refuge Ecologist	dune ecologist	USFWS Humboldt Bay NWR
Terrazas	Louis	Wildlife Refuge Specialist, ADNWR	ADEP, CCW, and ADNWR	USFWS San Francisco Bay NWR Complex

Last	First	Title	Expertise	Affiliation
Thomson	Diane	Associate Professor of Biology and Environmental Science	invasive plants, ADEP	Claremont McKenna College
Wallace	Gary	Plant Research Associate; USFWS volunteer	plant taxonomy	Rancho Santa Ana Botanic Garden; USFWS Carlsbad Fish and Wildlife Office
Whittall	Justen B.	Associate Professor	CCW geneticist and pollinator	Santa Clara University, College of Arts and Sciences, Biology Department

Notes: ADEP = *Oenothera deltoides* subsp. *howellii* (Antioch Dunes evening-primrose); ADNWR = Antioch Dunes National Wildlife Refuge; CCW = Contra Costa wallflower; NWR = National Wildlife Refuge; USFWS = U.S. Fish and Wildlife Service

APPENDIX B:

Taxonomic Status Discussion

Lange's Metalmark Butterfly

No taxonomic revisions affecting the Lange's metalmark butterfly were brought forward during the development of recovery criteria.

Oenothera deltoides subsp. *howellii* (Antioch Dunes Evening-Primrose)

No taxonomic revisions affecting *Oenothera deltoides* subsp. *howellii* were brought forward during the development of recovery criteria.

Erysimum capitatum var. *angustatum* (Contra Costa Wallflower)

In the course of developing the recovery criteria, the Service became aware of a question as to whether *Erysimum capitatum* var. *angustatum* (Contra Costa Wallflower) is recognized as distinct from the nominate variety *E.c.* var. *capitatum* and reviewed available information relative to a recent change in taxonomic treatment.

The intraspecific taxonomic status of *Erysimum capitatum* (Douglas) Greene var. *angustatum* (Greene) G.B. Rossbach has been maintained by Rossbach (1958 in Al-Shehbaz 2012) as a variety, Price (1987, 1993) as a subspecies, and Rollins (1993 in Al-Shehbaz 2012) as a variety. More recently, the taxonomic treatments provided by Al-Shehbaz (2010) in the *Flora of North America* and Al-Shehbaz (2012) in *The Jepson Manual, Vascular Plants of California* treat the taxon as being distinct from *E.c.* var. *capitatum*. These revised treatments were based on re-evaluation of morphological differentiation. Genetic analysis was not included in this reconsideration and it is not clear that any was available at the time of the revisions. These treatment revisions were attributed specifically to the “lack of sound morphological differences” and led to the conclusion that “subsp. *capitatum* is so variable and widespread that the features allegedly separating var. *angustatum* from it were rather trivial if that subspecies is considered throughout its distribution in North America.” (Al-Shehbaz pers. comm. May 30, 2018). Al-Shehbaz (2010) lists both nomenclatural combinations, *Erysimum capitatum* var. *angustatum* and *E.c.* subsp. *angustatum* as synonyms of *E. calitatum* var. *capitatum*.

Price's (1987) Doctoral Dissertation reviewed the systematics of the *Erysimum capitatum* alliance. In that review Price recognized the infraspecific taxa at the rank of subspecies. However, because the combinations were never published beyond this document, they have no nomenclatural standing in the official compendia. Price (1987, p. 137, 138) seems to point to the ambiguity of the morphological features of the taxon, “Subspecies *angustatum* is a fairly distinctive local race of *Erysimum capitatum*, differing from typical subsp. *capitatum* in usually having rather woody basal caudex very elongate stems and leaves...” and “Somewhat similar features are seen in other local races of the species in California that grow on sand deposits...”. Price (1987, p. i) noted that the more morphologically distinctive taxa of the group occur along

the periphery of the distribution of the species and often are narrow endemics on unusual substrates. Such is the case for the *E.c. var. angustatum*.

The Service also reviewed genetic analysis of Whittall (2014) that was not available at the time of the *Flora of North America* and *Jepson Herbarium, Flora of California* revisions. The analysis used microsatellite markers to investigate genetic differentiation between *E.c. var. angustatum* and *E.c. var. capitatum*. Whittall (2014) included nearby and more distant samples of *E.c. var. capitatum* to compare with samples of *E.c. var. angustatum*. Under the heading, Microsatellite Genetic Diversity Conclusions, Whittall (2014, p. 22, 23) states “The Bayesian genetic clustering strongly supports *E. capitatum var. angustatum* as genetically unique, yet there is no clear evidence of genetic subdivision within the species across the two existing populations. Thus, *E. capitatum var. angustatum* warrants taxonomic recognition as distinct from *E. capitatum var. capitatum*.” The Service’s review of Whittall’s analysis concluded that the results were limited by insufficient data to support a definitive conclusion; however, they do suggest some consistency with differentiation.

The Service considered the data from genetics, morphology, and ecology of the *E.c. var. angustatum* described above and solicited opinions from the Contra Costa Wallflower Recovery Criteria Workgroup about the same. The Service then determined that the best available information does not provide definitive evidence to support a change in taxonomic designation at this time. Based on that determination, the Service proceeded with developing the recovery criteria for the Contra Costa wallflower.

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Personal Communication:

Ihsan Al-Shehbaz, Missouri Botanical Garden. May 30, 2018.

APPENDIX C:

Derivation of Calculated Lange's Metalmark Population Index

To get a better understanding of the Lange's metalmark population status for this document, a population index was calculated from the count data. Typically, with Pollard walks, a summation of the weekly counts per site is used to produce the index (Pellet *et al* 2012). As the refuge has changed over time in terms of habitat units managed and refuge units occupied by the Lange's metalmark, we treated the refuge as one site. We also used a modified equation (below), which included the use of residence times as demonstrated in Schultz and Dlugosch (1999), where r = residence time, n_i = the number of Lange's metalmarks in census i , t_i = the time interval of census i , d_i = Julian date of census i , and w = the number of census counts.

$$N = \frac{1}{r} \sum_{i=1}^w n_i t_i \text{ where } t_i = \frac{d_{i+1} - d_{i-1}}{2}$$

The residence time was to account for any overlap of individuals and was based on an average residence time estimate of 8.85 days from the 1978 data collected during earlier ecological studies carried out by Dr. Richard Arnold (Arnold 1983). Data from 1978 was chosen because it was a year when Dr. Arnold was able to collect data throughout a majority of the flight period.

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APPENDIX D:

Summary of Public and Peer Review Comments Received

Summary of Public Comments

We published a notice of availability in the *Federal Register* on August 6, 2019 (84 FR 38284) to announce that proposed amendments to 28 recovery plans that cover 53 species were available for public review, and to solicit comments by the scientific community, State and Federal agencies, Tribal governments, and other interested parties on the general information base, assumptions, and conclusions presented in the draft revisions. The announcement includes the draft amendment to the *Recovery Plan for Three Endangered Species Endemic to Antioch Dunes, California (Lange's metalmark butterfly, Contra Costa wallflower, Antioch Dunes evening-primrose)* (Recovery Plan; Service 1984), an electronic version of which was posted on the Service's Species Profile website ([here](https://www.fws.gov/news/)). Outreach included (1) publishing a news release on our national webpage (<https://www.fws.gov/news/>) on August 5, 2019, (2) sending notifications to Congressional contacts with U.S. Senators Diane Feinstein and Kamala Harris and U.S. Representative Mark DeSaulnier (California's 11th congressional district), and (3) sending specific notifications to key stakeholders in conservation and recovery efforts. These outreach efforts were conducted in advance of, or concurrent with, the *Federal Register* publication to ensure that we provided adequate notification to all potentially interested audiences of the opportunity to review and comment on the draft amendment to the Recovery Plan.

We received four responses total. These included comments from interested citizens, an industrial company, and a non-governmental organization.

Public comments included one of general support for developing recovery criteria, one of concern about threats to all endangered species and the need to keep them listed, and several comments for specific recommendation on plan content. We thank the reviewers for their comments. Most of the comments did not lead to changes in the draft amendment. The comment offering general support for developing recovery criteria is noted without response. The comment expressing concern about threats to all endangered species and the need to keep them listed is also noted without response, except to state that the amendment does not propose delisting *Oenothera deltooides* subsp. *howellii* (Antioch Dunes evening-primrose), *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower), or Lange's metalmark butterfly (Lange's metalmark; *Apodemia mormo langei*). We have considered the substantive comments; below is a summary of the comments and our responses.

Public Comment:

Commenter #1

Commenter #1, Comment (1): This commenter stated that *E. c. var. angustatum* (Contra Costa wallflower) is not recognized as a distinct subspecies in the *Flora of North America 2010* and therefore is not a listable entity.

Response: This commenter was a member of our Antioch Dunes plant species (*O. d.* subsp. *howellii* and *E. c.* var. *angustatum*) technical workgroup, which we assembled to assist us in developing the recovery criteria (see the *Methodology Used to Complete the Recovery Plan Amendment* section and *Appendix A* for description of our technical workgroups). During development of the draft criteria, this member presented this same information, engaged in meetings discussing this and additional information that we used in our analysis, and provided comments and information during review of an iterative version of the draft amendment. The comment presented during this public comment period does not provide information beyond what we have already considered and explain in *Appendix B: Taxonomic Status Discussion* of the amendment, and therefore does not change our handling of the taxonomic status of *E. c.* var. *angustum* (Contra Costa wallflower).

Commenter #2

Commenter #2, Comment (1): This commenter stated that “It is important to note that the Recovery Plan identifies as the primary threat to these species the establishment of invasive plants that stabilize the dunes soil and result in increased competition for limited nutrients (USFWS 1984). The Recovery Plan also lists other factors such as reduced habitat area, pest insects, periodic disking, hiking, fires, and ORV abuse as likely adversely affecting the Lange’s metalmark butterfly (“LMB”) and its habitat (USFWS 1984). The Recovery Plan does not, however, include gypsum dust in this list. Indeed, in a far more recent threat assessment conducted by the USFWS, the agency identified and ranked by importance 17 different threats to LMB, and although it included gypsum dust on that list, the agency classified/ranked gypsum dust as only 16th out of 17. (Richmond, O.M.W., Kelly, D. and Longcore, T. 2015. Lange’s Metalmark Butterfly Threat Assessment and Ranking of Potential Management Alternatives: Final Report. U.S. Fish and Wildlife Service, Pacific Southwest Region. National Wildlife Refuge System Inventory and Monitoring Initiative. Sacramento, CA, USA. (“2015 Threat Assessment”).)”

Response: Endangered species recovery planning and assessment is an adaptive process where documents produced are iterative by necessity. The Service uses the best scientific and commercial information available at the time a document is produced. The threats and stressors affecting a species may change over time (as conditions change) and our understanding of threats and stressors also changes over time (as information gaps are filled and new information becomes available). Additionally, threats and stressors may be singular or may interact synergistically.

Since the release of the Recovery Plan, the potential threat presented by gypsum dust deposition has been mentioned in at least the *Antioch Dunes National Wildlife Refuge, Comprehensive Conservation Plan* (Service 2002), the *2008 Five-Year Review* (Service 2008), and the *Lange’s Metalmark Butterfly Threat Assessment and Ranking of Potential Management Alternatives* (Richmond *et al* 2015).

In the draft amendment to the Recovery Plan, we explain on page 1 that the draft amendment provides a brief overview and synthesis of information related to the recovery criteria and is not intended as a comprehensive review of the Recovery Plan or a five-year review of species’

status. We also refer the reader to the most recent recovery planning and assessment documents for detailed descriptions of each species biology, previous population status and trends, and threats assessments. We additionally advise that updates to five-year reviews for each species are in progress or scheduled within the near future. On page 13 of the draft amendment, we also explain that the *Threats and Stressors Under the Five Factors* section synthesizes information from the Recovery Plan, 2008 Five-Year Review, *Lange's Metalmark Butterfly Threat Assessment and Ranking of Potential Management Alternatives* (Richmond *et al* 2015), additional references (as cited), and the 2018 development of recovery criteria. Finally, as explained in our response to *Commenter #2, Comment (2)* below, in the final amendment we acknowledge that the "magnitude of this potential stressor requires further investigation." Within the context explained above, we believe that the information and reference citations in the *A. Present or threatened destruction, modification, or curtailment of its habitat or range, 4. Habitat degradation due to gypsum dust deposition from neighboring plant (facility)* section of the draft amendment are accurate (see also response to *Commenter #2, Comment (2)*, immediately below).

Commenter #2, Comment (2): The commenter added that the findings they identify above in *Commenter #2, Comment (1)* "...are consistent with the statement made in the Draft Recovery Plan, with which Georgia-Pacific concurs, that "there was no evidence that gypsum dust is adversely affecting *O.d. subsp. howellii* or *E.c. var. angustatum*. The same is true for LMB, which explains why the Draft Recovery Plan cites to no scientific authority to the contrary, only anecdotal personal communications that gypsum dust has been observed on the ADNWR, particularly on the Sardis Unit."

Response: The statement in the draft amendment is "At the time of the 2008 Five-Year Review, staff noted a reduction in dust from G-P efforts and that there was no evidence that gypsum dust is adversely affecting *O.d. subsp. howellii* or *E.c. var. angustatum* (Service 2008)." The statement has been revised in the final amendment to include information from the 2008 Five-Year Review about concern relative to the Lange's metalmark follows: "At the time of the 2008 Five-Year Review, staff noted a reduction in dust from G-P efforts. The review noted that there was no evidence that gypsum dust was adversely affecting any of the three species (Service 2008). However, it also cited a study that demonstrated that dusts may adversely increase transpiration through the cuticle of insect larvae and cause desiccation and abrasion of the cuticle (Wigglesworth 1945 *in* Service 2008), which may affect Lange's metalmark and pollinators of *O.d. subsp. howellii* or *E.c. var. angustatum*." Additionally, a sentence has been added to the section indicating that the magnitude of this potential stressor requires further investigation. The Service's use of personal communication with subject matter experts is consistent with its requirement to use the best available scientific and commercial information. Please note that the Wigglesworth citation is actually from 1945 as corrected here, and not 1944 as cited in the 2008 Five-Year Review. Also note that the date cited for the Susan Euing December 2018 pers. comm. is actually December 12, as corrected in the final amendment and not December 15, as cited in the draft amendment.

Commenter #2, Comment (3): The commenter added that "In the Literature Cited section, the Draft Recovery Plan inexplicably contains a reference to a 2015 Urban Wildlands document that purportedly analyzes the effects of gypsum dust on another species of metalmark butterfly, but the document is not actually cited in the text of the Draft Recovery Plan. This is not surprising

since the “study” depicted in that document was not peer reviewed and merely describes an incomplete experiment conducted in 2007 that had to be abandoned early because of logistical problems of evacuation due to wildfire and termination of larval experiments to provide larvae for another study on the effects of herbicides. Moreover, the results presented were not statistically significant due to small sample sizes (as little as 3-5 individuals), and the “study” did not quantify the amount of gypsum applied to the (single) treatment group, failed to standardize the amount applied, and did not provide any information on baseline conditions for LMB in the ADNWR. For these reasons, reference to this document should be removed.”

Response: As stated in the comment, there is no within-text reference to the *Effect of Exposure to Gypsum Dust on Survival of Behr’s Metalmark, Los Angeles* (Clause *et al* 2015) in the draft amendment. Therefore, no such reference can be removed. The *Literature Cited, Lange’s Metalmark Butterfly* section of the draft amendment contained five citations, including Clause *et al* (2015), for which no reference was made within the text of the document. Inclusion of these citations was in error and they have been removed from the final amendment.

Commenter #2, Comment (4): The commenter added that “Moreover, as noted in the Draft Recovery Plan, Georgia-Pacific has at the same time “increased efforts to reduce airborne gypsum” associated with its operations, efforts that have met with success as noted by USFWS staff during the 2008 Five-Year Review. Those efforts have even significantly increased since that time with Georgia-Pacific’s preparing, in collaboration with the USFWS, and implementing a formal “Fugitive Dust Control Plan.” Finalized in 2016, the Fugitive Dust Control Plan incorporates a host of best management practices and monitoring requirements--including wind monitoring that is tied back to enhanced BMP implementation during high winds--and includes a commitment to regularly confer and collaborate with ADNWR staff. Indeed, feedback provided by ADNWR staff to Georgia-Pacific during such meetings has so far been positive, reinforcing that Georgia-Pacific’s implementation of the Fugitive Dust Control Plan has met with success.”

Response: The Service appreciates efforts by Georgia-Pacific to reduce airborne gypsum and the continued collaboration with ADNWR staff. We have added text to the final amendment explaining that the partnership with Georgia-Pacific is ongoing. The draft amendment explains that ADNWR staff met with Georgia-Pacific about concerns over the dust and G-P increased efforts to reduce airborne gypsum (beyond the standards for air pollution control) by keeping it wetted down when possible during production activities. We also consulted with ADNWR staff on September 10, 2019, and verified that at this time, no 2019 Lange’s metalmark surveys have been canceled due to concerns about gypsum dust deposition. Text has also been added to the final amendment providing temporal clarification that the previously canceled surveys took place in 2018 and regarding this newer information about the 2019 surveys.

Commenter #2, Comment (5): The commenter added that “If gypsum dust was causing declines in LMB populations, it would be expected that the populations would begin to rise as these ongoing reductions in dust generation continue due to decreasing production levels and enhanced dust suppression efforts at the Georgia-Pacific facility. As described in the Draft Recovery Plan, that has not been the case, evidence that other activities and factors are threatening and stressing these endemic species and should be the focus of modifications to the Recovery Plan (threats like those ranked highest in the 2015 Threat Assessment).”

Response: The spirit of the comment is appreciated. The draft amendment lists 13 general categories of threats and stressors. As explained above in responses to other comments, threats and stressors may behave synergistically and need to be considered in that context. As mentioned, the magnitude of the potential threat posed by gypsum dust deposition, including exposure pathways and routes and thresholds of effects in receptors (e.g., changes in soil chemistry or structure, species composition, or individual organism physiology) are not fully understood at this time. For these same reasons, how and whether the potential threat of gypsum dust deposition may interact with other threats or the spatial and temporal thresholds for effects and responses are also not understood at this time. We certainly did not intend to suggest that gypsum dust is the sole driver of Lange's metalmark population dynamics, nor would we attempt to explain observed trends in population abundance in the context of a single, unquantified, and incompletely understood factor, which we acknowledge is only a potential stressor given our current state of scientific understanding.

With regard to the focus of modifications to the Recovery Plan - the focus of modification to the Recovery Plan proposed via the draft amendment is to add recovery criteria. Also as explained above in responses to other comments from this commenter, the draft amendment is not intended as, nor does it constitute, a comprehensive review of the Recovery Plan or a five-year review of species' status. Relative to all threats and stressors, recovery criteria are proposed endpoints for a species' population spatial distribution and abundance, that once achieved, should qualify the species for a status reclassification or delisting because threats and stressors have been ameliorated to an extent that the species no longer meets the definition of endangered or threatened.

Summary of Peer Review Comments

We solicited independent peer review of the draft amendment to the Recovery Plan in accordance with the requirements of the Act from individuals with a combination of subject matter expertise, independence, and objectivity and without conflict of interest. Criteria used for selecting peer reviewers for the *O. d.* subsp. *howellii* and *E. c.* var. *angustatum* criteria included their demonstrated expertise and specialized knowledge related to *O. d.* subsp. *howellii* and *E. c.* var. *angustatum*, plant physiology, plant life history and evolutionary ecology, plant population ecology and viability analysis, and experience in the development of recovery criteria for other plant species. Criteria used for selecting peer reviewers for the Lange's metalmark criteria included their demonstrated expertise and specialized knowledge related to Lange's metalmark, butterfly life history and evolutionary ecology, butterfly population genetics and ecology, rare butterfly species' responses to environmental stressors, and experience in the development of recovery criteria for other butterfly species. The qualifications of the peer reviewers are in the decision file and the administrative record for this recovery plan amendment.

In total, we solicited review and comment from six peer reviewers. We received comments from one peer reviewer. The reviewer provided copy edits and several substantive comments for specific recommendation on plan content, which are discussed below.

We considered all substantive comments, and to the extent appropriate, we incorporated the applicable information or suggested changes into the final revised recovery plan. Below, we provide a summary of specific comments received from the peer reviewer with our responses; however, we addressed many of the reviewer's specific critiques and incorporated their suggestions as changes to the final revised recovery plan. Such comments did not warrant an explicit response, and as such, are not addressed here.

We had a telephone-conference June 11, 2019 with the peer reviewer to discuss comments and answer questions. We held a video-conference August 23, 2019 with the peer reviewer and our Lange's metalmark technical workgroup, which had been assembled to assist us in developing the recovery criteria (see the *Methodology Used to Complete the Recovery Plan Amendment* section and *Appendix A* for description of our technical workgroups), to discuss our re-evaluation of a minimum population size for the Lange's metalmark recovery criteria (see the first *Peer review comment* and *Response*, below). We appreciate the input from the peer reviewer and the technical workgroup members, which helped us to consider and incorporate the best available scientific and commercial information during development and approval of the final revised recovery plan.

Peer Review:

Peer Review Comment (1): The peer reviewer questioned our use of the Traill *et al* (2007) standardized minimum viable population (MVP) size for five non-aquatic insect taxa of 10,841 individuals and recommended instead the use of one of the three, or an average of the three, Lepidoptera MVP sizes used by Traill *et al* (2007). We also received a similar comment from a member of our Lange's metalmark technical workgroup.

Response: After receiving the comment from the peer reviewer in April 2019, we began re-evaluation of the suitability of previously reviewed potential surrogate butterfly MVP sizes and our draft recovery criteria minimum population size for the Lange's metalmark. Our re-evaluation methodology and result is briefly summarized below (see the *Justification for Recovery Criteria, Lange's Metalmark* section of the Recovery Plan amendment for a detailed explanation).

In our re-evaluation we reviewed 18 population viability assessments (PVAs) for 11 butterfly species from 13 publications for potential suitable MVP models and sizes and species biology/life history surrogacy for Lange's metalmark. Based on our re-evaluation, we determined that our use of the standardized MVP size (10,841 individuals) for five insect species (one fly, one cricket, and three butterflies) from Traill *et al* (2007), as proposed in our draft amendment, was not the best surrogate fit—concurring with our peer reviewer.

We then identified the most suitable surrogates based on a combination of MVP models and evaluation of species biology/ecology/life history and held a video-conference August 23, 2019 with our technical workgroup and the peer reviewer to gain their input about our re-evaluation. Based on our re-evaluation and our technical workgroup and peer reviewer input, we decided it was important to use more than one species and more than one MVP model to buffer our uncertainty from lack of a very robust surrogate species. We also decided to round the resulting

MVP size to the nearest hundred to avoid implied precision in MVP sizes given the lack of confidence intervals for our selected MVP sizes. (Note: We applied the same rounding approach to the recovery criteria minimum population size for *O.d. subsp. howellii*.) We used an average of the Sawchick et al (2002) MVP size of 2,000 females for bog fritillary, adjusted to 3,374 individuals using Lange's metalmark female:male densities from Antioch Dunes National Wildlife Refuge in 1977 (Arnold 1980 in USFWS 1984), and the Schtickzelle et al (2005) MVP size of 1,740 individuals for marsh fritillary, for a result of 2,557 individuals, which rounded to 2,600 individuals.

Using this result we revised the Lange's metalmark recovery criteria minimum population size in our final amendment to 2,600 individuals from the 10,841 individuals proposed in our draft amendment.

Peer Review Comment (2): The peer reviewer explained taxonomic naming differences between references and suggested correcting from seven to six, the number of subspecies of Mormon metalmark (*Apodemia mormo*) stated in our species description for Lange's metalmark.

Response: We revised the corresponding text from "...is one of seven recognized subspecies..." to "...is a recognized subspecies...".

Peer Review Comment (3): The peer reviewer noted our omission of the threat from disease or predators for Lange's metalmark butterfly from two parts of the draft amendment. The reviewer noted that our treatment for Lange's metalmark in the *Threats and Stressors Under the Five Factors, Factor C, Disease or predation* section and *Table 4. Cross-reference of relevance and integration of criteria to existing primary recovery objective, primary recovery actions, and the five factors for Lange's metalmark butterfly (LMB)* was not consistent with our treatment in corresponding sections of the *Five-Year Review for the Lange's metalmark butterfly (Apodemia mormo langei)*, *Antioch Dunes evening-primrose (Oenothera deltooides subsp. howellii)*, and *Contra Costa wallflower (Erysimum capitatum var. angustatum)* (2008 Five-Year Review; Service 2008).

Response: We agree that omission of information from the 2008 Five-Year Review about Lange's metalmark butterfly larval parasitism by flies and wasps in respective sections of the draft amendment was an error and have incorporated respective edits into the final amendment. This comment also made us aware of an error we made by transposing column contents between the columns with the headings *Primary Recovery Objective Addressing Criterion* and *Primary Recovery Action Addressing Criterion* in Tables 5 and 6, and we have also incorporated those edits into the final amendment.

Peer Review Comment (4): The peer reviewer noted that the family classification for metalmarks should be Riordinidae, not Lycaenidae, in the *Justification for Recovery Criteria, Lange's Metalmark, Redundancy* section.

Response: We have incorporated the edit with the appropriate citation into the final amendment.

Peer Review Comment (5): The peer reviewer expressed confusion about the geographic scope of the Recovery Plan by questioning the feasibility of establishing the recovery criteria prescription of three and five separate populations of *O. d. subsp. howellii*, *E. c. var. angustatum*, or Lange's metalmark. The reviewer explained their understanding that the Recovery Plan only addresses the geographic area currently occupied by the Antioch Dunes National Wildlife Refuge (ADNWR; approximately 67 acres) and therefore, the reviewer did not agree that achieving the number of separate populations and population sizes in the recovery criteria was possible.

Response: We do not expect that recovery of any of the three species is possible within only the current geographic context of the ADNWR. We do expect that the ADNWR will remain integral to recovery and believe it may constitute one or more of the populations prescribed for each species.

The Recovery Plan addresses the three species endemic to the Antioch Dunes ecosystem. Unfortunately, there is inconsistent phrasing within and across the Recovery Plan, the 2008 Five-Year Review, and the draft amendment that promotes conflation of the "Antioch Dunes ecosystem" and the "ADNWR". The Recovery Plan introduces the recovery objective on page 33 as follows: "The prime objective of this recovery plan is to prevent the further loss of the Lange's metalmark butterfly, Contra Costa wallflower, and Antioch Dunes evening-primrose; to protect introduced populations and their habitats; and to determine the number of populations which are necessary to reclassify each species to threatened and to delist." The Recovery Plan then states on page 34 that the prime objective is "To prevent the further loss of habitat at Antioch Dunes for the Lange's metalmark butterfly (LMB), Antioch Dunes evening-primrose (ADEP), and Contra Costa wallflower (CCW); to protect introduced populations of each species and their habitats; and to determine the number of populations which are necessary for reclassifying each species." The Recovery Plan goes on to state on page 39 that "The prime objective of this recovery plan is to prevent the further loss of habitat at Antioch Dunes and to restore and protect the Antioch Dunes ecosystem to provide additional habitats for the Lange's metalmark butterfly, Contra Costa wallflower, Antioch Dunes evening primrose." The 2008 Five-Year Review restates the prime objective as "to prevent the further loss at the Antioch Dunes for the Lange's metalmark butterfly, Antioch Dunes evening-primrose, and Contra Costa wallflower; to protect introduced populations of each species and their habitats; and to determine the number of populations which are necessary for reclassifying each species."

Our draft amendment used the wording from the 2008 Five-Year Review, but to clarify correct geographic context and scope, in the final amendment we will replace all citations of the Recovery Plan prime objective with the wording from its first use, as it appears on page 33 of the Recovery Plan: 1a) to prevent the further loss of the Lange's metalmark butterfly, Contra Costa wallflower, and Antioch Dunes evening-primrose; 1b) to protect introduced populations and their habitats; and 1c) to determine the number of populations which are necessary to reclassify each species to threatened and to delist.

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Personal Communication:

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