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

DRAFT AMENDMENT 1

The U.S. Fish and Wildlife Service (Service) has identified best available information that 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 proposed 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 proposed modification, we review the need for recovery criteria, show proposed criteria, and describe the justification and rationale supporting this proposed Recovery Plan modification.

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

March 2019

INTRODUCTION

The purpose of this document is to propose recovery criteria for the Lange's metalmark butterfly, *Oenothera deltoides* 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 proposed 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 deltoides 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 PROPOSED 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 the proposed amended 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 some or all of the experts are expected to provide further technical assistance when the proposed criteria are published in the *Federal Register* and the Service responds 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 (Service 2018e), *Oenothera deltoides* 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 (CNDDB) element occurrence data (CNDDB 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, generalized minimum viable population (MVP) sizes, after Traill *et al* (2007) were also referenced to propose threshold population sizes until a time when more robust species specific data and other information allows for more refined calculations.

Peer review of the proposed criteria will be 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 will be conducted simultaneously with the public comment period. Comments will be taken into consideration when finalizing the criteria and a summary of the comments received will be included as an appendix to the 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 proposes amendment to 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 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" (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, in spite of 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 proposed 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 exercise, because a question arose about taxonomic status for one of the species (*Erysimum capitatum* var. *angustatum*; Contra Costa wallflower) during development of the proposed 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, *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 was 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.

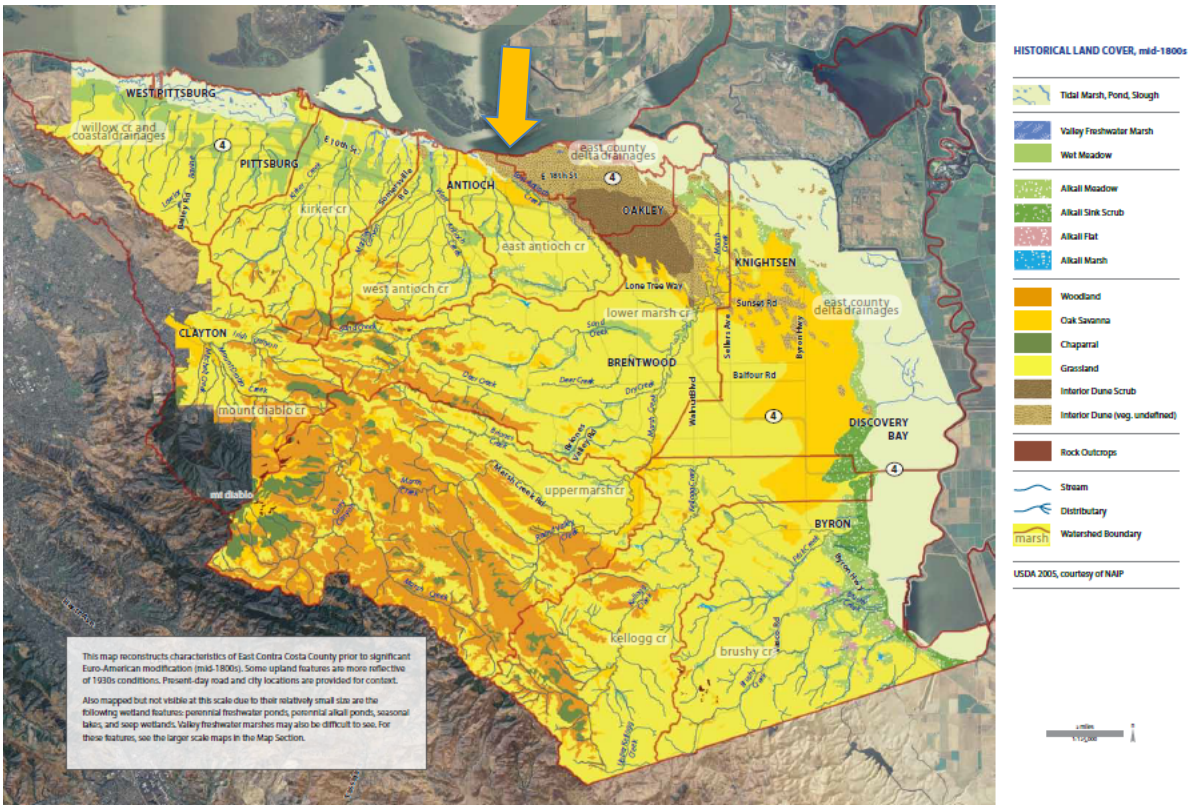

Figure 1. East Contra Costa County mid-1800s land cover showing the estimated distribution of the interior dune habitat (interior dunes scrub [dark brown]; interior dunes – vegetation undefined [light brown]) (figure from Stanford *et al* 2011) with arrow pointing to the location of the Antioch Dunes.

Since the mid- to late-1800s, the Antioch Dunes habitat has been mostly destroyed and degraded by sand removal 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 butterfly is now considered entirely restricted to the remaining Antioch Dunes habitat at the ADNWR, 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.

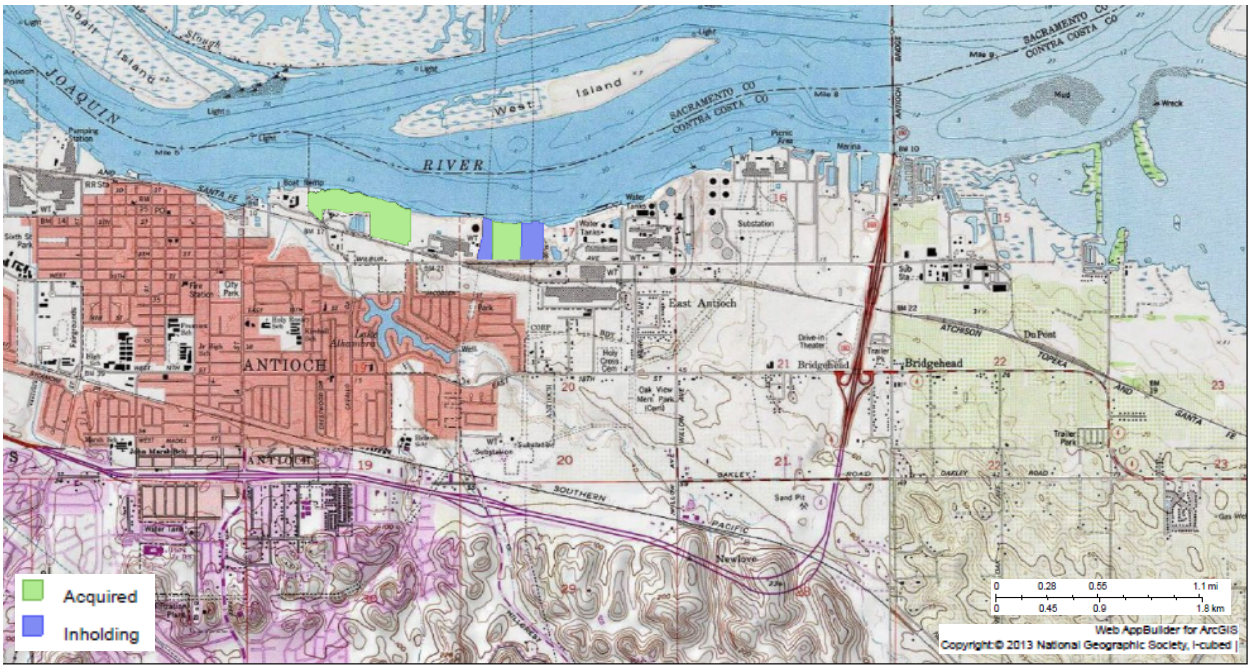

Figure 2. Location of the Antioch Dunes National Wildlife Refuge. The approved 67-acre refuge boundary includes Service-owned (green polygons) and privately-owned (blue polygons) property.

Species Descriptions

Lange's Metalmark Butterfly

Lange's metalmark butterfly (hereafter referred to as Lange's metalmark) is one of seven recognized subspecies of the Mormon metalmark (*Apodemia mormo*) according to the Integrated Taxonomic Information System (2018) and is isolated from all other occurrences of the *A. mormo* complex. It is a univoltine subspecies, producing one brood in a season. 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, oviposition site, and 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 the 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 is 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. v*ar. *angustatum* populations was not genetically constrained, but was environmentally constrained due to limited habitat, and related 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 (CNDDB) 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 CNDDB 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 Butterfly

According to the CNDDB (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 (CNDDB) 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) CNDDB 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 (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 three or so decades, and also Lange's metalmark's potential for dramatic inter-annual increases and declines in abundance. For the period from 1986-2017, the 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).

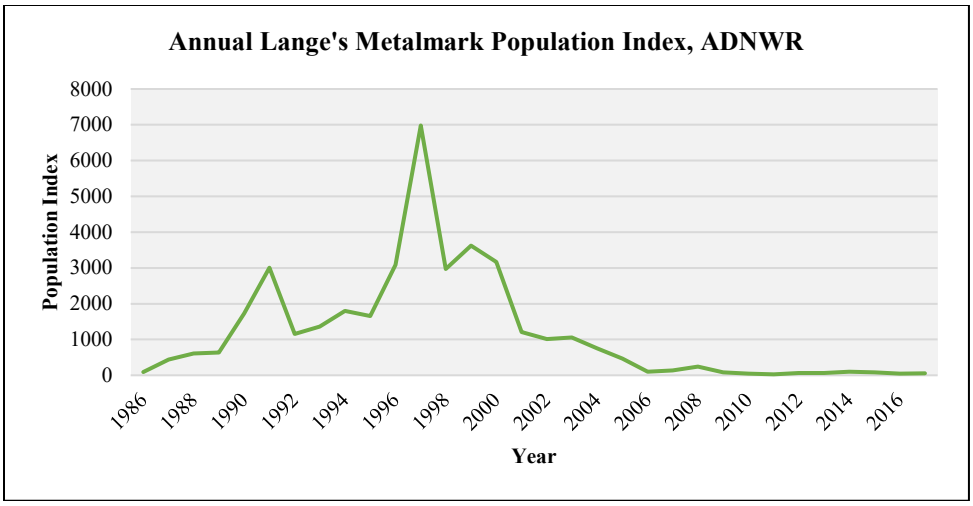

Figure 3. Calculated population index of Lange's metalmark from 1986 to 2017 at the Antioch Dunes National Wildlife Refuge (ADNWR).

In 2007, a captive breeding program was established. However, breeding in captivity has been generally unsuccessful and the program has shifted to a head starting approach--annually collecting three to five females from the wild 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).

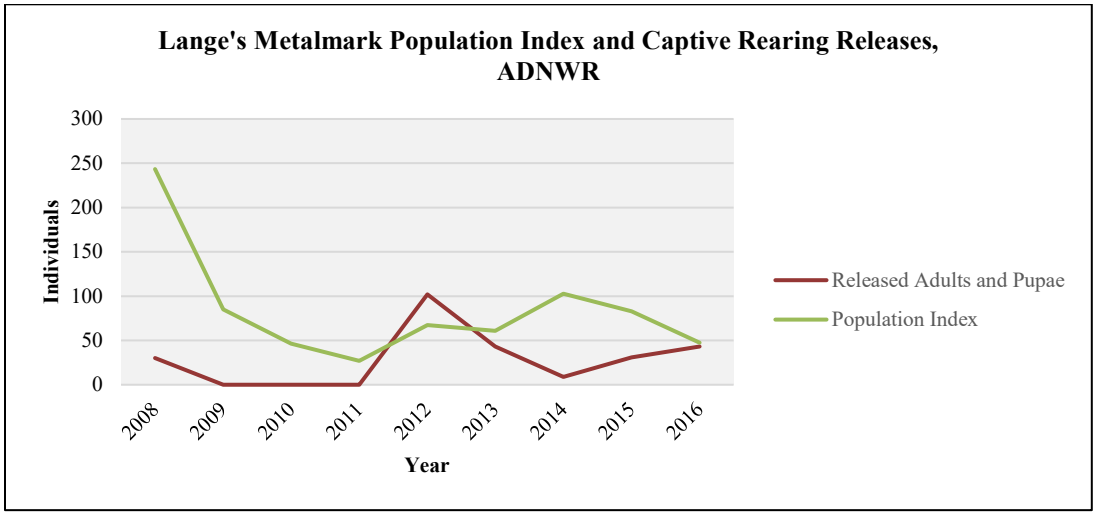

Figure 4. Comparison of Lange's metalmark population index and the number of pupae and/or adults released from the captive rearing program at the Antioch Dunes National Wildlife Refuge (ADNWR).[1]

[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 deltoides subsp. howellii

According to the CNDDB (2018a), *Oenothera deltoides* 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 CNDDB 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 (CNDDB) element occurrence (EO) information for *Oenothera deltoides* 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) CNDDB 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 was 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.

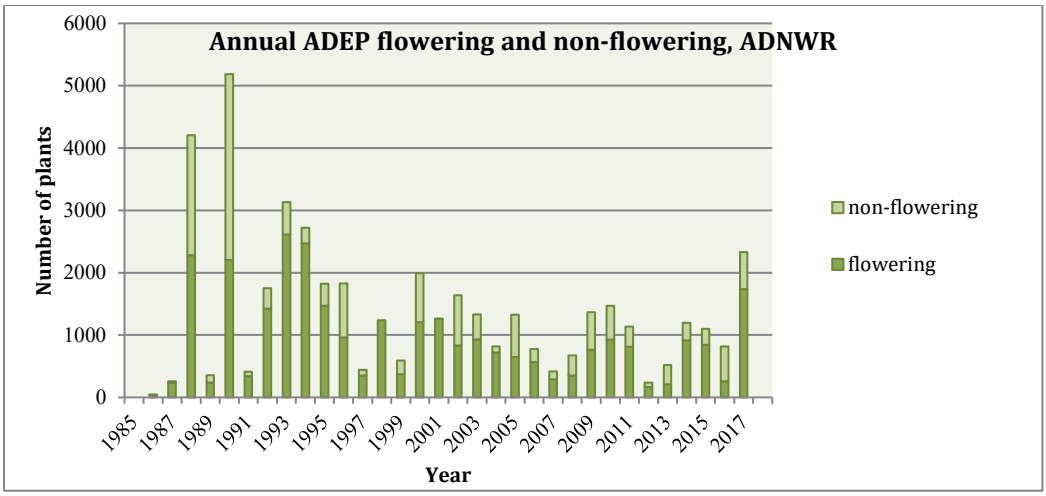

Figure 5. Annual counts of flowering and non-flowering *Oenothera deltoides* subsp. *howellii* (Antioch Dunes evening-primrose; ADEP) at the Antioch Dunes National Wildlife Refuge (ADNWR).

Erysimum capitatum var. angustatum

According to the CNDDB (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 CNDDB 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 (CNDDB) 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) CNDDB 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 was 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.

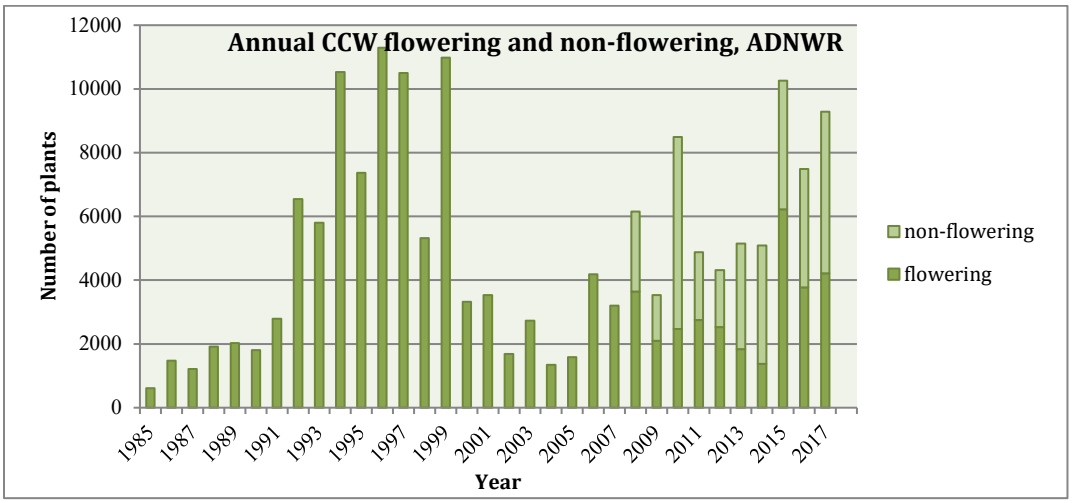

Figure 6. Annual counts of flowering and non-flowering *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower; CCW) at the Antioch Dunes National Wildlife Refuge (ADNWR) (non-flowering plants were not counted until 2008).

Threats and Stressors Under the Five Factors

A brief review of the five factors and underlying threats and stressors to the Lange's metalmark butterfly, *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 proposed 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. <u>Present or threatened destruction, modification, or curtailment of its habitat or range</u>

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).

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. 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 and that there was no evidence that gypsum dust is adversely affecting *O.d.* subsp. *howellii* or *E.c.* var. *angustatum* (Service 2008). However, ADNWR staff reported an increase in gypsum dust deposition at ADNWR in 2017-2018 (Susan Euing pers. comm. December 15, 2018). Staff noted that gypsum is still being deposited on the refuge at concentrations that coats plants and has recently been so concerning that surveys for the Lange's metalmark butterfly were canceled in some parts of the refuge (Susan Euing pers. comm. August 17, 2018).

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 15, 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

Disease or predation are not considered threats or stressors to the Lange's metalmark.

Evidence exists of *O.d.* subsp. *howellii* infestation by beetles (possibly Chrysomelids), 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 (*Calcus* 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 includes 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*. 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 (identified as a questionable threat)

There is 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; actual pollinator taxa are unknown. This threat requires investigation.

4. Low population numbers

Extinctions and declines of Lepidoptera species have been widely observed with building evidence that the cause is usually 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, 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 deltoides subsp. *howellii* and *E.c.* var. *angustatum* are threatened by few and small populations 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 deltoides 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*.

Proposed Recovery Criteria

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 Proposed Criteria* and *Rationale for Proposed Criteria* sections, below. A summary of how the proposed criteria fit into the existing framework of, and address, the five factors and recovery objective and actions is provided below in the *Rationale for Proposed 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 Proposed Recovery Criteria* section below. Justification for the proposed Lange's metalmark criteria is presented in the context of the 3 Rs and justifications for the proposed *Oenothera deltoides* 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 propose both downlisting and delisting criteria for Lange's metalmark, *Oenothera deltoides* subsp. *howellii*, and *Erysimum capitatum* var. *angustatum* as follows:

Lange's Metalmark Butterfly

Downlisting Recovery Criteria

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

1. At least three populations are established at separate, managed locations[2].
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 10,841 individuals *and* minimum effective population size of 50 with a stable or increasing growth rate (lambda).

Delisting Recovery Criteria

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

1. At least five populations are established at separate, managed locations[2].
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 10,841 individuals *and* minimum effective population size of 500 with a stable or increasing growth rate (lambda); *OR*
   b) population viability analysis determines that Lange's metalmark, range-wide, has a 95% probability of persistence over a 100-year period.

[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.

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 4,824 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 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 *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 4,824 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 ≥ 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 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 ≥ two flowering seasons post-outplanting. This would indicate the individual has completed the life cycle in situ.

Justification for Proposed Recovery Criteria

Lange's Metalmark Butterfly

Resiliency

Traill *et al* (2007) conducted a meta-analysis of MVPs for multiple animal and plant taxa. The authors attempted to standardize MVP methods across species, thereby allowing estimation of a broader taxonomically-appropriate metric. This effort yielded a mean estimate for six insect species to be 10,841 individuals (95% confidence interval = 1,650-103,625). We attempted a PVA (per Schultz and Hammond 2003) and found the underlying data insufficient to derive any confidence in an estimate of a minimum viable population specifically to Lange's metalmark. We searched the literature to identify possible surrogates, looking for con-generics or even butterflies from the same or different families with similar ecological features of high endemism, and were unable to locate any applicable examples. Further, the examples we could locate all contained MVPs for species with multiple populations across a range of habitat types (i.e., species with greater redundancy, representation, and resiliency) rendering the imposition upon Lange's metalmark current landscape inadvisable (Settele *et al* 2009).

We applied our proposed downlisting and delisting criteria to the available Lange's metalmark data (as illustrated in Figure 3). Historically observed values of the 15-year moving median at

ADNWR peaked in the year 2000 at approximately one-third our proposed criteria for downlisting. Since the time series of abundance indices at ADNWR declined from a 15-year moving median of ~3,000 individuals in 2000 to a single year index in 2017 of ~30 individuals (near extirpation over a short time span of less than two decades), it follows that this figure is below a numeric benchmark reflecting "threatened" status, a species that is likely to become "endangered" in the near future. In other words, a moving median at less than 3,000 Lange's metalmark individuals empirically was, and is, endangered. Finally, as mentioned above, our available data likely underestimates real abundance over the analyzed time series. We therefore conclude that the derived estimate for insects of 10,841 individuals as an MVP from Traill *et al* (2007) is a reasonable estimate of an MVP for the Lange's metalmark until further research, and improved monitoring, defines some other figure with greater statistical certainty.

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 lycaenids, 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). 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 deltoides 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 deltoides 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 deltoides* 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 minimum viable population (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 proposed 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 standardize 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. *eurekense*; 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 (*Ne*). The *Ne* 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 *Ne*. For *H.a.* var. *glabra*, the *Ne* 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 *Ne* 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, it is noted that 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*.

<u>*Population Monitoring Time Interval*</u>

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 3 "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 time frame is the minimum interval necessary to capture sufficient climatic variability and provide a reasonable quantitative benchmark indicating population viability.

Oenothera deltoides 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 deltoides* 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 proposed 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; 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 proposed size and number of populations is based on a resiliency and redundancy step-wise from a 15-year moving median of at least 17,472 naturally recruiting flowering plants across five locations for reclassification to threatened status and a 15-year moving median of at least 27,120 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 deltoides* 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 proposed 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.

<u>*Separation Distance Between Individual Populations*</u>

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 deltoides* 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 (*Evylaeus* [*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 proposed 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 proposed criteria including: at least 40 acres to support the large populations (4,824 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 proposed 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 proposed 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 proposed 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 proposed 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 deltoides 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 for the proposed criteria 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 Proposed Recovery Criteria

Our rationale is that the proposed 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 proposed 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 proposed criteria to existing primary recovery objective, primary recovery actions, and the five factors for Lange's metalmark butterfly (LMB).

Proposed 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, C, 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, E1, E2, E3, E4, E5
3. As determined by direct monitoring, each population must have a 15-year moving median of 10,841 individuals and minimum effective population size of 50 with a stable or increasing growth rate (lambda).	1a, 1c	1, 2	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, E1, E2, E3, E4, E5
3. a) As determined by direct monitoring, each population must have a 15-year moving median of 10,841 individuals and minimum effective population size of 500 with a stable or increasing growth rate (lambda); OR	1a, 1c	1, 2	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	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 at the Antioch Dunes for the LMB, ADEP, and CCW;
1b. to protect introduced populations of each species and their habitats; and
1c. to determine the number of populations which are necessary for reclassifying each species

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 C. Disease or predation* and *Factor D. Inadequacy of existing regulatory mechanisms* are not considered threats/stressors for the Lange's metalmark, so are 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

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 proposed criteria to existing primary recovery objective, primary recovery actions, and the five factors for *Oenothera deltoides* subsp. *howellii* (Antioch Dunes evening-primrose; ADEP).

Proposed 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 4,000 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants.	1, 2	1a, 1b, 1c	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.	1, 2	1a, 1b	E1, E2, E4
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.	1, 2, 3	1a, 1b	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 4,000 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.	1, 2	1a, 1b, 1c	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.	1, 2	1a, 1b	E1, E2, E4
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.	1, 2, 3	1a, 1b	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
2. A post-delisting monitoring plan for the species has been developed	1	1a, 1b	E4, E5

Recovery Plan Primary Objective (Service 1984, p. 33)
1a. To prevent the further loss at the Antioch Dunes for the LMB, ADEP, and CCW;
1b. to protect introduced populations of each species and their habitats; and
1c. to determine the number of populations which are necessary for reclassifying each species
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 deltoides* 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 proposed criteria to existing primary recovery objective, primary recovery actions, and the five factors for *Erysimum capitatum* var. *angustatum* (Contra Costa wallflower; CCW).

Proposed 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.	1, 2	1a, 1b, 1c	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.	1, 2	1a, 1b	E1, E2, E4
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.	1, 2, 3	1a, 1b	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. Or, population viability analysis determines that *E.c.* var. *angustatum* has a range-wide 95% probability of persistence over a 100-year period.	1, 2	1a, 1b, 1c	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.	1, 2	1a, 1b	E1, E2, E4
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.	1, 2, 3	1a, 1b	A1,A2, A3, A4, A5, B, C, E1, E2, E3, E4, E5
2. A post-delisting monitoring plan for the species has been developed	1	1a, 1b	E4, E5

Recovery Plan Primary Objective (Service 1984, p. 33)
1a. To prevent the further loss at the Antioch Dunes for the LMB, ADEP, and CCW;
1b. to protect introduced populations of each species and their habitats; and
1c. to determine the number of populations which are necessary for reclassifying each species
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 butterfly, *Oenothera deltoides* subsp. *howellii*, or *Erysimum capitatum* var. *angustatum*.

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

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

Diane Thomson, Claremont McKenna College. October 31, 2018.

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Susan Euing, USFWS San Francisco Bay National Wildlife Refuge Complex. December 15, 2018.

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

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 deltoides* 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

Lange's Metalmark Butterfly

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

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

In the course of developing the proposed 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 provide 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 Whittal (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 Whittal'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 proposed recovery criteria for the Contra Costa wallflower.

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Appendix C:

Calculated Population Index

To get a better understanding of the 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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