Antioch Dunes evening-primrose
(*Oenothera deltoides* subsp. *howellii*)

5-Year Review:
Summary and Evaluation

Photo credit: B. Williams

U.S. Fish and Wildlife Service

San Francisco Bay-Delta Fish and Wildlife Office

Sacramento, California

5-YEAR REVIEW

Antioch Dunes evening-primrose (*Oenothera deltoides* subsp. *howellii*)

GENERAL INFORMATION:

Species: *Oenothera deltoides* subsp. *howellii*
Date listed: April 26, 1978
FR citation(s): 43 FR 17910
Classification: Endangered species

BACKGROUND:

Most recent status review:
U.S. Fish and Wildlife Service. 2020. Antioch Dunes evening-primrose (*Oenothera deltoides* subsp. *howellii*) 5-year Review: Summary and Evaluation. San Francisco Bay-Delta Fish and Wildlife Field Office. Sacramento, California. 21 pp.

FR Notice citation announcing this status review:
89 FR 83510 83514, Initiation of 5-Year Status Reviews of 59 Pacific Southwest Species; October 16, 2024

Purpose of 5-year reviews:
The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, the Service recommends whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing of a species as endangered or threatened is based on the existence of threats attributable to one or more of the five threat factors described in section 4(a)(1) of the Act, and the Service must consider these same five factors in any subsequent consideration of reclassification or delisting of a species. In the 5-year review, the Service considers the best available scientific and commercial data on the species and focuses on new information available since the species was listed or last reviewed. If the Service recommends a change in listing status based on the results of the 5-year review, the Service must propose to do so through a separate rule-making process defined in the Act that includes public review and comment.

Methodology Used to Complete this Review:
Staff of the San Francisco Bay-Delta Fish and Wildlife Office prepared this review. Information was compiled from papers published in peer-reviewed scientific journals, technical and data reports published by other federal agencies, published and unpublished Service reports, and Service documents related to the Antioch Dunes National Wildlife Refuge (ADNWR) and endangered species that occur at this Refuge. These documents were used to consider the current condition of this subspecies, the threats this subspecies has been, and is being, exposed to, how the current status of this subspecies compares to the recovery criteria described for this subspecies, and recommendations for future actions and research. Biologists and natural resource managers who have been actively engaged in activities at ADNWR were also consulted on recovery activities for the next five years.

ASSESSMENT:

Application of the 1996 Distinct Population Segment (DPS) policy:
The Endangered Species Act defines "species" as including any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition of species under the Act limits listing as distinct population segments to species of vertebrate fish or wildlife. Because the species under review is a plant, the DPS policy is not applicable, and the application of the DPS policy to the species' listing is not addressed further in this review.

Updated Information and Current Species Status

Taxonomy

There have been no taxonomic revisions to this subspecies since the last 5-year review conducted by the Service in 2020.

Species overview

Oenothera deltoides subsp. *howellii*, commonly known as the "Antioch Dunes evening-primrose," is a subspecies of birdcage evening-primrose (*Oenothera deltoides*; Klein 1962). Birdcage evening-primrose is a member of the evening-primrose family (Onagraceae) that occurs in suitable habitat in northwestern Mexico, the Baja Peninsula, and arid regions of the southwestern and interior western United States. The use of "birdcage" in the common name highlights the dry seedpod structure, which can resemble a birdcage in this group of species generally referred to as the "birdcage" evening-primroses in western North America (Evans et al. 2009). The Antioch Dunes evening-primrose is an herbaceous perennial with a relatively short lifespan (e.g., 5-7 years; Pavlik and Manning 1993, Pavlik et al. 1993) characterized by large white flowers that tend to be open at night through morning hours in spring through mid-summer.

Antioch Dunes evening-primrose was first described by Munz (1949) based on specimens collected at the Antioch Dunes sand dunes near Antioch in Contra Costa County, California. This subspecies is historically only known from the Antioch Dunes ecosystem and nearby sandy locations near the confluence of the Sacramento and San Joaquin rivers (Munz 1949; Klein 1970; Service 1984, 2008; Jones et al. 2019). For a detailed discussion of the Antioch Dunes ecosystem, including its geography, geology, and historical ecology, see McNally (2014). Antioch dunes evening-primrose can be differentiated from other members of the species based on its location, perennial life history, leaf and flower structure, and long pointed buds (Munz 1949, Service 1984). The plant grows to roughly 0.50-0.80 meters (m) tall, and has fleshy roots and grey-green leaves covered with short, stiff hair. The leaves are runcinate-pinnatifid in that they have lobes that tend to be divided halfway or more toward the central axis of the leaf that generally point back toward the base of the plant, similar to the structure of a dandelion leaf (Munz 1949). The flower buds are roughly 2.0-2.5 centimeters (cm) long, and are oblong with rounded, grooved tips. The flowers are 6-8 cm in diameter and have four white or pink heart-shaped petals and prominent, yellow stamens. Klein (1970) and Evans et al. (2009) compared the morphological, ecological, and evolutionary differences among the evening-primrose species and subspecies in western North America, including Antioch Dunes evening-primrose. Munz (1949) described this plant as a new variety of *O. deltoides*, which Klein (1962) changed to subspecies status. The subspecies status has been retained since that time. See Service (1984) for a history of the taxonomy of this subspecies.

Antioch Dunes evening-primrose is self-incompatible (Klein 1970, Pavlik and Manning 1993, Pavlik et al. 1993) and is pollinated by insects, including bees and hawkmoths (Service 1984). The seeds do not possess specialized morphology to aid in dispersal, and so tend to disperse a short distance by wind and air movements (Pavlik and Manning 1993, Pavlik et al. 1993). Most seedlings are found near adult plants (Pavlik and Manning 1993; Thomson 2005a, 2005b). Some specialists have concluded that this species can successfully become established, grown, and reproduce on a variety of soil substrates, including sand dunes, but also clay soil (Pavlik and Manning 1993, Pavlik et al. 1993, Greene 1995).

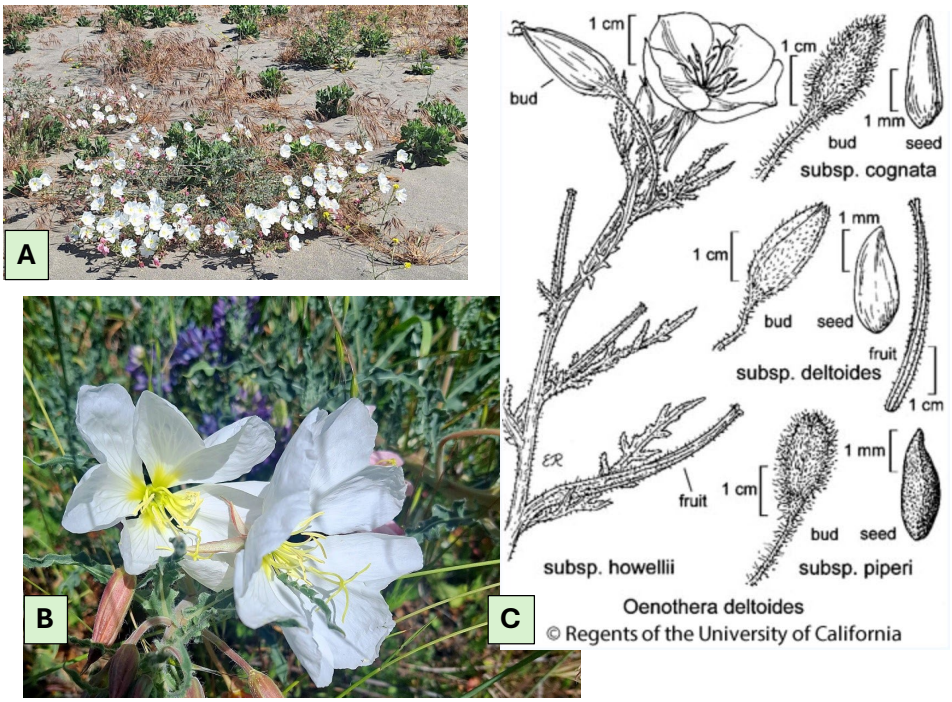

Figure 1. A. Photo of a flowering, mature plant of *Oenothera deltoides* subsp. *howellii* growing in sand dunes located at ADNWR in spring 2025, photo credit: B. Williams; **B.** Photo close-up of *Oenothera deltoides* subsp. *howellii* flower in bloom at ADNWR in spring 2025, photo credit: B. Williams; **C.** Botanical illustration of *Oenothera deltoides* spp. including *O. deltoides* subsp. *howellii.* This illustration was sourced from the Jepson eFlora taxon page for *Oenothera deltoides* subsp. *howellii*, "Antioch Dunes evening-primrose," at https://ucjeps.berkeley.edu/eflora/eflora_display.php?tid=51748

Habitat, Distribution, and Abundance

The Antioch Dunes evening-primrose (*Oenothera deltoides* subsp. *howellii*) is endemic to a highly restricted area known as the Antioch Dunes, located along the southern bank of the San Joaquin River in Contra Costa County, California. This unique inland dune ecosystem historically spanned between approximately 120 and 500 acres (Stanford et al. 2011; Service 1978), depending on how topographic relief is interpreted—specifically, the height and extent of the dunes and their distinction from surrounding natural communities, which has changed significantly throughout the last century. The Antioch Dunes are part of a broader historic landscape of interior dune habitats shaped by eolian (wind-driven) processes, which once covered an estimated 6,800 to 8,400 acres in the region (Standford et al. 2011). This habitat complex consisted of two main types: an "interior dune" with undefined vegetation (~5,600 acres) and an "interior dune scrub" that was more heavily vegetated (~2,800 acres). Both habitat types historically supported native oaks, scrub oaks, and other drought-tolerant plant species. The degree of vegetative cover primarily distinguished the two, with implications for species composition, fire regimes, and ecological function (Stanford et al. 2011). There is limited information available on the historical distribution of the Antioch Dunes evening-primrose,

specifically. However, based on soil suitability and overall habitat characteristics where it currently lives, it is reasonable to think that it may have also occurred in the "interior dune" habitat and in relatively open spaces in both the "interior dune" and "interior dune scrub" habitats (Service 2019a).

Critical habitat was designated for the Antioch Dunes evening-primrose in 1978, and it essentially encompasses the entirety of ADNWR. Antioch Dunes evening-primrose primarily inhabits the western most management area of the Stamm Unit, known as "Management Area 1," at the Refuge. Most recently, Antioch Dunes evening-primrose was confirmed to exist at a few sites (Jones 2019; Jones et al. 2024), including ADNWR, another naturally occurring site within the presumed historical range, and at least three sites that were outplanted using seed sourced from ADNWR in the 1970s (Service 1984). The species is not evenly distributed across these sites. Management Area 1 at the Stamm Unit supported 96% of all adult primrose plants surveyed in 2019 (Jones 2019), highlighting the critical importance of the Refuge to the persistence and future survival of this species. There are three more sites (Dutch Slough Restoration, Big Break Regional Shoreline, Rose Avenue) at which Antioch Dunes evening-primrose might exist but current knowledge is incomplete regarding the taxonomic identity of evening-primrose at those sites. Additional research to further clarify the taxonomic identity of the evening-primrose at those three sites would inform whether the Service should consider those populations in tracking the status of the Antioch Dunes evening-primrose.

Since at least as early as 1985 through 2025 the Service has conducted nearly annual surveys to count the Antioch Dunes evening-primrose on the Refuge. The only years in which a count was not done on the Refuge were 2018, 2020, 2022, and 2023. The Antioch Dunes evening-primrose counts showed that the species was experiencing a significant population increase since approximately 2017 with the population size more than doubling between 2017 and 2019 (from 1,735 to 5,344), then increasing again to 8,506 in 2021 (Euing and Rizza, 2018; Jones, 2019; Thorne and Vandergast, 2021; Euing, pers. comm., 2024). It increased again in 2024 being recorded as 9,295 flowering Antioch Dunes evening-primrose plants at the Refuge, which was the highest recorded number since the counts began in 1985 (Euing, pers. comm., 2024). The 2024 survey was intended to begin a triennial survey cycle by the Refuge based on increasingly strong count results in recent years. However, due to extenuating circumstances that limited habitat management in 2025, it was determined that another count should be done in 2025. The 2025 survey showed a substantial drop in flowering Antioch Dunes evening-primrose at the Refuge, where the total count was recorded as 2,756 (Williams, 2025). The 2025 count results are higher than all other years counts except for one year (2,845 in 1986) prior to 2019. However, the drop from 9,295 to 2,756 from 2024 to 2025 represents a ~71% decrease in population size at the Refuge that appears to have been primarily driven by a decline in Management Area 1 of ~88.7% (Williams, 2025).

Threats Analysis (threats, conservation measures, and regulatory mechanisms)

This section contains a review of the five categories of threat factors, including the known specific threats and stressors, impacting *Oenothera deltoides* subsp. *howellii*. Here, we have reviewed and summarized information from prior Service documents, including the revised

recovery plan for three endangered species endemic to Antioch Dunes, California (Service, 1984) and the Recovery plan amendment: Revised recovery plan for three endangered species endemic to Antioch Dunes, California (Service, 2019a); the most recent 5-year review for *Oenothera deltoides* subsp. *howellii* (Service, 2020); unpublished resources; and other communications with individuals with relevant expertise.

Factor A: The present or threatened destruction, modification, or curtailment of habitat or range

Habitat loss and degradation—Human settlement of the San Francisco Bay and Sacramento–San Joaquin River Delta region since the mid-1800s (Barth 1988) has had profound influences on the Antioch Dunes ecosystem (Powell 1983). Human activities since this time have changed the abundance and distribution of human structures, native and invasive vegetation and trees, and water resources in and near the Antioch Dunes, and as a result have substantially influenced the Antioch Dunes evening-primrose populations and distribution in the area (see Powell 1983, Service 2002, and McNally 2014 for detailed reviews of this history). Mining of sand, use of the area for agriculture purposes, and development of human structures have all resulted in radical changes to the biotic and abiotic dynamics associated with this ecosystem, and fragmentation amongst naturally-occurring dunes. The revised recovery plan (Service 1984) and most recent 5-year reviews (Service 2008, 2020) emphasized that habitat loss and destruction were important threats to Antioch Dunes evening-primrose. These documents emphasized the role that sand removal, industrial and agricultural use conversion of sand dunes, and persistent pressures from invasive species have contributed to habitat loss and degradation in the Antioch Dunes ecosystem.

Natural sand dunes are dynamic systems that experience regular and ongoing disturbance, especially from wind. Prior to human exploitation, the constant shifting of the Antioch Dunes, natural hydrology, the adjacent San Joaquin River, and a wind regime strongly influenced by the region's topography resulted in a unique natural disturbance regime that maintained and constantly changed the Antioch Dunes (Powell 1983). These conditions tended to favor the germination and growth of Antioch Dunes evening-primrose (Service 1984, 2008, 2020; Evans et al. 2005, 2009). The modifications in dune topography caused by sand mining resulted in substantial changes to this natural disturbance regime, and thus have influenced the habitat available for Antioch Dunes evening-primrose. Loss of dune habitat at Antioch Dunes may also have reduced populations of the pollinators of Antioch Dunes evening-primrose, including bee and hawkmoth populations, thereby reducing cross-pollination and reproductive performance (Service 1984, 2008, 2020).

The acquisition of properties containing sand dunes by the Service and the establishment of the ADNWR has substantially reduced habitat loss and degradation (Service 2008, 2020). Thus, habitat loss is not currently considered a major threat to populations of Antioch Dunes evening-primrose at ADNWR, but habitat degradation due to invasive species and other anthropogenic factors likely continues to influence these populations.

Unintentional degradation of habitat, such as by unauthorized human activities, continues to be a threat to this species—chiefly through the threat of errant wildfire. A key conservation strategy used at ADNWR is to restrict human access by installing chain link fences and gates, which

prevents unauthorized people from entering the Antioch Dunes area. Since 1986, the Refuge is fenced with a chain-link fence and gated at key access points along the roads (Service 2008, 2020). However, the Refuge can be accessed from the river, and the various fences and gates can be breached by people who are motivated to access the site without authorization. Refuge staff continue to find evidence of unauthorized visitation (Service 2019a), and these visits have occasionally resulted in habitat degradation (Service 1984, Service 2008), including fires (see below). Although human activity is not currently a significant driver of habitat degradation, it is a continuing threat (Service 2019a).

Habitat fragmentation—Prior to human activity, the Antioch Dunes ecosystem consisted of a continuous sand dune system on the southern banks of the San Joaquin River (Service 2002, McNally 2014), and it is likely that Antioch Dunes evening-primrose occurred throughout these dunes (Service 1984, 2002, 2008). Sand mining, agricultural, residential, and industrial development and activities in and near the Antioch Dunes have combined to fragment the Antioch Dunes system into two core areas, now known as the Stamm and Sardis Units of the ADNWR (Figure 2). This bifurcation and fragmentation of the spatial distribution of Antioch Dunes evening-primrose has decreased the quantity and quality of suitable habitat available for primrose, and separated suitable habitat patches from each other. This fragmentation has reduced rates of dispersal among the primrose populations at the refuge.

Invasive species—In recent years biologists and managers have become increasingly concerned about habitat degradation caused by invasive plant species on Antioch Dunes evening-primrose. Service (2002) discussed the establishment of invasive plant species at ADNWR, including the impacts of non-native plant species (such as yellow starthistle [*Centaurea solstitialis*] and ripgut brome [*Bromus diandrus*]) on Antioch Dunes evening-primrose, and emphasize the role these plants can play in reducing germination and seedling survival rate, changing dune disturbance regimes, and competing for resources. Thomson (2005a, 2005b) considered and analyzed the impacts of invasive plant species at Antioch Dunes, with a focus on the invasive grass ripgut brome. Thomson (2005a) developed a stage-structured population dynamics model for Antioch Dunes evening-primrose and estimated the various survival, growth, and recruitment parameters associated with this model, including under the influence of invasive plants. Thomson (2005a, 2005b) and Beck (2014) concluded that invasive plants have important influences on Antioch Dunes evening-primrose, including competing with primrose for resources (e.g., space, sunlight, water, and nutrients; Service 2002) and changing sand dune dynamics and reducing sand disturbance, which in turn can reduce seed germination and seedling recruitment (Service 2002, Thomson 2005b). Service (2002) concluded that Antioch Dunes evening-primrose tolerates removal of nearby non-native plants, and therefore this activity to remediate interspecific competition should continue.

The Service's 2008 and 2020 reviews for Antioch Dunes evening-primrose both discussed the ongoing impacts associated with invasive plants. The spread of non-native plant species at the Refuge can be seen by comparing historical photographs with more recent conditions at the Refuge. Both reviews (Service, 2008, 2020) also discuss the role hairy vetch (*Vicia villosa*) is presumed to have had in stabilizing the sand dunes and reducing available nutrients; the risk of stabilizing sand dunes is also seen with woody perennial encroachment and increased vegetative landcover in general. According to the most recent vegetation survey conducted at the Refuge

(Miller and Munnecke, 2023), an additional 16 non-native and invasive plant species have been documented to occur at the Refuge, along with multiple non-native and invasive plants species representing an additional three plant genera (Table 1).

Table 1. List of non-native, invasive plant species observed at ADNWR, adapted from Table 11 in the vegetation inventory report by Pyramid Botanical Consultants in 2023 (Miller and Munnecke, 2023).

Taxonomic ID	**Common name**
Ailanthus altissima	tree of heaven
Brassica nigra	black mustard
Hirschfeldia incana	shortpod mustard
Centaurea group	thistles
Cynodon dactylon	Bermuda grass
Ditrrichia graveolens	stinkwort or stinking fleabane
Erodium cicutarium	common stork's-bill or redstem stork's-bill
Genista monpessulana	French broom
Lepidium latifolium	perennial pepperweed
Malva group	mallows
Melilotus albus	honey clover or sweet clover
Nicotiana glauca	tree tobacco
Raphanus sativus	radish
Robinia pseudoacacia	black locust
Rubus armeniacus	Himalayan blackberry
Salsola tragus	Russian thistle or tumbleweed
Tamarix group	salt cedar
Tribulus terrestris	puncture vine
Vicia sativa	common vetch
Vicia villosa	hairy vetch or winter vetch

Furthermore, both reviews (Service 2008, 2020) suggest that invasive plant species could be changing the diversity and abundance of native pollinators, which in turn may influence pollination rates in Antioch Dunes evening-primrose. However, it remains unclear which species pollinate primrose at Antioch Dunes, and how the diversity and abundance of various potential pollinators may be influencing the population dynamics of Antioch Dunes evening-primrose. McNally (2014) compared the current conditions of the Antioch Dunes and emphasized the impacts non- native plant species have had on this ecosystem. Jones *et al*. (2019) evaluated the current status of Antioch Dunes evening-primrose associated with Antioch Dunes and elsewhere, and concluded that reducing the density of non-native plants near primrose might help promote growth and development in juveniles and also increase population growth rates of primrose.

Dust deposition—A riverfront gypsum-based manufacturing and processing facility is located between the Stamm and Sardis Units of ADNWR. This facility is currently owned and operated

by Georgia-Pacific L.L.C. and focuses on producing interior and exterior gypsum panels for residential and commercial buildings (Georgia-Pacific, 2012, 2016). Service (2002, 2008, 2019a, 2019b), and McNally (2014) have all highlighted that dust from the gypsum plant has been, and continues to be, a source of habitat degradation, and that this dust can settle on leaves and other plant material and may reduce exposure to sunlight and decrease rates of photosynthesis. Addition of gypsum-based dust to sand and soil can also potentially change soil mineral composition (especially calcium and sulfates), which could in turn influence and negatively affect plant growth and physiology. Since the 2020 review (Service) Georgia-Pacific installed facilities to reduce the amount of dust entering the Refuge. Gypsum dust is still present on the refuge but we do not currently have data to compare dust deposition levels pre- and post-mitigation.

Pollinators—Service (1984) considered the conjecture that the Antioch Dunes ecosystem experienced a reduction in primrose pollinator populations and species diversity (e.g., bees and hawkmoths). At that time, it was not clear which species pollinated Antioch Dunes evening-primrose, and whether the populations of those species had experienced declines. The two previous 5-year reviews for Antioch Dunes evening-primrose (Service 2008, 2020) both mentioned that reduced pollinator populations might have negative impacts on primrose populations. To date, specific pollinators have not been confirmed for the Antioch Dunes evening-primrose.

Factor B: Overutilization for commercial, scientific, or educational purposes

Overutilization for commercial, recreational, scientific, or educational purposes has not been considered a significant threat to Antioch Dunes evening-primrose (Service 2008, 2020) and is not currently considered a substantial threat to this subspecies (Service 2019a, 2019b).

Factor C: Disease or predation

Plant diseases have not been identified as a significant threat to Antioch Dunes evening-primrose (Service 2008, 2019a, 2020). Mammals and insects are known to eat various evening-primrose species (Service 2002). Birds have not been documented predating Antioch Dunes evening-primrose. Consumption of the tap-root of Antioch Dunes evening-primrose has been observed, but the mammal species responsible has not been identified (Service 2002). Several insect predators have been reported associated with and feeding on Antioch Dunes evening-primrose, including various beetles and moths (Service 1984, 2002). Johnson (1978) described observing leaf beetles (Chrysomelidae) on the leaves and flower buds of Antioch Dunes evening-primrose and concluded that these beetles were reducing the reproductive output of the infected plants. Early reports at the Refuge concluded that insects regularly consume a variety of primrose plant parts, including petals, seed pods, and pollen (Service 1984). Leaf-eating beetles (*Altica* spp.) have apparently been observed consuming most of a primrose plant and have been considered a substantial potential threat to the species by some biologists (Service 2002). Moth species have also been observed consuming primrose but are not deemed to represent a substantial threat to the species (Service 2002). Predation of Antioch Dunes evening-primrose at the Refuge appears consistent with rodents or other mammal species but detailed accounts of which mammal species

regularly consume primrose are not available (Service 2002). Despite the significant impacts on some plants, predation by mammals and insects is not currently considered a significant threat to Antioch Dunes evening-primrose populations.

Factor D: Inadequacy of existing regulatory mechanisms

Service (2019a) reviews the federal regulatory mechanisms related to ADNWR and Antioch Dunes evening-primrose, which include: the Endangered Species Act; the National Wildlife System Administration Act; designation of the ADNWR; listing of Antioch Dunes evening-primrose as an endangered species; the Refuge Recreation Act; the Clean Water Act; and other federal mechanisms. Service (2019a) also reviews the State of California regulatory mechanisms related to ADNWR and Antioch Dunes evening-primrose, which include: the California Endangered Species Act and the California Environmental Quality Act. Antioch Dunes evening-primrose is listed as an endangered species by the state of California (https://wildlife.ca.gov/Conservation/Plants/Endangered). The Service is not aware of regulatory mechanisms associated with Contra Costa County or the City of Antioch that specifically relate to Antioch Dunes evening-primrose.

Factor E: Other natural or manmade factors affecting its continued existence

Wildfires—The previous two 5-year reviews for Antioch Dunes evening-primrose (Service 2008, 2020) have recognized the risk of wildfires to Antioch Dunes evening-primrose clearly stating that the species is most vulnerable to fire during germination through fruiting (approx. December through mid-summer), i.e., the entire time the plant is vegetatively and reproductively active. The 2008 review concludes that plants that are native to the Antioch Dunes ecosystem are likely to recover relatively quickly from wildfires and the 2020 review supports this (Service 2008, 2020). However, four wildfires occurred at ADNWR in fairly rapid succession between May-July 2024 (L. Terrazas, personal communication, July 2024). In total, approximately 11.5 acres of the Sardis Unit at ADNWR were burned by those four fires but few Antioch Dunes evening-primrose were affected due to the fires being contained to the Sardis Unit primarily, thereby burning areas where few Antioch Dunes evening-primrose plants typically exist. The other federally-endangered plant, *Erysimum capitatum* var. *angustatum* ("Contra Costa wallflower"), and the host plant for the federally-endangered Lange's Metalmark butterfly, *Eriogonum nudum* var. *psychicola* ("Antioch Dunes buckwheat), which has a California state rank of S1, critically imperiled, and a California rare plant rank of 1B.1 (indicating that it is rare and endemic to California) suffered significant losses due to the four fires. This underscores wildfire as a risk to the Antioch Dunes evening-primrose populations at ADNWR. The source of fires is presumed to have been due to the presence of unauthorized visitors at the Refuge, which is a persistent challenge for the closed-to-the-public Refuge. Although native plants in the Antioch Dunes ecosystem are predicted to recover quickly from wildfire, four fires in three months is a rapid interval for herbaceous plant populations to recover. In consideration of the 2024 wildfires at the Refuge, there is an increasing and significant risk posed by the wildfires occurring at shorter intervals at the Refuge. This threat is further amplified by the fact that this species' existence is almost entirely restricted to the Refuge.

Variability in climate trends— As reported in the 2020 review (Service, 2020), the Service characterized altered climate conditions as a "high to very high threat" to the Antioch Dunes ecosystem (Service 2019c, p. 96). The report specifically identified more frequent droughts and extreme heat events as factors likely to reduce germination rates, hinder seedling establishment, and increase mortality during vulnerable plant life stages. Projected changes in temperature and precipitation patterns are also likely to alter insect and plant phenology, distribution, abundance, and diversity—factors that could have cascading impacts on the Antioch Dunes evening-primrose and its pollinators. The cumulative effect of these stressors may undermine ongoing conservation and habitat restoration efforts. The complexity of changing environmental conditions in combination with the Antioch Dunes evening-primrose's limited geographic range underscore the need for continued interagency coordination to support additional research and adaptive management strategies that will be essential to ensure long-term species viability.

Information acquired since the last status review

Antioch Dunes evening-primrose surveys (Euing et al., 2020-2024; Williams et al., 2025)

Standardized surveys for Antioch Dunes evening-primrose at ADNWR were conducted in 2021, 2024, and 2025 (Euing, 2021; Euing, 2024; Williams, 2025). Each report describes the methods used, results, a discussion, and recommendations for future work. The "*Habitat, Distribution, and Abundance*" section of this review summarizes the results of these surveys, and the results (showing total flowering Antioch Dunes evening-primrose plants counted by year on the Refuge) of all surveys are shown in Figure 2.

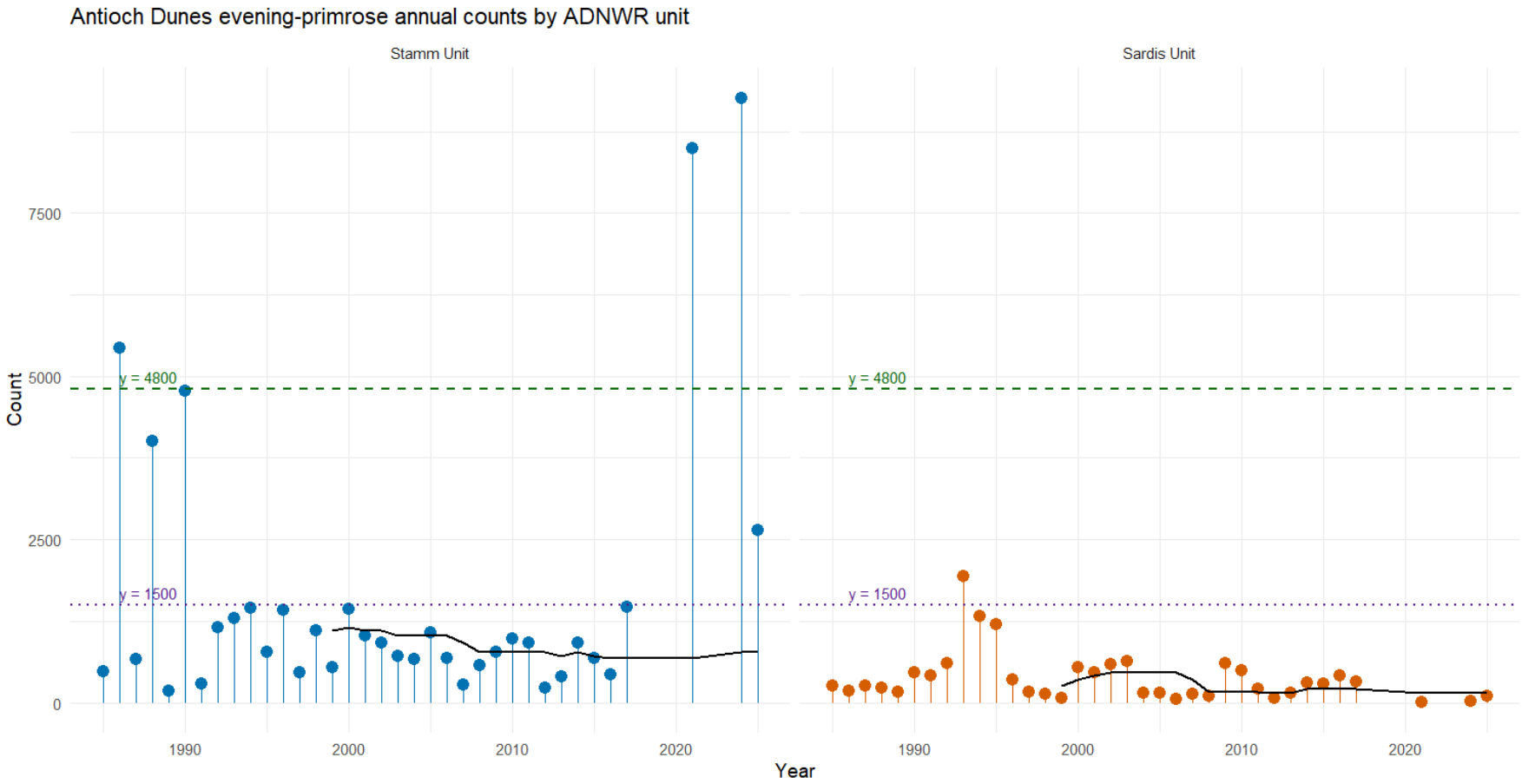

Figure 2. Lollipop plot showing annual count data of Antioch Dunes evening-primrose at each Unit of the Refuge for years 1985-2017, 2021, 2024, and 2025. The dotted and dashed lines represent the requirements for five separate populations of the primrose; (y=4,800) on the y-axis "Count" is the 15-year moving median target for at least three populations and the dashed line (y=1,500) on the y-axis "Count" is the 15-year moving median target for at least two populations. These are targets for consideration regarding whether to downlist the species to "threatened." The same targets apply for seven populations total (five and two, respectively) when considering whether the species is "recovered."

Developing population viability analyses for endangered plants (Pantiga, 2022)

In May 2022, a Directorate Fellow (T. Pantiga) was hired as part of the Service's Directorate Fellowship Program. Pantiga worked on a project titled "Developing population viability analyses for endangered plants" which involved developing a modeling tool to predict future populations and extinction risk. Pantiga developed age-structured matrix models and ran Monte Carlo simulations to estimate the population viability of two endangered plant species: the Antioch Dunes evening-primrose and the Contra Costa wallflower. Conceptual models were created based on life history traits, using four age classes. The seedbank was excluded in this initial modeling phase. Due to limited species-specific demographic data, parameter estimates for survival and fecundity were sourced from published literature. To simulate population outcomes, 10,000 Monte Carlo simulations were run (2,500 runs, four times) per species over 50 years, using an initial population of 1,000 individuals divided among age classes. Demographic stochasticity was introduced by allowing survival to vary between 50–150% and fecundity between 25–175% of base estimates using triangular distributions. A sensitivity analysis tested how changes to individual parameters influenced population growth, helping identify the most influential life stages. Early results indicated high risk of extinction within 50 years; however, the model is still considered to be in-development with additional work needed to better refine the model parameters and increase confidence in the results.

Antioch Dunes National Wildlife Refuge 2023 Vegetation Inventory (Miller and Munnecke, 2023)

In September 2022, Pyramid Botanical Consultants (PBC) was contracted to conduct a comprehensive, field-based vegetation inventory at the ADNWR (Miller and Munnecke, 2023). The survey focused on key landcover types and the distribution of native and nonnative plant species, using an updated version of the protocol originally developed in 2017 (Mathers and Service, 2018). Fieldwork was completed in May 2023.

The findings provide a quantitative assessment of habitat management efforts aimed at supporting federally listed and priority species, including Lange's metalmark butterfly (*Apodemia mormo langei*), Antioch Dunes buckwheat (*Eriogonum nudum* var. *psychicola*), Antioch Dunes evening-primrose (*Oenothera deltoides* subsp. *howellii*), and Contra Costa wallflower (*Erysimum capitatum* var. *angustatum*), as well as the riverine dune ecosystem. The results also document the current distribution and relative abundance of priority native dune species, invasive plant species, and landcover classifications within the Refuge. This information serves as a critical reference point for evaluating the effectiveness of past vegetation management activities, identifying emerging threats, and prioritizing future restoration actions. It also contributes to long-term monitoring efforts essential for adaptive management and recovery planning under federal and state conservation frameworks. Overall, the report presents a comparative analysis of vegetation data collected, including native and non-native, invasive species, as well as estimates of landcover, in 2023 relative to 2017 conditions in order to assess the impact of management activities on observed differences. For a complete list of invasive species that were observed at the Refuge during the 2023 vegetation inventory, see Table 1 (adapted from pg. 35, Miller and Munnecke, 2023).

The 2023 vegetation inventory revealed mixed outcomes in relation to habitat management objectives and the effects on native plants at the ADNWR. Notable positive trends were observed, particularly within the Stamm Unit where sand deposition treatments had been implemented in 2014-2015 and

again in 2020-2021. These included increased cover and frequency of Antioch Dunes evening-primrose, expansion of bare sand (a critical feature of dune dynamics) and declines in annual grasses and key invasive species (including various mustards, star thistles, redstem stork's bill, wild radish, winter and spring vetch, Russian thistle, and Himalayan blackberry) (Miller and Munnecke, 2023). However, despite these gains, the inventory also identified several areas of concern. There were widespread declines in native dune species, including reduced abundance of Lange's metalmark butterfly nectar plants, except in areas where supplemental seeding occurred. In addition, several invasive species demonstrated increased presence across the Refuge, including tree-of-heaven, Italian thistle, bermudagrass, French broom, and whitetop (Miller and Munnecke, 2023). The proliferation of oak seedlings, particularly within the 2014-2015 sand deposition treatment area, was identified to pose a long-term threat to the open, dynamic structure of the dune ecosystem, potentially altering plant community composition and habitat suitability for federally listed species. These findings underscore the effectiveness of and need for continued adaptive management approaches, including supporting the dynamics of the sand dune ecosystem through sand deposition, targeted invasive species control, native plant restoration support (such as annual surveys and seeding efforts), and ongoing monitoring to track the impacts of vegetation change and inform future habitat management strategies.

Distribution, abundance, and genomic diversity of the endangered Antioch Dunes evening-primrose (Oenothera deltoides ssp. howellii) surveyed in 2019 (Thorne and Vandergast, 2021) and Investigation of taxonomic identity of a conspecific to the Antioch Dunes evening-primrose (Jones et al., 2024)

This work is the published product of the *"Antioch Dunes evening-primrose field survey (Jones et al., 2019)"* discussed in the "Information acquired since the last status review" section of the 2020 5-year Status Review (Service, 2020). The official USGS Report titled, "Distribution, Abundance, and Genomic Diversity of the Endangered Antioch Dunes evening-primrose (*Oenothera deltoides* subsp. *howellii*) Surveyed in 2019" was submitted to the Service in 2021 (Thorne and Vandergast, 2021). The report summarized findings from a multi-part study that included a comprehensive literature review, field survey, and genomic analysis of *Oenothera deltoides* subsp. *howellii* (Antioch Dunes evening-primrose). The study provides critical data to inform conservation management, recovery planning, and habitat restoration for this federally listed species.

Part One of the study involved a range-wide field survey across the historical and documented range of Antioch Dunes evening-primrose. Survey teams identified eight extant populations, with over 90% of adult plants and nearly 99% of juvenile individuals found within the boundaries of the Refuge. The data showed a strong negative correlation between the evening-primrose abundance and invasive weed cover, emphasizing the species' dependence on open, mobilized sand and its vulnerability to vegetation encroachment. Importantly, the team modeled the acreage needed depending on percent total plant cover in order to achieve the specified target population sizes as stated in the 2019 Recovery Plan Amendment (Table 2). Their results indicate a tradeoff between total plant cover and approximate acreage needed to support the target population sizes.

Table 2. Modeled acreage needed to reach an adult Antioch Dunes evening-primrose population size of 1,500 and 4,800 individuals. Adapted from Table A3 in Thorne and Vandergast, 2021.

[Total plant cover is the percent cover of the entire plant community. Acres presented as means with 95% confidence intervals in parentheses.]

Total plant cover (percentage)	Acres needed for population of 1,500	Acres needed for population of 4,800
5	2 (2-3)	7 (5-10)
25	5 (4-7)	17 (13-22)
50	15 (12-18)	47 (39-57)
75	41 (32-52)	131 (103-167)
90	76 (57-102)	243 (181-327)

Part Two of the study assessed genomic diversity, which included estimating the population genetic structure and levels of diversity across all known occurrences of Antioch Dunes evening-primrose. The genomic dataset also included samples from the closely related and widespread *Oenothera deltoides* subsp. *cognata*, and three occurrences of a taxon of potentially unknown identity that appears to be morphologically intermediate and is found on the Antioch sand sheet east of the Refuge. Genetic clustering and phylogenetic analyses suggest that these three groups—Antioch Dunes evening-primrose, *Oenothera deltoides* subsp. *cognata*, and the putative intermediate taxon display some degree of genetic differentiation with the strongest differences observed between the widespread *O. deltoides* subsp. *cognata* and the rest of the plants that were sampled. The genomics investigation was also detailed in a published manuscript (Jones et al. 2024).

Their results indicate that the ADNWR population contained the highest levels of genetic diversity among all sampled occurrences of Antioch Dunes evening-primrose, which reinforces the Refuge's central role in the long-term viability of the species and supports the continued prioritization of conservation actions in this area. These results provide scientific evidence for strategic habitat management (such as periodic sand deposition to rebuild and mimic the historically natural dunes), invasive plant species management, and supporting the preservation of genetic diversity through seed collection and dispersal at the Refuge.

Recovery Plan or Outline

Revised recovery plan for three endangered species endemic to Antioch Dunes, California. Approved: March 21, 1980 and revised: April 25, 1984.

Recovery plan amendment: Revised recovery plan for three endangered species endemic to Antioch Dunes, California. Approved: September 26, 2019.

Recovery Criteria

The Service uses recovery criteria to measure the progress made towards reducing or removing threats to a given endangered or threatened species. These recovery criteria are not binding when deciding to downlist or delist a given species, but they do provide guidance in making these decisions. In 2019, the *Revised recovery plan for three endangered species endemic to Antioch Dunes, California* (Service 1984) was amended (Service 2019a) to include objective, measurable criteria as required by the Endangered Species Act (section 4(f)(1)(B)(ii)). The 2019 amended recovery plan (Service) describes the recovery criteria for downlisting Antioch Dunes evening-primrose from endangered to threatened status and the delisting criteria for this species.

The criteria to downlist Antioch Dunes evening-primrose from endangered to threatened (Service 2019a, pp. 20) specifies that: "...at least five separate self-sustaining...populations, including: at least three populations, each with a 15-year moving median of at least 4,800 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants." These downlisting criteria also describe details related to the distance between adjacent populations, potential use of firebreaks between populations, and that a long-term management plan should be established and in the process of being actively implemented.

The criteria to remove Antioch Dunes evening-primrose from the endangered species list (delist; Service 2019a, pp. 20) specifies that: "...at least seven separate self-sustaining...populations, including: at least five populations, each with a 15-year moving median of at least 4,800 flowering plants; and at least two populations, each with a 15-year moving median of at least 1,500 flowering plants." These delisting criteria also describe details related to potential use of population viability analysis to evaluate probability of extinction, the required distance between adjacent populations, potential use of firebreaks between populations, that a long-term management plan should be established and in place, and that a post-delisting monitoring plan should be established and actively implemented.

Synthesis

The Antioch Dunes evening-primrose is a federally endangered plant species endemic to the Antioch Dunes ecosystem in Contra Costa County, California. This unique dune system, shaped by wind-driven processes, historically spanned 120 to 500 acres, forming part of a broader 6,800–8,400-acre inland dune complex. Currently, the species is primarily confined to the approximately 67-acre property of ADNWR, where ongoing habitat restoration and monitoring have focused on reversing the effects of habitat loss, fragmentation, and mitigating the effects of invasive species. The primrose is especially dependent on open, shifting sand for germination and survival and has limited dispersal capacity.

Field surveys and population monitoring have shown fluctuating trends. Between 2017 and 2024, populations at the Refuge increased substantially—from 1,735 to a peak of 9,295 flowering individuals—reflecting the success of habitat management practices, including sand deposition and invasive species control. However, a sharp population decline occurred in 2025, with numbers dropping to 2,756, largely due to a significant reduction within Management Area 1 as compared to the year prior. Despite this drop, the 2025 count remains one of the highest since monitoring began in 1985, highlighting the primrose's continued vulnerability to environmental fluctuations and the importance of consistent management support.

Threats to the species include habitat degradation and competition from invasive plants, unauthorized human activity, the potentially increasing risk of wildfires, and reduced management efforts at the Refuge. While the acquisition of the Refuge has reduced large-scale habitat destruction, invasive plants and unauthorized access continue to impact habitat quality. Wildfires have emerged as an increasing threat, especially following multiple fires in 2024 that highlight the species' sensitivity to frequent disturbance during critical growth stages. Reduced management efforts in 2025 are predicted to exacerbate the risk posed by other identified threats.

Recent genomic analyses confirmed that the Refuge population harbors the greatest genetic diversity among all known occurrences of Antioch Dunes evening-primrose. Field surveys also found that the majority of flowering Antioch Dunes evening-primrose plants occur within the Refuge, reinforcing the Refuge's critical role as the species' stronghold. The results demonstrated a negative correlation between invasive weed cover and primrose abundance, further supporting the need for ongoing sand disturbance and targeted vegetation management to address the harmful effects of invasive plant species. These findings are critical for guiding recovery efforts, including the strategic habitat restoration and management activities.

Although the Antioch Dunes evening-primrose has demonstrated population resilience under intensive management, it remains highly vulnerable due to its restricted range and the persistence of multiple stressors. The continued implementation of adaptive management strategies, combined with surveys and interagency coordination, will be essential to ensure the species' long-term viability. Furthermore, multiple self-sustaining populations of Antioch Dunes evening-primrose need to be established in order to advance the species' recovery. Meeting these goals will require sustained commitment and collaborative work at the Refuge and beyond.

RESULTS

Recommended Classification:

____ **Downlist to Threatened**

____ **Uplist to Endangered**

____ **Delist** *(Indicate reasons for delisting per 50 CFR 424.11)*

____ *Extinction*

____ *Recovery*

____ *Original data for classification in error*

__X__ **No change is needed**

FUTURE RECOMMENDATIONS

Over the next five years, recovery actions for the Antioch Dunes evening-primrose should align with objectives outlined in the Revised Recovery Plan for Three Endangered Species Endemic to Antioch Dunes (Service 1984). Key priorities include: continued restoration of riverine dune habitat within ADNWR, including measures to control invasive plant species, and exploration of adjacent or nearby sites suitable for restoration activities; research on habitat requirements, life history traits, and seed bank dynamics of the species; data collection and analysis, and ecological modeling to better understand (and improve predictions of) population response to management actions; consideration of a centralized, publicly accessible online platform for sharing documents, datasets, and literature related to the species; and continued collaboration and information exchange among Refuge and BDFWO partners who comprise the Antioch Dunes Recovery group.

To broaden the species' recovery footprint, the Service should work closely with conservation partners to expand restoration efforts beyond federal lands, including establishing new populations on lands managed for conservation purposes or sites with high restoration potential. The Service should promote the inclusion of Antioch Dunes evening-primrose in suitable habitat restoration efforts and streamline processes for the collection, propagation, and distribution of plant materials (e.g., seed or nursery-grown propagules) to support timely integration into restoration projects. This could include developing guidance documents on seed collection, storage and handling, germination, and outplanting the species.

Future research efforts should build upon the existing species-wide genetic assessment (Jones et al., 2019) by developing a long-term conservation genetics monitoring program and expanding efforts to collect demographic data on populations. Such a program would help evaluate how interannual population fluctuations affect genetic diversity, and inform decisions about seed collection, translocation, and augmentation. In addition, research should assess the species' adaptive capacity in response to climate variables, such as changes in precipitation and temperature, to guide future restoration site selection and management under climate change scenarios. Additional work could also focus on advancing the population viability analysis developed by Pantiga (2022) to further refine parameters of the model. Another knowledge gap is the identity and ecological role of pollinator species associated with the Antioch Dunes evening-primrose. Conducting a pollinator study would improve understanding of the subspecies' reproductive ecology and inform pollinator conservation strategies. Identifying and monitoring pollinator species critical to primrose reproduction will be essential to maintaining ecosystem functionality and supporting population viability within and around the Antioch Dunes.

Together, these targeted actions and research initiatives will provide a stronger scientific foundation for adaptive management and help advance the species toward recovery goals established in the recovery plan (Service, 1984; 2019).

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Oenothera deltoides* subsp. *howellii*

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

____ **Downlist to Threatened**

____ **Uplist to Endangered**

____ **Delist** *(Indicate reasons for delisting per 50 CFR 424.11)*

____ *Extinction*

____ *Recovery*

____ *Original data for classification in error*

__X__ **No change is needed**

Appropriate Listing/Reclassification Priority Number, if applicable:

FIELD OFFICE APPROVAL:

Donald Ratcliff, Project Leader, San Francisco Bay-Delta Fish and Wildlife Office, Pacific Southwest Region, U.S. Fish and Wildlife Service

Approve DONALD RATCLIFF Digitally signed by DONALD RATCLIFF Date: 2025.08.27 16:33:17 -07'00' Date_____

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.