5-YEAR REVIEW

San Diego fairy shrimp
(*Branchinecta sandiegonensis*)

GENERAL INFORMATION

Species: San Diego fairy shrimp, *Branchinecta sandiegonensis,* an invertebrate species
Date listed under the Endangered Species Act: February 3, 1997
Federal Register citation: USFWS 1997 (62 FR 4925)
Classification: Endangered
Recovery Plan: Final, September 3, 1998. Recovery Plan Clarification, October 1, 2019.
Recovery Priority: Number: 8C
Final Critical Habitat Designation: December 12, 2007 (72 FR 70648)

BACKGROUND

Under the Endangered Species Act of 1973, as amended (Act; 16 U.S.C. 1531 et seq.), the U.S. Fish and Wildlife Service's (USFWS), referred to as "we" in this document, maintain lists of endangered and threatened wildlife and plant species (referred to as the List) in the Code of Federal Regulations (CFR) at 50 CFR 17.11 (for wildlife) and 17.12 (for plants). Section 4(c)(2)(A) of the Act requires us to review each listed species' status at least once every 5 years.

Most recent status review: USFWS 2008. San Diego fairy shrimp (*Branchinecta sandiegonensis*) 5-year review: Summary and evaluation. Prepared by the Carlsbad Fish and Wildlife Office, Carlsbad, California. September 2008. 56 pp. + appendices

We initiated a status review for San Diego fairy shrimp in 2008. The review was finalized on September 30, 2008 and recommended no change in listing status.

Federal Register notice announcing this status review: On January 27, 2020, we published a *Federal Register* notice announcing initiation of the 5-year review of this species, and the opening of a 60-day comment period to receive information (USFWS 2020, pp. 4692–4694). We received one comment with information about San Diego fairy shrimp. Staff from the U.S. Marine Corps Base Camp Pendleton (MCBCP) responded to the *Federal Register* notice with new information relative to the species status on the military base (Asmus 2020, *in litt*). According to the comments, 3 locations on MCBCP have newly detected occurrences of San Diego fairy shrimp (at Tango, Gold Beach and Del Mar 21), 10 pools are at risk to bluff erosion, and 2 pools with incorrect data have been updated in their monitoring database. The comments also discuss the conservation work occurring on base, including vernal pool restoration at multiple locations and the continued progress on developing a vernal pool conservation plan.

Species Overview and Habitat: The San Diego fairy shrimp (*Branchinecta sandiegonensis*; SDFS) is a small aquatic crustacean generally restricted to vernal pools in coastal southern California and northwestern Baja California, Mexico. San Diego fairy shrimp are usually observed from January to March when seasonal rainfall fills vernal pools and initiates cyst (egg) hatching.

Vernal pools are landscape depressions within specific soil types that are underlain with a relatively impermeable layer of claypan or hardpan, allowing the depression to hold an ephemeral body of standing water following seasonal rains. Vernal pools and vernal swales are often clustered into pool ‘‘complexes’’ (Bauder 1986, Appendix 1, 4; Keeler-Wolf et al. 1998, pp. 60–61, 63–64) separated by tens of meters, and may form dense, interconnected mosaics of small pools, or a sparse scattering of larger pools. Vernal pool complexes that support from one up to many distinct vernal pools are often interconnected by a shared watershed. Both the pool basin and the surrounding watershed are essential for a functioning vernal pool system.

ASSESSMENT

Information acquired since the last status review

This 5-year review was conducted by the USFWS Carlsbad Fish and Wildlife Office. Data for this review were solicited from the public and interested parties through a *Federal Register* notice announcing this review on January 20, 2020 (USFWS 2020, pp. 4692–4694). Our assessment of the species status relied heavily on available GIS data. Data sources included observations submitted to the Carlsbad Fish and Wildlife Office (CFWO) in association with surveys conducted under Section 10(a)(1)(A) of the Act and the California Natural Diversity Database (CNDDB 2021). In addition, project or region specific data was provided by the Western Riverside Multispecies Habitat Conservation Plan, U.S. Marine Corps Air Station Miramar, U.S. Marine Corps Base Camp Pendleton, the City of San Diego, California State Parks, and San Diego Association of Governments. Vernal Pool Management Areas identified in this status assessment follow the Recovery Plan for Vernal Pools of Southern California (Service 1998, p. 38). We also conducted a literature search and a review of information in our files.

SUMMARY OF NEW INFORMATION SINCE 2008

Distribution

Since the last status review was conducted in 2008, the distribution of SDFS has expanded to include one location in Riverside County, where the species was not known to occur previously (Figure 1). This is the first detection of SDFS east of the coastal range in southern California. In 2017, the species was detected at the Clayton Ranch mitigation site (also known as the Schleuniger pool) [California Natural Diversity Database (CNDDB) 2021, Element Occurrence (EO) 117] in Riverside County. Prior to the Clayton Ranch development project, soil was collected from the development site and placed at the Clayton Ranch mitigation site in 2012, inoculating the mitigation pools. SDFS was subsequently documented at the mitigation site in 2017 (CNDDB 2021) and again confirmed in 2020 (Livergood 2020, p. 1). SDFS was not known to occur at the development site or the mitigation site prior to either development project or restoration work, so it’s unclear exactly how the species came to occupy the mitigation site, but the species appears to be surviving onsite. Otherwise, the distribution of SDFS at the county level in the United States has not changed since 2008. The species continues to occur throughout its historic range in San Diego County and Orange County, California.

The species was considered extant at two locations in Mexico at the time of listing, known from the general areas of Baja Mar and Valle de las Palmas (USFWS 1998, p. 17); the status of the species at these Mexico locations is unknown.

Abundance

Abundance is characterized by the number of locations reported in survey reports to CNDDB and CFWO before and after the last 5-year review in 2008 (Figure 2 through 5). It is difficult to characterize the status of each location because most have not been revisited both before and after the last review and there is some degree of overlap between the datasets. However, we believe the majority of locations to be extant or presumed extant and that the number of locations where SDFS is known to occur within the historical range of the species has increased since the last status review (Figure 2 through 5; USFWS 2008, p. 6). A total of 877 occupied locations were identified prior to 2008. After 2008, 397 locations were surveyed many of which were included in the original 877 locations surveyed (Table 1; USFWS 2021; CNDDB 2021). Post 2008 survey records, indicate that the species is still extant in all 6 counties and we presume them to be extant in the majority of locations. The status, as reported by CNDDB, indicates that approximately 94% (51 of 53) occurrences after 2008 are considered extant or presumed extant (CNDDB 2021). The greatest increase in reported locations were recorded in San Diego Southern Coastal Mesa in the vicinity of Otay Mesa (Figure 5) and San Diego Central Costal Mesas (Figure 4; Table 1), with notable new records in the vicinity of Mission Bay, Poway, Bonita and Jamul in San Diego County.

Table 1 Estimate of SDFS reported locations before and after the last review in 2008.*

Location	Pre-2008	Post-2008
Riverside County	0	2
Los Angeles Basin-Orange	18	15
San Diego North Coastal Mesas	44	47
San Diego Central Coastal Mesas	463	86
San Diego Inland Valleys	132	46
San Diego Southern Coastal Mesas	220	201
Total	877	397

** This is an estimate of the number of reported locations based on available data and includes an undetermined overlap between the CNDDB and CFWO datasets.*

Overall, the number of locations lost since 2008 is likely to be few relative to the number of currently occupied locations due to the protections afforded to the species and its habitat (e.g., through the Act and regional conservation planning) and through the conservation efforts of our partners. Where habitat loss has occurred (e.g., as the result of residential development projects, road construction or military trainings activities), conservation measures to minimize and offset those losses have largely been implemented through section 7 and section 10 of the Act. Overall, we estimate that the number of locations known to be occupied by SDFS has increased since the last status review in 2008 as shown in Figures 2 through 5, despite some losses of previously known locations.

Research

Recent research focused on SDFS has greatly improved our understanding of the species, especially regarding the topics of hybridization, identification and population genetics.

Hybridization

At the time of the last status review, we understood that the versatile fairy shrimp (*Branchinecta lindahli*), a generalist species common throughout western North America but which historically had little geographic overlap with SDFS, had been documented in a few locations within the range of SDFS at pools where habitat had been disturbed (USFWS 2008, p. 31). At that time, *B. lindahli* was primarily found in Southern California at inland playas and largely separated geographically from SDFS. Additional information was needed at the time of the last status review to better understand the threat of hybridization and competition from *B. lindahli*.

We currently understand that *Branchinecta lindahli* is now found at many locations within the range of SDFS (Patel 2018, pp. 77-82), including many coastal vernal pools where SDFS occurs (Figure 6). SDFS and *B. lindahli* readily hybridize in the lab and *in situ* (Patel 2018, p. 2). In addition to hybridization, invasion of *B. lindahli* may also lead to increased competition for resources where the two species co-occur.

The erosion of the geographic barrier between SDFS and *Branchinecta lindahli* likely occurred as a result of human-assisted dispersal. Vehicles associated with development, military training and law enforcement in Southern California (e.g., construction equipment) likely created road ruts in suitable vernal pool habitat during various activities. Tires and equipment likely inoculated the new, unnatural depressions with *B. lindahli* cysts moved from offsite locations. As construction, conservation efforts, and vehicular traffic continues in Southern California, *B. lindahli* may continue to be introduced into vernal pool complexes occupied by SDFS throughout the range of the species.

As a generalist that inhabits many habitat types and environmental conditions, *Branchinecta lindahli* cysts (eggs) hatch more readily and individuals mature faster than SDFS (Patel 2018, p. 61). Combined with reproductive bet-hedging (i.e., not all cysts will hatch in any given year), *B. lindahli* has the potential to dominate road rut pools and overwhelm the cyst bank even after years of poor environmental conditions (Patel 2018, p. 61). In relatively natural coastal vernal pool systems, SDFS can maintain an advantage over *B. lindahli*, in part due to its relatively higher fecundity (Patel 2018, p. 53).

Research shows that SDFS continues to dominate intact coastal vernal pools, and *Branchinecta lindahli* dominates inland playas (Patel 2018, pp. 46, 84). In coastal systems, *B. lindahli* invasion and the extent of hybridization often depend on the extent of habitat disturbance (Patel 2018, p. 46); highly disturbed or road rut pools greatly favor *B. lindahli* either because the environmental conditions more closely resemble *B. lindahli* habitats abiotically, or because the generalist species has a selective advantage in the novel/disturbed habitat (Patel 2018, p. 56). However, habitat disturbance of intact systems in and of itself does not always lead to invasion of *B. lindahli* or hybridization but can lead to introduction of *B. lindahli* from other areas (Patel 2018, p. 48).

Our understanding of the current distribution of *Branchinecta lindahli* is based on observations during SDFS permitted surveys. Beginning in approximately May 2015, *B. lindahli* records were included in support of reporting requirements under Section 10(a)(1)(A) of the Act. Researchers are not required to submit this data to CFWO. As such, this dataset may be incomplete and observations prior to 2015 may not have been submitted. There may also be inaccuracies due to misidentification of *B. lindahli* or hybrids. Therefore, Figure 6 is an illustration of the potential extent of *B. lindahli* within the range of SDFS, where the species historically had limited geographic overlap. Patel 2018 (p. 77-82) provides more detailed analysis of known *B. lindahli* locations using genetic tools.

Identification

Researchers have recently developed multiple tools to genetically and morphologically identify SDFS, *Branchinecta lindahli,* and hybrids (Simovitch et al 2013, p. 734; Steele et al 2009, pp. 1778-1779; Vandergast et al 2009, pp. 767-770; Andrews et al 2014, pp. 401-403; Patel et al 2018a, pp. 897-905; Patel et al 2018b, pp. 349-353). Morphological identification of captured individuals is challenging and is not always concordant with genetic results. The improved identification tools developed in recent years will assist future conservation efforts aimed at monitoring the status of SDFS at vernal pool complexes and monitoring the expansion of hybrid zones. Similarly, research has improved our understanding of best practices for field preservation of specimens for future utility and genetic analysis (Wall et al 2014; p. 1).

Most recently, researchers completed an environmental DNA (eDNA) metabarcoding bioassessment of SDFS and *Branchinecta lindahli*. This eDNA tool can detect the presence of both fairy shrimp species from water samples collected from pools, eliminating the need to capture individuals for identification during survey and monitoring efforts. The study showed functionally equivalent specificity and sensitivity between traditional dip net sampling and eDNA sampling for SDFS and *B. lindahli* (Gold et al 2020, p. 3). Additional work is needed to determine if the eDNA tool will help in the identification of hybrids (Gold et al 2020, p. 4).

Population Genetics

The concept of population genetics is important in the context of conservation, especially as it relates to population boundaries. Research was conducted on SDFS from 50 vernal pools from 23 vernal pool complexes in San Diego County and found that there is substantial diversity within pools and genetic differentiation among pool complexes is strong (Andrews 2013, p. v). Geographic distance between occupied locations is a significant barrier to gene flow. This study found that treating vernal pool complexes as unique management units is important for future conservation efforts, as well as, maintaining the historical divergence among pools as it relates to genetic variation and dispersal (Andrews 2013, p. v).

Past work on population genetics found evidence of two divergent groups by isolation with a putative contact zone (Andrews 2013, p. v). A follow up study with additional samples from the contact zone at U.S. Marine Corps Air Station Miramar (MCAS Miramar) confirmed the status of the two regional gene pools with a distinct geographic break coinciding with a large canyon as a barrier to gene flow (Goddard 2017, p. iv). Roads were also found to be barriers to gene flow.

Researchers were able to use the results of the genetic work to designate five local management units for SDFS on MCAS Miramar.

In Baja California, a recent study concludes that populations of SDFS in the southernmost part of the range contain important genetic and phenotypic diversity (Artega et al. 2019, p. 159). Recent genetic sampling at one of the geographic regions (Valle de las Palmas) indicates the SDFS are genetically differentiated from the other sampled regions. Due to fragmentation from agriculture and urban development, the region is probably evolving in isolation from other coastal regions due to limited gene flow. This is especially relevant in northwest Baja California, where historically limited population dispersal is being negatively affected by fragmentation.

Threats

In 2008, we considered all remaining SDFS habitat to be threatened to some degree by indirect impacts of development (including off-highway vehicle use and other human access and disturbance impacts, runoff, dumping of trash and litter, and pollution) resulting from the proximity of occupied habitat to development. Off-highway vehicle use by recreators, law enforcement, and the military were known to threaten this species throughout much of its range. Nonnative plants also threatened SDFS habitat throughout the range of the species. While SDFS habitat is naturally fragmented, development projects further fragmented and isolated vernal pools within and between vernal pool complexes, which have the potential to disrupt the population dynamics of the species (USFWS 2008, p. 40). Finally, regulatory mechanisms were considered inadequate for the protection of SDFS (USFWS 2008, p. 27).

We believe threats discussed in the 2008 status review are still relevant and acting upon the species throughout its range, although the magnitude of each threat may vary compared to 2008. Similarly, predation, drought, climate change, fire, pesticides, and other pollutants were discussed in 2008 as potential threats to SDFS, and the discussion of these threats from 2008 remains accurate. The discussion below provides updates related to development, off-highway vehicles and human access, hybridization and competition, disease and altered hydrology.

Development

The magnitude of the threat of development and its associated indirect effects has been reduced through conservation. Conserved lands are areas designated for conservation or are unlikely to be developed due to their inclusion in regional conservation plans, lands conserved by non-profits, and public or quasi-public lands. For example, regional conservation plans include the Southern Subregion and Central/Coastal Habitat Conservation Plans in Orange County and Western Riverside Multispecies Habitat Conservation Plan. In San Diego County, the conserved lands are an inventory of lands conserved for the purpose of protecting open space and natural habitats, including lands inside and outside of Natural Community Conservation Plan areas

Within the City of San Diego, considerable conservation and management has been achieved through the recent adoption of the Vernal Pool Habitat Conservation Plan (VPHCP). There are approximately 517 vernal pools occupied by SDFS within the City of San Diego; 55 will be developed and 462 will be protected with management actions implemented across 33 vernal pool sites through the VPHCP and the City's Multiple Habitat Planning Area (City of San Diego 2020, p. 2).

Off-Highway Vehicles and Human Access

Off-highway vehicles and human access continue to be threats throughout the range of the species, although fencing to preclude access has occurred at some locations. Non-native plants continue to threaten the species by degrading suitable habitat, and while conservation actions at some locations have alleviated this threat to some degree, it is likely to remain a habitat management challenge in Southern California. The threat of habitat fragmentation and the resulting alteration of population dynamics remains due to ongoing development throughout the species range.

Hybridization and Competition

Hybridization and competition from *Branchinecta lindahli* was identified as a threat to SDFS in 2008 but additional information was needed (refer to the research section above for a detailed description of this threat). We now understand that hybridization and competition with *B. lindahli* may affect SDFS locations throughout the range of the species (Figure 6). Simovich (et al 2013, p. 737) described a homogenization cascade as the potential result of development in Southern California, leading to functional homogenization and loss of ecosystem resilience. The magnitude of the threat of hybridization and competition with *B. lindahli*, and the ability of our conservation partners to manage it, remains to be seen. If the threat becomes increasingly widespread, conservation actions beyond simple habitat protection for SDFS may be needed (Simovich et al 2013, p. 738).

Because we understand that *Branchinecta lindahli* and hybrids dominate highly disturbed (e.g., road ruts) pools, conservation actions should be focused on these degraded habitats, and considerations should be made about whether landowners should remove such features especially where they exist near intact coastal vernal pools supporting SDFS. These pools have the potential to act as steppingstones for invasion of *B. lindahli*. The conservation action of removing road rut pools occupied by *B. lindahli* or hybrids adjacent to intact coastal pools is already being attempted at MCAS Miramar (Black 2021, *in litt*) to slow the invasion. In addition, conservation partners throughout the range of SDFS should continue to take all necessary precautions to prevent the spread of *B. lindahli* through contaminated equipment and movement of soil.

Disease

In addition, a new potential threat of disease has been identified for SDFS. *Wolbachia* or similar bacteria can induce cytoplasmic incompatibility (Simovich et al 2013, p. 735). These types of bacteria can also lead to biased sex ratios, parthenogenesis (female asexual reproduction), feminization of males, and a high juvenile male mortality (City of San Diego 2019, p. 3-27). Because *Branchinecta lindahli* can harbor feminizing endoparasitic bacteria, hybridization with SDFS may lead to genetic and reproduction issues for the listed entity. Additional information regarding this potential threat is needed.

Altered Hydrology

While SDFS is protected by the Act, alteration of hydrology remains a threat to the species that was formerly ameliorated to some degree through the implementation of Section 404 of the Clean Water Act. Since the last 5-year review there has been a change in the regulatory definition of what is considered a jurisdictional water or wetland that is subject to the regulatory protections of the Clean Water Act. These regulatory changes have eliminated U.S. Army Corps of Engineers oversight of vernal pools and other ephemeral water bodies unless they meet a narrow definition of an adjacent wetland (i.e., water bodies that have a surface connection to a navigable water or territorial sea through flooding in a typical year) (DOD and EPA 2020, p. 22251). While we no longer consider the lack of regulatory mechanisms as a threat, these changes to the regulations have removed the protections that were formerly in place that helped reduce impacts. Therefore, SDFS are more at risk due to alterations in the hydrology of vernal pools and ephemeral water bodies.

Summary of Threats

Since the 2008 5-year review, we have received new information about ongoing threats at SDFS locations. This new information related to the threats of development, off-highway vehicles and human access, hybridization and competition, disease and altered hydrology. The threats identified at listing and discussed in the 2008 5-year review are on-going and hybridization and competition, disease and altered hydrology have been identified as new threats. This new information does not alter the conclusion of our 2008 5-year review.

CONCLUSION

In the 2008 5-year review, we recommended no status change for SDFS. Since 2008, we have received new occurrence information for SDFS. The number of SDFS locations has increased including a new record in Riverside County. After reviewing the best available scientific information, we conclude that SDFS remains an endangered species. With the updates provided in this document, our evaluation of threats affecting the species under the factors in 4(a)(1) of the Act and analysis of the status of the species in our 2008 status review remains an accurate reflection of the species current status.

RECOMMENDATIONS FOR FUTURE ACTIONS

The actions included below are recommendations intended to reduce threats to SDFS and provide information to better understand the status of populations. We recognize that conservation of SDFS will require cooperation and coordination with partners to minimize impacts from current threats, aid future restoration, and maximize effectiveness of limited funding.

1. Work with internal and external partners to address the threat of hybridization and competition with *Branchinecta lindahli* based on current research.

    a. Analyze the effectiveness of removing highly disturbed vernal pools (e.g., road ruts) occupied by *B. lindahli* or hybrids to ameliorating the threat of hybridization and competition in nearby intact pools occupied by SDFS.

b. Work with conservation partners and landowners to reduce the threat of inoculation of coastal vernal pools with *B. lindahli* and hybrids from offsite locations.

c. Work with partners to research additional topics related to hybridization and competition with *B. lindahli* as needed to better understand the extent and magnitude of the threat to SDFS.

d. Complete a guidance document for future actions related to the threat of hybridization and competition with *B. lindahli*.

2. Support the continued work by researchers to designate local management units for SDFS based on population genetics, especially for conservation activities featuring the movement of soil and restoration of vernal pools (Andrews 2013, p. v; Goddard 2017, p. iv).

3. Complete a thorough review of all remaining occupied habitat, including status (e.g., conserved, restored, managed, monitored, impacted, illegally impacted) and management needs (e.g., conservation, restoration, management, monitoring) categories for all SDFS habitat complexes, including locations in Baja California. Utilize this information to update Appendix 1 of the 2008 review (USFWS 2008, Appendix 1). Cross-reference Appendix 1 of the 2008 review with the appendices to the Recovery Plan (USFWS 1998, Appendix E, F, and G).

4. Develop protocols for quantitative estimates of adult and cyst abundance, as feasible, and define ranges within which –

    a. cyst banks would be considered adequately populated; and

    b. adult numbers (given sufficient pooling) reflect a healthy population. The SDFS survey protocol should be updated to include collection of such abundance data. The defined abundance ranges should be used to model a population viability analysis (PVA) for SDFS, and as standards for determining SDFS habitat restoration success.

5. Work with partners to explore the feasibility of using eDNA for wet season sampling instead of dip-netting and update the Survey Guidelines for the Listed Large Branchiopods as appropriate.

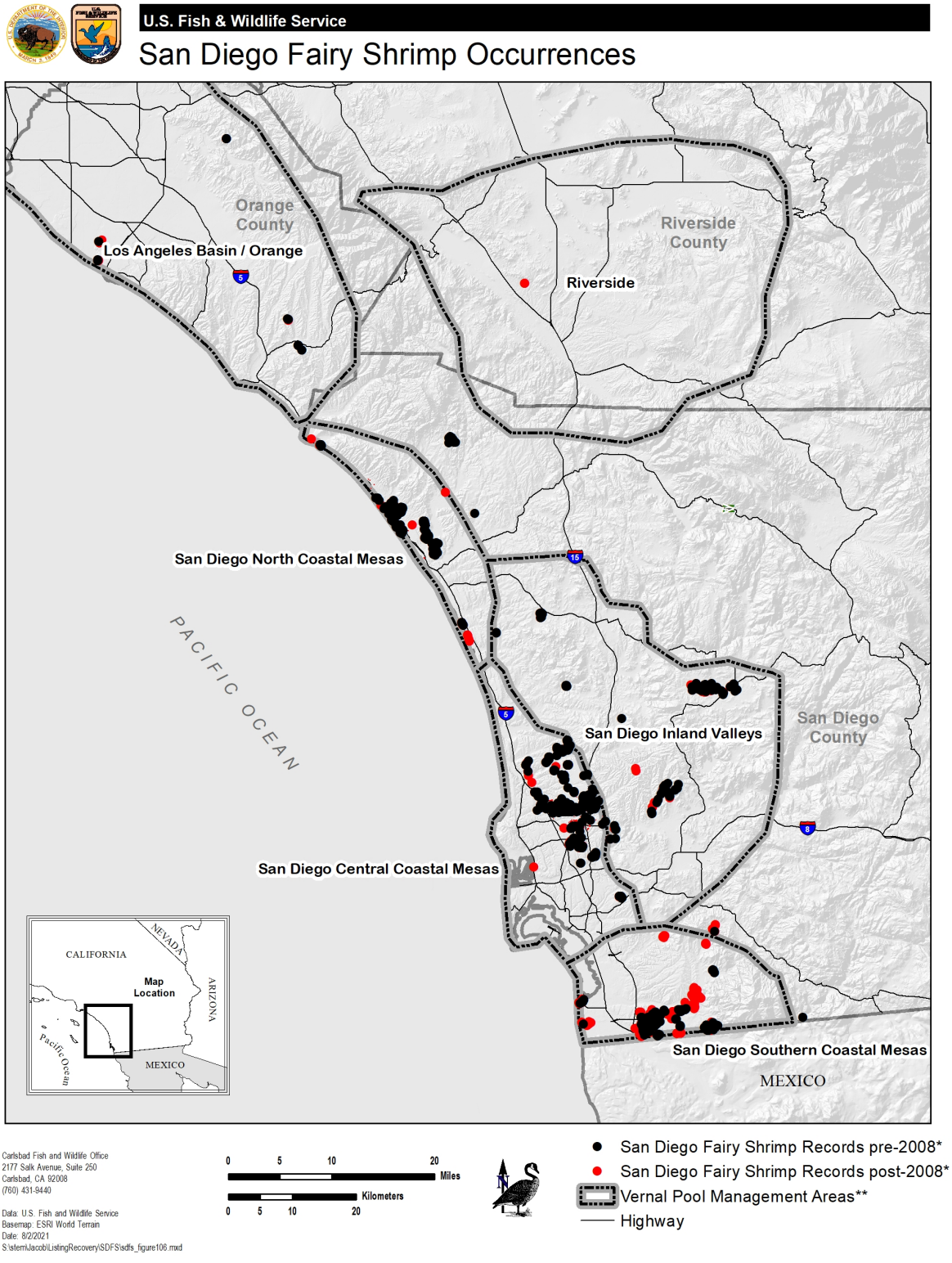

Figure 1. Distribution of San Diego fairy shrimp throughout the range of the species

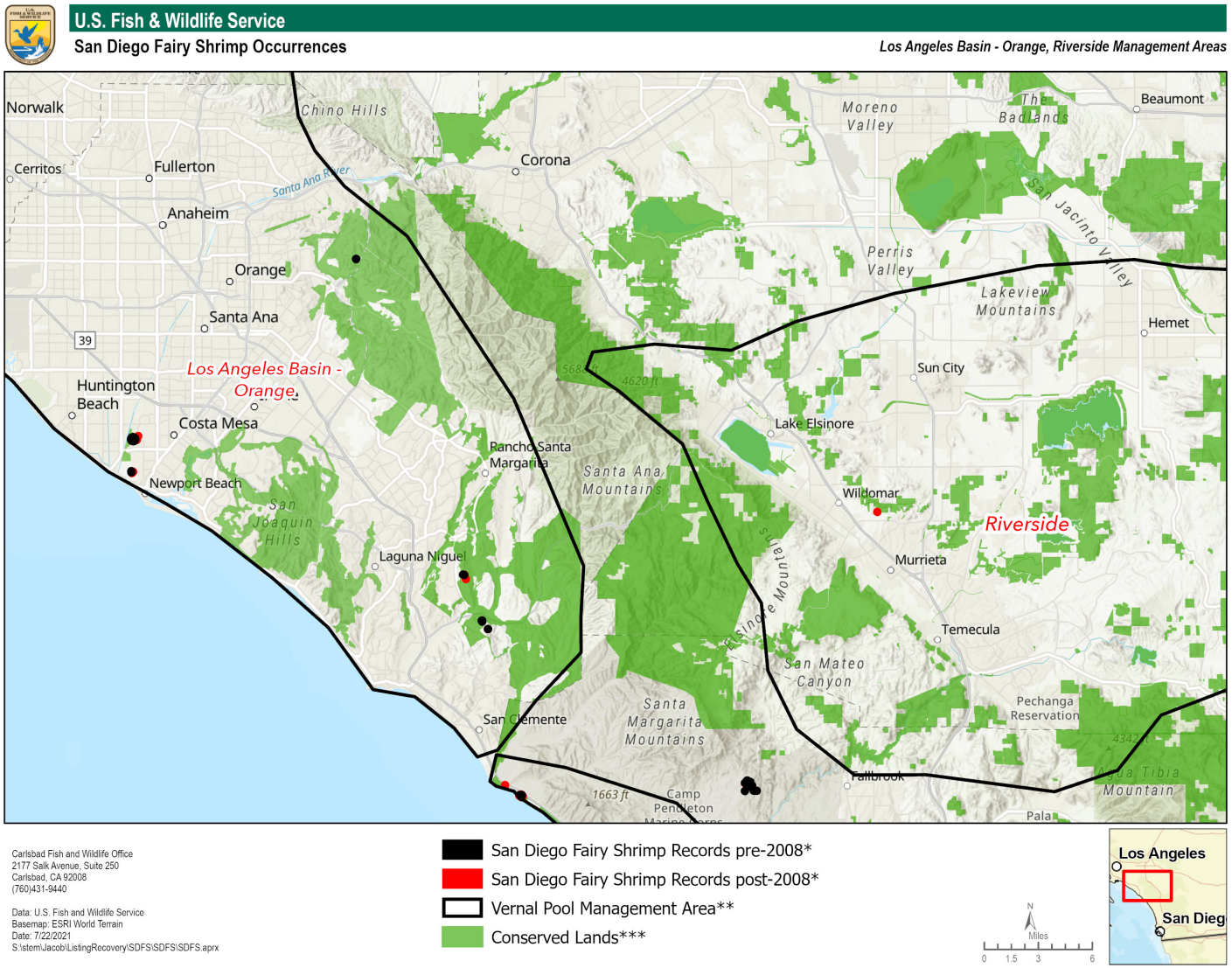

Figure 2. San Diego fairy shrimp locations in the northern portion of the species range

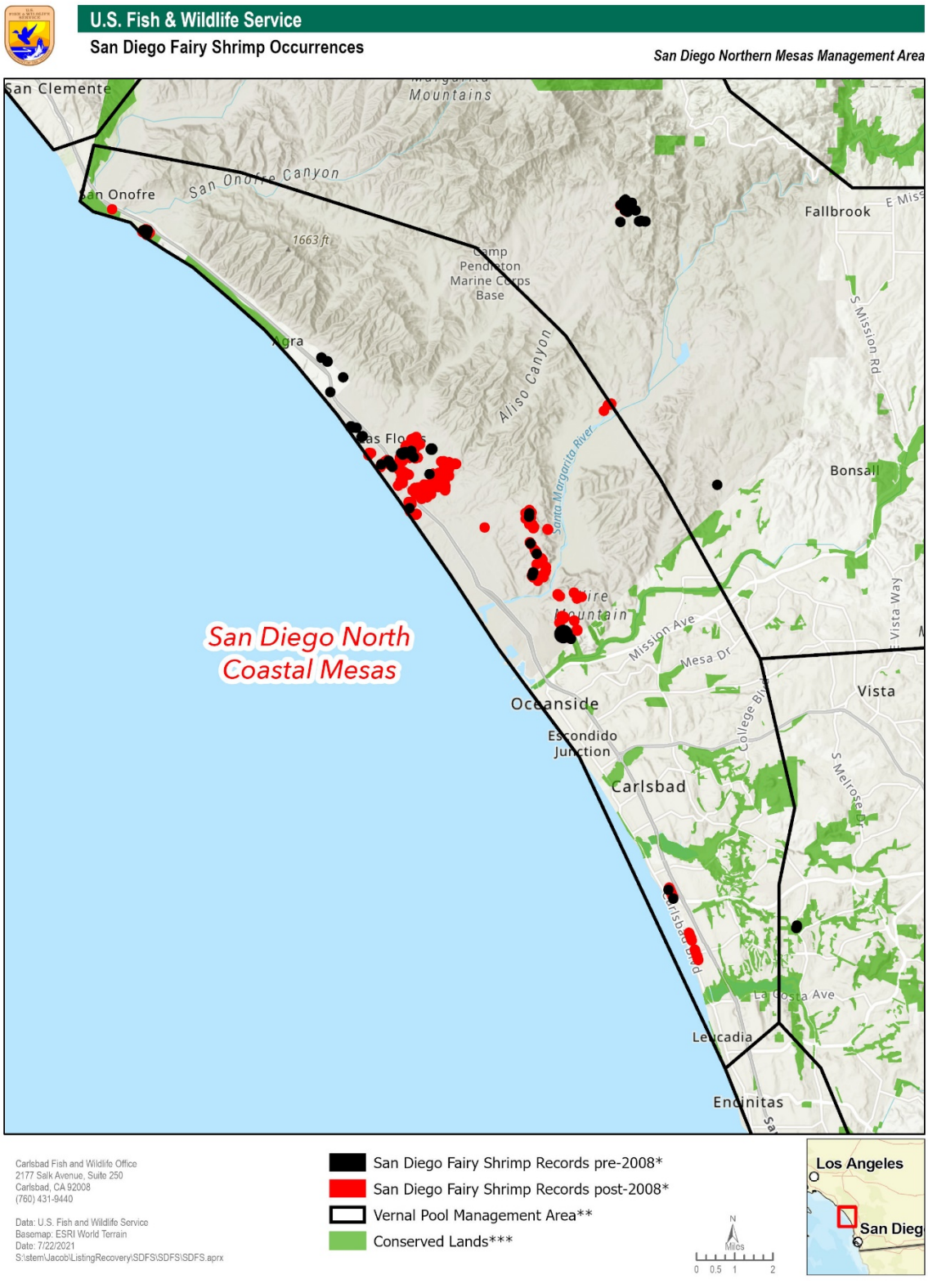

Figure 3. San Diego fairy shrimp records in northern San Diego County

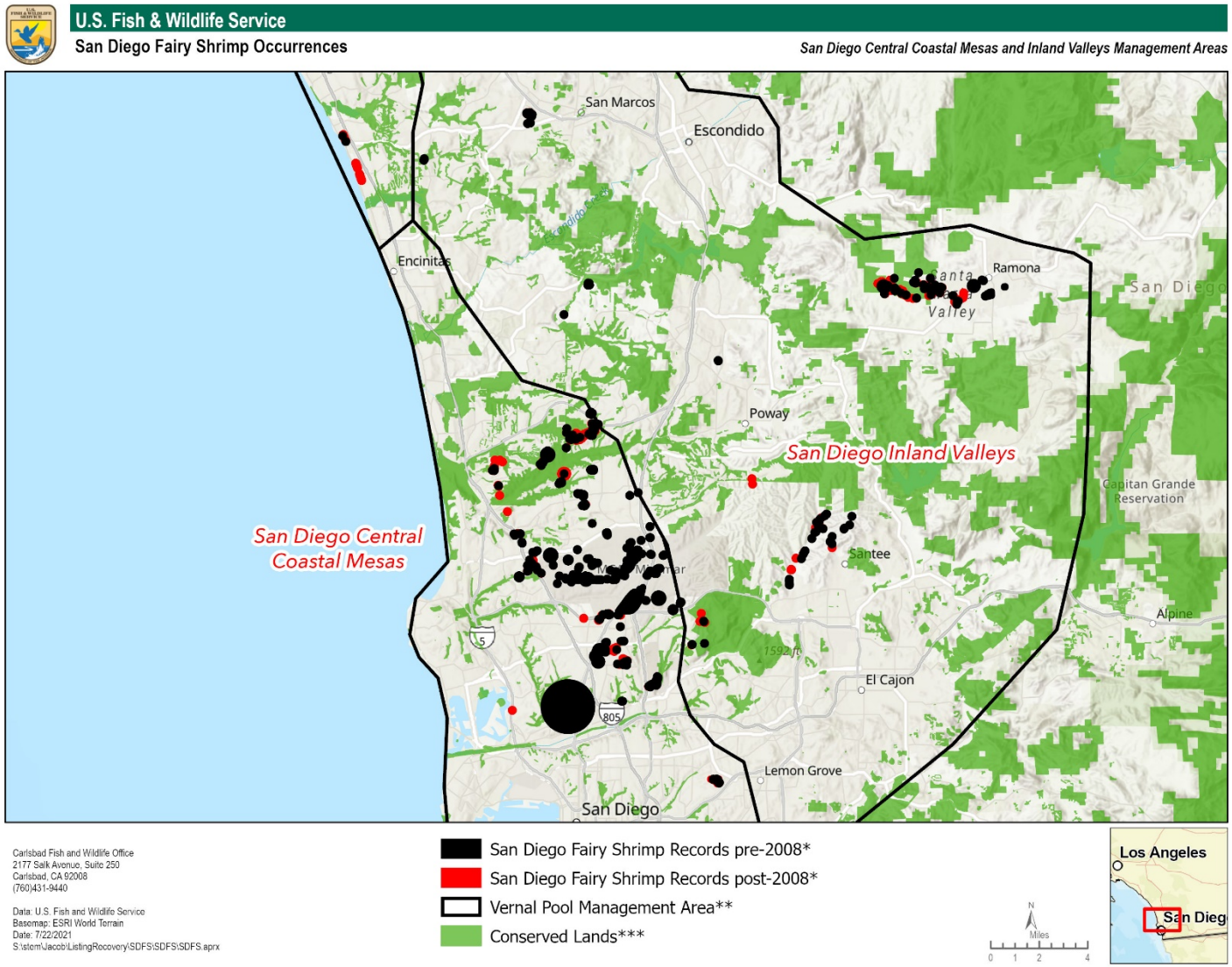

Figure 4. San Diego fairy shrimp in central San Diego County

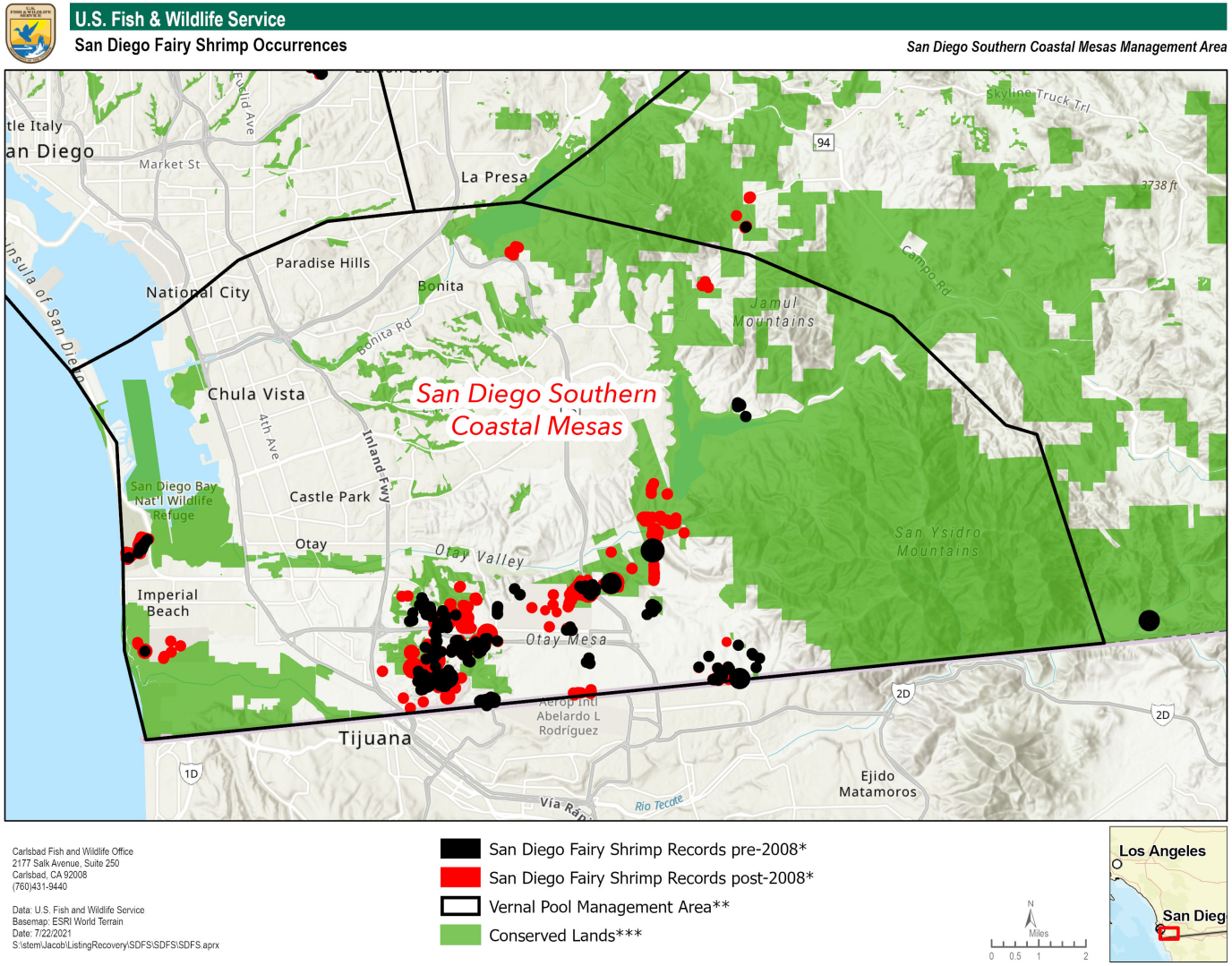

Figure 5. San Diego fairy shrimp in central San Diego County

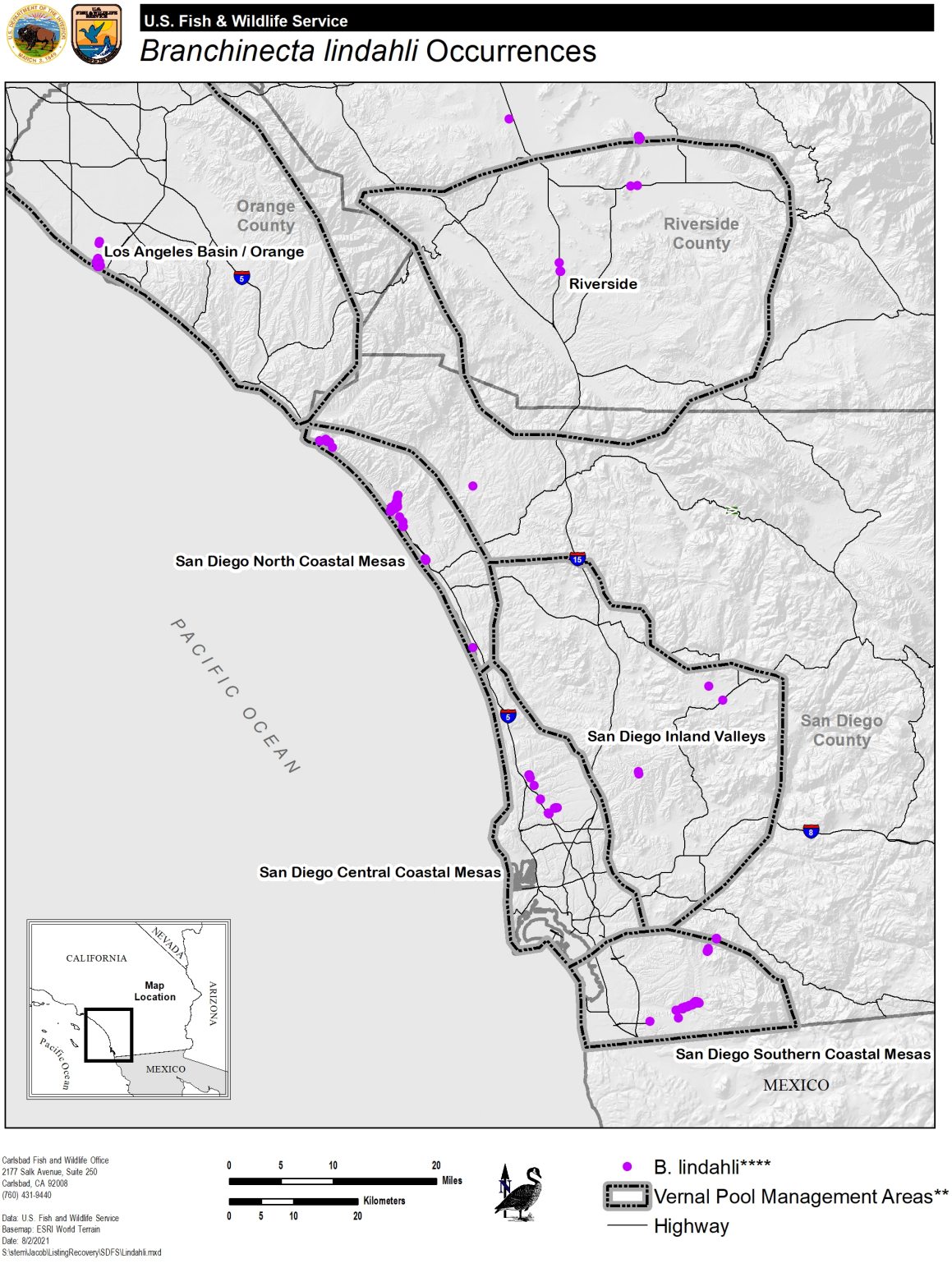

Figure 6. Recent Branchinecta lindahli observations within the range of San Diego fairy shrimp.

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FIELD OFFICE APPROVAL

Lead Field Supervisor, Fish and Wildlife Service

☒ Approve

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